
Swissgrid Service System Analysis

Yassin Alnuaimee

yassinuaimee@gmail.com

November 2024

Contents

1 Abstract	1
2 Introduction	1
3 Principles of Swissgrid Ancillary Services	1
3.1 Primary Control (Frequency Containment Reserve - FCR)	1
3.2 Secondary Control (Frequency Restoration Reserve - FRR)	1
3.3 Tertiary Control (Manual Frequency Restoration Reserve - mFRR and Replacement Reserve - RR)	2
3.4 Voltage Support	2
3.5 Active Power Losses and Inadvertent Deviation	2
4 Analysis overview	2
4.1 Primary Reserve Load	2
4.2 Secondary Reserve Load	6
4.3 Tertiary Reserve Load	13
5 Data 2019	20
5.1 Primary control auction 2019	20
5.2 Secondary control auction 2019	22
5.3 Tertiary control auction 2019	23
6 Data 2020	29
6.1 Primary control auction 2020	29
6.2 Secondary control auction 2020	32
6.3 Tertiary control auction 2020	34
7 Data 2021	39
7.1 Primary control auction 2021	39
7.2 Secondary control auction 2021	42
7.3 Tertiary control auction 2021	43
8 Data 2022	48
8.1 Primary control auction 2022	48
8.2 Secondary control auction 2022	51
8.3 Tertiary control auction 2022	52
9 Data 2023	57
9.1 Primary control auction 2023	57
9.2 Secondary control auction 2023	60
9.3 Tertiary control auction 2023	61
10 Data 2024	66
10.1 Primary control auction 2024	66
10.2 Secondary control auction 2024	69
10.3 Tertiary control auction 2024	70
11 Conclusion	75

1 Abstract

This analysis explores Swissgrid's ancillary services market, focusing on the mechanisms and pricing dynamics involved in Switzerland's electricity balancing system. Ancillary services, such as primary, secondary, and tertiary control reserves, are critical for maintaining grid stability by balancing supply and demand fluctuations in real time. By examining data on bidding volumes, attributed costs, and prices from Swissgrid's records, this study investigates patterns and trends in the procurement of reserves. The research particularly examines the potential revenues a company could generate by investing in battery storage systems with a total capacity of 10 MW, providing insights into the economic viability of such an investment. The findings offer valuable information for stakeholders aiming to optimize their participation in Swissgrid's auctions and evaluate the business case for battery-based reserves in the ancillary services market.

2 Introduction

In the context of an evolving energy landscape driven by the increasing integration of renewable energy sources, the role of ancillary services in ensuring grid stability has become indispensable. Unlike conventional energy sources, renewable energy—primarily from wind and solar—is inherently variable and less predictable, introducing new challenges for grid management. Ancillary services address these challenges by providing essential reserves and support activities that ensure the reliable operation of the electricity grid. Swissgrid, the national transmission system operator for Switzerland, manages these services to maintain critical parameters such as grid frequency, voltage stability, and the balance between supply and demand. This is achieved through the contracting of various reserves, including primary, secondary, and tertiary control reserves, facilitated by a competitive bidding system.

This analysis delves into Swissgrid's ancillary service auctions, examining historical data on prices and volumes for different control reserves, with a particular emphasis on secondary control. A unique aspect of this research is the exploration of smaller volume bids—specifically those utilizing battery storage with a total capacity of 10 MW—to evaluate potential revenue generation and market impact. With battery storage emerging as a flexible solution for quick-response reserve provision, understanding the dynamics of bidding with a 10 MW battery system can offer valuable insights into the profitability and strategic advantages of such investments in the ancillary services market. This study contributes to a deeper understanding of the economic and operational aspects of Swissgrid's balancing services, providing a data-driven perspective for market participants and policymakers as they navigate the complexities of grid stability in a renewable-rich energy system.

It is noteworthy to inform you why this analysis starts from 2019 when we have data from 2015. It appears that the service system infrastructure has changed a lot along the years. Indeed, from 2015 to 2018, there wasn't a distinction between SRL+ and SRL- and the PRL was traded weekly. Moreover, in 2015 There was no daily TRL+ bid. Therefore, for the sake of homogeneity and good comparison, i chose to start the analysis from 2019.

3 Principles of Swissgrid Ancillary Services

Swissgrid, as the national transmission system operator for Switzerland, manages a range of ancillary services essential for maintaining grid stability, including Primary Control, Secondary Control, Tertiary Control, Voltage Support, and services to compensate for active power losses [1] [2] [3].

3.1 Primary Control (Frequency Containment Reserve - FCR)

Primary control, also known as Frequency Containment Reserve, is the first line of defense to stabilize grid frequency at 50 Hz. This service addresses disturbances within seconds and involves daily competitive bidding for four-hour slots. Bids are symmetric with a minimum bid size of 1 MW, applying to both increases and decreases in frequency, and prices are offered in EUR per MW.

3.2 Secondary Control (Frequency Restoration Reserve - FRR)

Secondary control, or Frequency Restoration Reserve, restores the frequency within minutes (5min after outage), managing fluctuations over a longer period. This reserve is divided into:

- **SRL+ (positive):** to increase generation or decrease demand when frequency is low.
- **SRL- (negative):** to decrease generation or increase demand when frequency is high.

Secondary control is tendered weekly, with a minimum bid size of 5 MW. Pricing is done in CHF per MW, with compensation based on bid prices and actual energy used.

3.3 Tertiary Control (Manual Frequency Restoration Reserve - mFRR and Replacement Reserve - RR)

Tertiary control provides additional support when secondary control is fully deployed, particularly for prolonged or large imbalances (15min after outage). Swissgrid uses two tender types:

- **Daily Tenders (weekdays only):** Cover four-hour periods (e.g., 00:00–04:00).
- **Weekly Tenders:** Run from Monday to Sunday.

Prices are awarded based on multi-level bids and platforms like MARI and TERRE coordinate reserve sharing with other European countries.

3.4 Voltage Support

Voltage support maintains voltage stability and involves different types of support:

- **Mandatory Voltage Support:** Required from all transmission-connected power plants.
- **Extra-Mandatory Support:** Involves distribution systems and other parties, with additional agreements for compensation.

Compensation varies based on compliance with reactive energy requirements.

3.5 Active Power Losses and Inadvertent Deviation

This service covers energy losses in grid operation. Swissgrid contracts yearly, quarterly, and monthly volumes to offset these losses. Only balance groups within the Swiss control area with framework agreements can participate in these tenders.

This structure not only breaks down each service but also provides insight into how these services operate within the Swissgrid system, ensuring a stable and reliable grid.

4 Analysis overview

4.1 Primary Reserve Load

Year	Count	Mean	Std Dev	Min	25%	Median	75%	Max
2019	7,742	288.24	460.43	0.00	104.00	134.00	166.00	3,343.00
2020	63,026	20.08	28.06	0.00	5.00	10.60	20.50	408.00
2021	89,939	29.19	35.45	0.00	7.90	19.00	38.00	491.53
2022	66,411	46.34	42.31	0.00	17.30	35.00	64.00	435.95
2023	50,881	30.42	23.71	0.00	15.50	25.00	40.00	263.44
2024	63,314	40.91	33.13	0.00	21.20	33.50	52.00	349.50

Table 1: PRL Price Statistics by Year

The analysis of Primary Reserve Load (PRL) price distributions from 2019 to 2024 reveals significant temporal trends and market characteristics. Figure [1] visually illustrates the trends in price variability over the years, while Table [1] provides detailed statistics to support this observation.

Observations by Year

- **2019:** The PRL market in 2019 displayed high variability in prices, with an average price of 288.24 EUR/MW and a standard deviation of 460.43 EUR/MW. The median price (134.00 EUR/MW) was significantly lower than the mean, highlighting the presence of extreme outliers, with prices reaching a maximum of 3,343.00 EUR/MW.
- **2020:** There was a sharp decline in average prices to 20.08 EUR/MW, with reduced variability (standard deviation: 28.06 EUR/MW). The distribution shifted downward, with the median price falling to 10.60 EUR/MW and the 75th percentile at only 20.50 EUR/MW.
- **2021:** A modest recovery was observed, with an average price of 29.19 EUR/MW and increased variability (standard deviation: 35.45 EUR/MW). The median price rose to 19.00 EUR/MW, indicating a positive trend in market prices compared to 2020.

PRL price distribution by Year

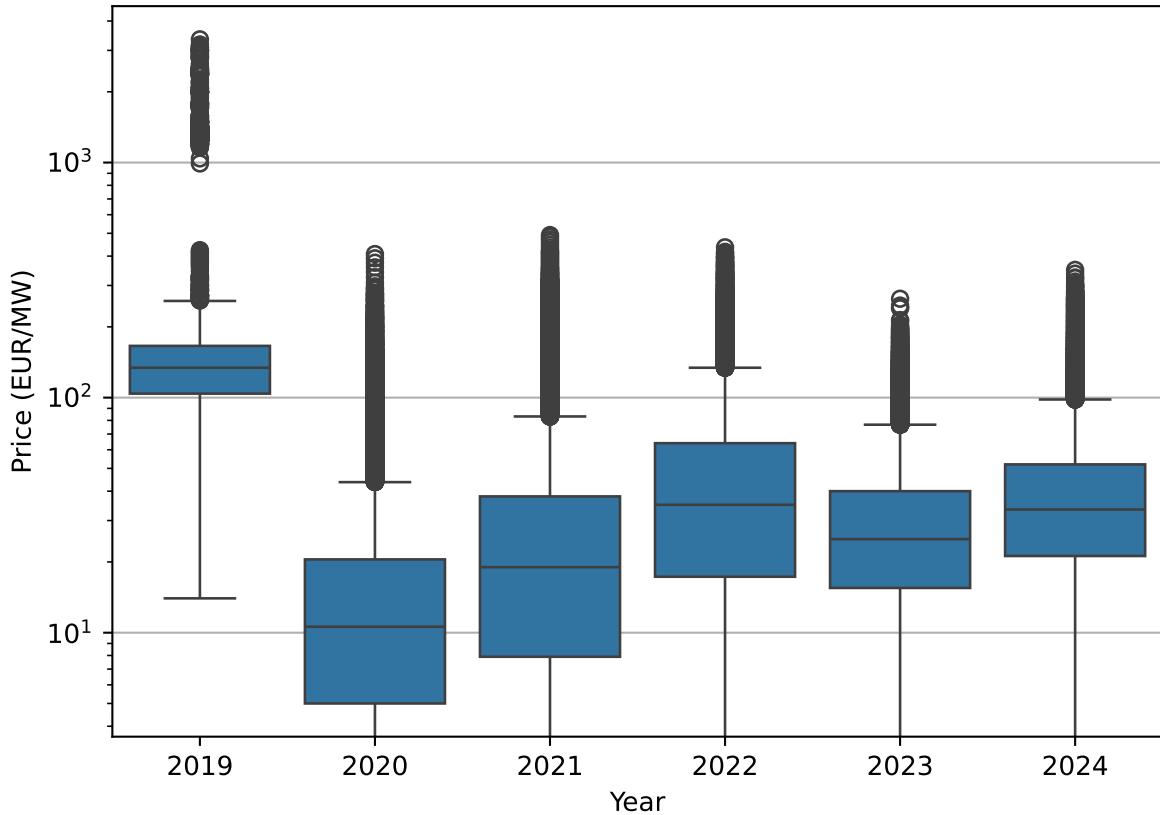


Figure 1: PRL price distribution by year

- **2022:** The market experienced a further rise in average prices to 46.34 EUR/MW, along with higher variability (standard deviation: 42.31 EUR/MW). Median and 75th percentile prices reached 35.00 EUR/MW and 64.00 EUR/MW, respectively, signaling an upward trend in price levels.
- **2023:** A slight decline in average prices to 30.42 EUR/MW was noted, with reduced variability (standard deviation: 23.71 EUR/MW). The median price (25.00 EUR/MW) remained higher than in 2021, suggesting some stabilization after the previous year's peak.
- **2024:** Prices recovered moderately, with an average price of 40.91 EUR/MW and a standard deviation of 33.13 EUR/MW. The median price (33.50 EUR/MW) and the 75th percentile (52.00 EUR/MW) reflected stabilization at higher levels.

Key Insights

- **Downward Shift in 2020:** The significant drop in average and median prices from 2019 to 2020 is most probably due to the fact we only have data starting from July for PRL for 2019. This can also be observed in the count of data in table [1]. However, it could also be due to a possible change in market conditions, such as increased competition, regulatory interventions, or demand shifts.
- **Recovery and Variability:** From 2021 onwards, prices exhibit a gradual recovery, with increasing variability through 2022. However, 2023 shows a temporary dip, possibly due to market corrections or external shocks.
- **Stabilization Trends:** By 2024, the market appears to stabilize, with prices achieving moderate growth compared to earlier years. The reduction in standard deviation from 2022 to 2023 highlights increasing price predictability, indicative of market maturation and better regulatory control.
- **Impact of MARI and PICASSO Group Dynamics:** MARI and PICASSO are European platforms for exchanging balancing energy, which aim to optimize cross-border electricity balancing. The dynamic participation of countries in these groups directly affects the PRL prices. Countries entering or exiting these balancing energy platforms can influence supply-demand dynamics, leading to variations in prices observed across the years.

Implications

The observed trends in PRL prices suggest that the market underwent significant fluctuations driven by external and structural factors. The high variability, particularly in earlier years, indicates a less mature market, which seems to have stabilized in recent years.

The influence of countries joining or leaving the MARI and PICASSO groups highlights the interconnected nature of balancing markets in Europe. These findings suggest the need for further investigation into how participation in these groups shapes market dynamics, as well as other factors such as regulatory impacts, seasonal effects, and market demand-supply conditions. Future studies could analyze the impact of renewable energy integration on PRL prices, as well as evaluate the effectiveness of cross-border collaborations in enhancing market stability.

Observations by Season

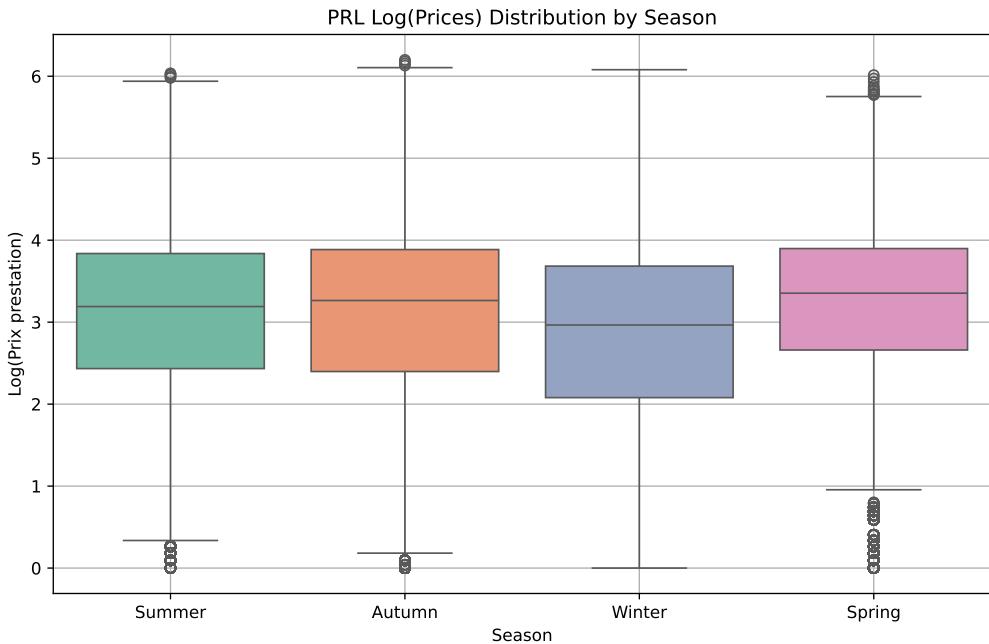


Figure 2: PRL Log prices distribution by season

Season	Count	Mean	Std Dev	Min	25%	Median	75%	Max
Autumn	90,652	38.11	42.96	0.00	10.00	25.16	47.70	491.53
Spring	73,845	36.32	33.26	0.00	13.30	27.60	48.30	408.00
Summer	109,634	35.65	38.31	0.00	10.40	23.30	45.40	417.07
Winter	66,303	29.04	31.85	0.00	7.00	18.40	38.80	435.95

Table 2: PRL Price Statistics by Season

- **Autumn:** The highest mean price (38.11 EUR/MW) and standard deviation (42.96 EUR/MW) are observed in Autumn, indicating significant volatility. The median price (25.16 EUR/MW) suggests moderate price levels, but the maximum price (491.53 EUR/MW) highlights periods of extreme demand.
- **Spring:** With a mean price of 36.32 EUR/MW and a standard deviation of 33.26 EUR/MW, Spring prices are slightly lower than those in Autumn but exhibit less variability. The median price (27.60 EUR/MW) reflects relatively stable market conditions.
- **Summer:** A mean price of 35.65 EUR/MW and a higher standard deviation (38.31 EUR/MW) than Spring indicate increased variability in Summer. The median price (23.30 EUR/MW) shows a lower central tendency compared to Autumn and Spring.

- **Winter:** The lowest mean price (29.04 EUR/MW) and standard deviation (31.85 EUR/MW) are observed in Winter, along with a median price of 18.40 EUR/MW. These statistics suggest reduced market activity and more predictable prices during this season.

Key Insights

- **Seasonal Variations:** Autumn exhibits the highest price levels and variability, likely driven by increased balancing needs during seasonal transitions. In contrast, Winter shows the lowest prices and variability, reflecting a more stable market environment.
- **Market Stability:** The reduced variability in Winter and moderate price levels in Spring suggest opportunities for cost optimization and improved predictability for stakeholders.
- **Operational Implications:** High volatility in Autumn and Summer may necessitate enhanced forecasting and reserve management strategies to mitigate risks.

Implications

The seasonal analysis of PRL prices highlights distinct patterns in market dynamics. Stakeholders can leverage these insights to optimize their operational strategies. For instance, Winter's stability offers a predictable period for budgeting, while Autumn and Summer's high variability require robust forecasting tools and contingency planning. Future analyses could explore the underlying drivers of these seasonal trends, such as weather-dependent demand and renewable energy integration.

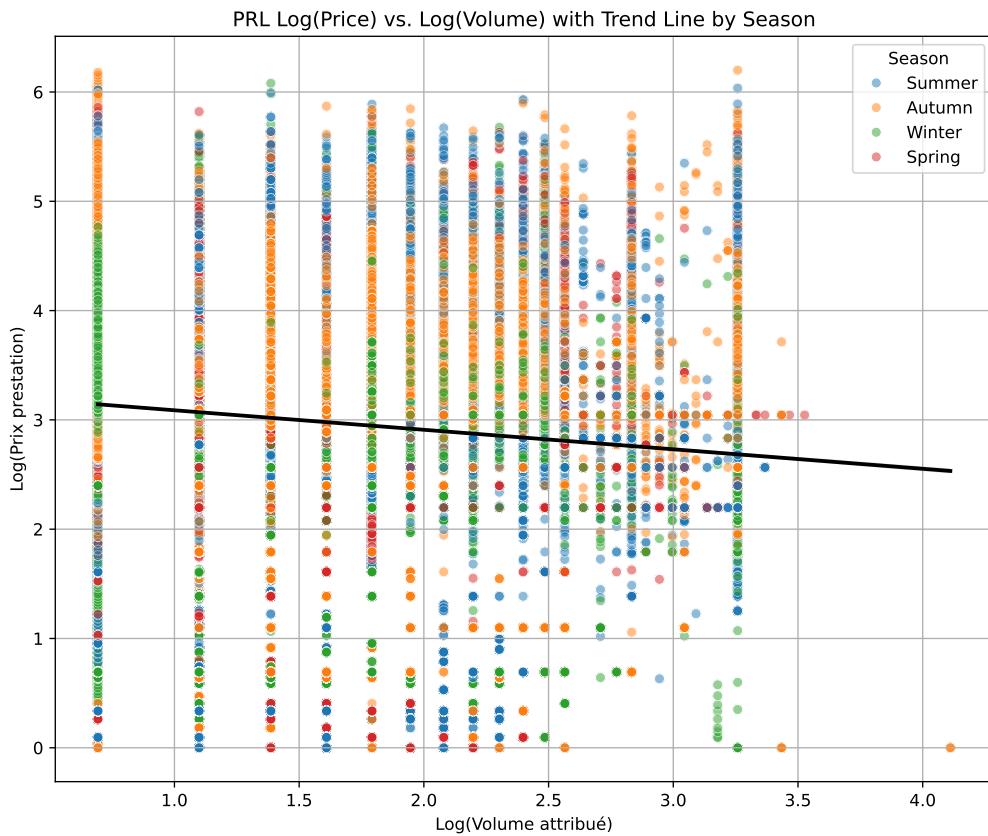


Figure 3: PRL Log price vs volume trendline by season

Regression Analysis

The regression analysis reveals important insights into the relationship between PRL log(price) and the predictors, including seasonality and log(volume).

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Intercept	3.3156	0.005	657.320	0.000
Season (Spring)	0.0666	0.005	12.130	0.000
Season (Summer)	-0.0013	0.005	-0.261	0.794
Season (Winter)	-0.2684	0.006	-47.421	0.000
Log(Volume attribué)	-0.1888	0.003	-56.407	0.000

Table 3: OLS Regression Results for PRL Log(Price) vs. Log(Volume)

- **Intercept:** The intercept is 3.3156, representing the expected log(price) when the volume is at its baseline and the reference season is Autumn. This corresponds to a base price of approximately $e^{3.3156} \approx 27.6$ EUR/MW.
- **Seasonal Effects:**
 - **Spring:** A coefficient of 0.0666 suggests that PRL prices in Spring are $e^{0.0666} - 1 \approx 6.9\%$ higher than in Autumn, holding volume constant.
 - **Summer:** The coefficient -0.0013 indicates no significant difference in prices compared to Autumn ($p = 0.794$).
 - **Winter:** A coefficient of -0.2684 shows that Winter prices are $e^{-0.2684} - 1 \approx -23.5\%$ lower than in Autumn.
- **Log(Volume attribué):** The coefficient -0.1888 indicates that a 1% increase in volume is associated with a 0.1888% decrease in price, highlighting a negative relationship between volume and price.
- **Model Fit:** The R^2 value of 0.019 indicates that the model explains about 1.9% of the variation in log(price), suggesting that other factors significantly influence PRL prices. The highly significant F-statistic validates the overall model.
- **Durbin-Watson Statistic:** The low value (0.688) suggests potential autocorrelation in the residuals, warranting further investigation.

Implications

The regression results emphasize the following:

- The negative relationship between log(volume) and log(price) highlights the importance of market competition in driving prices down.
- Seasonal effects are significant, particularly for Spring and Winter, where prices deviate notably from Autumn.
- Future analyses should consider additional predictors, such as grid demand, renewable energy penetration, and regulatory impacts, to improve the model's explanatory power.

