The Future of the Italian Electricity Generation Sector. An Analysis of the Possible Strategic Models

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Abstract

The present paper investigates the possible future evolution of the Italian power system. In particular, the generation sector is considered by analyzing its recent development, which has been pushed forward by EU regulations that support the deployment of renewables-based power plants. These radical changes will determine the restructuring of the system. It is therefore critical to try to understand which trajectories its possible evolution could take according to different market and economic conditions. To this aim, a scenario analysis was implemented in order to determine the strategic implications that the various situations can yield for generators. As a result, four strategic models are envisaged, namely Traditional Generator, Innovative Generator, Green Generator, and Energy Service Provider.

Keywords:
electricity generation; renewable energy sources; development strategies; roadmap; scenarios; Italy

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The European energy strategy attributes pivotal importance to the development of renewable energy sources [European Commission, 2018]. In this regard, the aim of European Union (EU) is twofold, namely to reduce the environmental impact of the energy sector and to increase the energy security of the EU system. In particular, an increase in the share of renewables leads to a decrease in the consumption of fossil fuels, which are massively imported by the EU, especially natural gas [*Smith,* 2013]. By reducing this consumption, the EU will reduce its energy dependence on third countries, such as the Russian Federation (which is the leading supplier of natural gas to the EU), Middle Eastern countries, and other third countries.

A reduction in this dependence will ensure an increase in European energy security as it decouples the EU from geopolitical issues affecting these areas [*Richter and Holz,* 2015].

In order to achieve this goal, each EU country has committed itself to fulfilling legally binding agreements in terms of the development of renewables, the reduction of carbon emissions, and the increase of energy efficiency. Among the different production sectors, the power generation sector has been particularly affected by these policies as it represents one of the most energy intensive segments and is a principal consumer of fossil fuels. In light of this, European directives have pushed the sector to reshape itself by promoting the massive deployment of renewable energy sources, in particular, solar, photovoltaic (PV), and wind. This has led to a drastic reduction in the utilization of fossil fuels and natural gas in particular, which represented a marginal technology on many EU markets.

The present paper focuses on an analysis of the Italian market, which is relevant as it represents the fourth largest EU market in terms of electricity consumption after France, Germany, and the UK. Therefore, several authors have studied the Italian power system, however, most studies are focused on forecasting electricity prices or an analysis of energy related topics.

For example, Vespucci et al. modelled the finding of equilibrium on a market where a large producer can exert market power, as is the case of Italy [*Vespucci et al.*, 2013]. Gianfreda and Grossi analyzed the Italian spot market with a focus on price dynamics by taking into account technologies, market concentration, the overloading of networks, and volumes. They employed a statistical and econometric approach [*Gianfreda, Grossi*, 2012]. Other authors investigated the impact that the introduction of nuclear power plants may have had on the Italian electricity market [*Guerci, Fontini*, 2014].

On the contrary, Franco and Salza developed an analysis of the Italian power system from an energy point of view. They analyzed the energy balances according to different scenarios of renewables penetration [*Franco, Salza*, 2011].

The analysis of the reviewed literature highlights that the available studies on the Italian power system are quite specific and focus on the analysis of concrete characteristics. This is important because detailed studies have been performed, but, on the other hand, there are very few strategic assessments of the market.

The present paper attempts to analyze the strategic implications that various economic factors can have on the power generation sector. In particular, the reduction of natural gas consumption has a significant impact upon the country's energy strategy and infrastructure planning, furthermore the prioritization of investments can strongly change as a result of modified energy balances (e.g. an increase in the construction of infrastructure for electricity storage and the reinforcement of power grids vs. natural gas pipelines, which increase import capacity). Furthermore, the reduced demand for natural gas may lead to changes in the sourcing strategy and in the relationships with the current supplying countries. In particular, new routes of supply may be established via LNG terminals available in Italy that are currently underutilized. This will contribute to a further increase of the country's energy security, since it moves Italy towards a reduction of its energy dependence upon a limited groups of countries (e.g., Algeria, Libya, and the Russian Federation).

The current analysis elaborates upon the "Ten Years Network Development Plan" (TYNDP) published by the European Network of Electric Transmission System Operators [ENTSOE, 2018], in order to come up with strategic insights concerning the Italian power system. In particular, the focus is on the analysis of the strategic implications deriving from the four scenarios proposed in the TYNDP. On the basis of this, it will be possible to develop strategic visions, which can be defined as possible future goals and play an important role in the decision making process.

