Techno-economic Impacts of COVID-19 Pandemic on the Italian Electricity System

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***Abstract*— Since the end of 2019, the sadly known Sars-CoV-2 has firstly spread to China and then to the rest of the world, giving rise to the pandemic known as COVID-19. The high number of deaths and the stressful conditions of public health systems suggested governments to impose social restrictions to contain the virus diffusion. The adopted measures differed from country to country, but they often resulted in the closure of schools, workplaces and meeting places. In Italy, in addition to local restrictions adopted in the areas where the health situation was particularly severe, the decree law of March 4, 2020 imposed social restrictions for the entire country (e.g. closure of schools and ban on gatherings). Subsequently, with a series of decree laws, the measures became more severe and on March 22, 2020 the government imposed the lockdown of all face-to-face activities related to production chains concerning non-essential goods. These decrees implicated a considerable reduction in the electrical demand with consequent impacts on both electrical markets and operation strategies of the Transmission System Operator (TSO). Due to the low demand, compared to usual load conditions, fewer conventional power plants were dispatched in the Day Ahead Market; therefore, a decrease in the price of energy occurred, as well as an increment of the renewable penetration. At the same time, conventional power plants played a key role in the Ancillary Services Market to ensure the safe operation of the transmission system. In this work, the reduction of the electrical demand and its impacts on both electrical markets and network operation strategies are analysed and discussed for the Italian power system.**

Keywords—COVID-19, power demand, power generation mix, electricity markets, renewable energy sources.

I. INTRODUCTION

The COVID-19 pandemic spread throughout the world in 2020 had unprecedented consequences in terms of implemented procedures for its containment and important impact on the whole economy, sociality, habits, and activities. Several countries forced quarantines and restrictions to prevent further spread of the pandemic and to avoid health system collapse. Lockdowns, conditioning behaviours and activities, have led to dramatic effects in the energy sector, with oil and gas prices drop, electricity demand reduction, with changes in daily power profiles, generation mix and market prices. Some preliminary effects on the power systems have been analysed in reports from utilities, energy research centres, grid and market operators, and agencies. Italy was the first country in Europe hit by the pandemic. The quarterly analysis released by ENEA showed a dramatic reduction of -7% in the energy demand and -5% in the Gross Domestic Product (GDP) already in the first three months of 2020 compared to the same period of 2019, in terms of oil, gas and electricity [1]. The electricity demand has reduced, in terms of energy and power, the market prices have decreased and the pandemic has affected the generation mix, increasing the Renewable Energy Source (RES) percentage, which has leaded to the beforementioned price reduction and also some concerns in term of system security [2]. Already in the end of February, when the containment measures were mainly limited to the Norther regions, a National average load reduction between 1 to 1.5 GW have been observed, increasing to 3 GW in the first week after the extension of the lockdown throughout the entire country [3]. The largest reduction was in the North and Central regions (with values around 8% and 13% in the first weeks of March), while the South and the two main islands were less affected by the load reduction (with values around 2% and 9%) [4]. The electrical demand fell down progressively from March 2020, with a total reduction of 10% compared to March 2019, reaching the negative peak in April, with -17% compared to April 2019 [5]. The changes in social habit are translated in load profile adaptation, with different peaks in time and magnitude. For instance, some countries observed a shift of morning peaks to later hours, while others, such as the CAISO system, have experienced a reduction in demand in the daylight hours and the worsening of the duck curve effect impacted by solar photovoltaic (PV) generation [6]. The presence in the energy mix of a predominant share of RES has some consequences on the secure operation of the power system, in terms of voltage and frequency management during the pandemic. With less electricity needed, but large amounts of solar PV and wind energy coming onto the system, the grid needs to work harder to provide energy when the sun stop to shine, and the wind stop to blow. This has led to significant curtailment of RES because the system cannot handle it all from a stability perspective [7]. In this sense, the pandemic is providing a glimpse into the challenges of the energy use and it shows what we can expect in the future in terms of higher penetration of RES, bigger duck curve and voltage management issues. In this paper, we track the impact of the COVID-19 outbreak on the Italian electricity system, which is important to test and analyse scenarios with high penetration of RES and their consequences on the electricity sector. The outline of this paper is as follows. In Section II, we report the impact in terms of electricity demand reduction and load profile's modifications, discussing from both national and market

zones perspectives. Section III highlights the impact on the generation mix during the pandemic, while Section IV reports the effects on the Day Ahead and Ancillary Service Markets. Section V presents concluding remarks and inspirations for future works.

