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Impact of fuel-dependent electricity retail charges on the value of net-metered PV applications in vertically integrated systems

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HIGHLIGHTS

- A top-down approach of developing traditional electricity charges is provided.
- The combined effect of pricing strategies, rate structures and fuels is examined.
- Fossil fuel prices can substantially affect the net metering compensation.
- A financial risk assessment for net-metered PV systems is performed.

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ABSTRACT

Retail electricity charges inevitably influence the financial rationale of using net-metered photovoltaic (PV) applications since their structure as well as their level may vary significantly over the life-cycle of a customer-sited PV generation system. This subsequently introduces a further uncertainty for a ratepayer considering a net-metered PV investment. To thoroughly comprehend this uncertainty, the paper employs a top-down approach – in vertically integrated environments – to model the volatility of partially hedged electricity charges and its subsequent impact on the value of bill savings from net-metered PV systems. Besides the utility's pricing strategy and rate structures, particular emphasis is given in modeling the fossil fuel mix component that introduces a significant source of uncertainty on electricity charges and thus on the value of bill savings of net-metered, customer-sited, PV applications.

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1. Introduction

Net metering (NEM) is an electricity policy that allows utility customers to offset some or all of their electricity consumption by using their own generating system, mainly rooftop photovoltaic (PV) systems. NEM is an alternative to feed-in-tariff (Fi) schemes that have been widely adopted as a cost-effective measure to promote the installation of distributed generation (DG) systems. A FiT scheme is a form of subsidy that guarantees a predetermined price to the PV electricity producers by enforcing the grid operators to purchase their electricity output under long-term contracts. On the other hand, NEM schemes work by offsetting households' energy consumption, while any excess energy may be credited back to consumers, at retail price or at an avoided cost rate. Alternatively, the excess energy may be transferred to a subsequent billing period to be used as energy credit against future electricity usage.

Thus, as the market for distributed PV generation is growing and as the associated capital costs continue to decline, NEM policies are becoming increasingly attractive to homeowners of all incomes. However, the return on investment in such schemes is highly related to the volatility of electricity retail prices as these are the dominating factors that affect the value of the net-metered applications. The picture becomes more complex, bearing in mind that the retail tariff charges are subject to change over the life-cycle of a distributed PV system. This introduces a further uncertainty for a ratepayer considering a long-term net-metered PV investment.

To this end, NEM policies have induced a skepticism on a range of stakeholders due to: (a) uncertainties arising from the major shifts in the way consumers are using and, subsequently, paying for their energy (Hatami et al., 2011), (b) the financial impact of such policies on ratepayers that do not participate to NEM schemes (Beach and McGuire, 2013), and (c) the sustainability of the existing retail energy market structures to accommodate such policies (Borenstein., 2007). Thus, utilities and regulatory authorities are actively searching for NEM schemes that can: (a)

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promote distributed PV energy penetration and (b) exhibit minimal distortions to utilities' revenue requirements.

It is, however, clear that electricity retail rate designs influence the customer-side financial rationale of using net-metered PV generation both for residential and commercial customers. In particular, a number of recent studies have examined the influence of specific rate structures (flat, tiered or time differentiated) on the annual bill savings of net-metered PV customers (Black, 2004; Mills et al., 2008; Darghouth et al., 2011; Poullikkas, 2013).

Some further studies (Borenstein, 2005; Suna et al., 2006) have discussed the impact of wholesale electricity market characteristics (e.g., renewable energy penetration, capacity, energy and loss savings) on the value of distributed PV systems. Within those studies, it is acknowledged that the wholesale electricity market profile can subsequently influence the cost of retail electricity supply and thus, the value of NEM compensation mechanisms. A primary step to address the influence of the retail price change on the value of NEM compensation mechanisms is found in Darghouth et al. (2013). The study in Darghouth et al. (2013) has considered retail rate designs and NEM in parallel with potential changes under future electricity market scenarios for California, US. It has particularly examined: (a) the influence of both high future PV and wind energy penetration, (b) the influence of high and low natural gas prices and (c) the influence of carbon emission pricing on the value of bill savings under a range of rate options and PV compensation mechanisms.