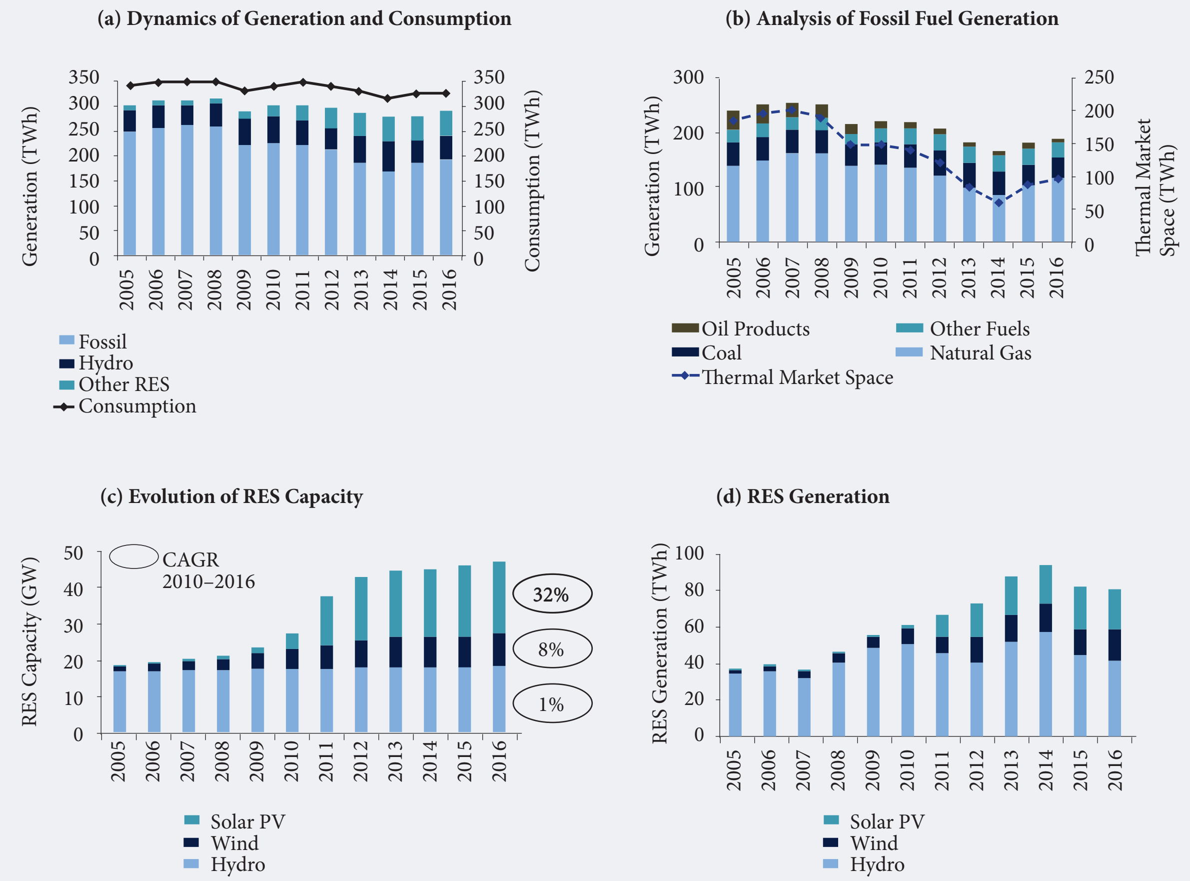
The Italian Power System in Brief

Over the last several years the Italian power sector has been subjected to radical modifications, which have reshaped its configuration. If the last ten years are taken into account, these changes are clearly highlighted, as reported in Figure 1.

Figure 1(a) shows that approximately ten years ago the electricity generation sector was dominated by the utilization of fossil fuels, primarily coal and natural gas with fuel oil representing a limited share. Renewables were represented by hydro power plants which are quite developed in Italy. It seems like most of the hydro potential of the country has been exploited. Only minor margins exist to increase the use of hydro power.

From a strategic point of view, power generators must be able to guarantee a competitive and continuous supply of natural gas and coal for their power plants. On the other hand, it should be noted that coal is much simpler to handle than natural gas because it can be easily transported and stored without necessitating

Figure 1. **Snapshot of the Italian Power Sector**



Source: compiled by the author.

particular types of infrastructure. Natural gas is very difficult to store and complicated to transport, pipelines or LNG ships are necessary.

Transportation via pipeline implies a point to point connection between the importing and exporting countries along with the likely presence of "transit" countries. In light of this, it is evident that the geopolitical context and international relations are fundamental in order to support business. The deterioration of the geopolitical situation has a substantial impact upon business operations, as shown by the Russian-Ukrainian dispute [*Lochner,* 2011] and the unstable political situation in Libya [*Lochner, Dieckhöner,* 2012].

Italy is particularly sensitive to such issues (e.g. the political instabilities in Libya are a clear example), because has scarce fossil fuel resources, therefore it is critical for the country to diversify its sources of supply, support the implementation of energy efficiency measures, and stimulate the utilization of renewable sources of energy.

As illustrated in Figure 1(a), from the 2007 onward, an increase in the development of renewable energy has been observed. Furthermore, it can be also noted that during the same years there was a reduction of consumption due to an economic downturn, as well as the implementation of energy efficiency policies.