II. Impact on the Demand Reduction

We analyse the impact of COVID-19 on the Italian electricity demand, both in terms of energy absorbed and requested power, referring to the whole national demand and to the absorbed demand by the six zones which compose the Italian electricity market. The market zones correspond to regions or aggregates of regions which have been affected by the pandemic in a different measure, and this is reflected in the electricity demand variation, considering the different productivity framework. The electricity data are taken from the transparency platform of Terna, the Italian Transmission System Operator [8]. Fig. 1 shows the load profiles in the period between the first Monday of March and the last Sunday of May 2020 and compares them with those of 2019, together with the polynomial trend lines of the second order (dashed lines). The impact and synchronism of the shock determined by the emergency measures on the electrical system is evident. In particular, the measures have been of different magnitude, starting from the Prime Ministerial Decree (DPCM) of 23 February 2020 for the municipalities of the Lombardy and Veneto Regions only, following with the extension of the containment measures throughout the national territory starting after the DPCM 8 March 2020 (Phase 1 - lockdown). On 11 March, President Conte signed the DPCM which ordered the closure of all commercial, retail activities, except for grocery stores, basic needs, pharmacies, with effect from 12 March 2020. On March 22, 2020, the government imposed the lockdown of all face-to-face activities related to production chains concerning non-essential goods. On these dates, the beginning of the recession is noted, with the gradual reduction of the national electrical load. The DPCM measures have been extended until May 3, although with partial reopening starting from April 14, 2020 (stationery stores, bookstores, clothing stores for children and babies, forestry, and the wood industry). On 26 April 2020, President Conte announced the measures to contain the emergency in the so-called "phase two", in force from 4 May and for the following two weeks, with the reopening of manufacturing, construction and brokerage activities real estate and wholesale. We note in Fig. 1 the slow economic recovery in the weeks of May 2020 following the reopening, which is also confirmed by the parabolic trend lines.

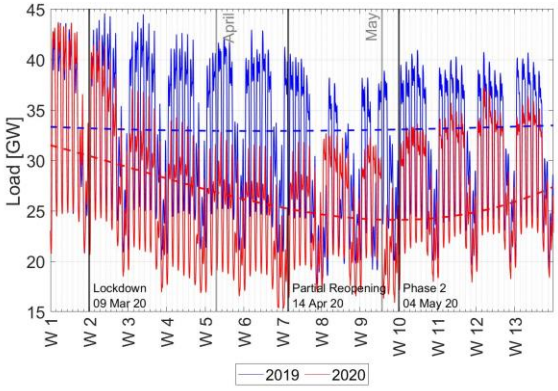


Fig. 1. Hourly Italian load pattern between the first Monday of March and the last Sunday of May: comparison 2019-2020.

Table I reports the behaviour in terms of electricity consumption by market zone for the months of January, February, March and April, compared between 2019 and 2020. The Italian market zones are: North (N), Centre-North (CN), Centre-South (CS), South (S), Sicily (Sic) and Sardinia (Sar). They compose the Italian market zone (IT). Externalities as weather effect or calendar have not been considered in the demand variation analysis, given that the difference of mean daily temperature between the same days of 2019 and 2020 have been within 0 and 3°C in the 71.5% of the cases, and differences above 4°C have been in less than 14% of the examined days. Comparing the same months of 2020 and 2019, while in January and February the demand has not changed significantly (-4% and 0.6% respectively at national level), in March and April the variations have been more pronounced, following the protracted international health emergency and the containment measures deployed. In March 2020, electricity consumption decreased by 10% compared to the same month of 2019, passing from 26.4 TWh to 23.7 TWh. The largest reduction in percentage occurred in the North and Centre North areas (with values around -13%), even if in absolute terms the largest difference was in the North with -2 TWh. The South and Islands areas were less affected by the load reduction (with values between -2% and -10%), with a maximum absolute value of -0.27 TWh in the Centre-South area. In April 2020, the electricity demand decreased by 17% compared to the same month last year, from 24.1 TWh to 19.9 TWh. In this case, the reduction affected all market areas in a more marked way, with higher values in percentage in the North and Central North areas (around -20% compared to April 2019) and a reduction in absolute value in the North equal to -2.7 TWh. In the South and Islands areas the maximum reduction in absolute terms (-0.53 TWh) and percentages (-14.7%) was in the Centre-South zone.

TABLE I. National and Market Zones Electricity Demand (January-May 2019/2020).

