

The Strategy and Technology Selection for Non-CO₂ Greenhouse Gas Emission Control

ZHOU Ya-Min¹, FENG Yong-Sheng²

¹National Institute of International Strategy, Chinese Academy of Social Sciences, Beijing 100007, China

²National Academy of Economic Strategy, Chinese Academy of Social Sciences, Beijing 100045, China

Abstract

The emission control of non-CO₂ greenhouse gases is conducive to slowing down global warming. It is also helpful in controlling environmental pollution, and beneficial in improving the local health benefits. This paper aims at six kinds of non-CO₂ greenhouse gases under United Nations Framework Convention on Climate Change, namely methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF₆), and nitrogen trifluoride (NF₃). This paper analyzes the emission status and trend of China's non-CO₂ greenhouse gases, and provides some technology selections for non-CO₂ emission reduction. Through strategic policy arrangements and appropriate technology choices, China can gain environmental protection and greenhouse gas control.

Keywords: non-CO₂ emission; status; trend; technology selection

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1 Introduction

The Kyoto Protocol (KP) signed in 1997 clearly defined the remaining five kinds of greenhouse gases (GHGs) besides CO₂, namely methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). During the 2011 Durban negotiations, the second commitment period of KP, nitrogen trifluoride (NF₃) was added to the GHG index. Thus, under United Nations Framework Convention on Climate Change (UNFCCC), there are six kinds of non-CO₂ GHG, which can be divided into three broad categories: CH₄, N₂O, and fluorinated gases (F-gases). CH₄ and N₂O are natural gases which already exist, and increase due to human activities, while F-gases are entirely the product of human activities. In order to measure the global warming effect of these non-CO₂ GHGs, the Third As-

essment Report of the Intergovernmental Panel on Climate Change (IPCC) introduced the concept of CO₂ equivalent (CO₂-eq). Through multiplying one gas's emissions in tons and its global warming potential (GWP), we can obtain the CO₂-eq of this gas. By such a method we can standardize the warming effect of different GHG.

Due to the dual pressures caused by global warming and environmental pollution, the international community is beginning to focus on non-CO₂ GHG emissions. The Nordic region (Denmark, Finland, Faroe Islands, Iceland, Norway, Sweden and the Aland Islands) signed the Svalbard Declaration, aiming at reducing the short-lived climate forcers (SLCFs) in March 2012, and released the report of Nordic Workshop on Action Related to Short-lived Climate Forcers on December 26, 2012. The report regarded that taking early actions on CH₄, black carbon (BC) and some

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Corresponding author: ZHOU Ya-Min, fengzhouyamin@foxmail.com

F-gases could reduce the speed of global warming in short term (20–30 years). In 2010 the global non-CO₂ GHG emissions were 11.702 Gt CO₂-eq [EPA, 2012a], accounting for 27.8% of the total GHG emissions. IPCC [2013] projected that emissions of HFCs will triple in 2015, which are due to the growing use of HFCs in the refrigeration industry, and also the HFC-23 emissions as byproduct of increased production of HCFC-22 (chlorodifluoromethane). Nordic Air Quality Working Group [NCCAQ, 2013] considered that, although the current proportion of HFCs is not high, its contribution to global warming will reach 19% in 2050. Rao and Riahi [2008] argued that under the same reduction targets, reducing CO₂ and non-CO₂ simultaneously will cut down mitigation costs significantly in a short time. Lucas et al. [2007] argued that CH₄ related to the energy activity and F-gases have huge reduction potential (in 2100 will reduce by about 90% compared with the baseline[Ⓣ]), while the CH₄ and N₂O related to land have difficulty in achieving emission reductions.

Domestic studies on the F-gases also began to take shape. It is pointed out [SNARCCWC, 2011] that China's F-gases are mainly concentrated in economically developed urban agglomerations and industrial areas, including Beijing, Tianjin, Hebei, the Yangtze River Delta, Pearl River Delta, Hong Kong and Taiwan. Domestic scholars have done a lot of work on CH₄ reduction. Huang [2012] argued that from the view of national sustainable development, the advantage of levying tax on GHG emissions from rice paddies outweighs the disadvantage. Ma et al. [2010] found that changing the fertilization strategy can effectively reduce CH₄ emissions from rice paddies. Le et al. [2012] have shown that China's largest source of anthropogenic CH₄ emissions comes from coal mining, followed by enteric fermentation and rice cultivation in the second and third place. Pan et al. [2010] argued that the development of biochar technologies can not only solve the problem of GHG released from the combustion of straw, but also improve the soil and increase production, and will be a future potential technology option of climate change mitigation. In addition, there are also studies calculating GHG emission

reduction potential of agricultural waste disposal at different costs [Qin, 2012].