Our paper, in particular, focuses on the customer-side financial rationale of using solar technology and investigates the impact of a key source of uncertainty in the future value of bill savings from residential net-metered PV systems, particularly in vertically integrated systems. The source of uncertainty rests with changes in retail electricity charges, mainly affected from volatile fossil fuel prices. To isolate the effect of fossil fuel varying prices in a vertically integrated environment, on the value of annual bill savings from PV net-metered systems, a top-down approach ranging from residential electricity tariff formulation to fossil fuel price forecasting and net metering compensation mechanisms is presented. Therefore, the scoping study responds to the ongoing efforts of developing risk and cost-based decision making processes for net-metered PV applications and investments in vertically integrated systems. The latter suggests that the generation, transmission and distribution facilities are owned either by private regulated utilities or by public companies/government agencies which operate as a natural monopoly for the supply of electricity in a given geographical area (Stoft, 2002). This type of electricity market organization has been predominant in the past century before the deregulation and the introduction of competition in the electricity sector (mainly at the supply side) (Kirschen and Strbac, 2004), however it is still applicable in many occasions and for various reasons (T. E. Parliament and the Council of the European Union, 2009). In such vertically-integrated systems, tariff structures aim to reflect on the fixed and variable costs incurred by utilities to produce and transmit each kWh of energy to all electricity end-users that receive services in their jurisdiction. Conversely, under liberalized electricity markets, customer tariffs reflect on the competitively determined electricity prices derived from the continuous interaction of multiple generating and load-serving entities (Kirschen and Strbac, 2004).

2. Methods

2.1. *Retail electricity charges and net metering compensation mechanisms*

Under net metering, retail customers can offset their electricity purchases from the grid with energy generated from their own rooftop PV systems. Thus, net metering values the energy produced by these PV systems at the rated value of retail electricity. The retail electricity rate includes the cost of producing electrical energy, the costs associated with investment in and operation of transmission and distribution facilities as well as any other costs incurred to ensure the reliability of the system.

Thus, this section provides a generic top-down approach that includes a sample of retail electricity tariff formulations as well as their interface with net metering compensation mechanisms.

2.1.1. *Total revenue requirements – vertically integrated systems*

The total revenues collected from the sale of electricity should recover the utilities' total costs of providing the service plus a fair rate of return. Under the traditional regulation of vertically integrated utilities, this revenue requirement is determined by inclusion of both fixed and variable costs. A generic illustration of the Total Revenue Requirements (*TRR*) is given in the following equation.

$$TRR = FiC + VrC \tag{1}$$

With reference to (1), *FiC* refers to the fixed cost component and comprises all the fixed related expenditure of the utility's total costs (e.g. levelized fixed costs from generation down to distribution, fixed price contracts, etc.). *VrC* refers to the variable cost component and represents the total variable costs (e.g., fossil fuels, CO_2 emissions, operation and maintenance, etc.) that are a function of the energy units produced.

The fixed cost component (*FiC*) is usually a function of the overnight costs of the generation, transmission and distribution facilities owned by the utility plus any other associated fixed price contracts and financial obligations (Stoft, 2002; Kirschen and Strbac, 2004). A general mathematical formulation of the annual fixed cost component is shown in the following equation.

$$FiC = \sum_{g=1}^{G} [(LC_g + FOM_g) \times P_g^{\max}] + LC_{TD} + FO \tag{2}$$

With reference to (2), *G* refers to the total number of generating units in a system, LC_g refers to the annual levelized capital cost of each generating unit *g*, FOM_g is the fixed operation and maintenance cost and $P_g^{\max}$ is the rated capacity of each unit *g*. Moreover, LC_{TD} refers to the annual levelized capital costs of transmission and distribution facilities. Finally, *FO* refers to the associated costs of any other annual financial obligation of the utility.

Unlike fixed costs, the variable costs (*VrC*) are a function of the energy units produced. These comprise fossil fuel costs, CO_2 emission costs as well as operation and maintenance expenditures (Stoft, 2002; Kirschen and Strbac, 2004). The mathematical formulation of *VrC* is shown in the following equation.

$$VrC = \sum_{g=1}^{G} ER_g \times (FC_g + EMC_g + VOM_g) \tag{3}$$

With reference to (3), FC_g is the fuel cost (in \$/MWh), EMC_g refers to the associated CO_2 emissions costs (in \$/MWh), whilst VOM_g refers to the variable operation and maintenance costs (in \$/MWh). Finally, ER_g refers to the total energy (in MWh) produced by each generating unit *g*.

2.1.2. *Formulation of retail electricity charges from first principles*

Vertically integrated utilities aim to allocate their total revenue requirements to all of their customers' classes (e.g. residential, commercial, industrial, rural, etc.) that receive service in their jurisdiction. To this aim, appropriate tariffs are designed to establish a revenue collection mechanism. Within each tariff, the

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