4.2 Secondary Reserve Load

4.2.1 Negative SRL

Year	Count	Mean	Std Dev	Min	25%	Median	75%	Max
2019	804	1832.94	1339.00	386.40	756.00	1495.20	2350.50	6400.00
2020	906	1363.62	908.26	274.00	695.13	1081.00	1627.19	4417.00
2021	1102	2597.84	2235.81	430.00	965.00	1867.00	3488.00	17700.00
2022	1104	10029.51	8792.91	2178.96	3685.68	5362.60	14950.50	41776.00
2023	1392	14625.81	15045.99	1588.00	2505.72	9142.00	20423.75	67144.00
2024	952	2283.62	2289.64	249.00	856.80	1246.00	2800.25	9376.00

Table 4: SRL- Price Statistics by Year

The analysis of Secondary Reserve Load (SRL-) price distributions from 2019 to 2024 reveals notable trends and variability across the years. Figure [4] visually illustrates the changes in price distribution over time, while Table [4] provides detailed statistics for each year.

SRL- price distribution by Year

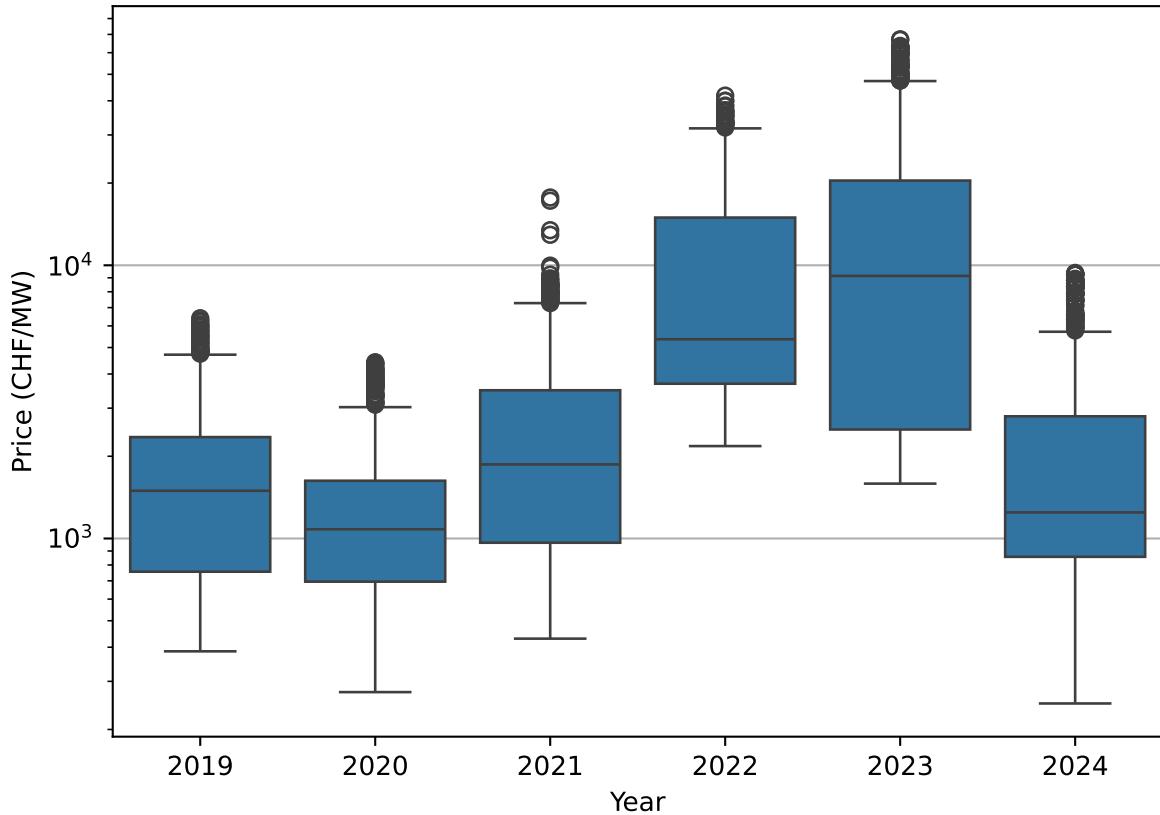


Figure 4: SRL- price distribution by year

Observations by Year

- **2019:** The mean price of 1832.94 CHF/MW and a relatively high standard deviation (1339.00 CHF/MW) indicate significant variability. The median price (1495.20 CHF/MW) is slightly below the mean, suggesting the presence of some outliers on the higher end, with a maximum price of 6400.00 CHF/MW.
- **2020:** A notable decrease in the mean price to 1363.62 CHF/MW is observed, with a reduced standard deviation (908.26 CHF/MW). The lower median price (1081.00 CHF/MW) reflects a general downward trend in the market compared to 2019.
- **2021:** The market shows recovery with a rise in the mean price to 2597.84 CHF/MW and an increased standard deviation (2235.81 CHF/MW). The median price (1867.00 CHF/MW) suggests that prices are becoming more variable, with a maximum value reaching 17700.00 CHF/MW.
- **2022:** A significant increase in the mean price to 10029.51 CHF/MW is observed, along with a high standard deviation (8792.91 CHF/MW). The median price (5362.60 CHF/MW) reflects a substantial upward shift, with maximum prices reaching as high as 41776.00 CHF/MW.
- **2023:** Prices peaked further with a mean of 14625.81 CHF/MW and a high standard deviation (15045.99 CHF/MW). The median price (9142.00 CHF/MW) and the 75th percentile (20423.75 CHF/MW) highlight increased volatility.
- **2024:** A significant decline in the mean price to 2283.62 CHF/MW and reduced variability (standard deviation: 2289.64 CHF/MW) suggest market stabilization. The median price (1246.00 CHF/MW) reflects this downward adjustment.

Key Insights

- **Volatility Trends:** SRL- prices exhibited high volatility, particularly in 2022 and 2023, likely driven by market shocks or increased demand for balancing services.

- **Market Stabilization:** The sharp reduction in prices in 2024 suggests stabilization, potentially influenced by regulatory changes or improvements in grid efficiency.
- **Impact of Demand-Supply Dynamics:** The trends indicate a strong influence of demand-supply dynamics on SRL- prices, with significant price increases during periods of high demand (e.g., 2022-2023).

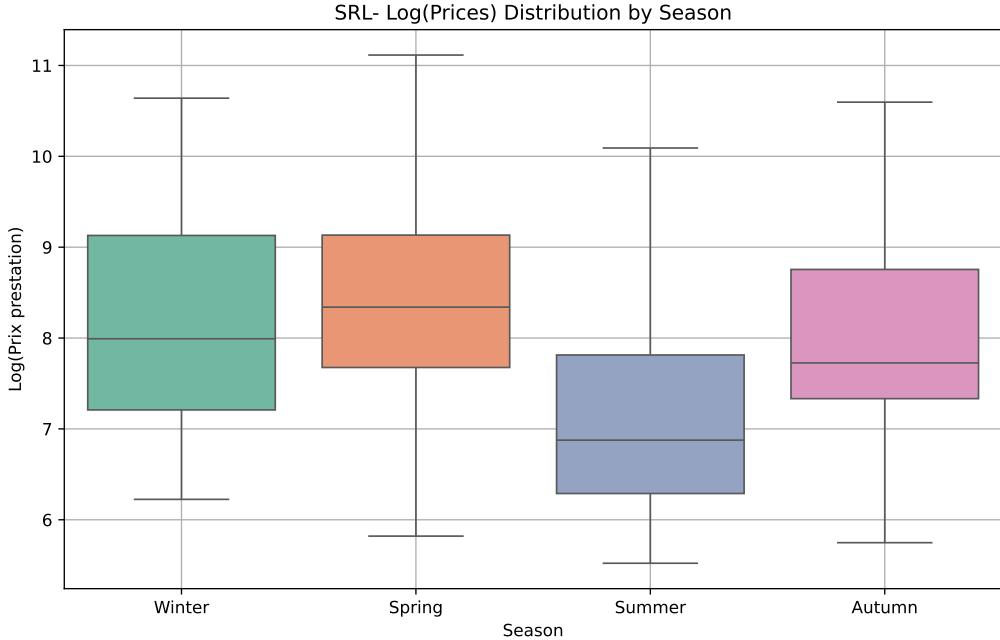


Figure 5: SRL- Log(Prices) Distribution by Season

Season	Count	Mean	Std Dev	Min	25%	Median	75%	Max
Autumn	1414	6160.98	8085.28	312.48	1528.80	2266.00	6341.25	39988.10
Spring	1890	10187.53	13855.84	336.00	2155.00	4188.24	9254.48	67144.00
Summer	1669	1960.80	2745.99	249.00	537.60	968.00	2473.00	24136.00
Winter	1287	6168.62	7144.22	504.00	1350.50	2956.80	9218.50	41776.00

Table 5: SRL- Price Statistics by Season

Observations by Season

- **Autumn:** Moderate prices with a mean of 6160.98 CHF/MW and high variability (standard deviation: 8085.28 CHF/MW). The 75th percentile (6341.25 CHF/MW) suggests occasional price spikes.
- **Spring:** The highest average price (10187.53 CHF/MW) and variability (standard deviation: 13855.84 CHF/MW) are observed, with maximum prices reaching 67144.00 CHF/MW.
- **Summer:** The lowest mean price (1960.80 CHF/MW) and standard deviation (2745.99 CHF/MW) are observed, reflecting reduced market activity.
- **Winter:** Prices remain moderate with a mean of 6168.62 CHF/MW and a standard deviation of 7144.22 CHF/MW. The 75th percentile (9218.50 CHF/MW) highlights occasional high-demand scenarios.

Key Insights

- **Seasonal Variability:** Spring exhibits the highest prices and variability, while Summer shows the lowest. This trend may be linked to seasonal demand fluctuations and grid conditions.

- **Operational Challenges:** The high variability in Spring and Autumn underscores the need for improved forecasting and reserve management strategies.
- **Market Efficiency:** The lower prices in Summer suggest opportunities for cost optimization and better resource allocation during this period.

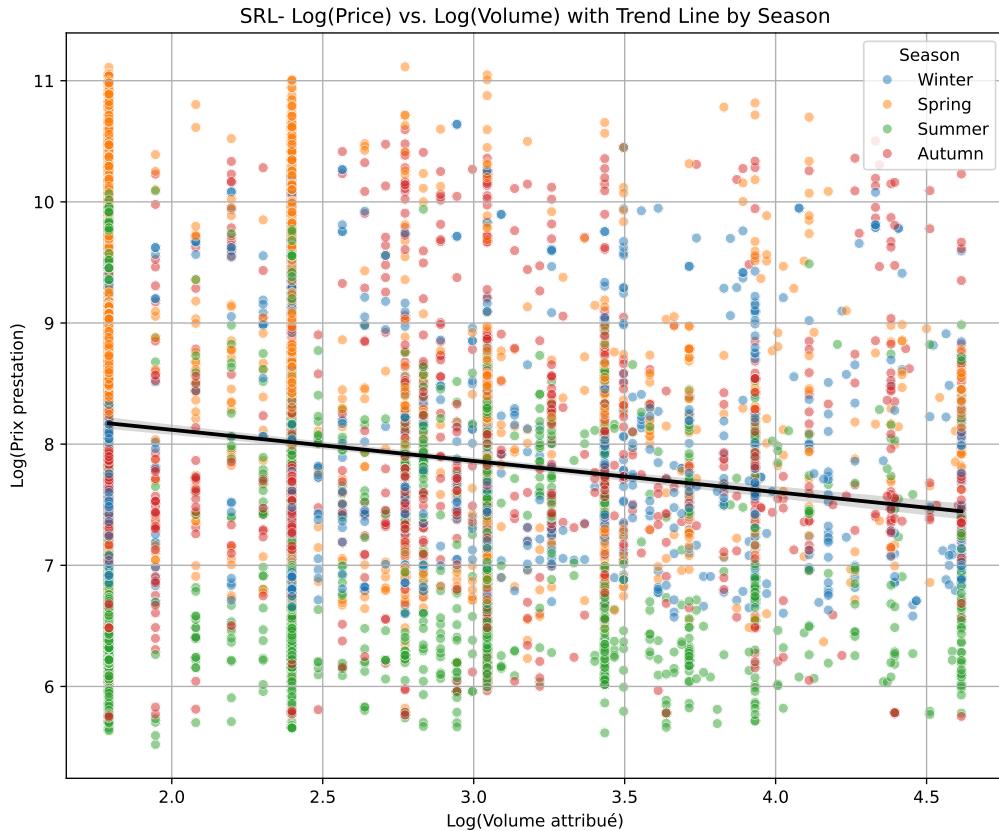


Figure 6: SRL- Log(Price) vs. Log(Volume) with Trend Line by Season

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Intercept	8.6713	0.053	163.279	0.000
Season (Spring)	0.3774	0.038	10.002	0.000
Season (Summer)	-0.9832	0.039	-25.529	0.000
Season (Winter)	0.1160	0.041	2.826	0.005
Log(Volume attribué)	-0.2248	0.016	-13.714	0.000

Table 6: OLS Regression Results for SRL- Log(Price) vs. Log(Volume)

Regression Analysis

The regression analysis highlights key relationships between SRL- prices, volume, and seasonality:

- **Intercept:** The baseline log(price) is 8.6713, corresponding to an average price of approximately $e^{8.6713} \approx 5800.10$ CHF/MW for Autumn.
- **Seasonal Effects:**
 - **Spring:** Prices are $e^{0.3774} - 1 \approx 45.9\%$ higher compared to Autumn.
 - **Summer:** Prices are $e^{-0.9832} - 1 \approx -62.8\%$ lower compared to Autumn.
 - **Winter:** Prices are $e^{0.1160} - 1 \approx 12.3\%$ higher compared to Autumn.

- **Log(Volume attribué):** A coefficient of -0.2248 indicates that a 1% increase in volume leads to a 0.2248% decrease in price, highlighting the inverse relationship between volume and price.
- **Model Fit:** The R^2 value of 0.227 suggests that the model explains 22.7% of the variation in SRL-prices, indicating a relatively strong fit compared to PRL model.

Implications

- **Volume-Price Relationship:** The negative relationship underscores the role of market competition in driving prices down as volume increases.
- **Seasonal Dynamics:** The significant seasonal effects indicate the need for tailored strategies during high-variability periods, such as Spring.
- **Grid Optimization:** Insights from the regression model can support grid operators in optimizing reserves and pricing strategies to enhance market efficiency.

4.2.2 Positive SRL

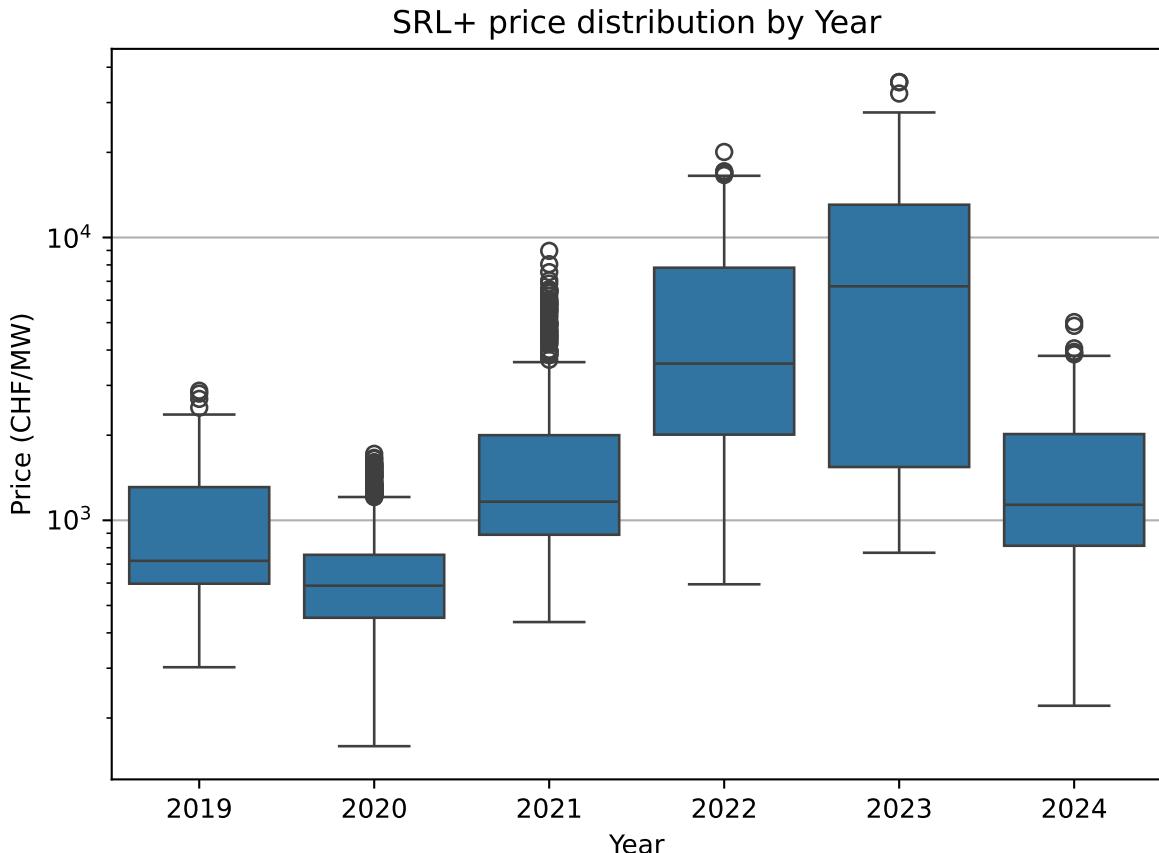


Figure 7: SRL+ price distribution by year

Year	Count	Mean	Std Dev	Min	25%	Median	75%	Max
2019	657	942.40	460.46	302.40	597.00	719.00	1310.40	2872.80
2020	678	666.25	315.65	159.00	452.40	587.50	755.16	1718.00
2021	846	1665.95	1291.64	436.80	889.25	1164.00	2000.00	8971.00
2022	1003	5062.00	3753.38	594.00	2009.00	3582.00	7820.00	20064.80
2023	1044	7981.94	6972.08	768.00	1543.50	6720.00	13058.75	35448.00
2024	701	1453.28	850.26	221.00	813.00	1135.00	2018.44	5023.20

Table 7: SRL+ Price Statistics by Year

The analysis of Secondary Reserve Load (SRL+) price distributions from 2019 to 2024 reveals notable trends and variability across the years. Figure [7] visually illustrates the changes in price distribution over time, while Table [7] provides detailed statistics for each year.

Observations by Year

- **2019:** The mean price of 942.40 CHF/MW and a standard deviation of 460.46 CHF/MW suggest moderate variability. The median price (719.00 CHF/MW) is below the mean, indicating the presence of higher price outliers.
- **2020:** A decline in the mean price to 666.25 CHF/MW with reduced variability (315.65 CHF/MW) reflects a downward trend. The median price (587.50 CHF/MW) is close to the 25th percentile, indicating less skewness.
- **2021:** Prices increased significantly with a mean of 1665.95 CHF/MW and a higher standard deviation of 1291.64 CHF/MW. The maximum price rose to 8971.00 CHF/MW, indicating periods of extreme demand.
- **2022:** A substantial rise in the mean price to 5062.00 CHF/MW, coupled with increased variability (3753.38 CHF/MW), reflects higher market activity. Median price rose to 3582.00 CHF/MW.
- **2023:** Prices peaked with a mean of 7981.94 CHF/MW and high variability (6972.08 CHF/MW). The median price (6720.00 CHF/MW) and maximum price (35448.00 CHF/MW) highlight significant volatility.
- **2024:** Prices decreased sharply, with a mean of 1453.28 CHF/MW and reduced variability (850.26 CHF/MW). Median price dropped to 1135.00 CHF/MW, reflecting market stabilization.

Key Insights

- **Volatility Trends:** Prices exhibited significant volatility, particularly in 2022 and 2023, likely due to increased demand for balancing services.
- **Market Stabilization:** The decline in prices in 2024 suggests stabilization, possibly driven by regulatory interventions or better grid management.
- **Demand-Supply Dynamics:** The trends indicate strong market influences on SRL+ prices, with notable increases during periods of high demand.

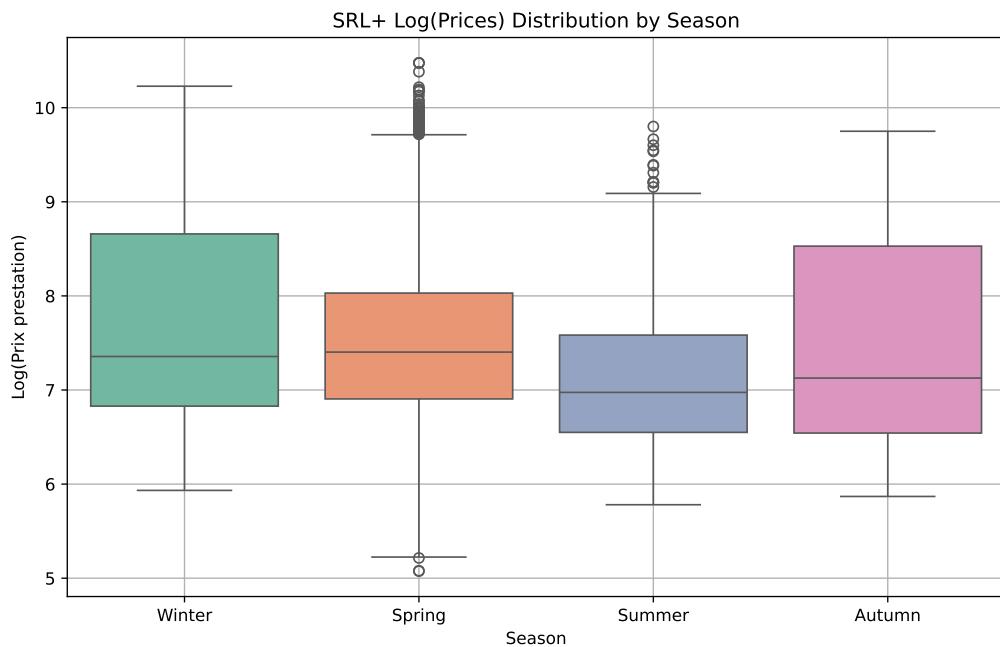


Figure 8: SRL+ Log prices distribution by season

Season	Count	Mean	Std Dev	Min	25%	Median	75%	Max
Autumn	1158	3083.57	3517.45	352.80	693.00	1244.04	5057.25	17150.56
Spring	1535	3979.01	5442.99	159.00	996.28	1639.68	3070.50	35448.00
Summer	1008	1615.86	1702.19	323.00	698.00	1068.00	1964.34	18041.00
Winter	1228	4561.90	5542.03	376.32	923.00	1564.50	5759.00	27679.20

Table 8: SRL+ Price Statistics by Season

Observations by Season

- **Autumn:** Prices averaged 3083.57 CHF/MW with moderate variability. The median price (1244.04 CHF/MW) and maximum (17150.56 CHF/MW) highlight occasional spikes.
- **Spring:** The highest mean price (3979.01 CHF/MW) and variability were observed, with a maximum price of 35448.00 CHF/MW.
- **Summer:** The lowest mean price (1615.86 CHF/MW) and variability suggest reduced market activity during this period.
- **Winter:** Prices averaged 4561.90 CHF/MW with significant variability, reflecting higher demand and occasional extreme values (maximum: 27679.20 CHF/MW).

