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Evaluating the effect of technology transformation on the electricity utility industry

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ABSTRACT

The technology shift from fossil-fuelled systems to renewable energies has been promoted by governments with the purpose of decarbonising the power industry. However, rapid technology progress has prompted disruptive changes that transformed market structures. Incumbent electricity utilities, particularly those based on fossil-fuel plant, are shifting from their stable and predictable situation to confront challenges from those that offer alternative energy services. In this new environment, the industry will benefit from mid- to long-term sector foresight.

The paper studies the potential impact of renewable energy sources (RES) on electricity systems, specifically on the generation and distribution businesses. For this purpose, a fairly detailed and integrated supply and demand-based system dynamics model has been built to quantify the extent of their potential impact; the model disaggregates the household sector, which may generate a significant part of its electricity using rooftop solar energy. This is illustrated by examining a utility engaged in the generation and distribution businesses in the Colombian electricity market. Through simulation runs, this paper concludes that, subject to policy and all other things remaining equal, solar rooftop generation is a major threat for utilities; while the generation business is most affected in the short-term, the distribution business is the one most impacted in the long-term, and jointly they may induce the utility "death spiral".

1. Introduction

In the late 1980s, following market efficiency principles, the liberalisation of the electricity industry was pioneered by Chile (1982) and Britain (1990), and soon after they were followed by many other countries around the world [1,2]. Nonetheless, as governments have presently set targets for decarbonisation and renewable generation, it seems that there is a shift towards a more centralised view of markets, as current liberalisation does not provide signals to meet investment goals with low-carbon generation [3,4]. Under these conditions, as renewable energy is becoming a political priority of governments around the world, electricity utilities face both a rapid technological transformation and regulatory uncertainty [5].

According to Schleicher-Tappeser [6], the technologies with significant potential for disrupting the electricity sector are solar and wind energy, the former to a greater extent than the latter; here, a 'disruptive' technology usually means "cheaper, simpler, smaller, and frequently, more convenient to use" [7]. Some authors have compared the disruption by renewables in electricity with that which took place in the telephone industry, in electric lighting, and in digital photography [8]. Regardless of the similarities with those cases, renewable energies are certainly transforming electricity markets [9]. Though the upcoming transformation offers great opportunities, it also poses regulatory and institutional challenges to the power industry as regards quality and reliability, such as the intermittency created by the deployment of solar photovoltaic technology (PV), as is now the case in Germany where distributed PV stands at 36 GW, over a peak load range of 40–80 GW [10].

Further, as electricity generation is shifting from fossil- to renewable-based technologies, utilities will need to confront the impact of environmental and energy policy changes on their current business model. In this direction, as the industry is experiencing a rapid penetration of renewables and as a good number of their customers will eventually self-generate a significant portion of their own needs from rooftop PVs, it is not completely clear how incumbent utilities may create value, and many are therefore venturing into new business models [11].

For studying the effect of technology transformation on the

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electricity utility industry, country specifics are important. Developing countries with a high share of hydropower confront challenges with the penetration of renewables energies, such as: i) power shortages and electricity price increases during dry seasons; ii) high intermittency and seasonality in power supply; and iii) financial impacts on utility businesses [12]. Thus, this paper considers the Colombian electricity market, which is characterised by a high share of hydropower resources combined with some thermo-power dependence.

Though much has been written about the likely impacts of renewable energies on electricity markets [13–16], the literature that focuses on the long-term effects of renewable energies on electricity utilities is not abundant, and there is even less of it from a systems-modelling perspective, with little of that focussing on the developing world. The paper studies the potential impact of renewable energy sources (RES) on electricity systems, specifically on the generation and distribution businesses, in the case of Colombia.

The paper is structured as follows. Section 2 discusses the impacts of renewable energy on utilities. Section 3 presents the simulation model that has been built to assess the impact of renewables on utilities, the main equations involved, the dynamic hypothesis of this research, model assumptions, data sources and scenario description. Section 4 incorporates research outcomes, and Section 5 provides the conclusions of this paper.

2. Impacts of renewable energy on utilities

Renewable technologies such as onshore wind and solar PV are penetrating swiftly in several geographic areas, worldwide [17]. While China (145.4 GW), the United States (74 GW) and Germany (45 GW) are the top three countries with wind power capacity in place, the top three for solar installed capacity are China (43.5 GW), Germany (39.7 GW) and Japan (34.4 GW) [17]. This section discusses how the penetration of renewables may impact the electricity generation business and the integrated utility business (where the generation and distribution businesses are combined), and discusses the modelling approaches that have been used to assess the extent of these impacts.