China emits much more non-CO₂ GHG than any other countries. In 2010, China's non-CO₂ GHG emissions accounted for 13.6% of the global emissions. With rapid urbanization and industrialization moving forward, China will inevitably consume a lot of energy and resources, and produce more emissions. Facing global climate change problem issues, China can cut down non-CO₂ GHG emissions to reduce international pressure on CO₂ emissions, and to provide more flexible spaces and policy choices for China's low-carbon economy. As survival time of some non-CO₂ GHGs in the air is short, and there are many practical and effective reduction measures, the effect of non-CO₂ GHG emission reduction will be seen in a short term. In addition, the reduction of non-CO₂ GHG emissions will also bring co-benefits to health, economy and agricultural activity. Under the strategic policy arrangements and appropriate technology choices, China can gain environmental protection and GHG control.

2 The status of China's non-CO₂ GHG emissions

In 2010, China's non-CO₂ GHG emissions were 1.587 Gt CO₂-eq [EPA, 2012b], accounting for 18% of the total GHG emissions. Among them CH₄ accounted for 58.3%, N₂O accounted for 26.2%, and F-gases accounted for 15.5%.

2.1 The status of China's CH₄ emissions

The GWP of CH₄ is 25 times as that of CO₂ (in 100 years), and its lifetime is 12 years. About 40% of atmospheric CH₄ emissions are from natural sources, including wetlands, alpine meadow plants, termites and oceans. The main sources of anthropogenic CH₄ are ruminant feeding, petroleum systems, landfills, rice cultivation, coal mining, wastewater treatment, and biomass burning. In China's oil and gas industry, 39% of CH₄ emissions is from the production of crude oil, 30% is from natural gas production, and 16% comes from natural gas transportation [Yang and Chen, 2012]. On the landfill aspect, China's current

[Ⓣ]The baseline refers to emissions without any abatement measures

annual production of landfill CH_4 is more than 5 billion m^3 , which can be transformed into about 20 billion kW h electrical energy. In those areas with more dense populations and higher economical development, the landfill gas production is higher, showing the geographical decreasing trend from east to west. If full use of landfill gases is achieved, China's annual consumption of alternative natural gas for livelihood will be about 30% [Bu and Zhang, 2012]. Paddy fields are one of the most important sources of atmospheric CH_4 emissions. According to the IPCC Fourth Assessment Report [IPCC, 2007], the annual CH_4 emissions from paddy fields are 31–112 Mt, accounting for 5%–19% of the total global CH_4 emissions. China is the world's largest producer of rice, and the rice paddies fields account for 22% of the world's total, so the quantity of CH_4 emissions from rice paddies is larger.

2.2 The status of China's N_2O emissions

The main factor leading to the atmospheric N_2O increase is the excessive use of agricultural nitrogen fertilizer, which causes an increase in emissions from agricultural soils. The GWP of N_2O is 296 times that of CO_2 (in 100 years), and its lifetime is 120 years. China's N_2O emissions from industrial production process have three main sources: the nitric acid production process, adipic acid production process, and caprolactam production process. Sewage treatment process is another important source of N_2O release. China has the largest sewage treatment capacity in the world. The N_2O emissions of landfill account for 3% of the total N_2O emissions. Studies have shown that landfill sites and leachate treatment plants are the main sources of N_2O from municipal solid waste landfill. The analysis and estimation of China's regional N_2O source show that the natural source and anthropogenic source accounts for 71% and 29%, respectively [Wang and Su, 1993].