Key Insights

- **Seasonal Variability:** Spring and Winter exhibited the highest prices and variability, while Summer showed the lowest. These trends are likely influenced by seasonal demand changes.
- **Operational Challenges:** High variability in Spring underscores the need for robust forecasting and reserve management.
- **Market Efficiency:** Summer's lower prices suggest opportunities for cost optimization and resource allocation.

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Intercept	8.0084	0.052	152.647	0.000
Season (Spring)	0.1202	0.040	3.023	0.003
Season (Summer)	-0.3056	0.044	-6.933	0.000
Season (Winter)	0.2867	0.042	6.867	0.000
Log(Volume attribué)	-0.1963	0.015	-12.737	0.000

Table 9: OLS Regression Results for SRL+ Log(Price) vs. Log(Volume)

Regression Analysis

The regression analysis highlights key relationships between SRL+ prices, volume, and seasonality:

- **Intercept:** The baseline log(price) is 8.0084, corresponding to an average price of approximately $e^{8.0084} \approx 3000.56$ CHF/MW for Autumn.
- **Seasonal Effects:**
 - **Spring:** Prices are $e^{0.1202} - 1 \approx 12.8\%$ higher compared to Autumn.
 - **Summer:** Prices are $e^{-0.3056} - 1 \approx -26.3\%$ lower compared to Autumn.
 - **Winter:** Prices are $e^{0.2867} - 1 \approx 33.2\%$ higher compared to Autumn.
- **Log(Volume attribué):** A coefficient of -0.1963 indicates that a 1% increase in volume leads to a 0.1963% decrease in price, highlighting the inverse relationship between volume and price.
- **Model Fit:** The R^2 value of 0.076 indicates that the model explains 7.6% of the variation in SRL+ prices, suggesting other factors significantly influence price trends.

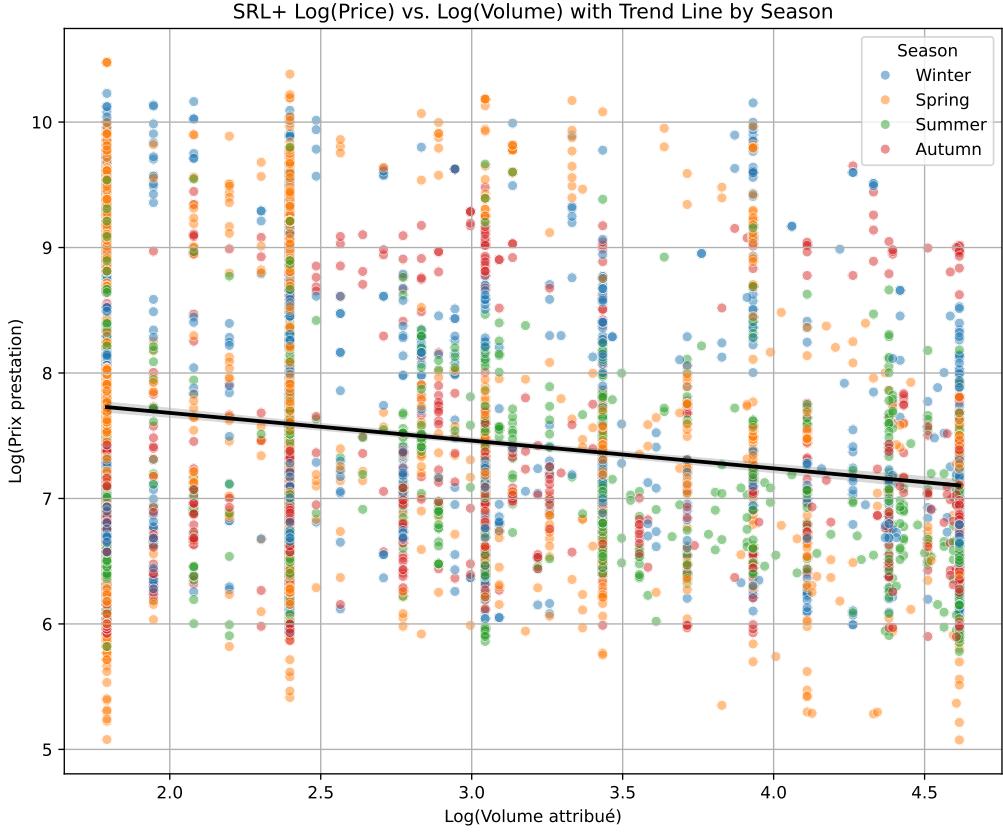


Figure 9: SRL+ Log price vs volume trendline by season

Implications

- **Volume-Price Relationship:** The negative relationship underscores the role of market competition in driving prices down as volume increases.
- **Seasonal Dynamics:** The significant seasonal effects indicate the need for tailored strategies during high-variability periods, such as Spring and Winter.
- **Grid Optimization:** Insights from the regression model can support grid operators in optimizing reserves and pricing strategies to enhance market efficiency.

4.3 Tertiary Reserve Load

4.3.1 Negative TRL

Year	Count	Mean	Std Dev	Min	25%	Median	75%	Max
2019	611	156.07	111.14	0.71	78.00	133.00	178.50	555.00
2020	778	316.96	126.12	78.96	226.24	344.00	397.00	1015.10
2021	1095	1646.53	1535.48	168.00	537.60	980.00	2211.00	9999.00
2022	1172	5139.41	3488.36	420.00	2221.25	4092.00	7096.50	21465.00
2023	1279	4102.37	4233.61	800.00	1396.50	1945.00	5500.00	21465.00
2024	1266	1053.85	570.97	232.00	702.48	999.60	1249.05	4872.00

Table 10: TRL- Price Statistics by Year

The analysis of Tertiary Reserve Load Downward (TRL-) price distributions from 2019 to 2024 reveals key trends and variability across the years. Figure [10] illustrates these changes, while Table [10] provides detailed annual statistics.

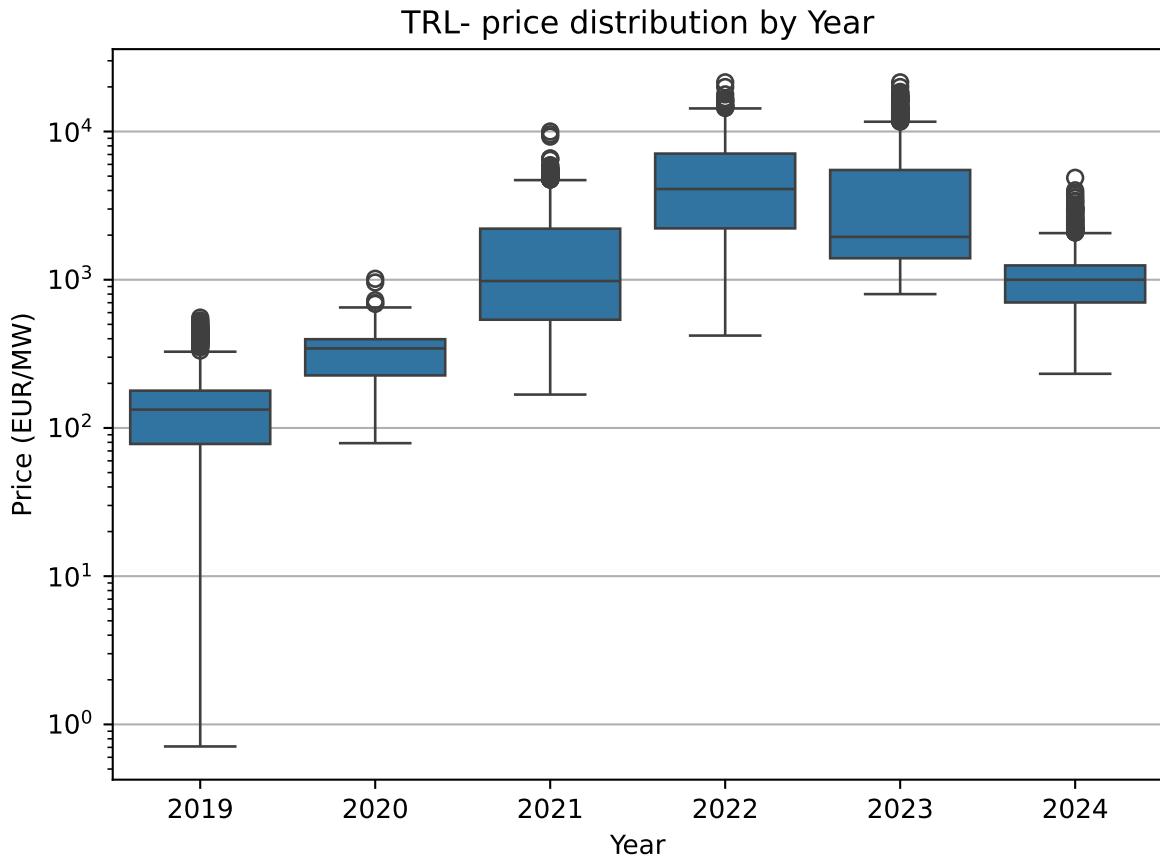


Figure 10: TRL- price distribution by year

Observations by Year

- **2019:** The mean price of 156.07 CHF/MW and a standard deviation of 111.14 CHF/MW suggest moderate variability. The median price (133.00 CHF/MW) reflects a slightly skewed distribution.
- **2020:** Prices increased to a mean of 316.96 CHF/MW with reduced variability (126.12 CHF/MW), indicating more stability.
- **2021:** A significant rise in the mean price to 1646.53 CHF/MW, along with increased variability (1535.48 CHF/MW), reflects heightened market activity.
- **2022:** The mean price reached 5139.41 CHF/MW, with substantial variability (3488.36 CHF/MW), reflecting extreme demand conditions.
- **2023:** Prices slightly decreased to a mean of 4102.37 CHF/MW but retained high variability (4233.61 CHF/MW).
- **2024:** A sharp drop in mean prices to 1053.85 CHF/MW with reduced variability (570.97 CHF/MW) suggests stabilization.

Key Insights

- **Volatility Trends:** Significant price spikes in 2021 and 2022 indicate heightened market volatility, likely due to demand surges.
- **Stabilization in 2024:** The decline in prices and variability reflects improved market conditions and potential regulatory interventions.
- **Demand-Supply Dynamics:** The observed trends underscore the influence of external factors such as grid demand and policy changes.

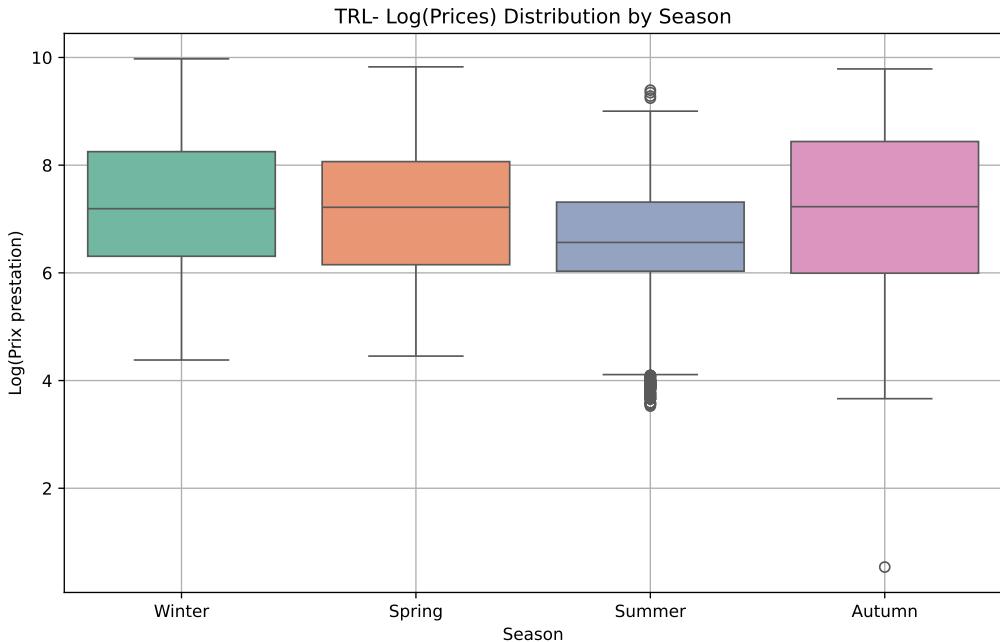


Figure 11: TRL- Log prices distribution by season

Season	Count	Mean	Std Dev	Min	25%	Median	75%	Max
Autumn	1435	3099.09	3546.52	0.71	400.00	1377.60	4624.50	17802.70
Spring	1728	2796.24	3620.64	85.00	468.50	1362.08	3184.47	18504.00
Summer	1775	1099.88	1123.75	33.00	415.00	708.96	1500.00	12000.00
Winter	1263	2785.45	3443.06	78.96	548.00	1327.20	3831.50	21465.00

Table 11: TRL- Price Statistics by Season

Observations by Season

- **Autumn:** The highest mean price (3099.09 CHF/MW) and significant variability (3546.52 CHF/MW) were observed, reflecting high market activity.
- **Spring:** Prices averaged 2796.24 CHF/MW with similar variability (3620.64 CHF/MW) compared to Autumn, highlighting strong seasonal effects.
- **Summer:** The lowest mean price (1099.88 CHF/MW) and reduced variability suggest lower demand during this season.
- **Winter:** Prices averaged 2785.45 CHF/MW with substantial variability, indicating occasional demand spikes.

Key Insights

- **Seasonal Variability:** Prices and variability peaked in Autumn and Spring, while Summer exhibited lower price levels, likely reflecting seasonal demand patterns.
- **Market Stability:** The relatively lower variability in Summer suggests opportunities for cost-effective resource allocation.
- **Operational Implications:** High variability in Autumn and Spring necessitates robust forecasting and management strategies.

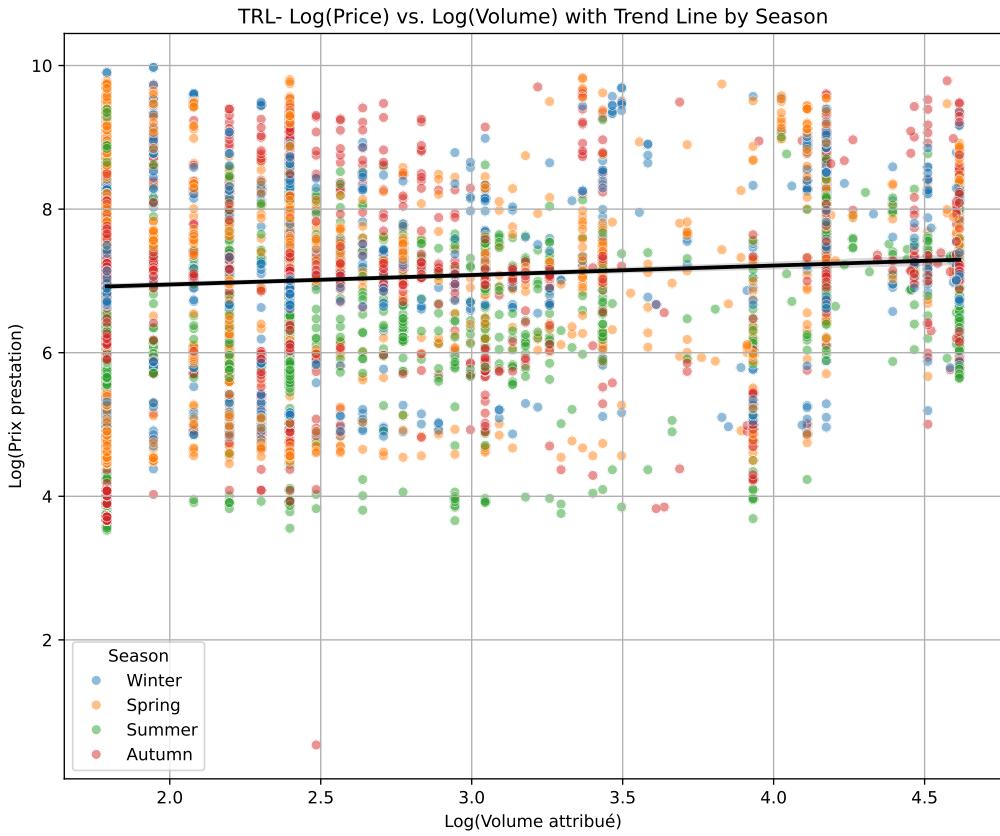


Figure 12: TRL- Log price vs volume trendline by season

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Intercept	6.9348	0.058	118.548	0.000
Season (Spring)	-0.0659	0.045	-1.454	0.146
Season (Summer)	-0.6748	0.045	-14.975	0.000
Season (Winter)	-0.0580	0.049	-1.184	0.236
Log(Volume attribué)	0.1219	0.019	6.524	0.000

Table 12: OLS Regression Results for TRL- Log(Price) vs. Log(Volume)

Regression Analysis

The regression analysis provides insights into the relationship between TRL- prices, volume, and seasonality:

- **Intercept:** The baseline log(price) is 6.9348, corresponding to an average price of approximately $e^{6.9348} \approx 1031.75$ CHF/MW for Autumn.
- **Seasonal Effects:**
 - **Spring:** A coefficient of -0.0659 indicates no significant difference compared to Autumn ($p = 0.146$).
 - **Summer:** Prices are $e^{-0.6748} - 1 \approx -49.5\%$ lower compared to Autumn.
 - **Winter:** A coefficient of -0.0580 indicates no significant difference compared to Autumn ($p = 0.236$).
- **Log(Volume attribué):** A coefficient of 0.1219 indicates that a 1% increase in volume corresponds to a 0.1219% increase in price.
- **Model Fit:** The R^2 value of 0.056 indicates that the model explains 5.6% of the variation in TRL-prices, suggesting other factors influence price trends.

Implications

- **Volume-Price Relationship:** The positive relationship indicates that higher volumes are associated with increased prices, contrary to typical supply-demand dynamics.
- **Seasonal Dynamics:** The significant reduction in Summer prices highlights seasonal demand fluctuations.
- **Market Optimization:** Insights from the regression model can support operators in optimizing reserve allocations and pricing strategies.

4.3.2 Positive TRL

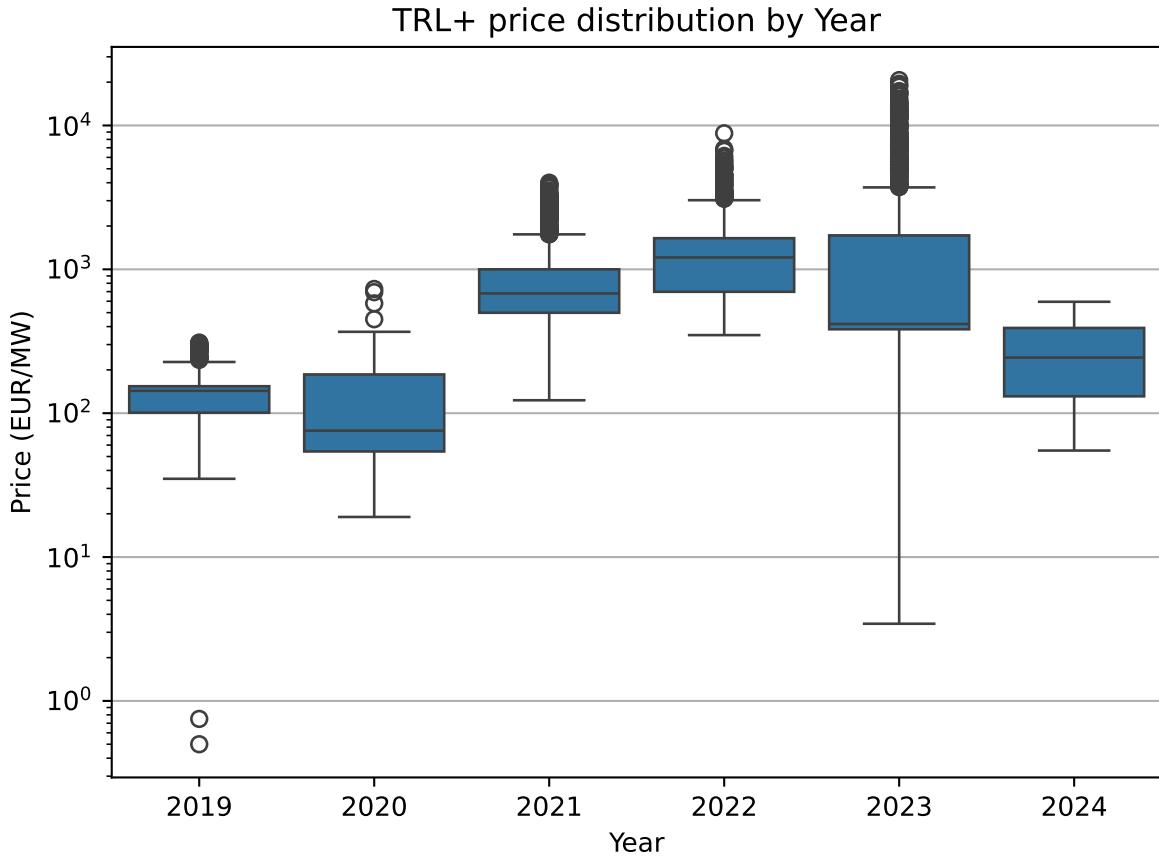


Figure 13: TRL+ price distribution by year

Year	Count	Mean	Std Dev	Min	25%	Median	75%	Max
2019	904	134.86	47.64	0.50	100.80	143.00	154.00	309.12
2020	855	113.03	90.71	19.00	54.20	75.60	185.90	730.00
2021	1192	947.82	754.63	123.00	499.00	680.00	1000.00	4000.00
2022	1281	1370.56	916.36	349.00	698.00	1209.60	1646.00	8825.00
2023	1469	1913.54	3201.48	3.44	383.04	417.00	1721.50	20664.00
2024	1239	264.35	139.89	55.00	131.00	243.57	391.42	595.00

Table 13: TRL+ Price Statistics by Year

The analysis of Tertiary Reserve Load Upward (TRL+) price distributions from 2019 to 2024 reveals significant temporal trends and variability. Figure [13] illustrates these changes, while Table [13] provides annual statistics.

Observations by Year

- **2019:** The mean price of 134.86 CHF/MW and a standard deviation of 47.64 CHF/MW suggest moderate variability. The median price (143.00 CHF/MW) reflects a relatively consistent distribution.

- **2020:** Prices decreased to a mean of 113.03 CHF/MW with higher variability (90.71 CHF/MW), indicating some market instability.
- **2021:** A significant increase in mean prices to 947.82 CHF/MW, coupled with high variability (754.63 CHF/MW), suggests heightened demand.
- **2022:** The mean price further increased to 1370.56 CHF/MW with substantial variability (916.36 CHF/MW), reflecting volatile market conditions.
- **2023:** Prices peaked at a mean of 1913.54 CHF/MW with extreme variability (3201.48 CHF/MW), likely due to market shocks.
- **2024:** A sharp decrease in mean prices to 264.35 CHF/MW with reduced variability (139.89 CHF/MW) suggests stabilization.

