Marginal CO2 emissions rates in Singapore's power generation sector: potentials for CO2 abatement

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Overview

Studying temporal patterns in emissions associated with electricity generation is increasingly important. On the supply side, there is interest in integrating renewable energy sources (solar, wind), which are known to vary daily and hourly. The CO2 abatement potential of such power sources is heavily dependent on the CO2 rates of substitued fossil power generators (marginal power generators). On the demand side, the concept of demand response is driving a need to better understand the impact of peak versus off-peak loading, with the objective of maximizing efficiency.

In this study, we examine the case of electric power generation in Singapore, and aim to assess the half-hourly variation in associated marginal carbon dioxide emissions. This result can be used to profile any electrical product or service for which temporal effects are important.

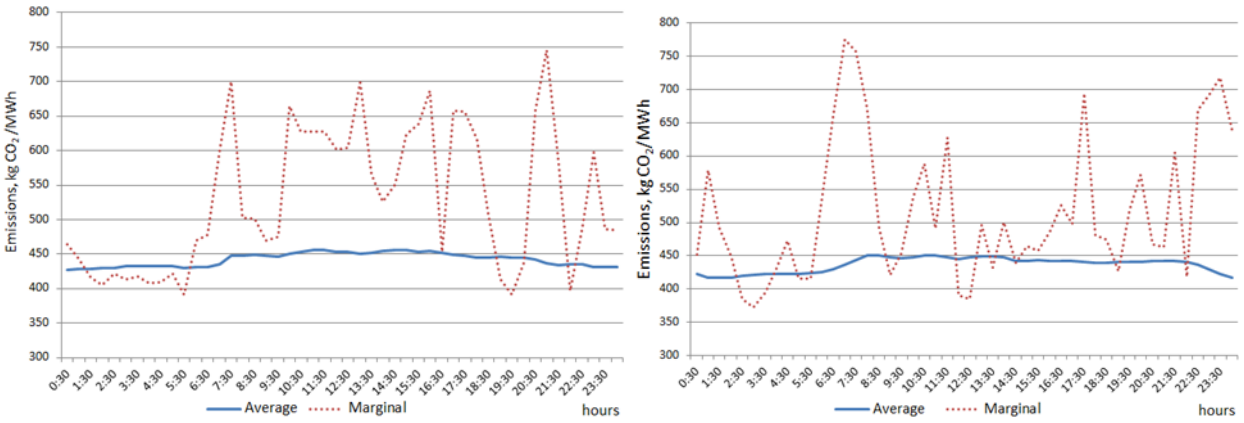
Power generation in Singapore is fuelled predominantly by natural gas in combined-cycle plants (about 90%). Other fuel sources include fuel oil, waste incineration and diesel, resulting in an estimated average grid factor of 487 kilograms of CO2 per MWh generated. Depending on the dispatch orders in the electricity market, the fuel mix would vary. Uncertainties also arise from the many (53) generating turbines with different technical parameters and operational efficiencies.

By associating representative generation data with the characterized fleet of power plants, half-hourly marginal emission factors show a fluctuating daily pattern and are generally higher than the average emission factors, exceeding 800 kg CO2/MWh during on-peak times. Consequently, the study shows that the abatement potential of any CO2 neutral power sources could be as high as 800 kg CO2/MWh. In the case of Singapore, such abatement could be effectively achieved by using solar energy, because its maximal production coincides with the peak demand hours.

Methods

The study employs a bottom-up method of estimating CO2 emissions. The analysis of the daily CO2 profiles is based on the actual half-hourly electricity generation data set for a representative weekday, weekend and a public holiday. Heating values and carbon contents of fuels used for power generation were sourced from the latest available IPCC database. Details about the municipal waste composition in Singapore were collected from the Singapore Waste Statistics. Information about power plant efficiencies and factors affecting power plants performance was estimated based on the technical documentation and from consultations with power companies. As far as possible, these parameters were obtained for the types of equipment used for power generation in Singapore.

Results



Conclusions

As showcased in this analysis, differentiating between the average and the marginal factors is critical for understanding of the environmental implications of load shifting activities that affect the grid in the short term. While the power generation sector in Singapore has one of the lowest average emissions rates in the region, the marginal emission rates are often exceeding the average values by a significant proportion over the daily cycle. For newer clean technologies and policies such as renewable energy integration, energy efficiency, demand response measures, and electric vehicles, this would have an important consequence when allocating the associated environmental benefits in terms of emission reductions.

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