2.3 The status of China's F-gases emissions

Although currently the F-gases' proportion of the total GHG is not high, these gases generally have a high GWP level, which is hundreds or even tens of thousands times that of CO_2 . In 2005, China's F-

gases emissions during industrial process were 93–282 Mt CO_2 -eq. With the help from an ideal technical and financial support, the relative reduction potential of China's industrial process F-gases by 2020 will be 96–346 Mt CO_2 -eq [Huang, 2012]. In the 1990s, HFCs were first produced and applied in developed countries, and the United States was the largest output country at that time. After 2007 HFCs entered the fast growth phase in developing countries, especially since the financial crisis, a number of developed countries have started to transfer HFCs production capacity to China, and as a result China's HFCs production has surpassed that of the United States. With the rapid development of the domestic auto industry, the policy implementation of electrical home appliances to the countryside as well as the real estate development, China's HFCs are experiencing rapid expansion of production capacity.

PFCs have excellent stability, low surface tension, water and oil repellency, and their production has over 50 years history. PFCs are widely used in chemical, textile and other fields. PFCs can be accumulated in blood, liver, kidneys and other organs of animals and humans. With long-distance transmission capacity, PFCs thus have a wide range of contamination. China has big production and use of PFCs organic compounds, and some studies indicate that there are PFCs contamination in water, biological and other media.

Although the impact of SF_6 accounts for only 0.1% currently, its GHG effect is 25,000 times that of CO_2 , and it has a very long lifetime about 3,400 years. Foundries use SF_6 as a protective gas to prevent the high melting magnesium from being oxidized. Usually all SF_6 used as a protective gas, will eventually be released into the atmosphere. According to SNARCCWC [2011], China will emit 3–33 Mt CO_2 -eq SF_6 during magnesium production process in 2020.

As an excellent plasma etching gas, NF_3 is widely used in chip manufacturing and high-energy lasers. In recent years it has been widely used for liquid crystal displays and photovoltaic fields. Most NF_3 is destroyed in the production process, but there is some slip escape into the atmosphere, which can retain in the atmosphere for 740 years. For 2005–2011, the ac-

tual average annual growth rate of global NF₃ production was 19.4% [CCN, 2009]. China has large capacity in the production and use of products from the semiconductor industry, photovoltaic industry and display industry. During the development of these emerging industries, there will be inevitably large NF₃ emissions.

3 China's non-CO₂ emission trend

According to the United States Environmental Protection Agency (EPA) forecast data (Fig. 1), regardless of the total emission perspective or the emission growth rate perspective, the amount of China's non-CO₂ emissions takes the first place in the world, and the two indices are both far above those of other countries. Such a situation is really worrying, because some non-CO₂ GHGs exist for a long time with high GWP, and have extremely negative impacts on the global environment. In the future, China will face huge international pressure to reduce emissions, and the domestic environmental conditions will deteriorate, possibly resulting in the economy and society stepping into a period of extremely unhealthy development.

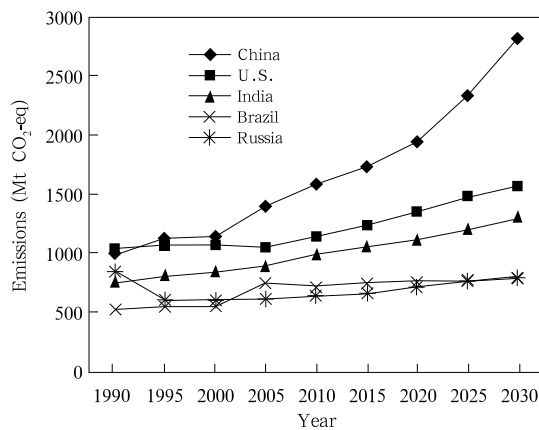


Figure 1 The global non-CO₂ emissions before 2030 [EPA, 2012b]

Seen from Figure 2, before 2030 among China's non-CO₂ GHG emissions, CH₄ will rank first for a long time, while N₂O will increase slowly. However, F-gases will show a sharply accelerated upward trend, and in 2030 it is likely to exceed CH₄. Since F-gases

are mainly emitted during the industrial processes, with the rapid development of China's automobile industry and new energy industry, there will surely be much more F-gases used in the manufacturing process. Therefore, finding a way to effectively control F-gases emissions, reducing its escape as well as leakage, and disposing the end gas safely, will become the future top priority of non-CO₂ GHG reduction strategy.