Key Insights

- **Volatility Trends:** The significant spikes in 2021 and 2023 highlight market volatility during these years.
- **Stabilization in 2024:** The decline in prices and variability reflects improved market conditions and potential regulatory interventions.
- **Market Dynamics:** The observed trends emphasize the influence of external factors such as demand surges and policy changes.

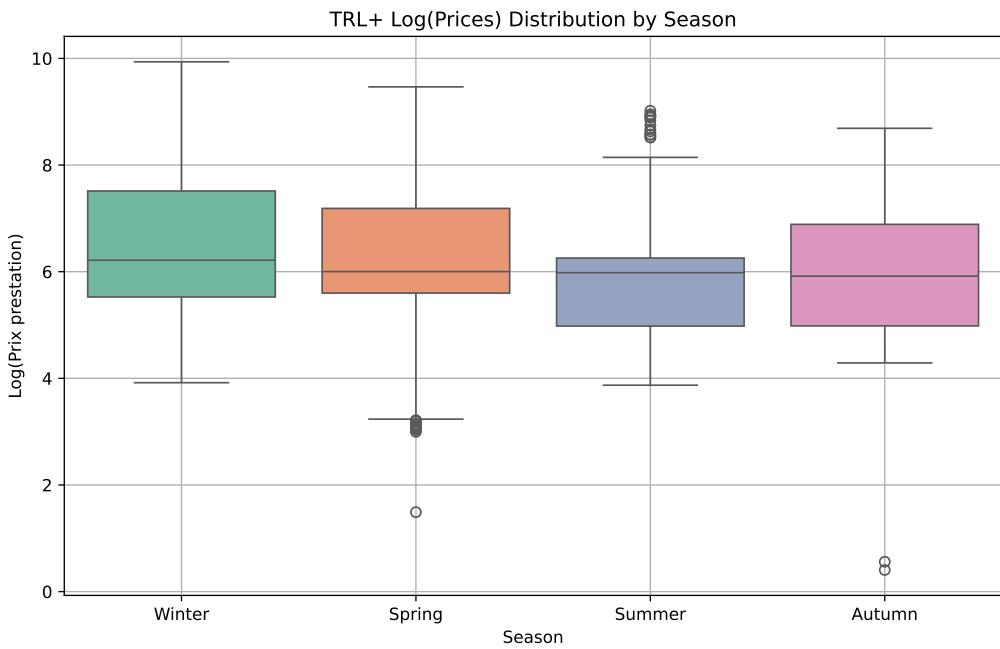


Figure 14: TRL+ Log prices distribution by season

Season	Count	Mean	Std Dev	Min	25%	Median	75%	Max
Autumn	1846	650.24	729.76	0.50	145.00	370.00	979.25	5936.00
Spring	1657	1058.20	1683.40	3.44	269.00	403.00	1321.00	12913.00
Summer	1813	398.23	570.13	47.00	144.48	395.00	520.00	8248.00
Winter	1624	1580.53	2781.62	49.30	250.00	498.96	1831.20	20664.00

Table 14: TRL+ Price Statistics by Season

Observations by Season

- **Autumn:** The mean price of 650.24 CHF/MW and high variability (729.76 CHF/MW) reflect significant demand fluctuations.
- **Spring:** Prices averaged 1058.20 CHF/MW with extreme variability (1683.40 CHF/MW), highlighting strong seasonal effects.
- **Summer:** The lowest mean price (398.23 CHF/MW) and reduced variability suggest lower demand during this season.
- **Winter:** The highest mean price (1580.53 CHF/MW) and substantial variability (2781.62 CHF/MW) indicate heightened market activity.

Key Insights

- **Seasonal Variability:** Prices and variability peaked in Winter and Spring, while Summer exhibited lower price levels, likely reflecting seasonal demand patterns.
- **Market Stability:** The relatively lower variability in Summer suggests opportunities for cost-effective resource allocation.
- **Operational Implications:** High variability in Winter and Spring necessitates robust forecasting and management strategies.

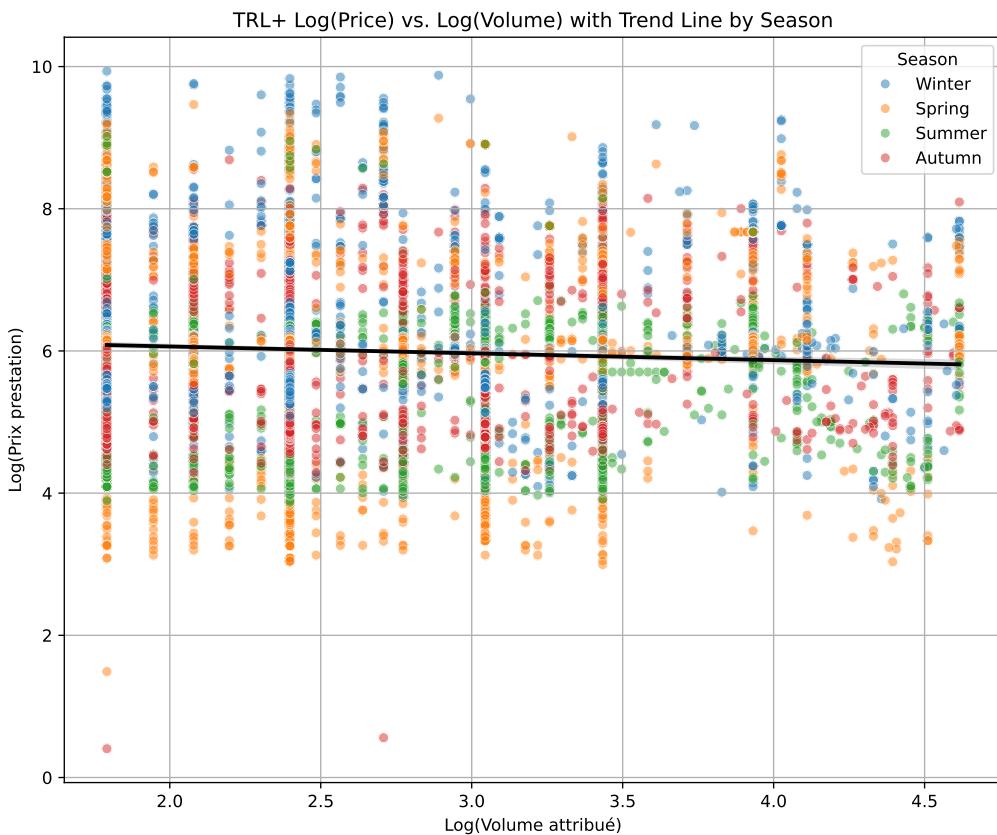


Figure 15: TRL+ Log price vs volume trendline by season

Regression Analysis

The regression analysis provides insights into the relationship between TRL+ prices, volume, and seasonality:

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Intercept	6.1900	0.057	109.334	0.000
Season (Spring)	0.0983	0.040	2.467	0.014
Season (Summer)	-0.3145	0.039	-8.079	0.000
Season (Winter)	0.4805	0.040	12.007	0.000
Log(Volume attribué)	-0.0918	0.019	-4.746	0.000

Table 15: OLS Regression Results for TRL+ Log(Price) vs. Log(Volume)

- **Intercept:** The baseline log(price) is 6.1900, corresponding to an average price of approximately $e^{6.1900} \approx 488.28$ CHF/MW for Autumn.
- **Seasonal Effects:**
 - **Spring:** Prices are $e^{0.0983} - 1 \approx 10.3\%$ higher compared to Autumn.
 - **Summer:** Prices are $e^{-0.3145} - 1 \approx -27.0\%$ lower compared to Autumn.
 - **Winter:** Prices are $e^{0.4805} - 1 \approx 61.7\%$ higher compared to Autumn.
- **Log(Volume attribué):** A coefficient of -0.0918 indicates that a 1% increase in volume corresponds to a 0.0918% decrease in price.
- **Model Fit:** The R^2 value of 0.057 indicates that the model explains 5.7% of the variation in TRL+ prices, suggesting other factors influence price trends.

Implications

- **Volume-Price Relationship:** The negative relationship indicates that higher volumes are associated with lower prices, aligning with supply-demand dynamics.
- **Seasonal Dynamics:** The significant increase in Winter prices highlights seasonal demand fluctuations.
- **Market Optimization:** Insights from the regression model can support operators in optimizing reserve allocations and pricing strategies.

5 Data 2019

5.1 Primary control auction 2019

It is worth mentioning that we only have data for PRL starting from July. The statistical description of PRL prices can be found in table [16]. The mean price was 126.24 EUR/MW, the maximum price was 218.02 EUR/MW was attained end of September and the minimum price was 73.02 EUR/MW attained mid November as can be seen in figure [16].

mean	126.24
std	24.83
min	73.02
25%	106.55
50%	123.99
75%	142.86
max	218.02

Table 16: Statistics of PRL daily mean price in EUR/MW for 2019

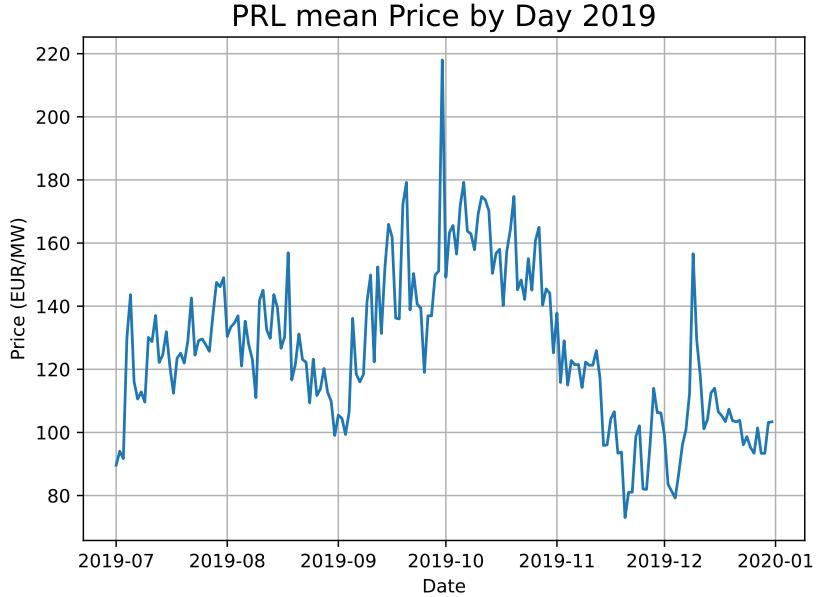


Figure 16: Mean prices per day of PRL bids EUR/MW 2019

From figure [17a], it can be observed that the distribution of PRL 2019 prices is right-skewed, with the majority of values concentrated in the lower price range (0–500 EUR/MW) and a long tail extending toward higher prices. A dominant peak is observed at low prices, with a smaller secondary peak around 1,000–1,500 EUR/MW. A few outliers exist at very high prices (above 2,500 EUR/MW), indicating rare occurrences of exceptionally high values. This suggests that prices were predominantly low to moderate, with occasional spikes that could be attributed to specific market conditions or events. The data exhibits significant variance, reflecting a wide range of price fluctuations.

Moreover, in figure [17b], the distribution of bid volumes for PRL 2019 reveals that most bidders tend to bid low volumes, as the majority of the frequencies are concentrated in the range below 5 MW. The highest frequency is at 1 MW (minimum bidding volume for PRL), which suggests that small-volume bids dominate the market. There are significantly fewer bids at higher volumes, with occasional larger bids distributed sparsely, reaching up to 25 MW.

This pattern indicates a preference among participants for bidding small amounts, likely to minimize risk or align with market dynamics that favor smaller, more manageable bids. It may also reflect strategic behavior to take advantage of pricing mechanisms that favor smaller increments. The presence of a few higher bids could be attributed to larger players or specific operational needs that require higher capacity offerings. This overall trend highlights a market tendency toward low-volume bidding with a small fraction of large-volume outliers.

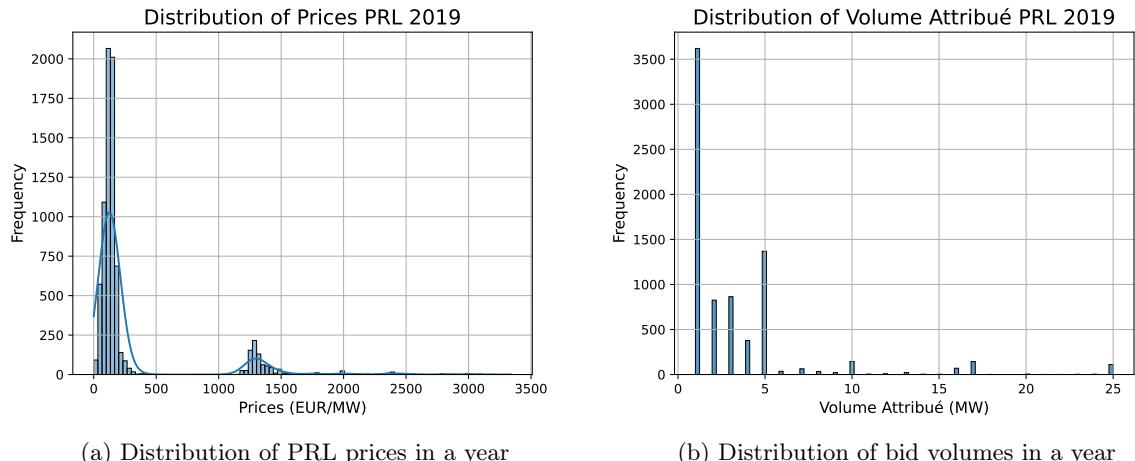


Figure 17: PRL 2019 distributions plots

5.2 Secondary control auction 2019

It is very clear from figure [18] that the prices of SRL- are almost always higher than the prices of SRL+ or at least very close when lower. This marks the need of Switzerland for negative energy to balance over-production. Moreover, this shows that there is almost double the money to be made when bidding in SRL-. Indeed, from table [17], it can be seen that the mean price of SRL- is of 1638.22 CHF/MW, which is almost the double of SRL+'s mean price of 901.55 CHF/MW.

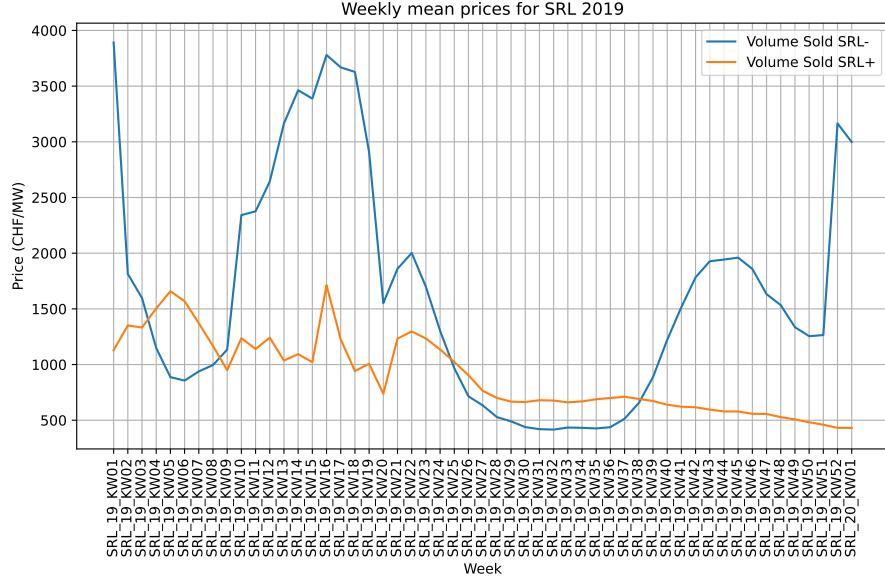


Figure 18: Weekly mean prices of SRL in CHF/MW 2019

Statistic	SRL- Prices	SRL+ Prices
Mean	1638.22	901.55
Std	1038.05	345.14
Min	416.09	431.05
25%	856.23	639.42
50%	1516.07	738.02
75%	2002.08	1167.50
Max	3891.67	1712.26

Table 17: Summary Statistics for SRL- and SRL+ Prices in CHF/MW 2019

The distributions of SRL bid volumes and prices for 2019 reveal distinct characteristics for both SRL- and SRL+ services. For bid volumes, both SRL- and SRL+ [19] exhibit right-skewed distributions, with the majority of bid volumes clustered at smaller values (below 20 MW), indicating that most participants bid low volumes. However, there are sporadic higher bids up to 100 MW, suggesting occasional large-volume offerings. For prices [20], the SRL- price distribution is broader and right-skewed, with a significant spread and a concentration around 1,000–2,000 EUR/MW. In contrast, the SRL+ price distribution is narrower and less skewed, with most prices concentrated between 500–1,500 EUR/MW. The SRL- prices are generally higher than SRL+ prices, reflecting potential differences in market dynamics or service characteristics. Both distributions highlight a preference for lower bids in terms of both volume and price, with rare high bids.

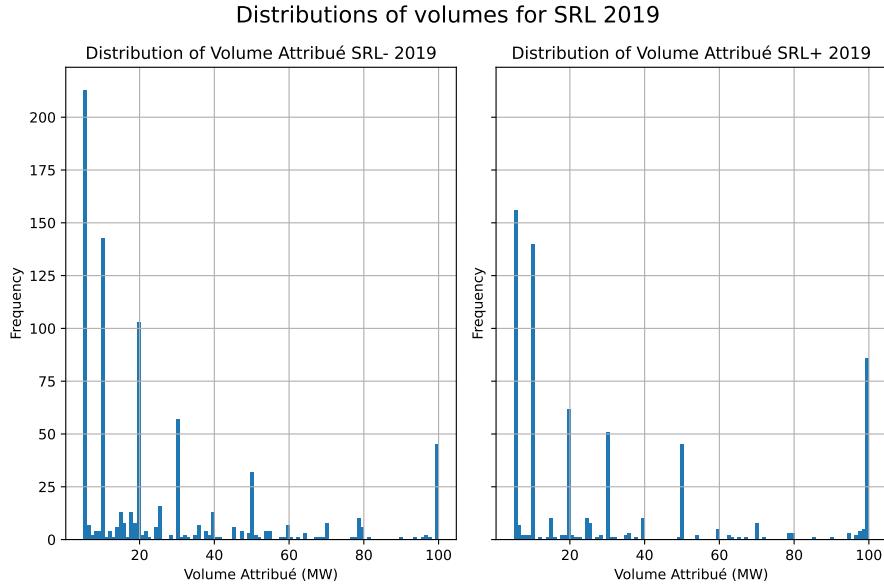


Figure 19: Distribution of SRL bid volumes in 2019

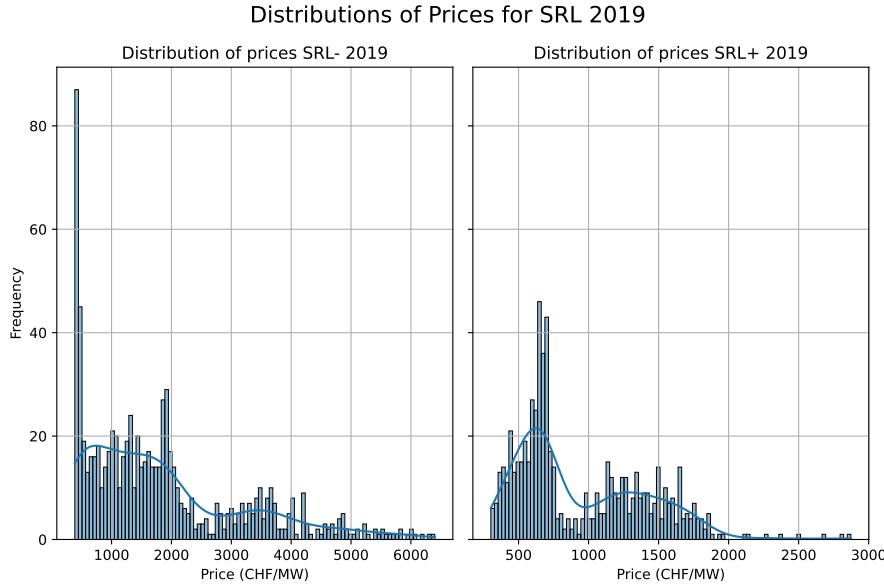


Figure 20: Distribution of SRL bid prices in 2019

5.3 Tertiary control auction 2019

A similar trend to SRL can be observed in figure [22]. indeed, The weekly mean prices of TRL- are in average higher than the prices of TRL+, 152.30 CHF/MW compared to 131.96 CHF/MW [18]. Furthermore, a peak of prices can also be seen from weeks 11 to 19 with a decrease later on until the prices of TRL- reach prices lower than TRL+ and then TRL- prices taking the lead again at the end of the year. Moreover, The prices of TRL- seems to vary a lot more than the prices of TRL+, this can also be seen with the standard deviation of TRL- which is almost 50 CHF higher than TRL+'s. This shows that the dynamics of the negative power market are a lot more rough and volatile.

The distributions of weekly volumes and prices for TRL- and TRL+ in 2019 exhibit again notable patterns. For bid volumes [22], both TRL- and TRL+ show right-skewed distributions, with most bids concentrated at smaller volumes below 20 MW. There are occasional higher bids extending up to 100 MW, indicating sporadic large-volume offerings. In terms of prices [23], the TRL- price distribution is broader, with a long tail extending toward higher values. The TRL+ price distribution is narrower, with the majority of bids concentrated between 50–150 EUR/MW and fewer outliers at higher prices. Overall, the data reflects again a tendency for lower bid volumes and prices in both categories, with occasional

larger bids and price outliers. This suggests strategic behavior aimed at minimizing risk while capturing market opportunities.

