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Abatement cost analysis in CO_2 emission reduction costs regarding the supply-side policies for the Taiwan power sector

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HIGHLIGHTS

- This study uses a multi-objective planning method.
- To minimize the cost and reduce carbon dioxide emissions by decreasing the dual objective.
- Nuclear units will be able to reduce the costs of power generation on electricity and carbon dioxide emissions.
- As fossil fuel prices increase, gas will experience a reduction in carbon reduction benefits.

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ABSTRACT

Because Taiwan is an island nation, it is difficult to obtain energy from external power suppliers; therefore, advance planning and scheduling of power development is crucial. This study uses a multi-objective planning method to minimize the cost of power generation and reduce carbon dioxide emissions by decreasing the dual objective of building the power supply scheduling model and the target year. This is conducted according to simulations of future carbon emission reduction policies for the scheduling of power supply situations. The results show that nuclear units will be able to reduce the power generation electricity costs and carbon dioxide emissions effectively; renewable energy has excellent potential to reduce emissions, and the cost of solar power technology with high fossil fuel prices will gradually enhance its cost competitiveness. Gas, although the cleanest fossil fuel, cannot be underestimated for its carbon dioxide emissions. As fossil fuel prices increase, gas will gradually experience a reduction in carbon reduction benefits; integrated gasification combined cycle with carbon capture and storage technology will replace part of the oil and gas power generation, and in addition to the reduction of carbon dioxide and costs, will achieve the goal.

1. Introduction

Electricity demand is similar to technological products. With advancements in technology and the stabilization of society, electricity has become an irreplaceable necessity in people's lives. However, electricity is and always has been difficult to store. With no reserves in stock, instantaneous electricity demand often requires immediate power production. Planning and construction for large power plants and power transmission and distribution infrastructure are time consuming and capital intensive. Meanwhile, Taiwan is an island nation unable to connect to external sources of energy. Accurate forecasting of future demand for power, however, can facilitate appropriate development and dispatching of power sources. This can simultaneously avoid stagnation in industrial development and reduce the difficulties caused to people's lifestyles, resulting from an insufficient supply of power and avoiding waste of resources and idle power plants because of over investments. Therefore, power demand forecasting is a crucial topic for the power industry.

The economy has flourished since the industrial revolution. Behind this advanced economization is a vast consumption of fossil fuels. Fig. 1 displays the speed of primary energy demand growth, in which fossil fuels continue to occupy an indispensable standing. International Energy Agency (2010b, c) estimated that CO_2 emissions will double between 2007 and 2050 (see Fig. 2).

Overall, analysis of the total energy consumed in Taiwan shows that power accounted for the highest proportion at 48.6% in 2010. In addition, coal-fired units were the main power supply structures

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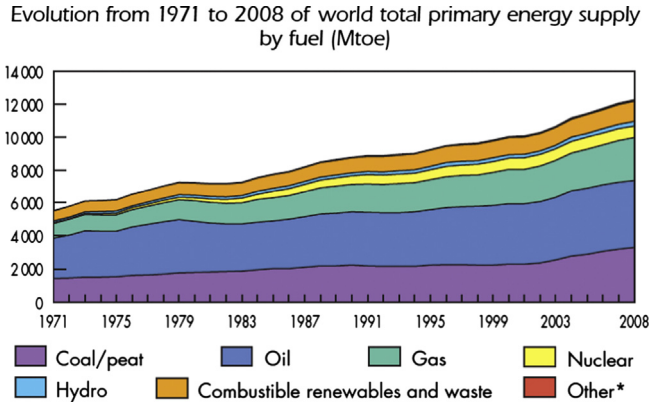

Fig. 1. World primary energy supply.
Source: International Energy Agency, 2010a.

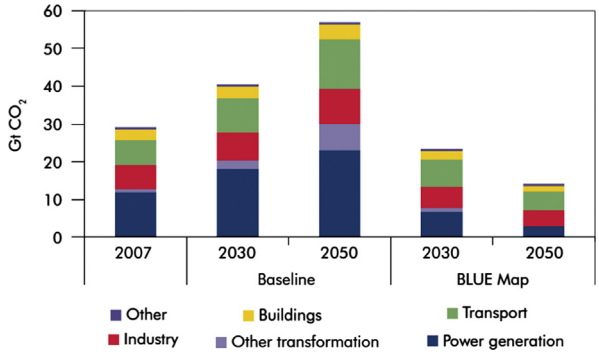

Fig. 2. IEA CO_2 emission estimates.
Notes: In this chapter, unless otherwise noted, industry includes blast furnaces and coke ovens, as well as the non-energy use of petrochemical feedstocks. Industrial-process emissions are excluded. Others includes agriculture, fishing and forestry. Unless otherwise indicated, all material derives from IEA data and analysis.
Source: International Energy Agency, 2010c