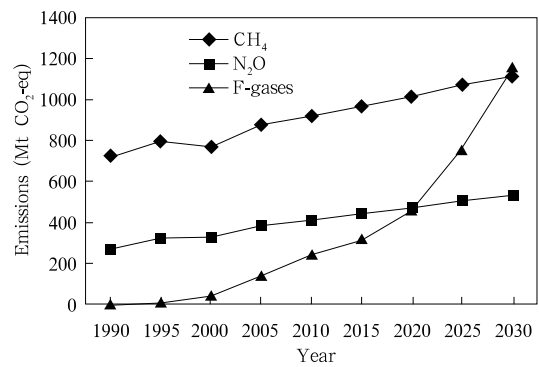


Figure 2 China's non-CO₂ emissions before 2030 [EPA, 2012b]

4 The technology selection of non-CO₂ emission control

Most of CH₄ emissions are from agricultural activities, hence there is a certain degree of difficulty in achieving rapid reduction. Comparing with continuous submergence during rice growing period, baking the field, intermittent irrigation and wetting irrigation can reduce CH₄ emissions from rice paddies by 45%, 59% and 83%^②, respectively. Comparing with stable manure, green manure and straw manure, no fertilizer or chemical fertilizer can reduce CH₄ emissions by 50%–66%, while compost or bio-gas residues can reduce CH₄ emissions by 45%–62%. By changing the planting and fertilizing method in the agricultural production process, China can reduce CH₄ emissions. During the coal mining process, China needs to quickly develop gas production technologies and processes which are suitable for the storage conditions of coal bed gas to reduce CH₄ escape. In terms of waste disposal, the main artificial controlling measures of

^② The data are obtained by collecting and analyzing CH₄ emission data of more than 70 domestic papers and 350 different water management tests

CH₄ emissions include: 1) the classification of waste and landfill, taking full advantage of CH₄ generated from organic waste as fuel or electricity; 2) improving landfill facilities, and reducing landfill humidity to suppress the generation of CH₄; 3) screening CH₄-oxidizing bacteria with good environmental adaptability, and inoculating it in landfills, promoting the oxidation of CH₄; 4) changing the landfill construction from oxygen-weary type to semi-aerobic type or leachate recirculation semi-aerobic type.

N₂O emissions from agricultural soil accounts for a large proportion. Although its fast reduction cannot be achieved in a short term, we are still able to reduce N₂O emissions by artificial means, such as using precision fertilizer, improving efficiency of nitrogen fertilizer and avoiding excessive fertilization. In China the fertilizer utilization rate of rice and wheat is only 28%–41%, hence choosing the appropriate nitrogen fertilizers, applying deep application of fertilizer or mixed fertilizer and using nitrification inhibitors can significantly lower emissions. During the process of farmland cultivation, the future mainstream strategy will be to vigorously promote formula fertilization by soil testing. If the formula fertilization by soil testing can become the nationwide standard, the fertilizer utilization rate is expected to increase by more than 3%, and can reduce farmland N₂O emissions by around 3% [Qin, 2012]. According to the statistics of UNFCCC[Ⓢ], the current abatement cost of N₂O in the CDM (clean development mechanism) projects is about \$9 per ton CO₂-eq.

Most of F-gases will generate toxic gases and powders after decomposition, which result in strong irritation and corrosion for the upper respiratory tract of humans as well as animals. There should be a requirement for the allowable concentrations of SF₆ and its toxic decomposition. It is suggested that in the workplace where SF₆ is produced and used, the maximum concentration of SF₆ should not exceed 6,000 mg m⁻³. Besides, it is suggested that measures be taken to improve gas recycling of SF₆ and its composition, reduce leakage rates and adopt other substitute gases. As a byproduct and escape gas, technically speaking, more than 90% of HFC-23 can be captured and eliminated

from the production of HCFC-22. However, from now until 2015, the anticipated production of HCFC-22 will increase, and the HFC-23 emissions may increase by 60%. A very effective mitigation option to capture and eliminate HFC-23 is thermal oxidation, and the clearance rate can reach 99% or more, but the impact of thermal oxidation equipment downtime on emissions must be taken into consideration. Assuming the lifetime of HFC-23 is 15 years, the abatement cost is less than \$0.2 per ton CO₂-eq.

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