Electricity demand (TWh)		N	CN	CS	S	Sic	Sar	IT
JANUARY	'19	15,92	3,11	4,41	2,68	1,75	0,74	28,60
	20	15,48	2,83	4,16	2,53	1,62	0,80	27,43
	Δ	-2,7%	-9,0%	-5,6%	-5,4%	-7,1%	7,9%	-4,1%
FEBRUARY	19	14,62	2,70	3,85	2,29	1,47	0,67	25,60
	20	14,79	2,69	3,81	2,33	1,47	0,66	25,75
	Δ	1,2%	-0,5%	-0,9%	1,5%	0,2%	-2,0%	0,6%
MARCH	19	15,15	2,89	3,88	2,35	1,50	0,67	26,43
	20	13,16	2,52	3,61	2,30	1,52	0,60	23,70
	Δ	-13,2%	-12,7%	-7,0%	-2,3%	1,7%	-9,8%	-10,3%
APRIL	19	13,55	2,66	3,62	2,20	1,38	0,63	24,05
	20	10,82	2,08	3,09	2,04	1,31	0,57	19,92
	Δ	-20,1%	-21,8%	-14,7%	-7,3%	-5,2%	-9,5%	-17,2%
MAY	19	14,39	2,73	3,78	2,27	1,39	0,70	25,26
	20	12,73	2,35	3,40	2,21	1,39	0,60	22,67
	Δ	-11.5%	-13.9%	-10.1%	-2.6%	0%	-14.3%	-10.3%

In May 2020, the national electricity demand was 22.7 TWh, with a slight increase compared to April 2020 (+12%), but still in decline w.r.t. May 2019 (-10.3%). In particular, starting from the week of 18-24 May, we see a slow and gradual recovery in the electricity demand, following the reopening of several productions and activities [9]. The average weekly power value went from a maximum of 36 GW

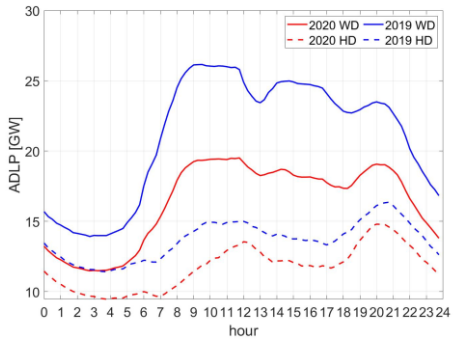
in the week 02-08 March 2020 (+ 2% compared to the same week in March 2019) to a minimum value of 26.4 GW in the week 13-19 April 2020 (-26 % compared to the similar week of April 2019, which had been in correspondence of the Easter holidays). The week of 6-12 April 2020 was the second week with the lowest average power value (27.4 GW). The average weekly power grew in the following weeks of May, after the partial reopening of 4 May, passing to 30.1 GW in the week 4-10 May 2020 (-13% compared to 33.9 GW in the similar week of May 2019) and 30.7 GW in the week 11-17 May 2020 (-10% compared to 33.9 GW of the similar week of May 2019).

Table II highlights the impact of the pandemic on the national power profile and it compares the evolution of the electrical situation of the different market areas, in terms of the monthly maximum power, average power and load factor (defined as the ratio between average and maximum power) for the weekdays of April 2019 and 2020, as the most influenced month by the full lockdown. While there is a slight reduction in the load factor for the Centre-South, South, Sicily and Sardinia areas, meaning a power profile fairly aligned between April 2019 and 2020, for the North and Centre-North areas it has slightly increased, meaning a maximum power value that decreases more than the average power. The maximum power decreases respectively by 23% and 26% for the North and Central North areas, while by 12, 7, 3 and 9% for the Central South, South, Sicily and Sardinia areas. The average power decreased by 21% and 23% for the North and Central North areas respectively, while by 15, 8, 6 and 11% for the Central South, South, Sicily and Sardinia areas. We evaluate the Average Daily Load Profile (ADLP), defined as the mean load for each time step during the days in a month. We evaluate it for April 2019 and 2020 and dividing it between working days (WD) and holidays (HD). Fig. 2 depicts the ADLP for the North and South zones, to extrapolate different electricity behaviour in different Italian areas. In general, morning and evening ramps are less steep on holidays, compared to working days, is mainly due to the system loading which is distributed over longer periods during holidays (few people getting up at the same time for going to work), especially for regions with high electricity intensity. In the ADLP of the North, the working days have maintained a different profile from the holidays, both in 2019 and 2020; but holidays and working days behaved in the same way in the two years, with a larger reduction in the demand for working days. In the South, the behaviour was different with a greater similarity of profiles for holidays and the working days in April 2020 approaching the holidays profile. In this case, we do not see evident differences in the morning and evening ramps between 2019 and 2020 and working days and holidays.