The increased amount of renewable energy on the power market displaced fossil fuel-based technologies, as shown in Figure 1(b), where a noticeable decrease of natural gas generation is detected. A substantial reduction of oil-based generation from 2005 to 2016 was also observed. This phenomenon is due to the closure of many oil power plants since they were no longer competitive in the new market context.

On the contrary, coal-based generation continued to be quite stable, as coal power plants provide a base load and exploit their infra-marginal position. All this led to a decrease of the market potential for thermal generation, which determined weak profitability conditions for fossil fuel generation [*Bianco et al.,* 2015].

At the same time, the implementation of EU regulations has led to the deployment of a significant amount of renewables-based power plants, especially solar PV and wind. Installed power increased from approximately 0 GW in 2007 to 19 GW of solar PV and from 3 GW to 9 GW of wind in 2017, with an average growth rate of 32% and 8%, Figure 1(c). This impressive development has caused a decrease in natural gas consumption, which has been substituted by renewable energy generation, reported in Figure 1(d).

The increase of renewables-based generation has caused a decrease in both fossil fuel generation and prices on the market, which negatively affects the profitability of thermal power plants.

This phenomenon can be also ascribed to the fall in consumption due to the economic downturn of the period 2008-2015. In fact, due to the slowdown of economic activities, there was a decrease in electricity consumption and, therefore, of thermal power generation.

On the basis of this, it is critical to ascertain whether this represents a transient condition or a new equilibrium point for the market and, consequently, whether power generators have to change their business strategies that have been in place until now.

In this new context, the role of fossil fuel power generators, in particular natural gas, seem radically changed. In fact, until ten years ago, they provided most of the electricity to the system, whereas now their role is more similar to a "strategic reserve" in order to balance the variability of renewables. Therefore, their future role could be more focused on providing services to the system, rather than working as main generators.

Such a change of position will have an impact upon the fuel market as well. For example, if natural gas is not used any longer for massive power generation, its consumption will decrease, therefore the plans to build large pieces of infrastructure should be reviewed.

Scenario Analysis

A scenario is an example of a probabilistic future, departing from a single point: the present [*Horner et al.,* 2016]. On the other hand, a scenario only represents a single vision of the future, which does not result in anything very helpful to policy makers in situations of high uncertainty. An approach to tackle this issue is represented by the "scenario planning", which is a framework where a limited number of scenarios are defined as the results of the most relevant strategic and planning options [*Peterson et al.,* 2003]. In this way, it is possible to scrutinize the consequences on the future of some important decisions being made now. Comprehensive overviews of the scenario planning methodology can be found in the literature [*Bradfield et al.,* 2005].

In the field of energy, it is quite common to use scenario analysis, as the sector is affected by relevant drivers such as the geopolitical context, which are quite uncertain in the short, medium, and long term. On the other hand, the strategic decisions taken in the energy sector often imply the investment of a huge amount of capital, therefore it is necessary to have an outlook on the possible future situations.

To this aim, different organizations (e.g. the International Energy Agency, Energy Information Agency, etc.) release various scenarios for the energy sector. It can be said that often these international forecasts could be defined as largely conventional in the sense that they are based upon the assumption that the current or emerging socioeconomic and science and technology trends are going to remain relevant in the long term [*Kuzminov et al.,* 2017].

Furthermore, the scenarios published by outstanding international organizations, even though they are independent, are often under the political influence of different interest groups. On the other hand, taking into account all the limitations, these scenarios are based upon the most comprehensive energy databases and up-to-date information, thus they can be taken as a reliable foundation upon which to develop further studies [*Kuzminov et al.,* 2017].

In the present paper, the scenarios provided by the European Network of Electricity Transmission System Operators (ENTSO-E) are considered. In particular, ENTSO-E issues a document called "Ten Years Network Development Plan" where development scenarios, called Visions, are reported for all EU countries in reference to their power sector.

The methodology applied in the present paper is based upon the development of four strategic options starting with the construction of four economic scenarios proposed in the TYNDP developed by ENTSO-E. The economic scenarios provide the context for the analysis, which focuses upon the strategic choices to be made on the basis of different boundary conditions.

