Here we provide an explanation of the extra payment of the source-based pricing method, namely, the Method 1. Fig. 1 illustrates the bidding curves and the demand curve of an energy market (typically, the coupled traffic-power networks in this work). The generation bidding curves are presented in different styles, with the solid line representing the bidding without the carbon tax and the dotted line representing the bidding when a carbon tax is imposed on generators. For illustrative purposes, the energy demand is assumed to be fixed (the conclusion still holds for elastic demand).

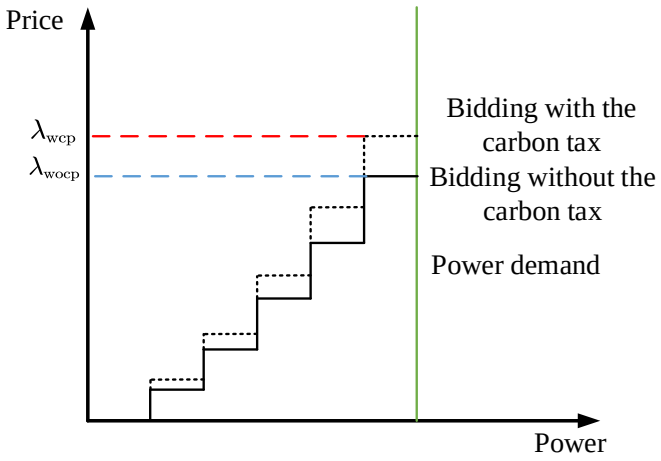

Fig. 1. Illustration of the extra payment of the source-based pricing method (Method 1)

According to Fig. 1, the energy price would be λ_{wocp} in the absence of a carbon tax. In contrast, the new energy-carbon integrated price (which is different from the definition in this article) becomes λ_{wcp} when the carbon tax is introduced. λ_{wcp} can be expressed as:

$$\lambda_{\text{wcp}} = \lambda_{\text{wocp}} + \phi\rho^{\text{bidding}}$$

where ρ^{bidding} is the carbon intensity of the marginal unit in the bidding process.

Therefore, the actual carbon price imposed on consumers can be calculated (in \$/MWh)

$$\phi_{\text{act}} = \frac{\lambda_{\text{wcp}} - \lambda_{\text{wocp}}}{\rho_{\text{act}}} = \frac{\rho_{\text{bidding}}}{\rho_{\text{act}}}\phi$$

where ρ_{act} expresses the carbon emissions per MWh of demand, specifically, the actual carbon emissions traced using the carbon emission flow theory.

In general, the marginal unit is more carbon-intensive, resulting in $\rho_{\text{bidding}} > \rho_{\text{act}}$. Thus, $\phi_{\text{act}} > \phi$, which implies that the actual carbon price charged to consumers per ton of CO_2 would be larger than the carbon tax. In essence, consumers would incur higher costs than the intended carbon tax rate for their carbon emissions, resulting in an extra payment.