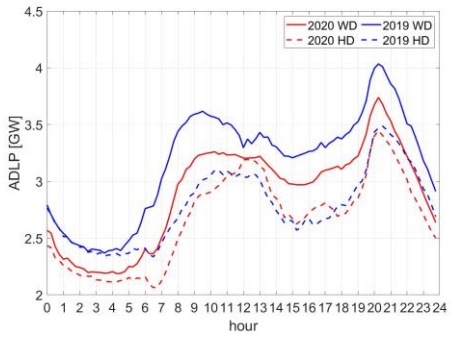
TABLE II. MAXIMUM POWER, AVERAGE POWER AND LOAD FACTOR FOR THE WEEKDAYS OF APRIL 2019 AND 2020 BY MARKET ZONE.

	[GW]	N	CN	CS	S	Sic	Sar
apr-19	Pmax	24,97	4,78	6,49	3,98	2,55	1,13
	Pmed	20,32	3,90	5,22	3,13	1,96	0,91
	u	0,81	0,82	0,80	0,79	0,77	0,81
apr-20	Pmax	19,21	3,53	5,70	3,72	2,48	1,02
	Pmed	16,11	3,02	4,42	2,88	1,85	0,81
	u	0,84	0,85	0,77	0,77	0,75	0,80

The load reduction is larger for the North, in both weekdays (from 21 to 16 GW) and holidays (from 14 to 12 GW). While in the North the peak load was in the morning for the weekdays of 2019, in April 2020 the distance between the morning and evening peaks weakened, approaching the behaviour of the holidays, which remained aligned between 2019 and 2020. The weekdays morning peak shifted in time from 9 a.m. to 11.45 a.m. and from 26 GW to 20 GW, while the evening peak kept the same time (20 p.m.) but reduced from 23.5 to 19 GW. The difference between the morning and evening peak reduced of -1.5% (2.5 GW vs 1 GW) in April 2020. These variations are lower for South, where the average load changed from 3 to 2.9 GW during weekdays, and from 2.8 to 2.7 GW during holidays. This is mainly due to the different consequences of the lockdown on the productivity of the zones: North is historically more electricity intensive than South, and the stop impacted more those regions.



a. North



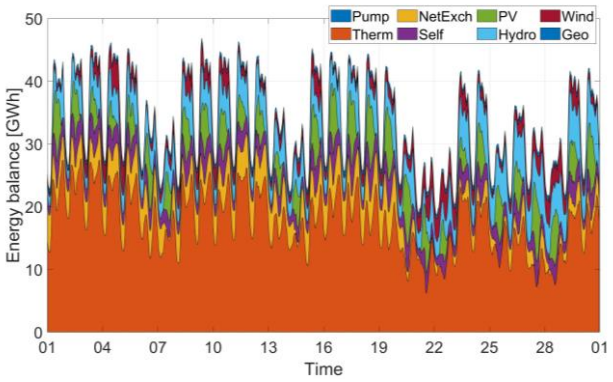
b. South

Fig. 2. Average daily load profile for N orth (a) and South (b) zone in April 2019, 2020.

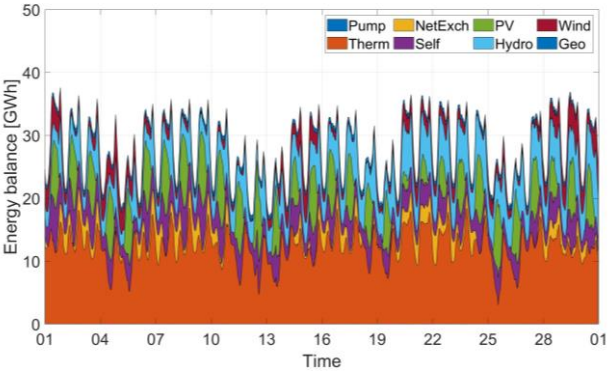
III. IMPACT ON THE GENERATION MIX

We analyse the impact of the lockdown on the national generation mix, with focus on April, as the most influenced month by the full lockdown. The monthly thermal generation decreased from around 13 TWh to 9 TWh in April 2020, with a 53% share in the production mix in April 2019 and 46% in April 2020. Hydroelectric generation increased from 3.2 TWh to 3.6 TWh, with a share of the production mix of 13% in April 2019 and 17% in April 2020. The self-consumption share went from 8% to 12% of the total, with an increase of 0.6 TWh (from 1.9 TWh in April 2019 to 2.5 TWh in April 2020). Wind and PV production increased slightly, from 3.2 TWh in April 2019 to 3.5 TWh in 2020. It is interesting to observe the reduction of about 70% in net foreign exchanges, with 2.5 TWh in April 2019 compared to 0.8 TW in the same month of 2020. Fig. 3 compares the coverage of national needs by source for the month of April 2019 and 2020. We can see the reduction in demand, net foreign exchanges, and the increase in the share of PV and wind power in the production mix in April 2020 compared to 2019. In particular, the monthly