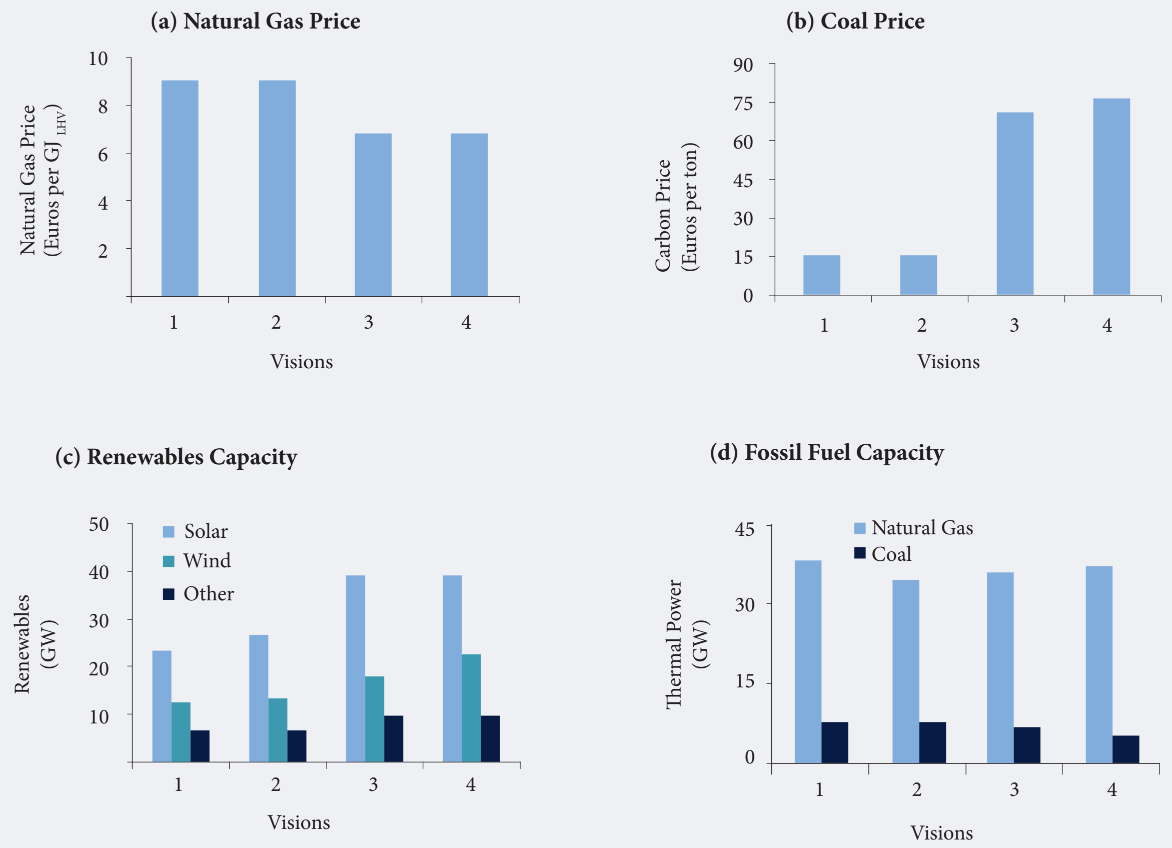
The main parameters considered in the economic scenarios are expected fuel price, expected electricity consumption, renewable development, and fossil fuel-based power generation.

Figure 2 reports the main market data associated with the four considered scenarios, called "visions" within the ENTSO-E TYNDP. Figures 2(a) and 2(b) report the natural gas and carbon prices, Figure 2(c) highlights the expected renewable development, and Figure 2(d) reports on the capacity trend of natural gas (mainly CCGTs) and coal power plants.

These data are the result of the hypothesis associated with the outlooks of each vision. In particular, the visions are developed along three dimensions, namely "economy and market", "demand", and "generation". The proposed visions are representative of the four situations, see Figure 3, determined by the consolidation or not of a European framework for the development of the electricity system and on the fulfillment or not of the European Energy Roadmap for the 2050. Table 1 presents a detailed description of the proposed visions.

In terms of the fuel market, two different scenarios are depicted. One with higher natural gas market prices and lower carbon prices and the other with lower natural gas prices and higher carbon prices. Basically,

Figure 2. **Economic and Market Scenarios Proposed in the TYNDP 2016**



Source: compiled by the author using [ENTSOE, 2018].

they are representative of two market conditions, namely a market equilibrium context, i.e., Visions 1 and 2, where the natural gas price is sustained by supply and demand, which also determine the level of the carbon price. On the contrary, Visions 3 and 4 depict a scenario where there is an oversupply of natural gas, which determines a relevant decrease in price (-30%). In such a context, regulatory intervention regarding the carbon price (e.g., the introduction of a "carbon floor") is possible in order to stimulate the adoption of clean technologies and avoid the massive utilization of natural gas (or coal). These measures are supported by sustained economic growth, which allow for the implementation of energy policies focused on the "de-carbonization" of the sector.

Accordingly, Figure 2(c) highlights the expected development of renewable energy sources. In Visions 1 and 2 a moderate increase of renewables is detected with respect to Visions 3 and 4, where a significant push for renewables development is foreseen. This is due to the different economic conditions. In fact, in Visions 1 and 2, modest economic growth is foreseen, therefore the resources to support a massive deployment of RES are limited. On the other hand, Visions 3 and 4 report better economic conditions, which permit the large-scale development of RES.