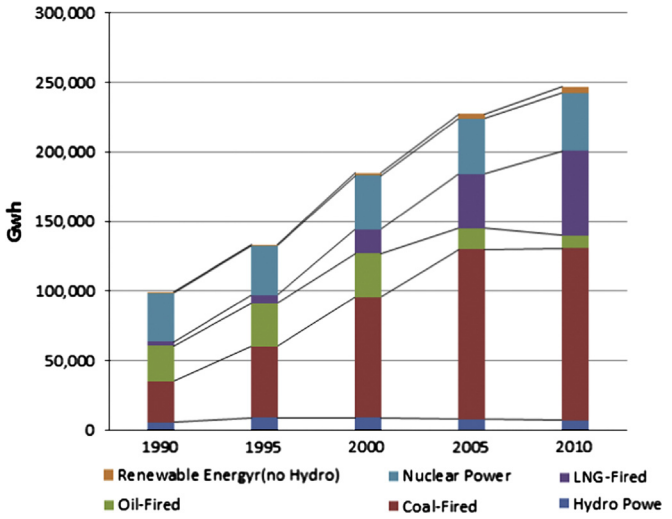

Fig. 3. Power generation structure in Taiwan.
Source: The Bureau of Energy, Ministry of Economic Affairs, 2011; compiled in this study.

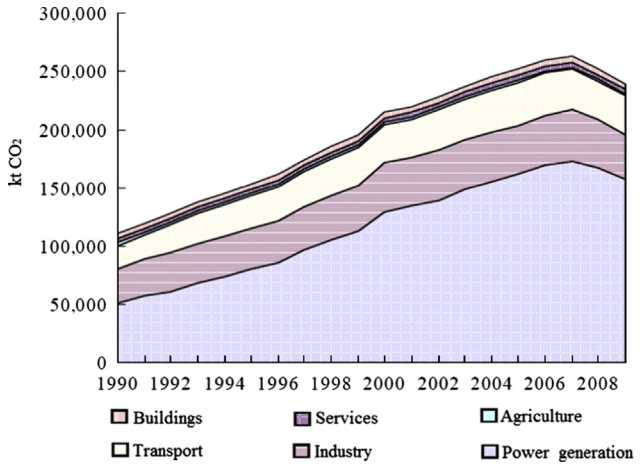

Fig. 4. CO_2 emissions in Taiwan by sector.
Source: The Bureau of Energy, Ministry of Economic Affairs, 2010.

in Taiwan, accounting for 49.91% in 2010, which caused the level of CO_2 emissions from the power sector to surpass that of other sectors (Figs. 3 and 4). Consequently, to achieve the government's reduction target, the power sector is frequently considered as the starting point for reduction endeavors. The development of a system for supporting power technology development decisions to achieve multiple objectives, such as a stable power supply, CO_2 reduction, and low costs, is a crucial topic.

Plans for a complete and stable national power supply system, in addition to depending on multiple expert opinions, must consider recent international trends in power development and should gradually conform to environmental awareness. Long-term power supply planning is a lengthy process requiring readjustments to any point. This study used multi-objective planning to construct a power supply model. Using past historical data and various corresponding energy policies, including data on private power plants and cogeneration under both CO_2 emission limits and the open market, various scenarios were simulated to enhance understanding on the ideal future power supply scenario. This study can act as a reference for future power planning development and power industry decision makers. Therefore, the primary research objectives were as follows: (1) to examine emerging technologies and future directions of CO_2 reduction in the domestic and foreign power sector, constructing a simulated scenario for the application of CO_2 reduction technologies; and (2) to construct a power supply planning model simulating CO_2 reduction potential and relative costs for each technology and scenario using either economization of power generation or reduction of greenhouse gases as the objective.

The power supply model comprised a demand-side power load forecasting model and a supply-side power supply planning model. However, because demand-side data are excessively complex and cannot be easily obtained, and considering that the main objective of this study was to investigate the effects that incorporating novel technologies, such as renewable energy and supercritical coal-fired units, has on power supply scheduling, we focused on reviewing literature related to the power supply planning model.

Chen et al. (1993) conducted a detailed review of the various power load demand forecasting methods. The results showed that before the 1970s, the power companies in various countries typically employed inexpensive and simple statistical methods (e.g., trend analysis and extrapolation forecasting methods) to predict the power load demand required by the country in the future.

Blok et al. (1993) discussed the potential for improving energy efficiency in the Netherlands by 2000 using a database of 300 energy conservation techniques. The investigation results showed that an emissions reduction of 41% was technically feasible with the application of all energy conservation techniques. The Dutch government's policy aims to increase energy efficiency by