demand in April 2020 was covered for the 47% by RES, with +7.5% compared to April 2019. The maximum hourly coverage of demand by RES in April 2019 was 67% (April 27, 2019 at 1 pm), while 76% in April 2020 (April 25, 2020 h13), with a total generation from RES equal respectively to 19.6 GWh and 19.2 GWh, distinguished between geothermal (0.7 GWh), hydroelectric (4.8 and 4.1 GWh), PV (10.2 and 11.1 GWh), and wind power (2.5 and 2 GWh) on a total demand of 29.4 and 25.2 GWh. In both cases, thermoelectric production is attested at around 9.5 GWh.



a. April 2019



b. April 2020

Fig. 3. National generation mix (April 2019 and 2020).

In May 2020, the electricity demand was covered for the 51% by RES (+11.9% compared to May 2019) [9]. The demand reduction during the lockdown and the growing non-conventional generation have led to a drastic drop in energy imports across the foreign border. Reducing import is necessary to keep thermal generation on to balance and secure the system. At the same time, the price differential with foreign areas has been growing. On the north border, in April 2020 there was an average hourly physical exchange in imports of 1541 MWh, a decrease compared to 3962 MWh in the same month of 2019. The decrease regards all foreign trade, particularly with Switzerland (-1373 MWh, from 1688 to 315 MWh), with France (-332 MWh, from 1394 to 1062 MWh) and Slovenia (-665 MWh, from 714 to 49 MWh). Considering the total of foreign exchanges, we can see (Fig. 4) an inversion of flows from Italy to abroad for about 30% of the hours of April 2020. The reduction of imported energy was 70% (equal to about 1.7 TWh) in April 2020 compared to last year, while in March 2020 there was a slight increase in total imported energy, from 3.8 TWh in 2019 to 3.9 TWh in 2020, due largely to higher imports in the first half of March 2020.

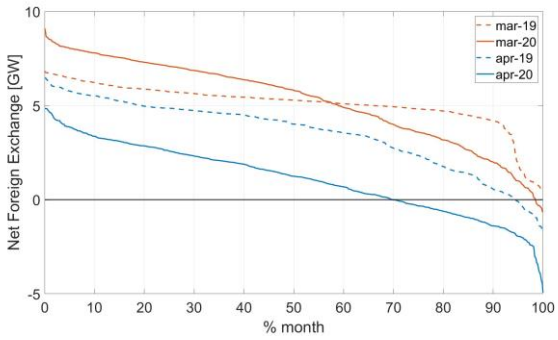


Fig. 4. Duration curve of the total exchanged power in March and April 2019 and 2020.

A preliminary assessment of the possible effects on the security of the events that have taken place following the spread of the epidemic from COVID-19 and the increase in generation from renewable sources, can be carried out with reference to the non-conventional penetration index σ, intended as the share of non-conventional generation compared to the total generation (sum of conventional and non-conventional). The σ index was calculated hourly for the months of March and April in 2019 and 2020 and reported in Fig. 5 as a duration curve. While in March 2019 and 2020 comparison there is no noticeable difference in the maximum values, but a decrease in the minimum values in 2020, an increase in the non-conventional penetration is visible in April 2020 compared to the same month of the last year. In particular, the maximum value grows from 0.47 to 0.52, with more than 60% of the month higher than in 2019.

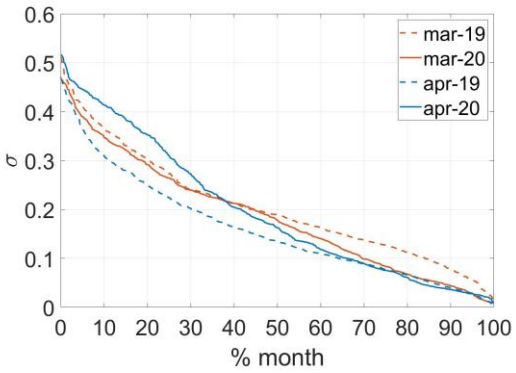


Fig. 5. Hourly duration curve of the non-conventional penetration index for March and April 2019 and 2020.