Finally, Figure 2(d) reports the capacity trend of natural gas (mainly CCGTs) and coal power plants. It can be noticed that it does not vary significantly between the scenarios. Coal power plants fall from 7.9 GW of Vision 1 and 2 to 5.4 GW of Vision 4. It can be also noted that natural gas power plants in Vision 2 are fewer than in Vision 1. This is due to the fact that in Vision 2, solar power plants increase with respect to Vision 1, therefore they displace natural gas power plants from the merit order. This can also be attributed to the fact that the number of coal power plants do not decline between Vision 1 and 2. Visions 3 and 4 highlight a slight increase in natural gas capacity with respect to Vision 2, since the more favorable economic conditions allow for the development of more back-up capacity to complement the massive development of renewables.

The expected evolution of electricity consumption is reported in Figure 4. It can be observed that consumption steadily decreases in Visions 1 to 3, whereas there is an increase in Vision 4. The decrease of electricity consumption is due to the implementation of aggressive energy efficiency measures in the power sector (e.g., the widespread utilization of LED lamps).

The increase detected in Vision 4 is due to the switching of different end-user sectors (e.g., transportation, heating, etc.) from the fossil fuel market to the electricity market.

The fuel switching is supported by the fact that power generation becomes "RES-dominated", therefore its carbon intensity decreases and it becomes more sustainable to use electricity rather than fossil fuels for the

Table 1. **Specific Features of the Considered Visions**

Vision 1 "Slowest Progress"	Economy and Market	Each EU country has its own framework for the reduction of carbon emissions and increase of the use of RES. Economic growth is modest. Old power plants are kept on line and coal represents the baseload technology.
	Demand	There are no major energy efficiency developments. The modest economic growth determines a limited increase of demand.
	Generation	The generation mix is determined by national policy schemes. A lack of EU coordination, which determines an evolutionary trajectory far from the 2050 objectives. Policies for further development of RES are only established at the local level.
Vision 2 "Constrained Progress"	Economy and Market	Economic conditions are a little bit better with respect to Vision 1, therefore some more resources are allocated for energy efficiency and RES. On the other hand, there are still uncertainties related to the EU "carbon policy", therefore the willingness to invest is limited. Coal still represents the baseload technology.
	Demand	Energy efficiency investments are slightly higher with respect to Vision 1, therefore lower demand is expected.
	Generation	The development of the energy mix is coordinated at the EU level, however, the resources in which to invest are limited. This encourages the extension of the operating life of existing thermal power plants and a slight increase of renewable capacity with respect to Vision 1.
Vision 3 "National Green Revolution"	Economy and Market	Economic growth is more favorable with respect to Vision 2. There is a lack of coordination at the EU level, but each country has more resources to invest. "Carbon policies" are implemented with the results that natural gas becomes the baseload technology.
	Demand	More significant development in energy efficiency measures with respect to Vision 2 determines a decrease in demand for electricity.
	Generation	The greater development of RES makes them competitive, but the lack of a coordinated EU framework does not allow them to be exploited to the full extent. The good economic conditions allow for the implementation of a capacity market and the installation of new back-up capacity.
Vision 4 "European Green Revolution"	Economy and Market	Better economic conditions with respect to all the other visions. Strong coordination at the EU level. Implementation of coordinated "carbon policies".
	Demand	Substantial effort in the implementation of energy measures. Massive development of e-mobility and electrification of heat and cooling sectors.
	Generation	Strong EU vision, which allows countries to be on track to fulfill the 2050 objectives. Large scale expansion of RES and the adequate development of back-up capacity. Phase-out of old nuclear power plants and corresponding replacement with RES. Natural gas represents the baseload technology.

Source: compiled by the author.

heating of buildings [*Bianco et al.,* 2017] by using heat pumps, or for transportation. Building heating and transportation are the two end users where a major penetration of electricity as the main source of energy is expected.

Discussion

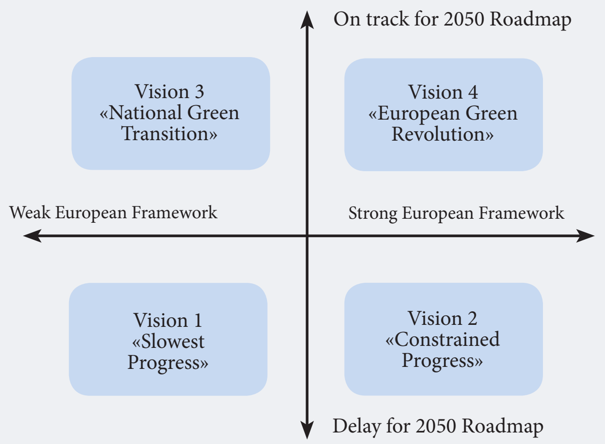
The visions described in the previous section represent four possible scenarios for the Italian generation sector. Despite their differences, they have a relevant common principle, which is the unprecedented transition the sector is undergoing. This transformation presents many challenges, but also a great number of opportunities for power generation sector. In the past, the sector was able to guarantee stable returns for investors and it presented a very low risk profile, but the policies implemented over the last ten years aimed at the reduction of the carbon intensity of the power sector has reshaped the generation business.

