# Merchant Storage Investment in a Restructured Electricity Industry

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**Abstract**

Restructuring and liberalisation of the electricity industry creates opportunities for investment in energy storage, which could be undertaken by a profit-maximising merchant storage operator. Because such a firm is concerned solely with maximising its own profit, the resulting storage-investment decision may be socially suboptimal (or detrimental). This paper develops a bi-level model of an imperfectly competitive electricity market. The modelling framework assumes electricity-generation and storage-operations decisions at the lower level and storage investment at the upper level. Our analytical results demonstrate that a relatively high (low) amount of market power in the generation sector leads to low (high) storage-capacity investment by the profit-maximising storage operator relative to a welfare maximiser. This can result in net social welfare losses with a profit-maximising storage operator compared to a no-storage case. Moreover, there are guaranteed to be net social welfare losses with a profit-maximising storage operator if the generation sector is sufficiently competitive. Using a charge on generation ramping between off- and on-peak periods, we induce the profit-maximising storage operator to invest in the same level of storage capacity as the welfare-maximising firm. Such a ramping charge can increase social welfare above the levels that are attained with a welfare-maximising storage operator.

*Keywords:* Energy storage, bi-level modelling, market power
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## 1. Introduction

Recent years have seen a renaissance in the development of energy storage. Sioshansi et al. (2012) note that this interest in storage is prompted by a number of recent electricity-industry developments. One is that storage was viewed almost exclusively as an alternative to high-cost peaking generation in the 1970s, when much of the pumped hydroelectric capacity that is installed today was first built (*cf.* the work of EPRI (1976) as one example showing this). More recent analyses of energy storage, with the work of EPRI-DOE (2003) being a seminal example, recognise that storage can provide many services beyond avoiding the cost of installing and operating peaking generation. A second major development is the advent of restructured electricity markets, which provide transparent price signals for many of the services that energy storage can provide. Finally, Denholm et al. (2010) note that energy storage is expected to have a growing role in electric power systems as the penetration of variable renewable energy grows. As another example of this,

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