Statistic	TRL- Prices	TRL+ Prices
Mean	152.30	131.96
Std Dev	78.44	26.31
Min	44.15	71.22
25%	86.29	118.78
50%	148.27	137.57
75%	203.16	151.66
Max	341.66	174.13

Table 18: Summary Statistics for weekly TRL- and TRL+ Prices in CHF/MW 2019

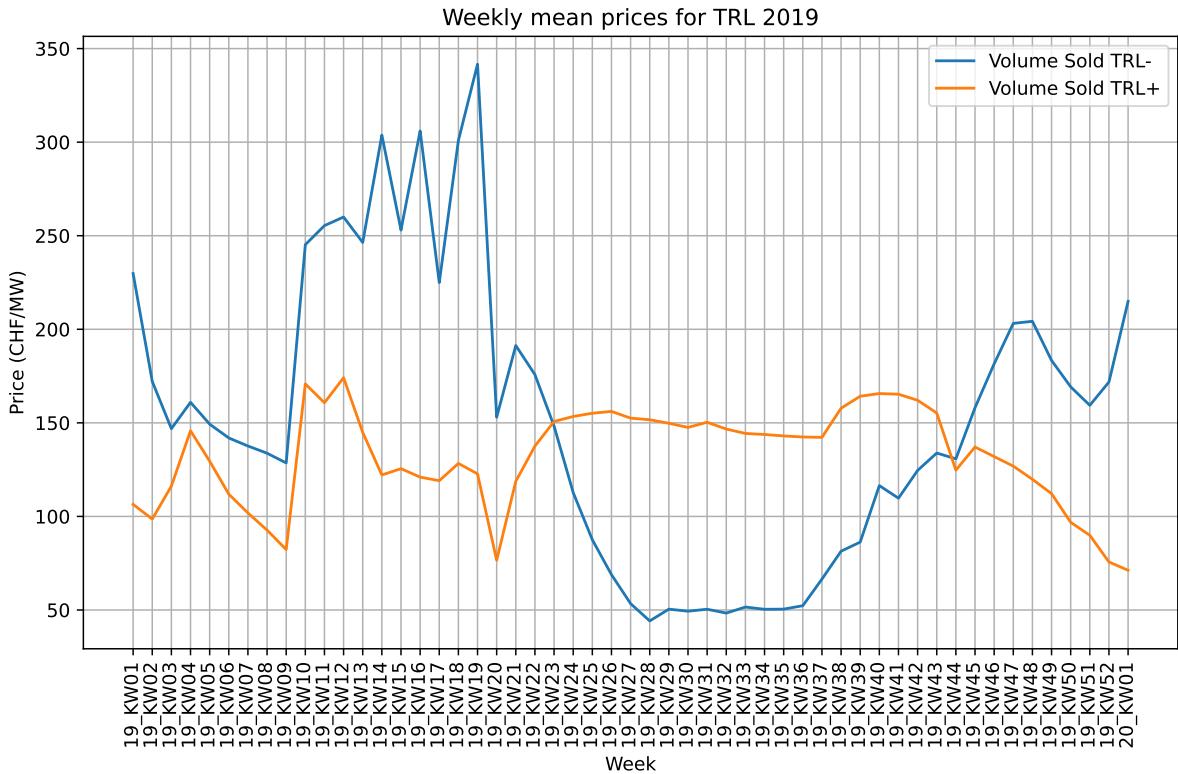


Figure 21: Weekly mean prices of TRL in CHF/MW 2019

The daily tendered TRL- and TRL+ exhibit notable differences and similarities in their characteristics across different time periods, as highlighted by the provided plots and tables [19][20].

The daily mean prices for TRL- are range from 1.38 to 3.55 CHF/MW and those of TRL+ from 0.44 to 4.35 CHF/MW. None of these two services exhibit consistent higher mean prices across the six four-hour time slots. Both prices display significant variability, reflecting broader fluctuations throughout the day. Peaks in prices are observed during specific periods, likely driven by heightened demand or limited supply conditions.

Distributions of weekly volumes for TRL 2019

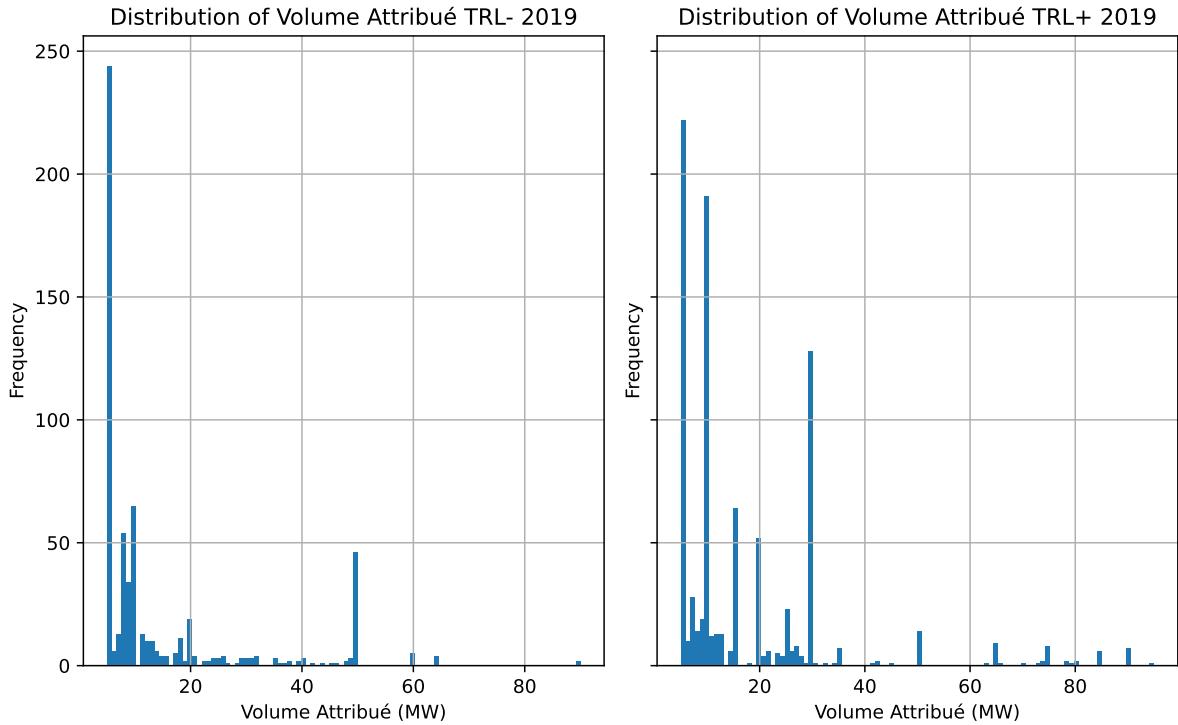


Figure 22: Distribution of TRL bid volumes in 2019

Distributions of Prices for TRL 2019

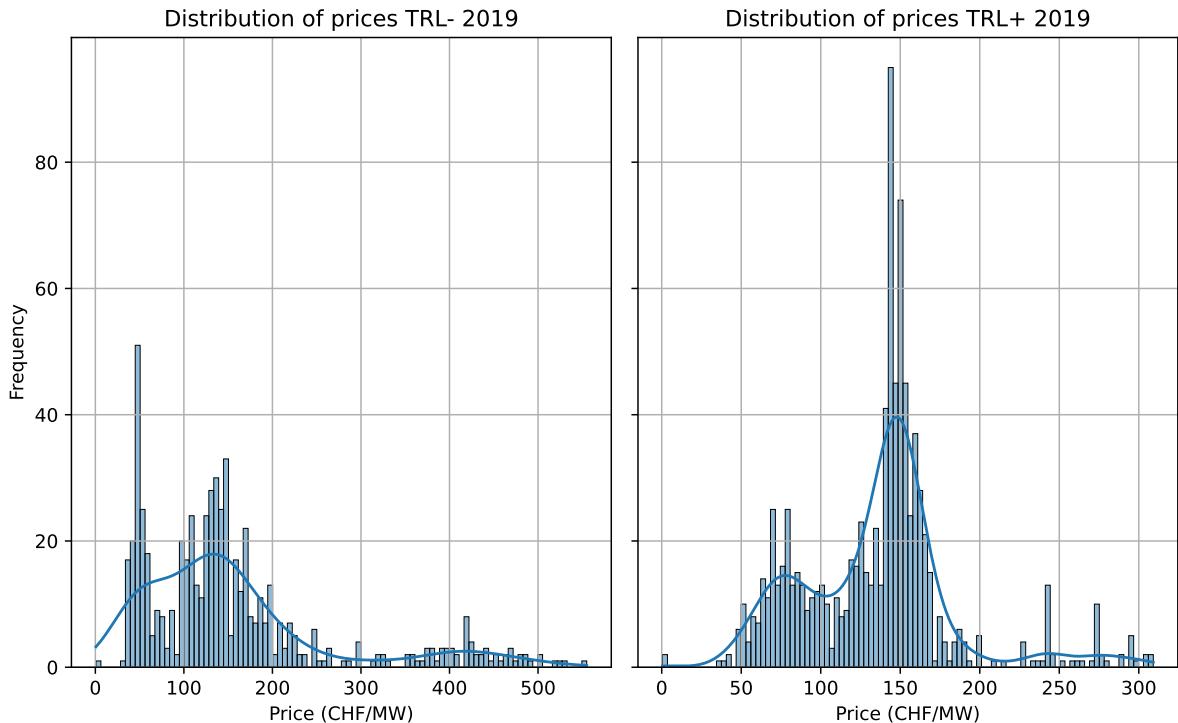


Figure 23: Distribution of weekly TRL bid prices in 2019

The distribution of tendered volumes for both TRL- and TRL+ shows a strong right-skewed pattern, indicating a predominant preference for small-volume bids. For TRL-, the majority of tendered volumes are concentrated at low values, with a few instances of higher bids acting as outliers. Similarly, TRL+ volumes follow the same skewed distribution but exhibit slightly lower frequencies of large-volume bids

compared to TRL-. This consistency in bidding strategies reflects the nature of both services and their respective market conditions.

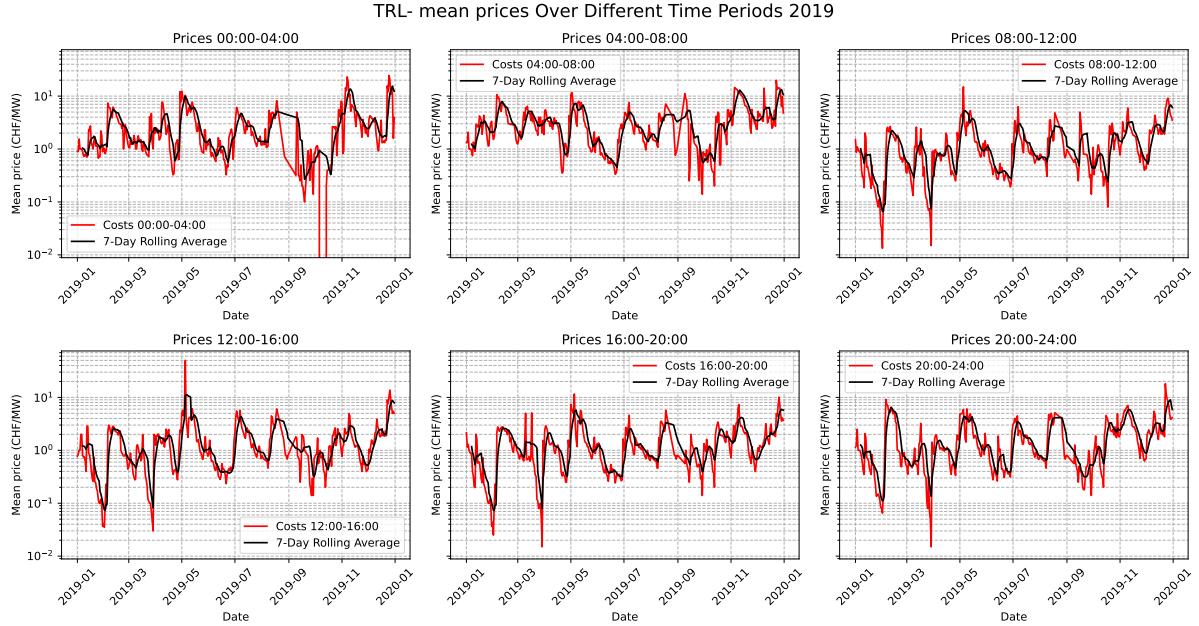


Figure 24: Mean prices per day of 2019 TRL- bids over the different four hours slots CHF/MW

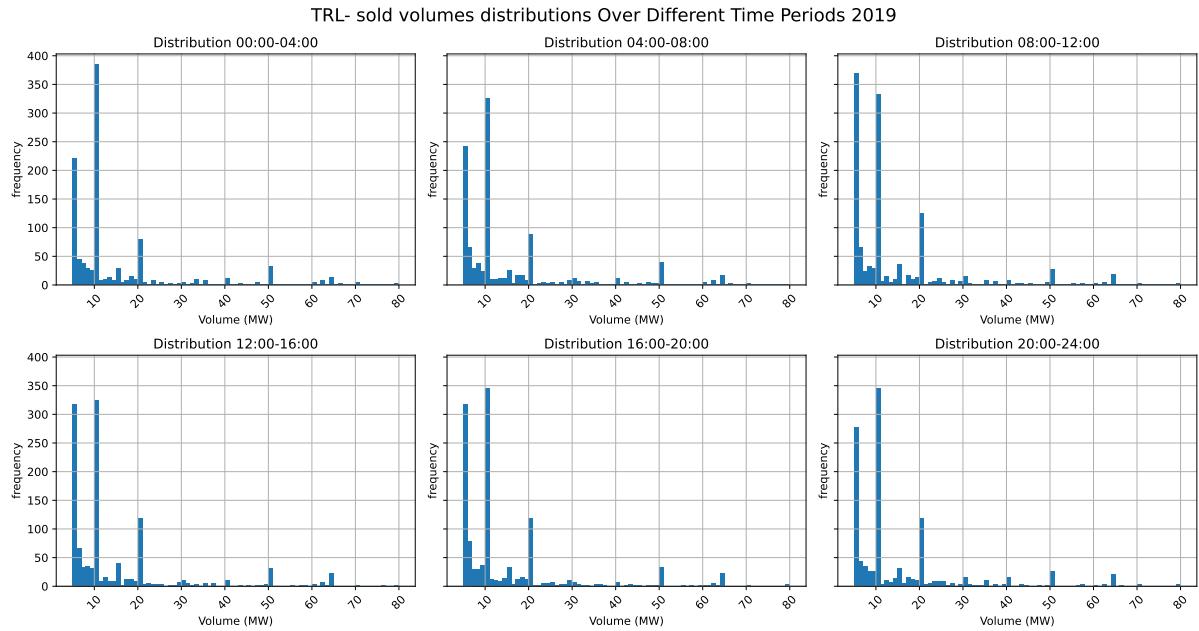


Figure 25: TRL- Distribution of 2019 bid volumes in a year over the different four hours slots

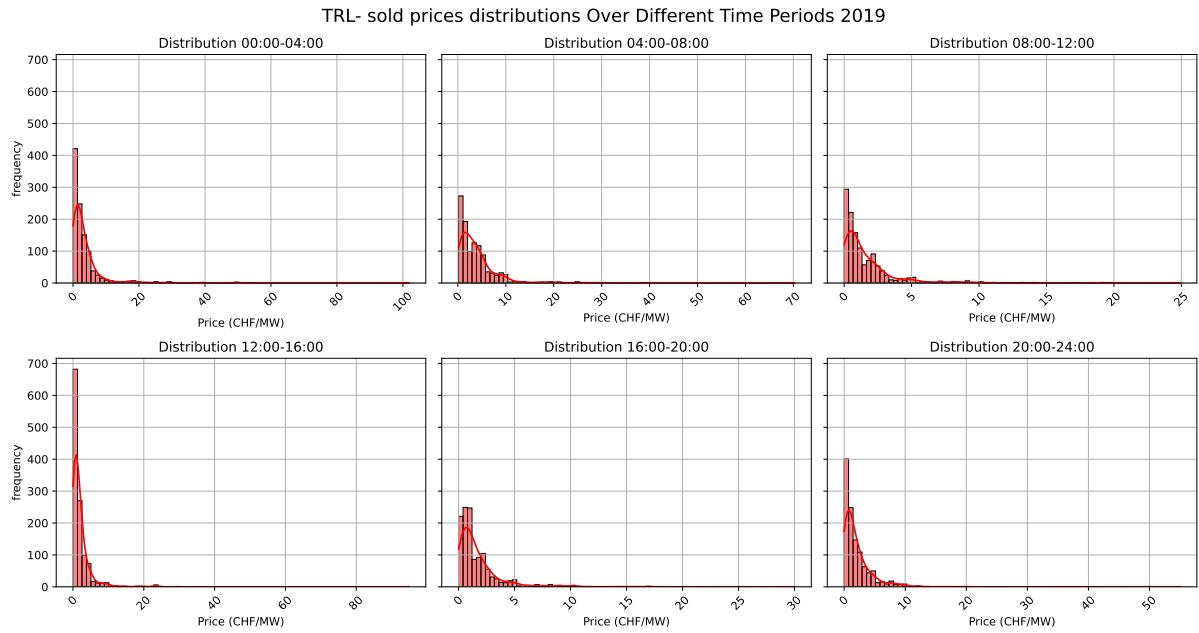


Figure 26: TRL- Distribution of 2019 bid prices in a year over the different four hours slots

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	2.95	3.55	1.38	1.72	1.50	1.89
Std Dev	3.37	3.11	1.55	3.08	1.49	2.02
Min	0.00	0.14	0.01	0.03	0.02	0.02
25%	0.99	1.37	0.45	0.56	0.59	0.55
50%	1.72	2.88	0.86	1.02	1.08	1.12
75%	3.78	4.60	1.90	2.04	1.90	2.42
Max	24.51	19.92	14.98	49.95	11.60	18.13

Table 19: Summary Statistics for TRL- daily mean price (CHF/MW) over different time windows in 2019

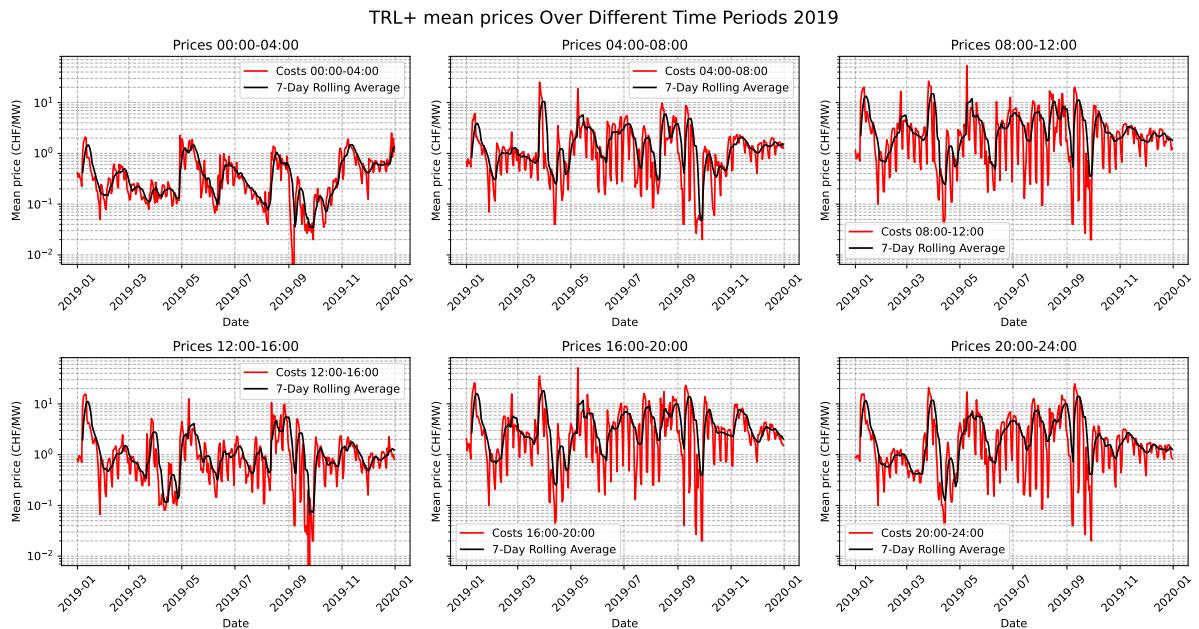


Figure 27: Mean prices per day of 2019 TRL+ bids over the different four hours slots CHF/MW

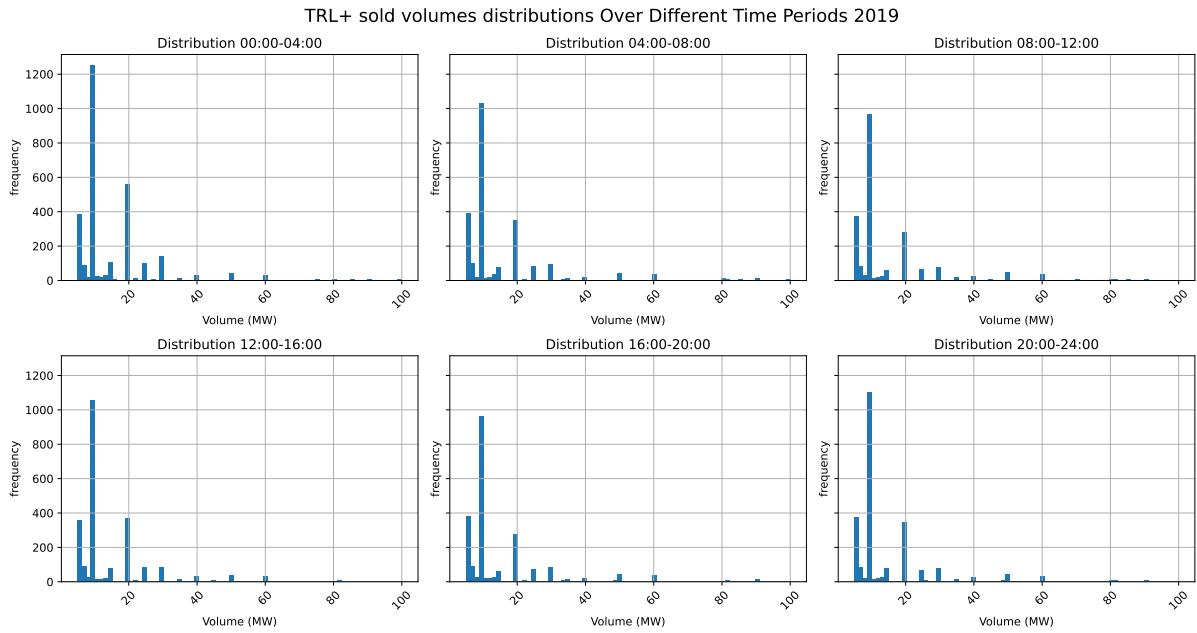


Figure 28: 2019 TRL+ Distribution of bid volumes in a year over the different four hours slots

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	0.44	1.79	3.69	1.43	4.35	2.93
Std Dev	0.44	2.51	4.96	2.12	5.46	3.96
Min	0.00	0.02	0.02	0.00	0.02	0.02
25%	0.14	0.49	0.85	0.43	1.04	0.64
50%	0.27	1.10	2.33	0.85	2.78	1.50
75%	0.62	2.01	3.97	1.48	5.04	3.31
Max	2.53	25.33	53.07	15.59	51.21	24.84

Table 20: Summary Statistics for TRL+ daily mean price (CHF/MW) over different time windows in 2019

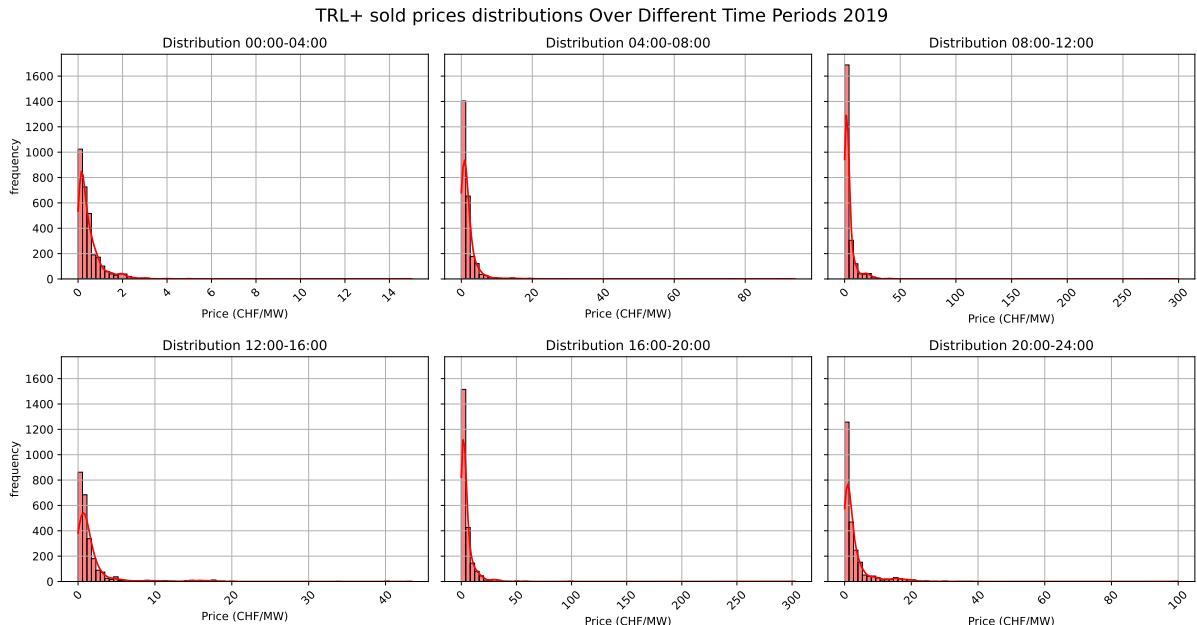


Figure 29: 2019 TRL+ Distribution of bid prices in a year over the different four hours slots

6 Data 2020

6.1 Primary control auction 2020

As described above, the PRL is tendered on a daily basis in slots of four hours. In 2020, a high level of PRL bid prices was observed from January to July, reaching peaks around 90 EUR/MW. However, a significant price drop occurred mid-summer, reducing the prices to approximately 15 EUR/MW, where they remained for the rest of the year as can be observed on figure [30]. The reason for this drop could be attributed to various factors, such as seasonal changes in demand, shifts in supply due to increased capacity, or regulatory adjustments. Understanding these factors could shed light on the causes of such substantial price fluctuations in the market.