Electricity generation operators, often large utilities, need to look for new business models in order to secure the margins that guaranteed the stability of the business. In order to do this, it is critical that they gain a clear vision of the possible future scenarios in order to implement an optimal strategy in relation to the possible changes of the situation.

In all the four scenarios reported in Figure 4, thermal power plants still represent the majority of the power capacity. There will be a mix of centralized and non-centralized generation, but the risk profile of centralized generators is changing due to the merit order effect of renewables [*Sensfuß et al.,* 2008; *Cludius et al.,* 2014] and the consequent "missing money problem" [*Hogan,* 2017; *Da Silva, Figueiredo,* 2017]. Furthermore, the implementation of energy efficiency measures, with the corresponding decrease in expected demand for electricty, makes the situation more unpredictable and complex. Therefore, the intervention of policy makers with instruments able to provide clear market signals is necessary in order to provide stability for the system. On the other hand, generators should target the optimization of their generation mix in order to remain competitive and ready for new investments.

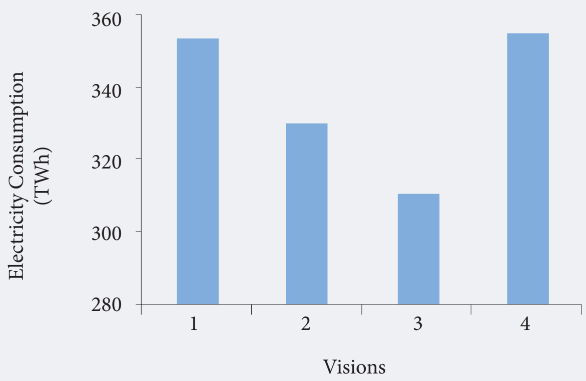
"Optimization" appears to be the key word for the future strategies of power generators, with specific reference to the optimization of energy sources (e.g., thermal power vs. renewables).

Figure 3. **Matrix of the Economic and Market Scenarios Proposed in the TYNDP 2016**



Source: compiled by the author using [ENTSOE, 2018].

Figure 4. **Expected Electricity Demand in the Considered Market Visions**



Source: compiled by the author.

According to the aforementioned visions, different strategic models for generators are envisaged, namely:
- Vision 1 "Slowest Progress", corresponding strategic model: "Traditional Generator"
- Vision 2 "Constrained Progress", corresponding strategic model: "Innovative Generator"
- Vision 3 "National Green Revolution", corresponding strategic model: "Green Generator"
- Vision 4 "European Green Revolution", corresponding strategic model: "Energy Service Provider"

Each strategic model is tailored to the corresponding business context in order to maximize the generator results, irrespective of policy makers' expectations. In the following, there is the detailed description of the aforementioned strategic options.

Traditional Generator

In the scenario characterized by weak economic growth, operators should opt for a "conservative" strategy that leaves no room for large investments due to the many unknowns affecting the future development of the sector, which is further exacerbated by the lack of a common EU agreement. In this situation, generators can opt for the optimization of their existing thermal power plants, such as the increasing the flexibility of CCGTs, in order to benefit from possible extra revenues on the ancillary services market. Furthermore, infra-marginal capacity (e.g., coal power plants) guarantees most of these revenues, therefore even old coal power plants should be kept online (except for the inefficient ones) despite their carbon intensity. There is no possibility of developing renewables unless they have already reached grid parity and, therefore, the investment is profitable. On the contrary, operators can improve the management of their existing renewable power plants, for example by massively implementing Virtual Power Plants (VPPs).

The combined management of the power and gas markets appears necessary in a limited economic growth scenario, as generators can secure more margin by trading part of their natural gas on the EU integrated market or on the international market by benefiting from the commissioning of new infrastructure previously under construction (e.g. pipelines, LNG terminals, etc.).

This strategy aims at the consolidation of large operators with a diversified fuel mix in their generation portfolio, which may have many opportunities for the merger and acquisition (M&A) of smaller operators, such as those with natural gas and some renewables in their portfolios. This period may end with a significant concentration of the power market among a few operators on the basis of the "survival" of the fittest principle.

Innovative Generator

In a situation characterized by limited economic growth, energy generators are not incentivized to invest and implement growth strategies. Rather, they try to keep their positions safe. The conditions of uncertainty are significant, especially with respect to a possible "carbon strategy", therefore it is not possible to assume clear positioning on the generating market. On the other hand, there is agreement at the EU level upon the willingness to pursue the de-carbonization of the power generation system by fulfilling the 2050 objectives, therefore it is necessary to monitor R&D, pursue innovative business practices, and organizational models, etc., related to a "RES-dominated" market. Pursuing such a market is necessary given that it is reasonable to assume that a push for renewables would be imminent once the economic situation improves. Therefore, it is necessary to be ready for such a situation by focusing on the "innovative" strategies to be put in place.