2.1. Impacts on the electricity generation business

Though renewable energies have great potential and many positive impacts in the electricity sector and society as whole, there are concerns about the challenges to the incumbent electricity utilities having assets in conventional energy sources [18]. A possible challenge for utilities is the "merit-order effect" that occurs when most renewable energies have low or negligible variable costs, thus displacing conventional generation (See Fig. 1), and inducing a low wholesale electricity price [19,20]. This may result in lower profits to the incumbent electricity generation business with stranded assets.

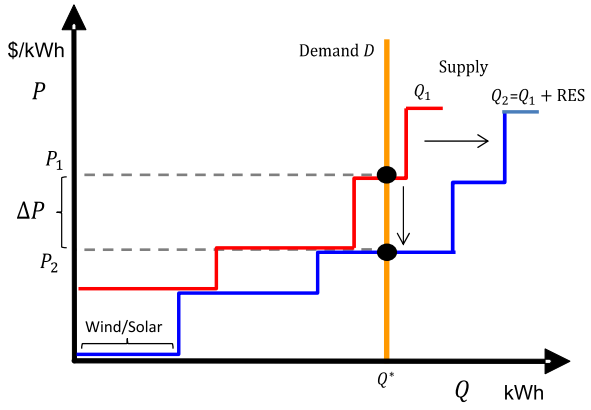

Fig. 1. Decrease of power price due to additional Renewable Energy Sources (RES) in the supply curve (merit-order effect).
Source: Authors.

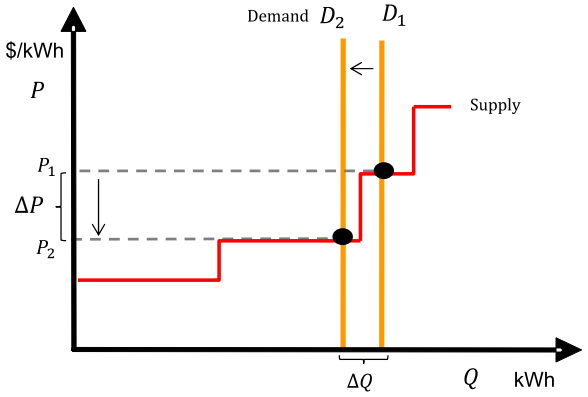

Fig. 2. Power price formation by reduction of electricity demand due to Distributed Generation (DG).
Source: Authors.

In a similar direction, as distributed generation (DG) encourages customers to produce their own energy, the incumbent generators may face a reduction in their energy sales [21] and a reduction in the marginal electricity price (See Fig. 2).

In the presence of renewables, it is important to take into account the merit-order effect as it would prompt changes in the incumbent utility business model since electricity demand could be predominantly satisfied by renewable energies. Thus, only a highly flexible generation fleet would be needed – for balancing purposes [15,16,18,19].

The reduction of wholesale electricity prices in Germany is clear evidence of the merit-order effect, which has also been experienced in other countries, such as Spain and Italy [22,23]. The swift decline in wholesale electricity prices in Germany has reduced the profitability of electricity utilities such as E.ON and RWE (formerly *Rheinisch-Westfälisches Elektrizitätswerk AG*), which has led E.ON to adopt a radical new strategy by divesting its conventional plant – shedding 13 GW of thermal generation assets – and instead focusing on renewables, DG and customer-support solutions [24].

2.2. Impacts on integrated utility business

The greatest threat from DG development is its reinforcement of the integrated-utility "death spiral" (Fig. 3) that results from the utilities' need to increase tariffs to compensate for the reduction in electricity demand from them. Consumers with PV panels produce their own energy, therefore buying less energy from the grid, further promoting solar PV adoption, which leads in turn to further tariff increases [25–

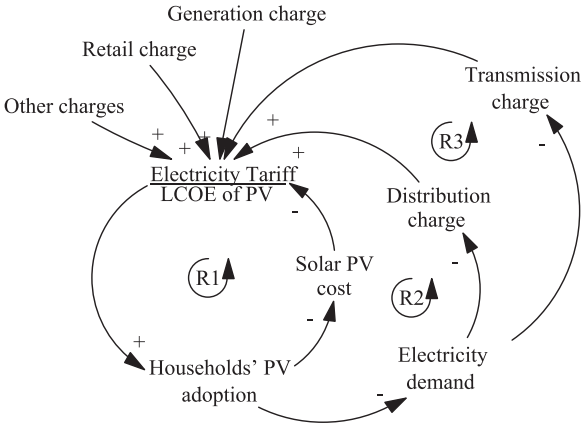

Fig. 3. Utility death spiral.
Source: Authors.