Moreover, in figure [31b] , it can be observed that the most frequent bid volume in the PRL is 1 MW, followed by 5 MW bids. Overall, the distribution is highly right-skewed with a long tail. This indicates that very few bids consist of large volumes of power, which may be a strategy for bidders to minimize potential financial losses. If a bidder was to place all their capacity into a single large-volume bid, there would be a high probability of losing out if other bidders offer a lower price. By partitioning bids into smaller volumes (e.g., 1 MW), bidders can set different prices for each, allowing them to take calculated risks depending on their risk aversion. This approach enables bidders to diversify their price points and adapt more flexibly to market conditions, potentially maximizing profitability while managing risk.

mean	50.32
std	40.49
min	5.09
25%	11.74
50%	21.35
75%	86.76
max	167.83

Table 21: Statistics of PRL daily mean price in EUR/MW

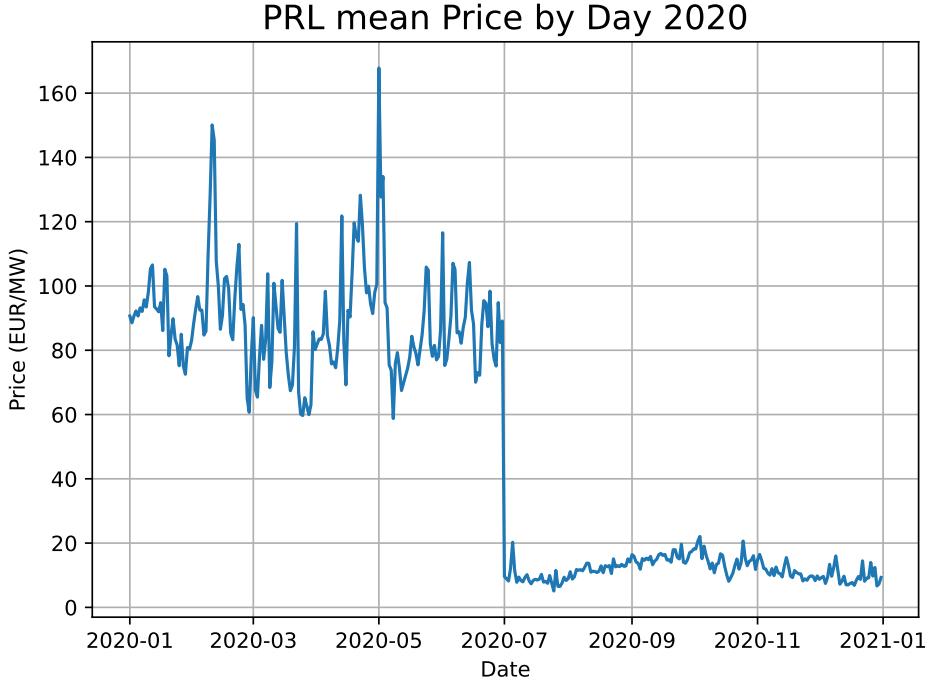


Figure 30: Mean prices per day of PRL bids EUR/MW 2020

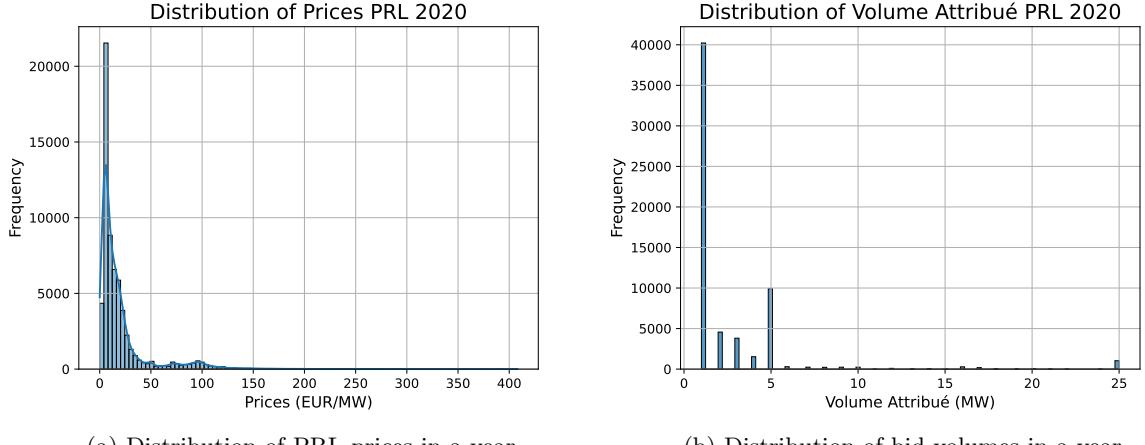


Figure 31: PRL 2020 distributions plots

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	12.04	12.40	11.53	11.71	11.77	11.37
Std Dev	3.79	3.59	3.87	4.51	4.03	3.43
Min	5.51	5.30	5.03	5.02	5.06	1.90
25%	9.39	9.52	8.68	8.27	8.69	8.76
50%	11.37	12.10	10.82	10.95	11.17	10.90
75%	13.80	14.55	14.11	14.11	14.52	13.85
Max	28.26	27.48	23.34	35.67	23.87	22.58

Table 22: Summary Statistics for PRL daily mean price EUR/MW over different time windows 2020

In table [22], the statistics of the PRL daily mean price can be found. From this table, we see that the highest mean price of bids at 12,40 €/MW is in the slot time of 04:00-08:00. Moreover, the highest volatility of prices is in the slot of 12:00-16:00 at 4.51 €/MW.

It is worth mentionning that only the data starting from july was in our possession for the PRL over time periods. The statistics from table [22] can also be observed through the graphs [32] that describes the evolution of the mean prices along the year. It can be observed in these graphs that the mean prices fluctuate a lot and that they are very stochastic. A general trend that can be observed on these plots is that the means prices seem to increase in a parabolic way until it reaches its optimum around october and then they go down again until january.

Moreover, a similar bid volumes distribution to [31b] can be observed over the different periods in figure [33]. Indeed it seems that the same volumes are bid over all the periods with some extra bids in the time slots 08:00-12:00 and 16:00-20:00 where a bit higher bars can be observed.

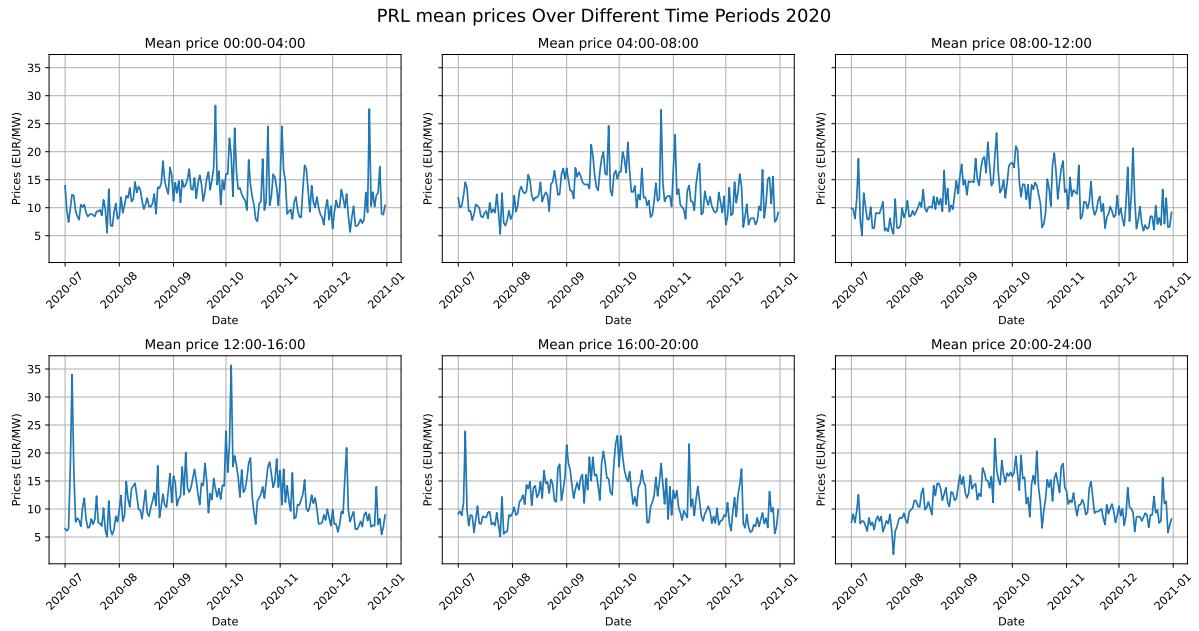


Figure 32: Mean prices per day of PRL bids over the different four hours slots EUR/MW

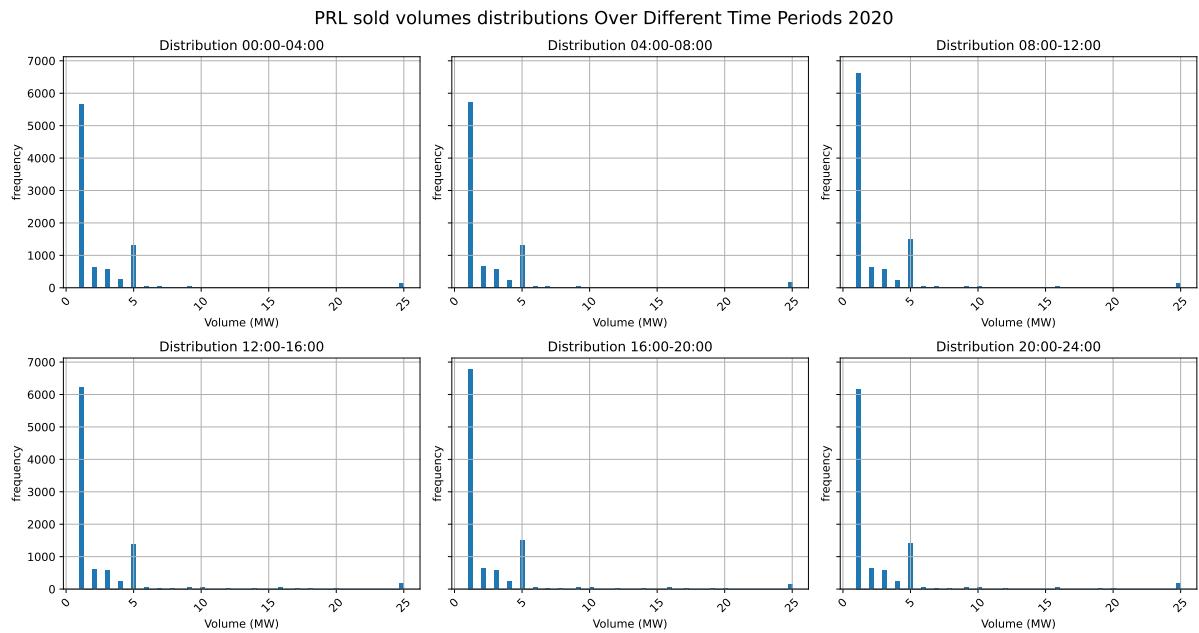


Figure 33: Distributions of bid volumes in a year over the different four hours slots



Figure 34: Distributions of PRL bid prices in a year over the different four hours slots

6.2 Secondary control auction 2020

Table 23: Summary Statistics for SRL- and SRL+ Prices in EUR/MW 2020

Statistic	SRL- Prices	SRL+ Prices
Mean	1325.48	638.07
Std	719.20	216.87
Min	464.92	375.48
25%	760.22	490.44
50%	1119.10	598.12
75%	1678.18	703.36
Max	2997.87	1155.24

It is clear from table [23] that the mean weekly prices of SRL- are more than double the mean prices of SRL+. Moreover, in figure [35], we observe that the weekly prices Of SRL- are almost always above the weekly prices of SRL+. This finding expresses a bigger need for Switzerland to adjust the grid frequency by decreasing the generation or increasing the demand. This insight informs us that more gains can be made by putting BESSs at swissgrid's disposition to regulate the grid's frequency. Furthermore, it can be observed that the mean prices increase around increase thremendously around weeks 14 to 17 (April) and then decrease a lot from week 18 to 33 (may to september) to increase once again from september to the end of the year. In other words, the prices are higher in autumn and spring and lower in winter and summer.

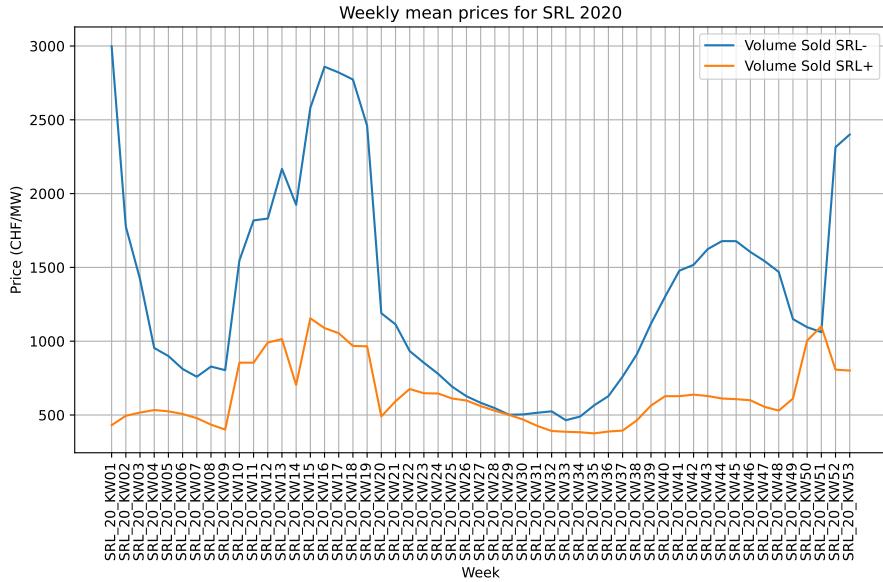


Figure 35: Weekly mean prices of SRL in EUR/MW 2020

The distributions of the bid volumes of SRL can be observed in figure [36]. Like for the PRL [31b] It can be observed that the distributions are right skewed and long tailed. SRL- was bid 906 times compared to 678 times for SRL+. the most bid volumes for SRL- are in descending order 5, 20, 10, 50 and 15 MW and 5, 10, 100, 20 and 50 MW for SRL+.

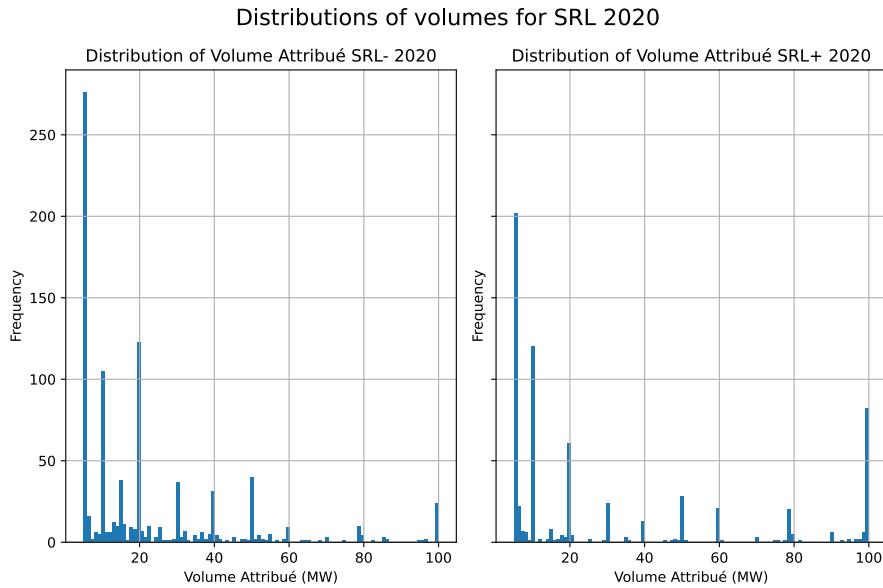


Figure 36: Distribution of SRL bid volumes in 2020

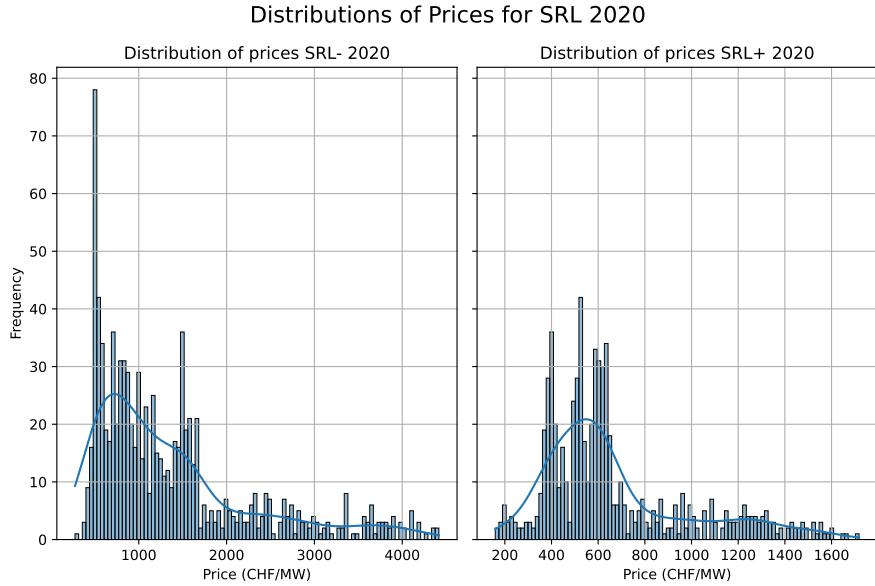


Figure 37: Distribution of SRL bid prices in 2020

6.3 Tertiary control auction 2020

A similar trend to the one of SRL can be observed in the weekly bid TRL in figure [38]. Indeed, it can be seen that the weekly mean prices of TRL- are always higher than the prices of TRL+. Moreover, it can be observed that during spring, a big jump in the prices of TRL- takes place.

A similar evolution in week 51 can be observed in figure [35] where SRL- and SRL+ move in an opposite way until prices are almost equal.

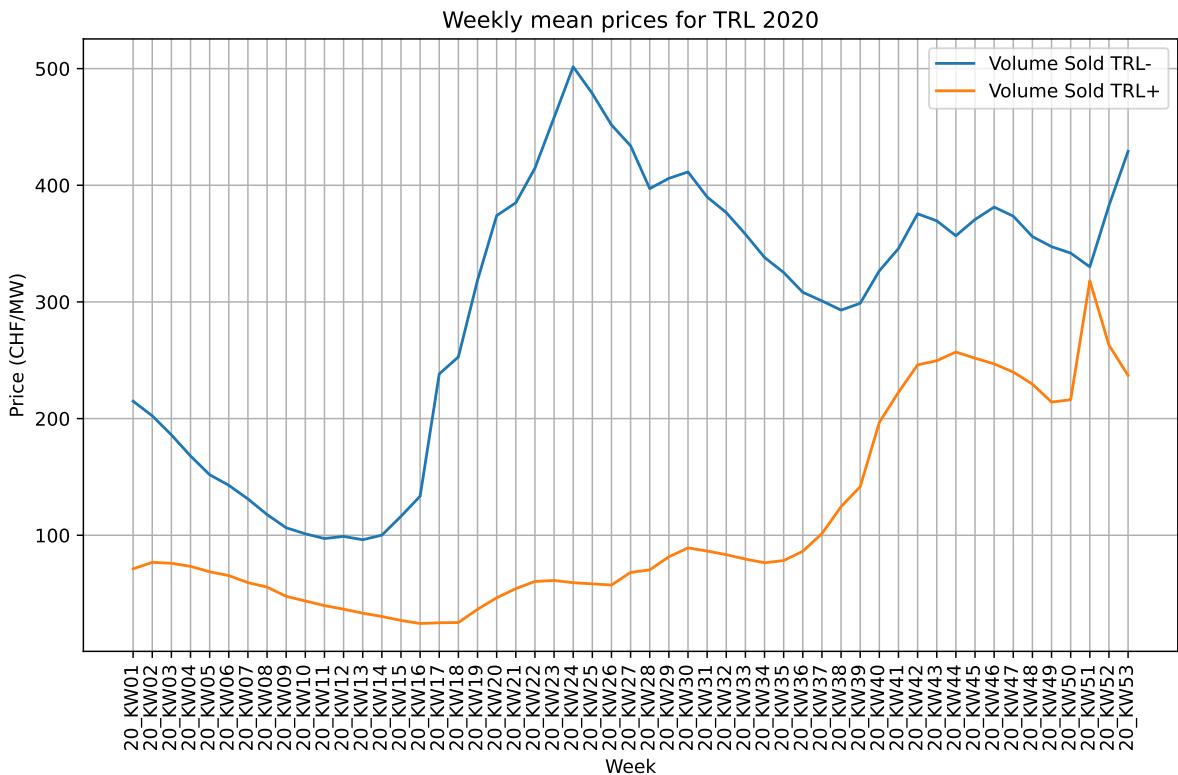


Figure 38: Weekly mean prices of TRL in EUR/MW 2020

Furthermore, from table [24] we again find that the TRL- mean prices are more than double the mean prices TRL+, however this time with a lower volatility difference between the two. This further enforces our hypothesis that the swiss grid needs more power down than up for frequency regulation. Additionally, the difference of prices between TRL and SRL are very striking given the fact that they are

both bid weekly. Indeed, SRL prices are more than four times higher than TRL's prices. What could be the reason behind that?