During this period of limited growth, some operators, especially those with an unbalanced amount of natural gas in their mix, could move into critical condition due to the unsatisfactory level of revenues. In such a situation, they can be the possible targets of M&A strategies of larger operators with a more balanced generation mix, for whom revenue issues are not a concern.

Therefore, also in this case, it is possible to have market concentration, which reduces the number of players active in the power generation sector.

Furthermore, operators can invest in optimizing the management of their power fleet in order to capture the opportunities available on all markets, namely the ancillary services, natural gas market, and VPPs.

Green Generator

In the context of sustained economic growth with local willingness to develop renewables, operators are pushed to invest massively in renewable capacity, but, at the same time, according to the policy signals, they also need to optimize their thermal power fleet. In particular, if clear indications are given concerning the carbon policy with a push for de-carbonization, coal power plants will be phased out and only the newest ones will be kept online. In such a context, it is possible that CCGTs will displace coal power plants and become an infra-marginal technology, therefore they will begin to generate revenues. Such a condition is advantageous for operators, usually the smaller ones, with an unbalanced presence of natural gas and some renewables in their mix.

The market will be very competitive and therefore a large range of generators will be active.

Given the lack of agreement at the EU level, it will be possible for the larger operators to exploit international strategies only to a small extent, since each country will develop its own regulations. This turns into an advantage for smaller and, usually, more flexible operators which can exploit all the opportunities available on the local market, and, furthermore, for smaller scale investments, which are usually not attractive for larger operators.

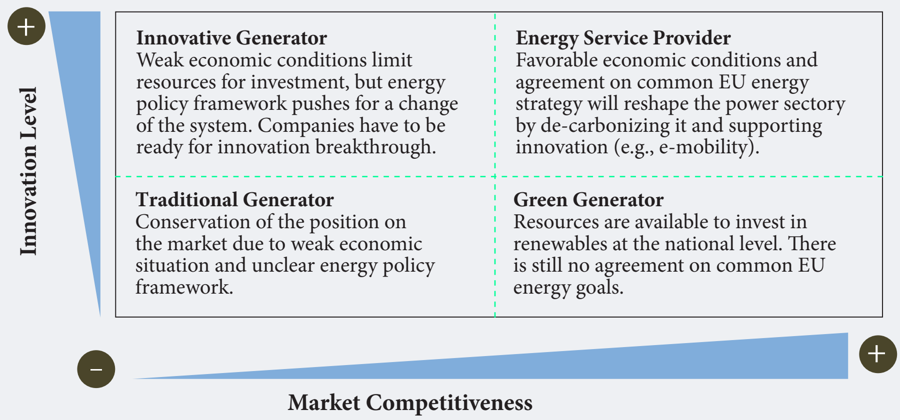
The strategy depicted here will aim at increasing the share of renewables in the power portfolio of all the operators, independent of their size. No critical modifications of the business model, services, and organizations are expected.

Energy Service Provider

In the context of sustained economic growth and strong agreement on the fulfillment of EU objectives for 2050, operators will be pressed to change their traditional approach to power generation and new business models may be adopted. In this new context, the massive development of renewables, e-mobility, etc., are expected. Therefore, clients' needs are completely changed. Customers will look for innovative solutions in order to support them in the efficient management of energy in their homes and businesses. Services such as storage, control, and monitoring will be fundamental in a context where consumers actively participate in the market.

Electric utilities will play a pivotal role in marketing new technologies. For example, they can finance, install, and run charging stations for e-mobility, as well as provide storage services, etc. In this new context, larger utilities can exploit large-scale synergies, whereas small operators may offer very customized services. Small or very small companies offering very innovative services can appear on the market and gain significant market shares, especially in the field of remote control and monitoring systems. There will be a highly competitive market situation, where the most innovative companies will be the winners, irrespective of their size.

Figure 5. **Positioning with Respect to Innovation Level and Market Competitiveness of the Analyzed Strategic Options**



Source: compiled by the author.

Conclusion

The present paper provides an overview of the Italian generation system by highlighting its main features deriving from the radical changes experienced over the last ten years, namely the substantial development of renewables.

Power generators need to plan their future well in advance as the sector is capital intensive and, usually, a long execution time is necessary in order to build infrastructure and develop investments (authorization and permit phases can take years), therefore it critical to perform scenarios analysis in order to discuss the various strategic implications.