IV. Impact on the Electricity Markets

The demand reduction has effects mainly on the market, having a direct consequence in the reduction in thermoelectric generation due to its higher positioning in the order of economic merit than renewable, with a reduction in energy prices in the Day Ahead Market. The health emergency therefore accentuated the typical seasonal market dynamics of the months of March and April, characterized by annual minimums in terms of quantity and prices.

The performance of different electricity markets in terms of prices and quantities was analysed globally for the months of January, March and April 2018, 2019 and 2020. The examined markets were the Day Ahead Market (MGP), the Intra-Day Market (MI), the Dispatching Services Market (MSD) and the Balancing Market (MB).

We defined the following metrics:

- PUN (Prezzo Unico Nazionale), P_{MI}, P_{MSD}, P_{MB}, defined as the monthly average price respectively in the MGP, MI, MSD and MB;
- ΔPUN, ΔP_{MI}, ΔP_{MSD}, ΔP_{MB}, defined as the variation of prices in percentage between the same month of the previous year respectively in the MGP, MI, MSD and MB;
- Q_{MGP}, Q_{MI}, Q_{MSD}, Q_{MB} defined as the total volumes moved respectively in the MGP, MI, MSD and MB;
- ΔQ_{MGP}, ΔQ_{MI}, ΔQ_{MSD}, ΔQ_{MB}, defined as the variation of volumes in percentage between the same month of the previous year respectively in the MGP, MI, MSD and MB.

For the MSD ex-ante, the total of purchases and sales was considered as volume and the weighted average between purchases and sales as price. For the Balancing Market, the secondary reserve was considered, with the same criteria adopted for MSD for volumes and prices. The data are taken from the Italian Market Operator (GME) transparency platform [10]. All electricity markets (MGP, MI, MB MSD) were affected by the reduction in volumes, from a maximum of 23% for MI to a minimum of 18% for MGP, except for the MSD which saw a 77% increase in volumes treated. In general, all markets have seen price cuts from 54 to 23%. A synoptic view of the behaviour of market prices is shown in Table III.

A. *Day Ahead Market (MGP)*

In the Day Ahead Market (MGP) the PUN (National Single Price) had a strong reduction in 2020 compared to 2019. In particular, in April 2020 there was a 53% reduction compared to the same month last year, down by 7.2 €/MWh on the previous value of March 2020 and reaching the lowest level ever recorded since the start of the electricity exchange, equal to 24.81 €/MWh [11]. The quantities treated in the MGP also decreased progressively in the months of March and April 2020 compared to the same months of 2019, with reductions of 10% respectively (24.57 TWh in March 2019, 22.09 TWh in March 2020) and 18% (22.39 TWh in April 2019, 18.42 TWh in April 2020). Fig. 6 shows the prices and volumes in the MGP comparing the years 2019 and 2020 from January to April.

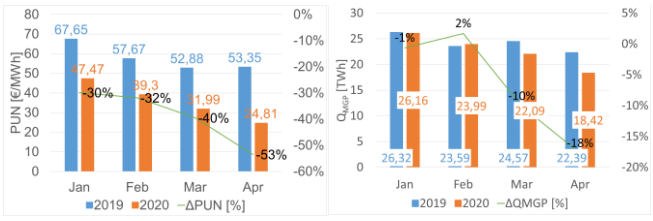


Fig. 6. PUN and overall volumes on the Day Ahead Market (January-April 2019, 2020).

The price reduction also affected the main neighbouring markets, also at historic lows and characterized by negative values in some hours of the month (on Easter Monday the daily price stood at -6.5 €/MWh in France and -13 €/MWh in Germany). In the context of demand contraction, the consequent reduction in the inter-zonal congestions led to decreasing differentials between the prices of the national market areas in March and April 2020, compared to the same months of last year, with a standard deviation going from 4.2 €/MWh to 0.75 €/MWh between March 2019 and 2020 and from 4.8 €/MWh to 0.56 €/MWh between April 2019 and 2020 (Fig. 7). The maximum price differential was 14 €/MWh in April 2019 and dropped to 1.6 €/MWh in April 2020. It is noticeable the proximity of prices between South and Sicily, the latter generally characterized by the highest selling prices, which occurred both in March and April 2020, compared to March 2019 alone. In particular, the South-Sicily transit was congested only in 6% of the monthly hours in April 2020, compared to 35% of the hours of April 2019.