Statistic	TRL- Prices	TRL+ Prices
Mean	297.40	110.74
Std Dev	119.70	83.75
Min	96.18	24.35
25%	186.05	55.57
50%	338.16	75.99
75%	381.28	196.72
Max	501.57	318.13

Table 24: Summary Statistics for weekly TRL- and TRL+ Prices in EUR/MW 2020

The distribution of TRL bids can be observed on figure [39], the distributions are once again right skewed and heavy tailed. It can again be observed that higher amounts of bids take place in TRL- (855 bids) compared to TRL+ (778 bids). The most bid volumes for TRL sorted in a descending order are 5, 10, 8, 9, 7 and 6 MW. For TRL+, the order is 10, 20, 5, 30 and 15 MW. An interesting observation is that people tend to commonly bid round numbers for volumes.

Distributions of weekly volumes for TRL 2020

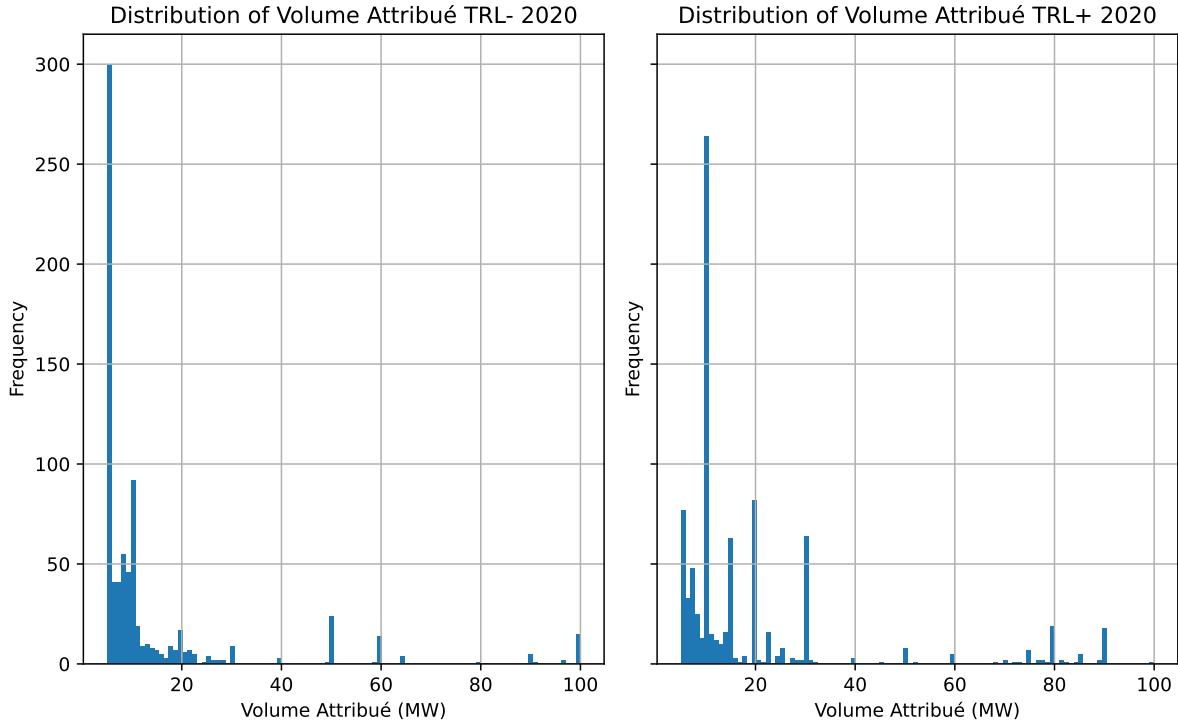


Figure 39: Distribution of TRL bid volumes in 2020

In figure [41], the mean prices of TRL- over the different four hours slots can be observed. As the range of the prices is high and because the prices fluctuate a lot, a logarithmic scale on the y axis was taken to make the visualization clearer. on top of that, a 7 day rolling average was computed. Since the graph is in logarithmic scale, when the price is at 0 CHF/MW, the red lines go to minus infinity and they reach they come out of the graph as can be seen in "Prices 08:00-12:00". This case typically happens when power plants want to charge back their enrgy storage system for free.

Distributions of Prices for TRL 2020

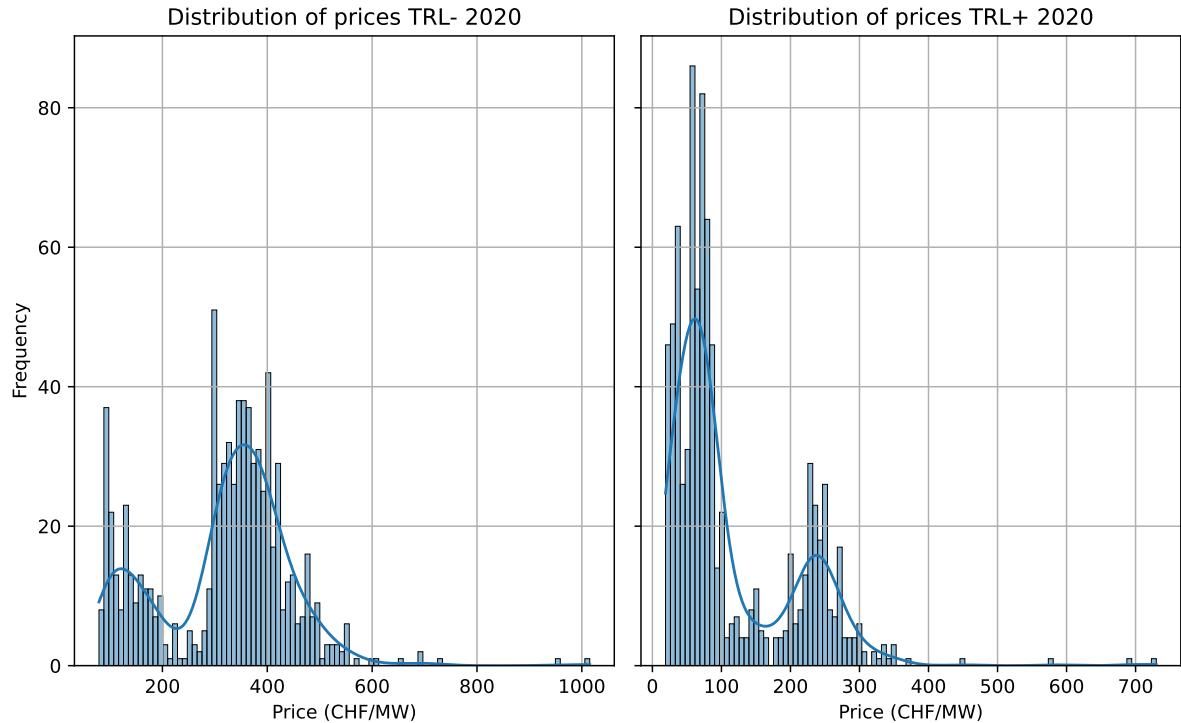


Figure 40: Distribution of TRL bid prices in 2020

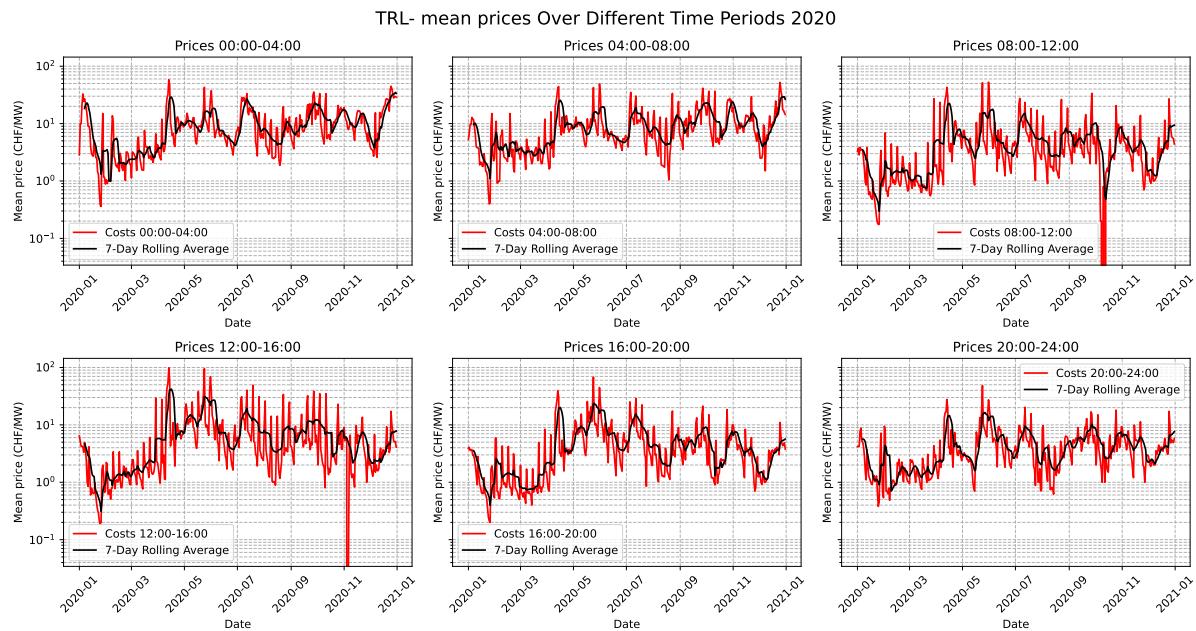


Figure 41: Mean prices per day of TRL- bids over the different four hours slots EUR/MW

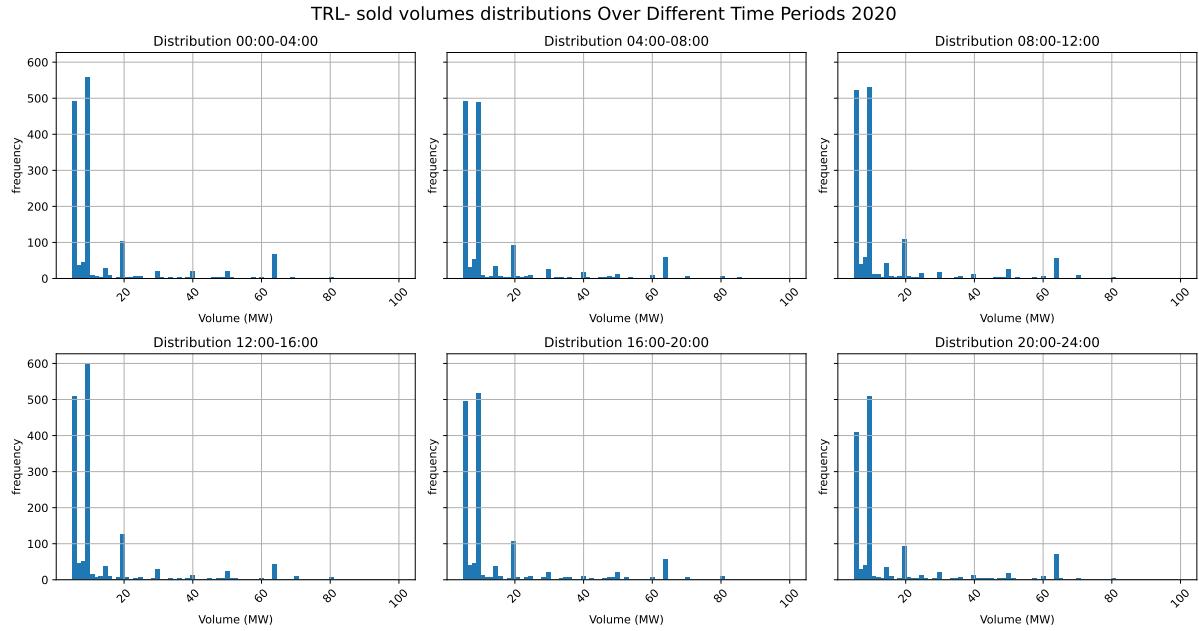


Figure 42: TRL- Distribution of bid volumes in a year over the different four hours slots

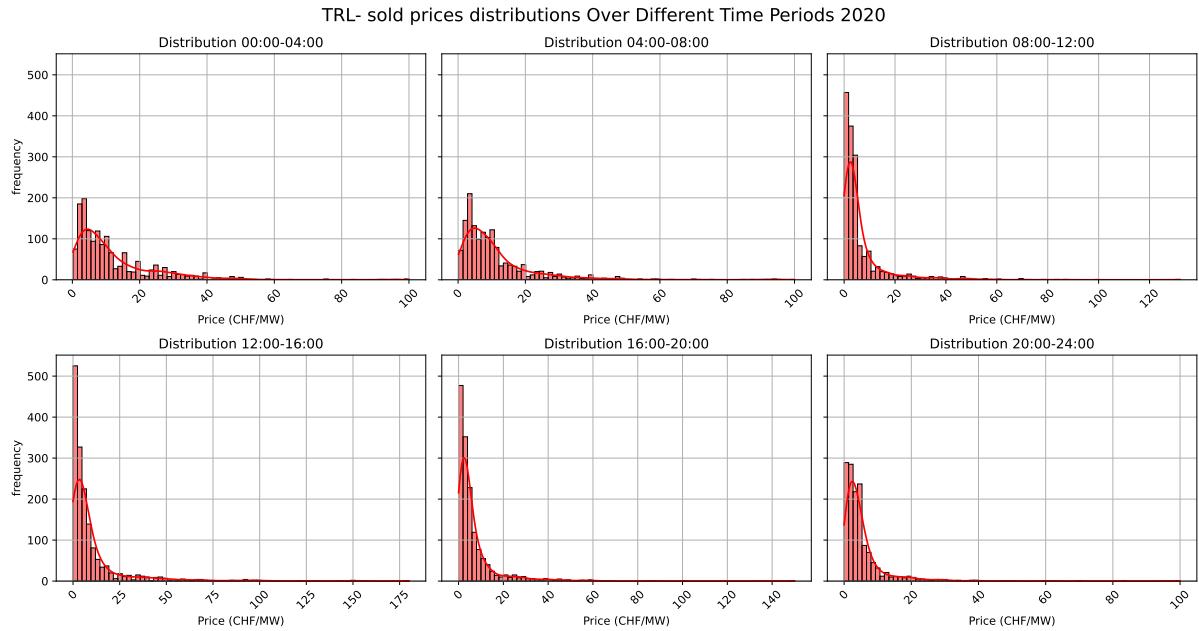


Figure 43: TRL- Distribution of 2020 bid prices in a year over the different four hours slots

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	10.26	9.58	5.01	7.49	5.09	4.50
Std Dev	8.94	8.44	6.81	11.61	6.64	4.59
Min	0.36	0.40	0.00	0.00	0.20	0.38
25%	3.90	3.91	1.25	1.70	1.29	1.75
50%	8.00	7.36	3.14	3.93	3.27	3.44
75%	13.39	11.82	5.55	7.73	6.00	5.49
Max	58.09	52.20	52.80	98.71	68.03	48.36

Table 25: Summary Statistics for TRL- daily mean price (EUR/MW) over different time windows in 2020

In figure [44], it can be observed that the prices are much lower for TRL+ and that they are often at 0 CHF/MW. The values of prices for TRL/+ can be found in tables [25] and [26].

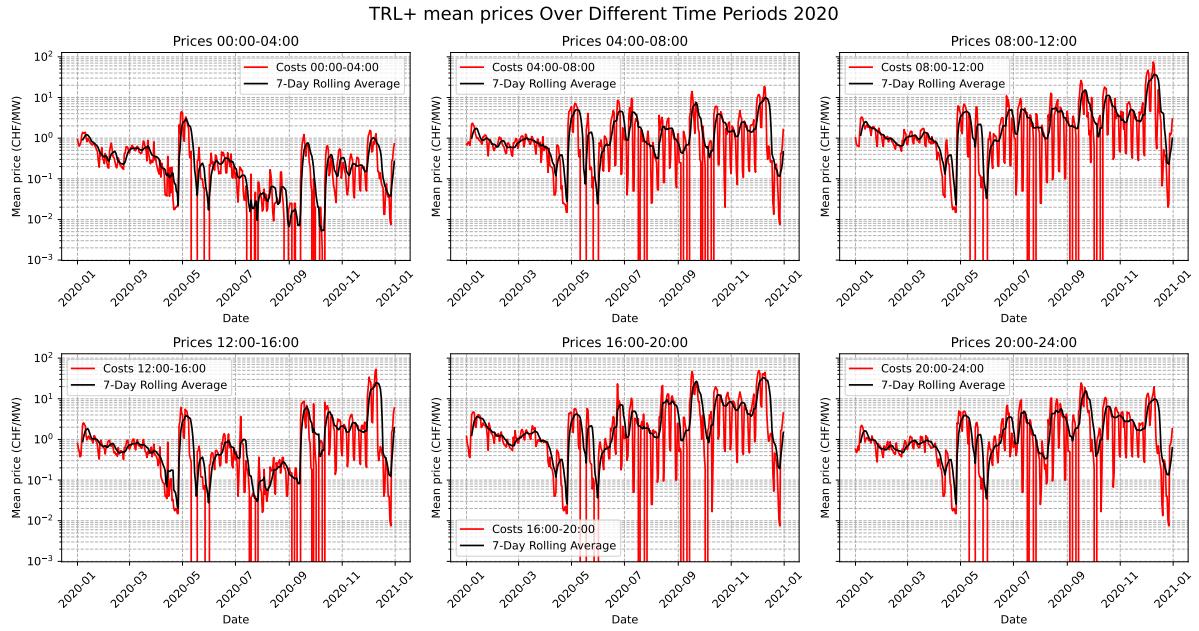


Figure 44: Mean prices per day of TRL+ bids over the different four hours slots EUR/MW

Moreover, the distributions of bid volumes in figures [42] and [45] over the different time periods seem to vary very little and this could potentially mean that bidders that have for example 30 MW of power, equally divides these 30 MW into 6 packs of 5 MW and bids them in the different periods at the same or different price for each pack.

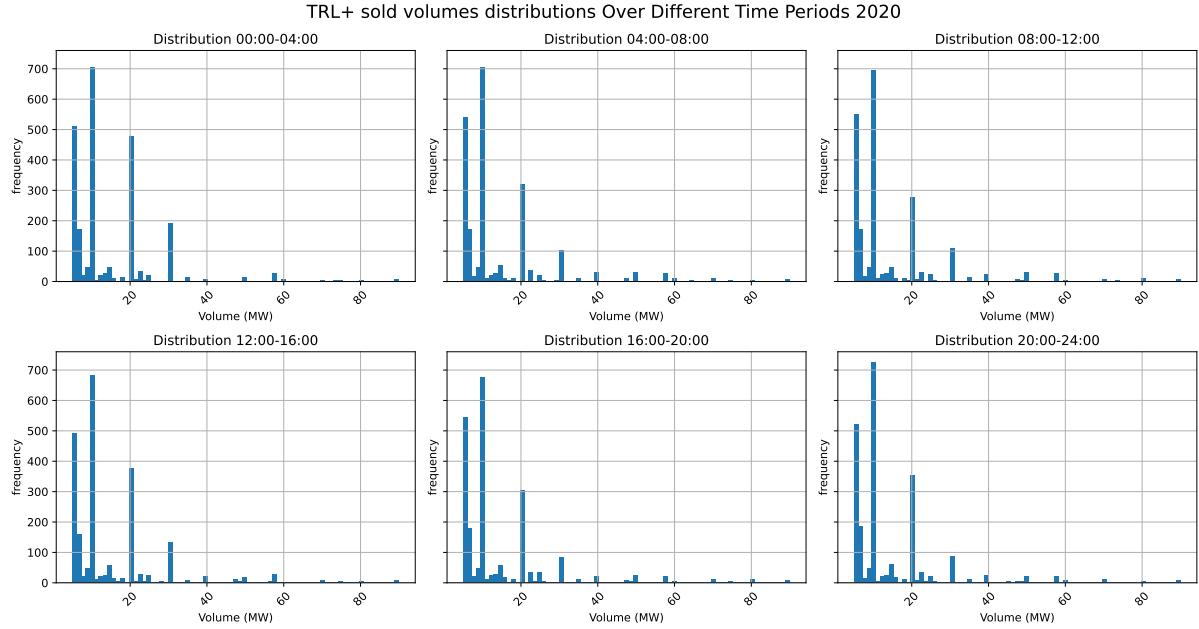


Figure 45: TRL+ Distribution of bid volumes in a year over the different four hours slots

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	0.35	1.67	3.70	1.76	4.36	2.23
Std Dev	0.55	2.57	7.84	5.15	7.97	3.45
Min	0.00	0.00	0.00	0.00	0.00	0.00
25%	0.04	0.24	0.46	0.16	0.53	0.40
50%	0.19	0.78	1.33	0.49	1.41	0.81
75%	0.46	1.86	3.76	1.02	4.45	2.61
Max	4.48	18.83	74.88	53.57	49.46	24.64

Table 26: Summary Statistics for TRL+ daily mean price (EUR/MW) over different time windows in 2020

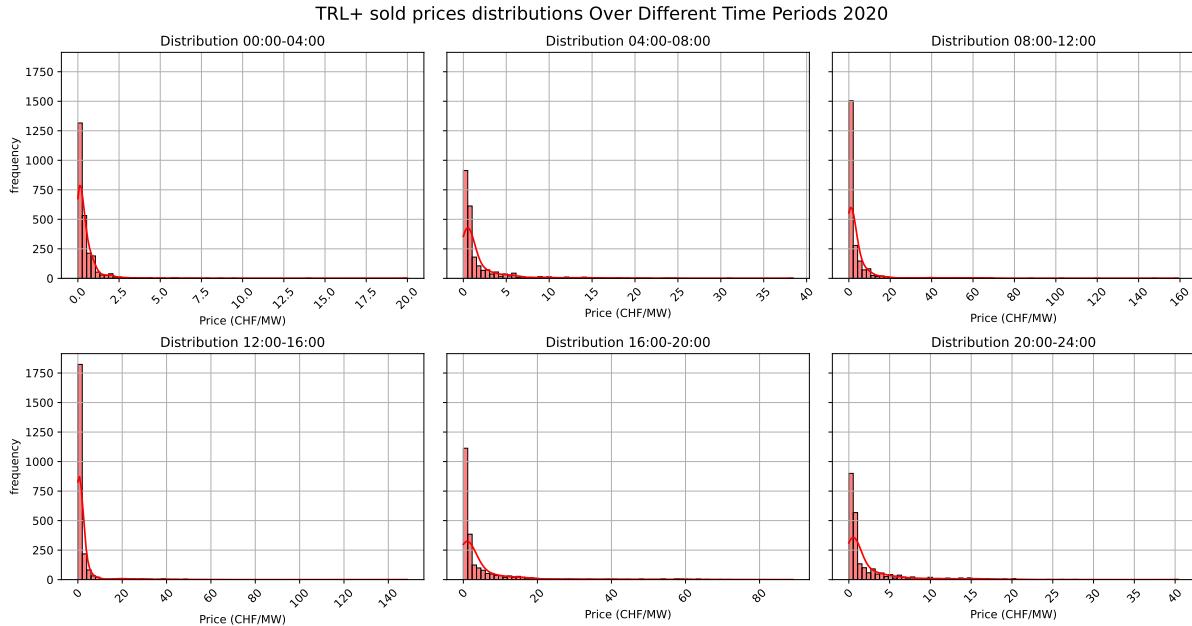


Figure 46: 2020 TRL+ Distribution of bid prices in a year over the different four hours slots

7 Data 2021

Since the same characteristics are observed along the years, i'll from now on comment the figures and tables only in cases where anomalies are observed.

