Italian coal phase-out: strategic co-optimization on the day-ahead and ancillary services markets

Edoardo Somenzi, Fondazione Eni Enrico Mattei, (+39)3282484876, edoardo.somenzi@feem.it
Ilaria Livi, Fondazione Eni Enrico Mattei, (+39)3342137936, ilaria.livi@feem.it
Federico Pontoni, Fondazione Eni Enrico Mattei and Bocconi University, (+39)3298664606, federico.pontoni@feem.it
Filippo Del Grosso, Fondazione Eni Enrico Mattei, (+39)3400589362, filippo.delgrosso@feem.it

Overview

Over the next five years, Italy will phase-out coal fired generation: by 2025 (2028 including Sardinia), Italy will be among the first countries in the World to ban coal from its generation mix. At present, coal contributes to less than 10% of the total electricity produced, but still to 1/5 of CO2 emissions of the overall Italian power system. It is the cheapest source of baseload power and contributes to the stabilization of the Italian transmission network. Phasing-out coal will have important consequences both on the day-ahead market as well as on the ancillary services market that could result in a weakening of the system or, worse, in a failure to achieve the objectives of decarbonisation. A number of factors complemenets the phase-out of coal, such as: the recent introduction of the Italian capacity market, the discussed reforms to increase competition in the ancillary service market with the deployment of VRES and the recent surge in gas prices. The latter showed how the Italian electricity market is still subject to the behavior of pivotal operators that can act strategically by co-optimizing their bids and offers on the day-ahead (in Italian "MGP") and the ancillary services market ("MSD"). This approach might have ambiguous effects on competition and therefore on emissions, as this work will demonstrate. Understanding the competitive dynamics on the two markets and testing alternative market reforms is therefore paramount if Italy wants to achieve a cost-efficient energy transition. Hence, we developed the CIES Model, a comprehensive structural power and gas market simulator that incorporates, on top of the standard technical transmission and generation constraints, the strategic behaviour of market participants which are allowed to maximize their profits by adopting an optimal strategy in the day-ahead and ancillary services markets. To the best of our knowledge a co-optimization simulator that allows different agents to strategically operate in the market is a novelty for the Italian power system.

Methods

Our CIES Model is based on Plexos, a state-of-the-art power system simulator. Plexos simulates, on an hourly basis, the day-ahead equilibria for all the Italian zones and the MSD ex-ante equilibria for the secondary and tertiary reserve, by employing different competition modelling approaches (perfect competition, Bertrand, Nash-Cournot and static or dynamic mark-up). It performs power system resilience and adequacy analysis and calculates GHG emissions and pollutants released into the atmosphere (CO2 and others). Besides, it conducts medium- and long-term assessments, to be integrated with short-term analysis, so as to take into account structural changes in the system and markets over a long period (30+ years). Among many, the main inputs for the model are:

1. Zonal hourly demand and its short-term elasticity to allow for demand-response and optimization of pumped-storage;
2. Ancillary services demand and profile according to the security and reliability requirements of Terna, the Italian TSO;
3. Technical and economic characteristics of all existing generation plants (derived from ENTSO-E and Terna databases and complemented with additional data retrieved with extensive desktop research);
4. Network topology and constraints;
5. Export, import and inter-zonal power flow profiles;
6. Wind and irradiation profiles;
7. Fuel costs profiles;
8. Financial data for the existing market players and their portfolio of generators.

At first, we set a cost-minimization algorithm to jointly solve both the day-ahead market and the ancillary services market. The simulator reproduces the iterative market splitting logic and the hourly equilibrium for the day-ahead and the provision of primary, secondary, and tertiary reserves as prescribed by ENTSO-E and Terna. These results serve as an ideal first best. Then we develop a simple sequential Bertrand strategic competition game, that allows market participants to bid strategically both on the day-ahead market and on the ancillary services market. The models are trained and calibrated using 2019-2021 real data. After calibration, the simulator is then run for several scenarios simulating the 2025 Italian power market, with different hypothesis on the coal phase-out, the demand and generation mix, fuel and ETS (Emissions Trading Scheme) prices and design of ancillary services markets.

Results

The back casting on real 2019 and 2021 market outcome shows a good fit of the model. It is possible to demonstrate that simulating separately the day-ahead and the reserve markets reduces both model fits and the level of predictability. Hence, day-ahead markets and ancillary services must be modelled and simulated jointly. The back casting also shows that strategic Bertrand competition improves the goodness of the fit (therefore better replicating the level of competition in the Italian market).

	Perfect competition with Reserves	Bertrand strategic competition with Reserves
% of hourly prices with less than 1 EUR difference from GME outcome	90%	95%
Correlation	0.83	0.86

From this important achievement, simulations both in perfect competition and with Bertrand strategic setting are carried out for the phase-out of hard coal power plants at year 2025. For both scenarios, the main results display that the dismission of hard coal power plants in Italy is feasible and there will not be emerging issues for the energy system reliability and security. On the other hand, ancillary costs will likely increase. The dismission of coal plants will be replaced by a higher production from gas power plants, triggering a higher price of electricity, particularly in the South. As for emissions, the phase-out of coal has the potential to reduce annual CO_2 emissions in Italy by 9 MT. This translates into a 15% decrease in emissions per year produced by the energy sector. On the other hand, higher baseload prices reduce even further the scope for pumped storage, hence slightly reducing its use. The table below qualitatively shows the main differences between the Bertrand strategic setting and the perfect competition. For each effect, we show in which scenario is stronger illustrating differences. Apart from expected results (higher prices and market splitting), it is worth noting that strategic behaviour increases emissions.

	Perfect Competition	Bertrand Strategic Setting
Price increase day-ahead		X
Price increase ancillary services		X
Market splitting		X
Variation of the mix	=	=
Emission reduction	X	

Following these results we further proceed to analyse the MSD market dynamics, by investigating the effects that some critical hours, in terms of security of supply, have on the formation of the PUN (Prezzo Unico Nazionale, the system marginal price).

Conclusions

It is possible to conclude that a well-designed model of the Italian electricity market is a powerful tool for carrying out simulations of future energy scenarios. The co-optimization of day-ahead and ancillary services markets allows to better investigate the impact of imperfect competition on energy production compared to a perfect competitive setting. Moreover, simulating sustainable development scenarios displays how competition and market reforms can deliver more rapidly the sustainability of the power sector. Further research will be conducted to analyse the historical relationships between price-cost markup and system conditions keeping into consideration the recovery of long-run marginal costs to investigate deeper strategic biddings in the market.

References

Bianco, V., Scarpa, F., & Tagliafico, L. A. (2015). Long term outlook of primary energy consumption of the Italian thermoelectric sector: Impact of fuels and carbon prices. *Energy, 87*, 153-164. doi:10.1016/j.energy.2015.04.097

Blake, M. (2003). *Game Theory Models in PLEXOS.* Adelaide: Drayton Analytics Research Paper Series.

Connolly, D., Lund, H., Mathiesen, B. V., & Leahy, M. (2010). A review of computer tools for analysing the integration of renewable energy into various energy systems. *Applied Energy, 87*(4), 1059-1082. doi:10.1016/j.apenergy.2009.09.026

Franco, A., & Salza, P. (2011). Strategies for optimal penetration of intermittent renewables in complex energy systems based on techno-operational objectives. *Renewable Energy, 32*(2), 743-753. doi:10.1016/j.renene.2010.07.022

GME. (2021, 10 04). *Esiti dei mercati e statistiche*. Retrieved from Gestore Mercati Energetici: https://www.mercatoelettrico.org/it/Download/DatiStorici.aspx