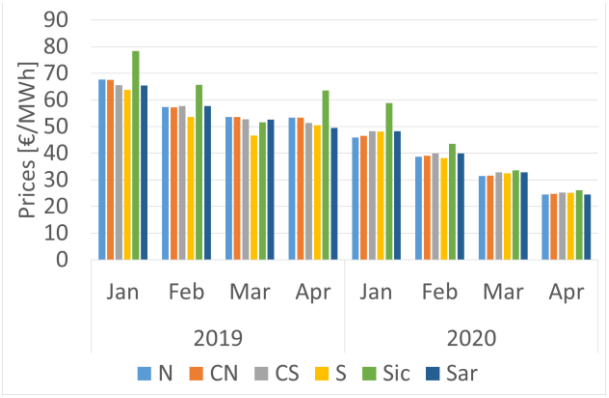


Fig. 7. Italian zonal market prices for the Day Ahead Market (January-April 2019, 2020).

Also in the seven sessions of the Intra-day Market in April 2020 the historical minimums for the average purchase price were reached, equal to 24.9 € / MWh, with an inflection of 53.7% compared to the same month last year, and a reduction of 22% compared to € 32.0 / MWh in March 2020 [12].

B. *Dispatching Services Market (MSD)*

In the examined context, there is an increase in the volumes purchased and sold in the ex-ante Dispatching Services Market (MSD), with values among the highest for over a decade. Fig. 8 shows the total quantities in MSD for the months of January, March and April, divided between purchases and sales, for the years 2018, 2019 and 2020.

TABLE III. PRICE TREND ON THE ITALIAN ELECTRICITY MARKETS (COMPARISON JANUARY-APRIL 2018-2020).

Month		MGP				MI				MSD				MB			
		PUN [Eur/MWh]	ΔPUN [%]	Q_{MGP} [TWh]	ΔQ_{MGP} [%]	P_{MI} [Eur/MWh]	ΔP_{MI} [%]	Q_{MI} [TWh]	ΔQ_{MI} [%]	P_{MSD} [Eur/MWh]	ΔP_{MSD} [%]	Q_{MSD} [TWh]	ΔQ_{MSD} %	P_{MB} [Eur/MWh]	ΔP_{MB} [%]	Q_{MB} [GWh]	ΔQ_{MB} [%]
Jan	'18	49,00		25,63		48,51		2,3		64,99		1,74		57,34		238,1	
	'19	67,65	38%	26,32	3%	66,82	38%	2,5	9%	105,51	62%	1,55	-11%	66,52	3%	240,3	1%
	'20	47,47	-30%	26,16	-1%	47,36	-29%	2	-20%	58,16	-45%	1,79	16%	47,17	-20%	265,4	10%
Mar	'18	56,91		25,48		56,24		2,3		91,63		1,77		58,90		245,8	
	'19	52,88	-7%	24,57	-4%	51,63	-8%	2,1	-9%	67,72	-26%	1,47	-17%	51,33	-13%	245,3	0%
	'20	31,99	-40%	22,09	-10%	32,03	-38%	2	-5%	44,31	-35%	2,47	68%	41,24	-20%	191,3	-22%
Apr	'19	49,39		22,16		49,22		2		101,00		1,75		43,72		231,3	
	'20	53,35	8%	22,39	1%	53,88	9%	2,2	10%	126,54	25%	1,60	-8%	50,17	15%	230,1	0%
	'20	24,81	-53%	18,42	-18%	24,95	-54%	1,7	-23%	89,70	-29%	2,84	77%	38,61	-23%	182,6	-21%

It is observed that typically the spring months are confirmed as those with the greatest movement in volumes, also being the months where the largest share of generation from non-programmable renewable sources is concentrated.

In particular, the further uncertainty due to the prolongation of the COVID-19 pandemic, and the consequent needs in terms of security, have increased volumes in 2020. In detail, in April the total purchases were equal to 1.2 TWh (+118% compared to April 2019), and sales stood at 1.6 TWh (+52% on April 2019), while in March total purchases were equal to 1.1 TWh (+109 % compared to March 2019), and sales stood at 1.3 TWh (+43% on March 2019).

