

The Impact of RES in the Italian Day–Ahead and Balancing Markets

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Electricity generation from renewable resources (RES) has become a significant factor affecting the Italian power market. RES-E increased from 59.5 TWh in 2010 to 91.4 TWh in 2013 (+53.6%), thanks to generous support schemes and priority dispatch granted to RES units in the day-ahead market. The spontaneous growth of renewable units also led to a significant increase in subsidy costs and technical problems in grid management. Power generated by some RES, such as wind or photovoltaics (PV), is volatile, and thus, further measures are needed to allow stable network operations. The high share of RES penetration has also challenged the functioning of the power exchange, since the presence of intermittent generation requires the availability of regulating power supplied by flexible production plants such as gas-fired units.

In this paper we analyze data for the sequence of market sessions that take place from the day-ahead to the real time to assess whether this market architecture is able to accommodate a high and increasing share of RES. We also provide empirical evidence on real time market prices and we estimate *premia of readiness* for production units responsible for regulating services in different zones. Finally, we verify the relationship between these *premia* and the amount of RES generation.

In the Italian day-ahead market, the GSE (Gestore dei Servizi Energetici) submits zero-price bids for a quantity equal to the forecast of non-programmable RES generation. These quantities shift to the right the aggregate supply function and more expensive conventional plants are displaced in the merit order. As the delivery time approaches, uncertainty about the actual availability of intermittent RES is resolved and flexible conventional plants are requested to provide up- or down-regulation. Therefore, an electricity market with a high share of RES and priority dispatch heavily relies on balancing and regulation markets that take place and close near to the real time. RES units can place bids in the day-ahead market and use intra-day sessions to adjust their production program on the basis of more accurate forecasts of sun irradiation or wind speed. Conventional production units may bid in all market sessions; however, the presence of RES in spot market sessions has significantly relocated conventional supply in regulation markets, where high *premia* can be realized for the available flexibility. Thus, conventional generators might partially compensate the profits foregone in day-ahead market sessions.

We postulate that well-integrated spot, intra-day, and balancing sessions can help the market adapt to stochastic RES. We empirically investigate the dynamics of price series generated in all market sessions from 2012 to 2014. We also account for physical constraints between zones, which may influence the value of regulating power. We analyze spot, intra-day, and regulation price series by examining common dynamics in the long run. Then, the short-run relationship between spot and regulation prices is considered, disentangling between situations of up- and down-regulation and accounting for traded quantities. We regress price series obtained from all market sessions analyzed in different combinations. When intra-day and MGP prices are considered, the estimated market premium is rather low and can be positive or negative. Negative premia registered in intra-daily sessions occur in cases of excess supply in the MI

markets. On the whole, MI sessions appear to be a good instrument for market participants to update their schedules with respect to day-ahead market results. This is considered particularly valuable for RES producers, since they have the chance to adjust their production plans as a result of more accurate forecasts of weather conditions. The policy of augmenting the number of sessions with the introduction of MI5 in 2015 appears to be sound.

On the other hand, when balancing market sessions are considered, we estimate high *premia of readiness* paid to flexible production units that may inject energy in the system with a few minutes' notice. *Premia* are high for both up- and down-regulation and higher in the first case. It is reasonable to think that real time sessions like MSD and MB are marketplaces where the low numbers of conventional operators are able to exploit a large degree of market power and partially retrieve profit margins lost in the day-ahead market. We finally estimate the relationship among price differences in regulation and spot markets and the amount of wind, solar, hydro, and geothermal production in all Italian zones, proving that geothermal power stabilizes the spread, whereas, as expected, wind generates high imbalance values. On the other hand, we found unclear results for solar, which turns from positive to negative influence, depending on hours and zones. Hydro generation is found to substantially increase the spread in the Northern zone at hour 19, confirming its peak-shaving function and that it substitutes solar production.