On the basis of the economic visions developed by ENTSOE in the TYNDP 2016, four strategic scenarios are envisaged, namely: Traditional Generator, Innovative Generator, Green Generator, and Energy Service Provider. Their positioning in terms of innovation level and market competitiveness is reported in Figure 5. It can be said that the Traditional Generator and Innovative Generator are two defensive positions, determined by limited economic growth and the uncertainties concerning future policies on renewables and carbon emissions. The Green Generator strategic scenario describes a situation where all the operators will increase the share of renewables in their mix and where there is a moderate advantage for generators with an unbalanced mix in favor of natural gas and renewables. Finally, the Energy Service Provider strategic scenario represents a change in the paradigm for the power generation sector, as companies will turn themselves in providers of advanced energy services, such as storage, e-mobility, control, and monitoring. Such a context will be very competitive, irrespective of the size of the competitors.

References

Bianco V., Scarpa F., Tagliafico L.A. (2017) Estimation of primary energy savings by using heat pumps for heating purposes in the residential sector. *Applied Thermal Engineering*, vol. 114, pp. 938–947.

Bianco V., Scarpa F., Tagliafico L.A. (2015) Long term outlook of primary energy consumption of the Italian thermoelectric sector: Impact of fuel and carbon prices. *Energy*, vol. 87, pp. 153–164.

Bradfield R., Wright G., Burt G., Cairns G., Heijden K. (2005) The origins and evolution of scenario techniques in long range business planning. *Futures*, vol. 37, no 8, pp. 795–812.

Cludius J., Hermann H., Matthes F.C., Graichen V. (2014) The merit order effect of wind and photovoltaic electricity generation in Germany 2008–2016: Estimation and distributional implications. *Energy Economics*, vol. 44, pp. 302–313.

Da Silva P., Figueiredo N. (2017) Renewables optimization in energy-only markets. *Analysis of Energy Systems. Management, Planning and Policy* (ed. V. Bianco), Boca Raton: CRC Press, pp. 149–169.

ENTSO-E (2018) Ten Years Network Development Plan. Available at: https://www.entsoe.eu/major-projects/ten-year-network-development-plan/planning-studies/Pages/default.aspx, accessed 03.03.2018.

European Commission (2018) *Energy Strategy and Energy Union. Secure, Competitive, and Sustainable Energy.* Available at: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union, accessed 05.03.2018.

Franco A., Salza P. (2011) Strategies for optimal penetration of intermittent renewables in complex energy systems based on techno-operational objectives. *Renewable Energy,* vol. 36, no 2, pp. 743–753.

Gianfreda A., Grossi L. (2012) Forecasting Italian electricity zonal prices with exogenous variables. *Energy Economics,* vol. 34, no 6, pp. 2228–2239.

Guerci E., Fontini F. (2014) The impact of the introduction of nuclear power on electricity prices in a power exchange-based liberalised market. *Progress in Nuclear Energy,* vol. 71, pp. 52–60.

Hogan M. (2017) Follow the missing money: Ensuring reliability at least cost to consumers in the transition to a low-carbon power system. *The Electricity Journal*, vol. 30, no 1, pp. 55–61.

Horner N., de Paula Oliveira A.G., Silberglitt R., Poppe M.K., Bressan Rocha B. (2016) Energy foresight, scenarios and sustainable energy policy in Brazil. *Foresight*, vol. 18, no 5, pp. 535–550.

Kuzminov I., Bereznoy A., Bakhtin P. (2017) Global energy challenges and the national economy: Stress scenarios for Russia. *Foresight*, vol. 19, no 2, pp. 174–197.

Lochner S. (2011) Modeling the European natural gas market during the 2009 Russian–Ukrainian gas conflict: Ex-post simulation and analysis. *Journal of Natural Gas Science and Engineering*, vol. 3, no 1, pp. 341–348.

Lochner S., Dieckhöner C. (2012) Civil unrest in North Africa — Risks for natural gas supply? *Energy Policy*, vol. 45, pp. 167–175.

Peterson G.D., Cumming G.S., Carpenter S.R. (2003) Scenario planning: A tool for conservation in an uncertain world. *Conservation Biology*, vol. 17, no 2, pp. 358–366.

Richter P.M., Holz F. (2015) All quiet on the eastern front? Disruption scenarios of Russian natural gas supply to Europe. *Energy Policy*, vol. 80, pp. 177–189.

Sensfuß F., Ragwitz M., Genoese M. (2008) The merit-order effect: A detailed analysis of the price effect of renewable electricity generation on spot market prices in Germany. *Energy Policy*, vol. 36, no 8, pp. 3086–3094.

Smith W.J. (2013) Projecting EU demand for natural gas to 2030: A meta-analysis. *Energy Policy*, vol. 58, pp. 163–176.

Vespucci M.T., Innorta M., Cervigni G. (2013) A Mixed Integer Linear Programming Model of a Zonal Electricity Market with a Dominant Producer. Energy Economics, vol. 35, pp. 35–41.