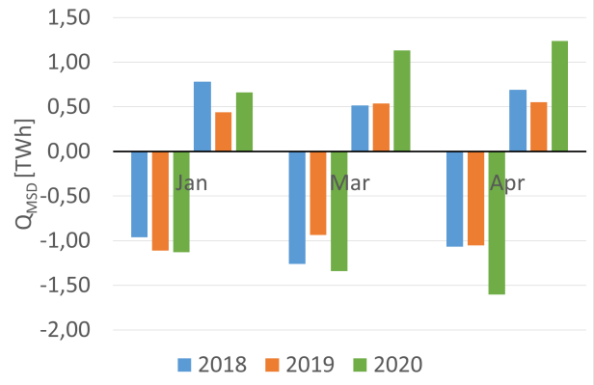


Fig. 8. Purchased and sold volumes in the MSD for the month of January, March and April 2018, 2019 and 2020.

The greater movement in volumes leads to a decrease in prices in €/MWh also in MSD. However, total costs increased both in March and April 2020 compared to the same months of last year, going from 99.7 million euros to 109.6 million euros between March 2019 and 2020 (+9.9%), and from 203.1 million euros to 254.9 million euros between April 2019 and 2020 (+25.5%).

V. Conclusions

Following the Italian lockdown due to the spread of the epidemic from COVID-19, questions raised from different sides about the security of the national electricity system with reference to the consequent reduction of the electrical load and the percentage ratio between fossil and renewable sources, particularly PV and wind power. In this paper, we analysed and discussed the reduction of the electrical demand on the Italian power system, following the measures imposed to fight the pandemic, and the consequent impacts on both electricity markets and system operation strategies. We described what has been observed and some actions taken to keep the lights on. The achievement of adequacy and security requirements implies the availability of a series of services (ancillary services) such as frequency regulation, reserve supply, voltage/reactive power regulation and network black-start which are also supplied following a market logic in a competitive context. The reduction of the thermoelectric generation implies consequently less conventional and synchronous rotating units. Therefore, the system may be subject to a reduction of inertia, reserve margins and of regulating resources (for frequency and voltage), and possible effects on the power system security. It is important to extrapolate some lessons from the pandemic experience, also in the power sector. For example, the increasing need of flexibility, necessary to intervene quickly, which could be met by hydroelectric generators, given the availability of resources from the storage basins. Exchanges with foreign countries can also be considered, reducing imports to maintain a greater number of conventional plants in production. In general, risks for the system are greater in the case of demand increase, a situation in which there may be a lack of redundancy in the generation and greater stress on the infrastructure. In the case of a significant drop in demand, the problem is currently related to the presence in the energy mix of a predominant share of non-conventional generation. However, if conventional plants are available to produce when they are needed, and when requested by the TSO, it is still possible to keep the system in safe conditions, with higher costs in the MSD, as we showed in the paper. This can mean, for example, keeping in production thermoelectric units necessary for quality and stability requirements, against environmental and market costs that could be higher for the system.

References

[1] Gracceva F., Bompard E., Baldissara B., Corgnati S., Mosca C. and Zini A., "Prime stime degli effetti dell'emergenza COVID-19 sul sistema energetico italiano," *Analisi trimestrale del sistema energetico italiano*, ENEA, Apr. 2020. [Online]. Available: https://www.enea.it/it/seguici/pubblicazioni/analisi-trimestrale-del-sistema-energetico-italiano.

[2] J. Giliberto, "Crolla la domanda di energia, per la rete c'è il rischio di black out," *Il Sole 24 Ore*, Mar. 2020.

[3] E. Bompard, C. Mosca, S. Cellura and S. Corgnati, "L'impatto del COVID-19 sul carico elettrico nazionale/1," *Blog di Energia*, March 2020. [Online]. Available: https://www.rivistaenergia.it/.

[4] E. Bompard, C. Mosca, S. Cellura and S. Corgnati, "L'impatto del COVID-19 sul carico elettrico nazionale/2," *Blog di Energia*, April 2020. [Online]. Available: https://www.rivistaenergia.it/.

[5] F. Gracceva, E. Bompard, B. Baldissara, S. Corgnati, C. Mosca and A. Zini, "COVID-19 e sistema energetico italiano: una prima valutazione," Energia, June 2020.

[6] IEEE Power & Energy Society. Sharing Knowledge on Electrical Energy Industry's First Response to COVID-19, Apr. 2020.

[7] S. A. Casa, E. Zanardelli and A. Marchisio, "Italia: nel sistema elettrico post-Covid più spazio per le rinnovabili," RiEnergia, Jun. 2020. [Online]. Available: https://rienergia.staffettaonline.com/.

[8] Terna. Transparency Platform, 2020.

[9] Terna. Monthly Report on the Electricity System, May 2020.

[10] GME. Transparency Platform. 2020.

[11] GME. Monthly Report, May 2020.

[12] GME. Monthly Report, April 2020.