7.1 Primary control auction 2021

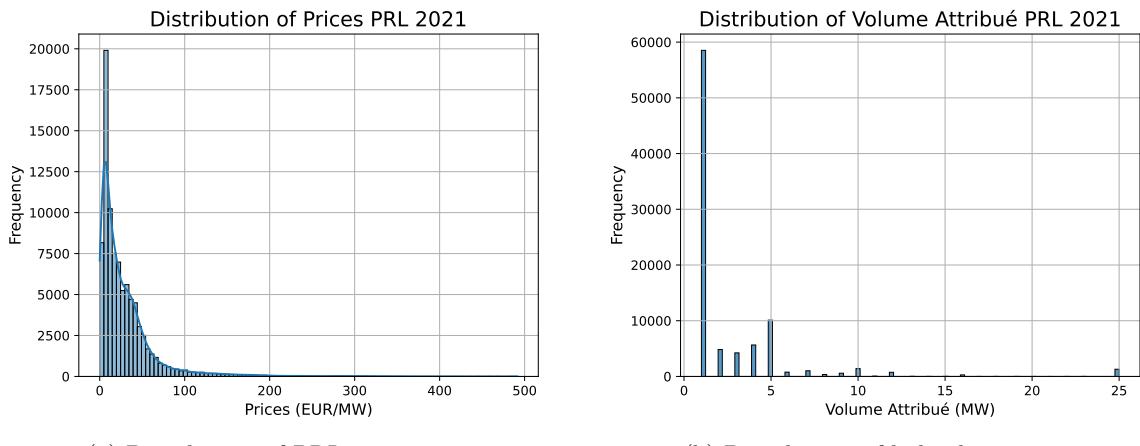


Figure 47: PRL 2021 distributions plots

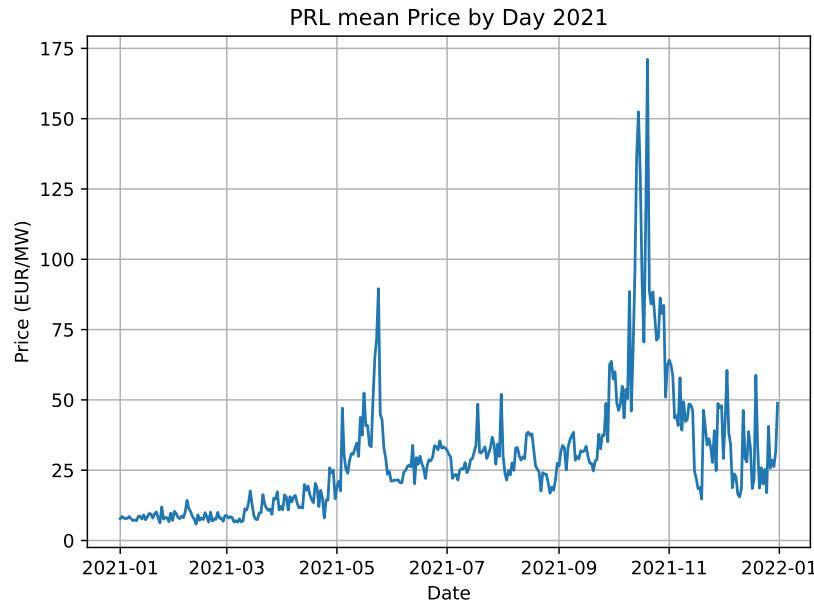


Figure 48: Mean prices per day of PRL bids EUR/MW 2021

mean	29.31
std	22.39
min	5.79
25%	13.21
50%	25.71
75%	34.35
max	171.10

Table 27: Statistics of PRL daily mean price in EUR/MW for 2021

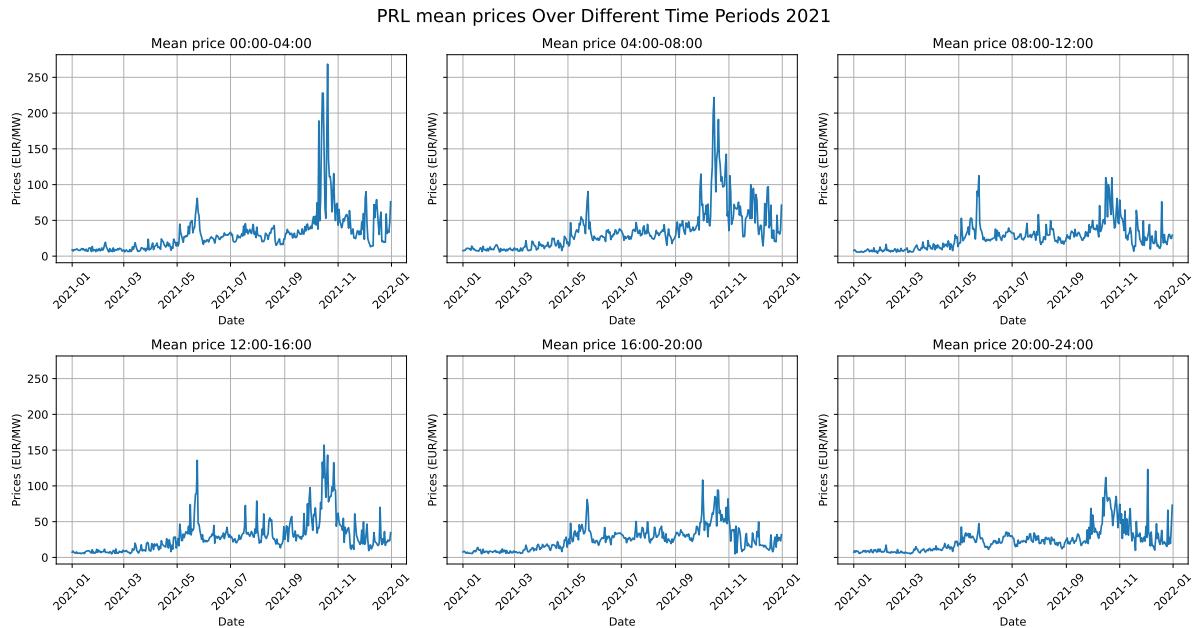


Figure 49: Mean prices per day of 2021 PRL bids over the different four hours slots EUR/MW

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	31.69	36.20	26.07	29.88	25.57	24.30
Std Dev	31.11	31.17	18.35	24.56	16.85	17.94
Min	5.68	5.63	4.01	4.85	4.91	4.81
25%	13.04	14.19	11.74	11.80	12.04	11.22
50%	25.87	28.54	23.81	24.93	24.42	21.03
75%	37.42	43.35	33.24	35.61	33.43	29.38
Max	268.39	221.76	112.49	157.09	108.24	123.03

Table 28: Summary Statistics for PRL daily mean price (EUR/MW) over different time windows in 2021

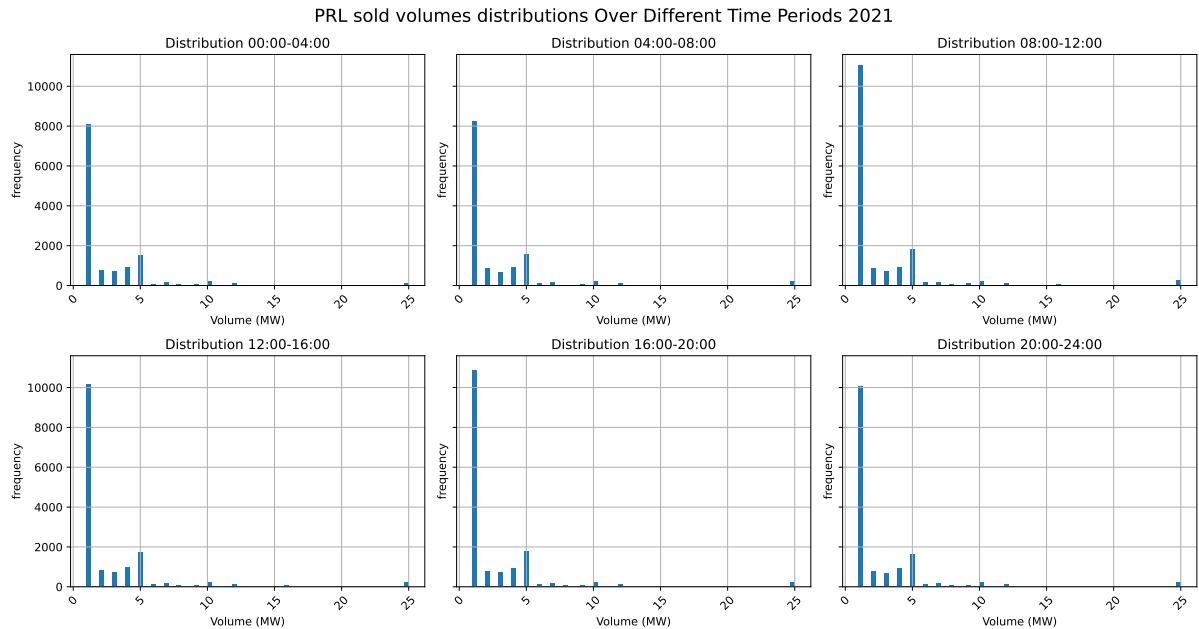


Figure 50: Distribution of 2021 bid volumes in a year over the different four hours slots

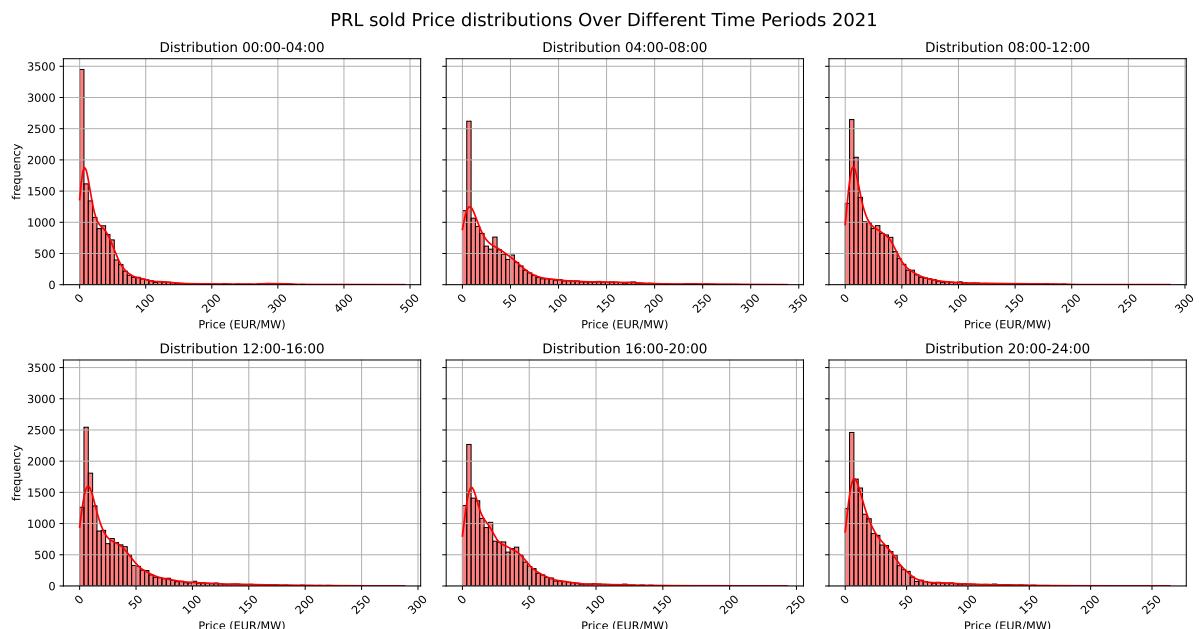


Figure 51: Distributions of PRL bid prices in a year over the different four hours slots

7.2 Secondary control auction 2021

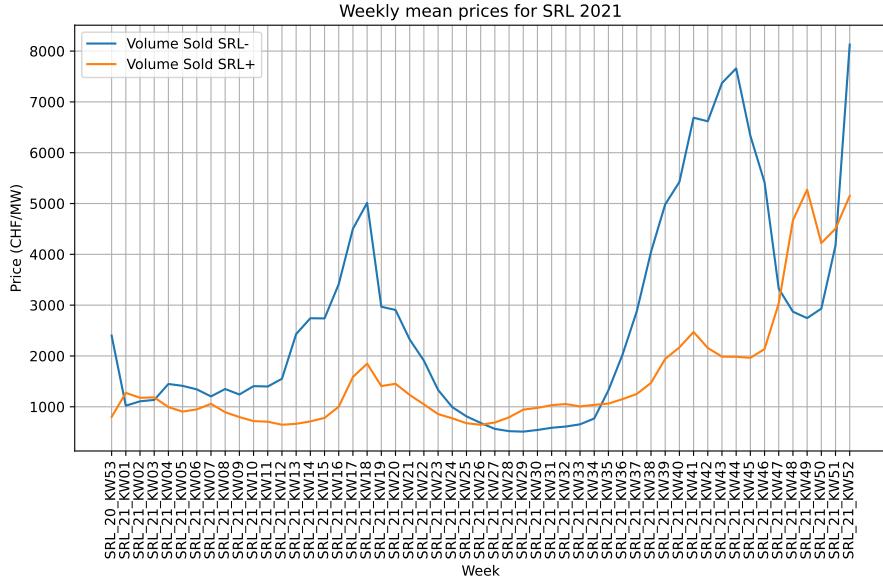


Figure 52: Weekly mean prices of SRL in EUR/MW 2021

Table 29: Summary Statistics for SRL- and SRL+ Prices in EUR/MW 2021

Statistic	SRL- Prices	SRL+ Prices
Mean	2688.63	1564.76
Std	2098.62	1175.10
Min	510.94	645.88
25%	1134.84	856.29
50%	2031.32	1058.15
75%	3412.62	1942.52
Max	8128.35	5272.64

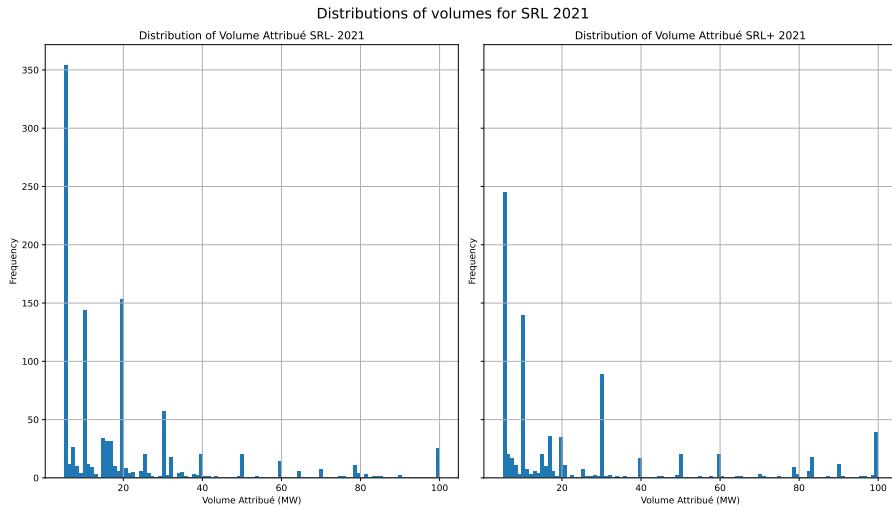


Figure 53: Distribution of SRL bid volumes in 2021

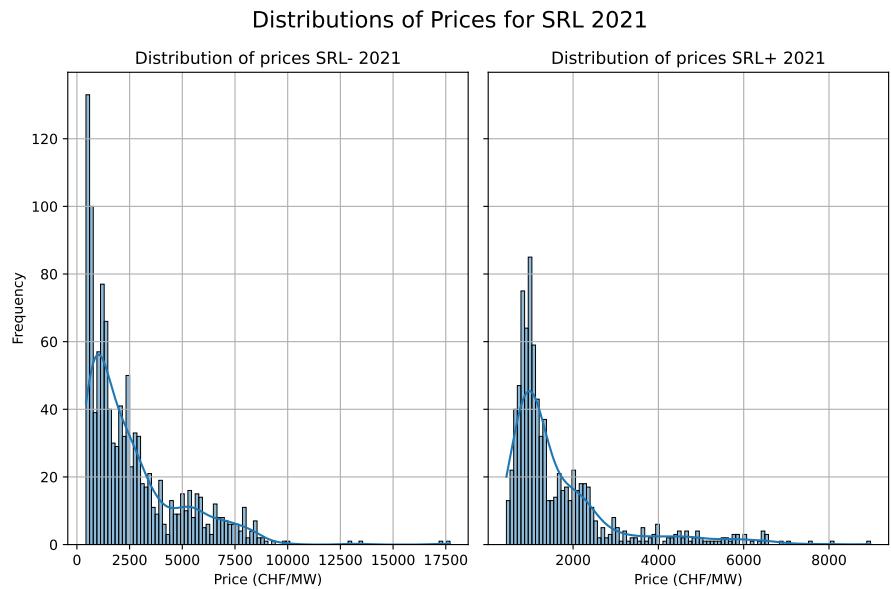


Figure 54: Distribution of SRL bid prices in 2021

7.3 Tertiary control auction 2021

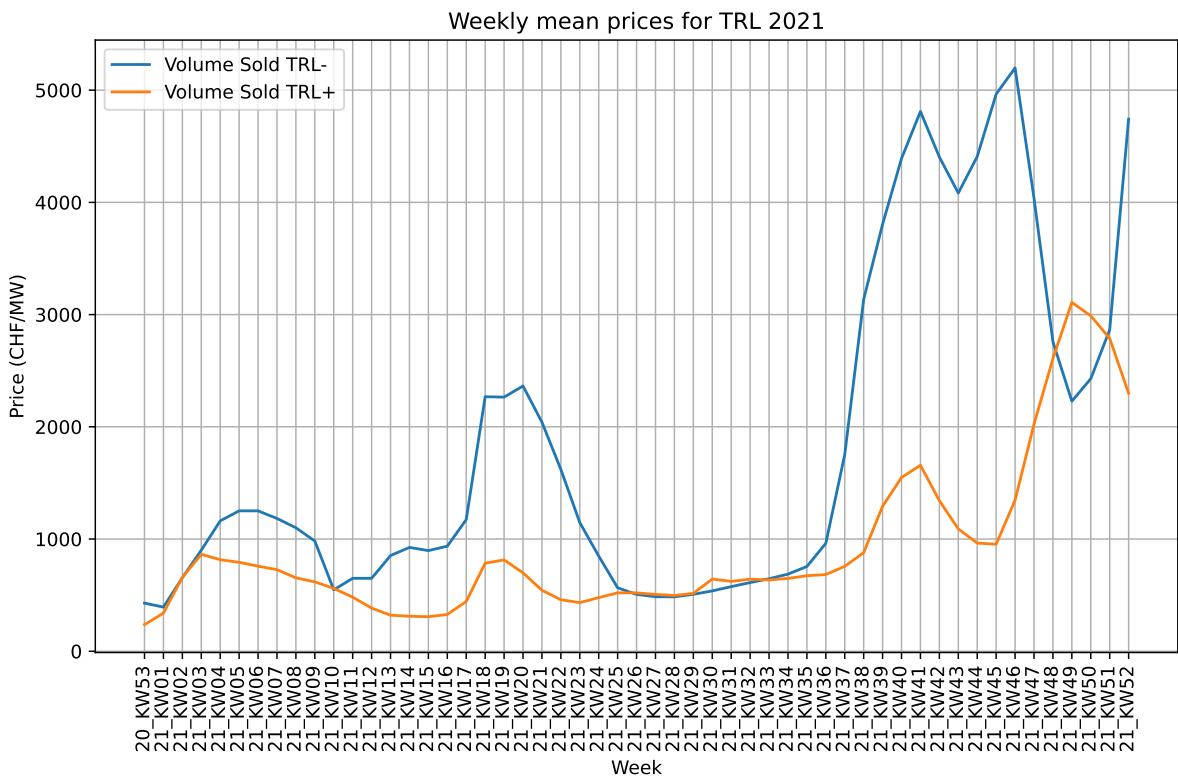


Figure 55: Weekly mean prices of TRL in EUR/MW 2021

Distributions of weekly volumes for TRL 2021

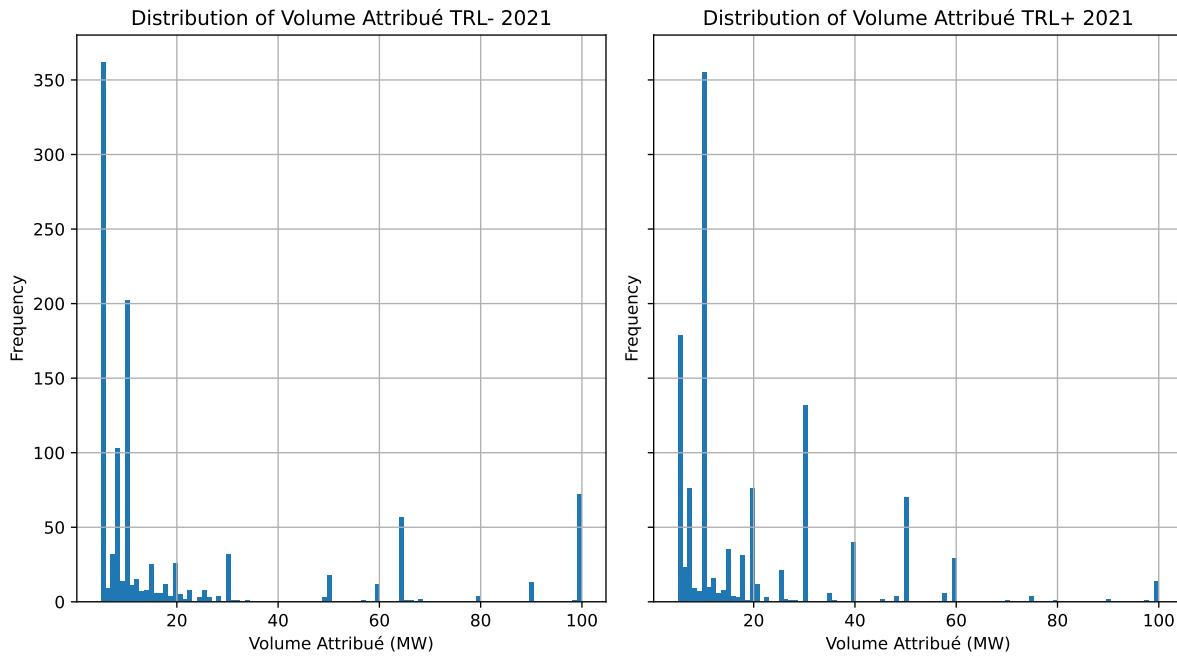


Figure 56: Distribution of TRL bid volumes in 2021

Distributions of Prices for TRL 2021

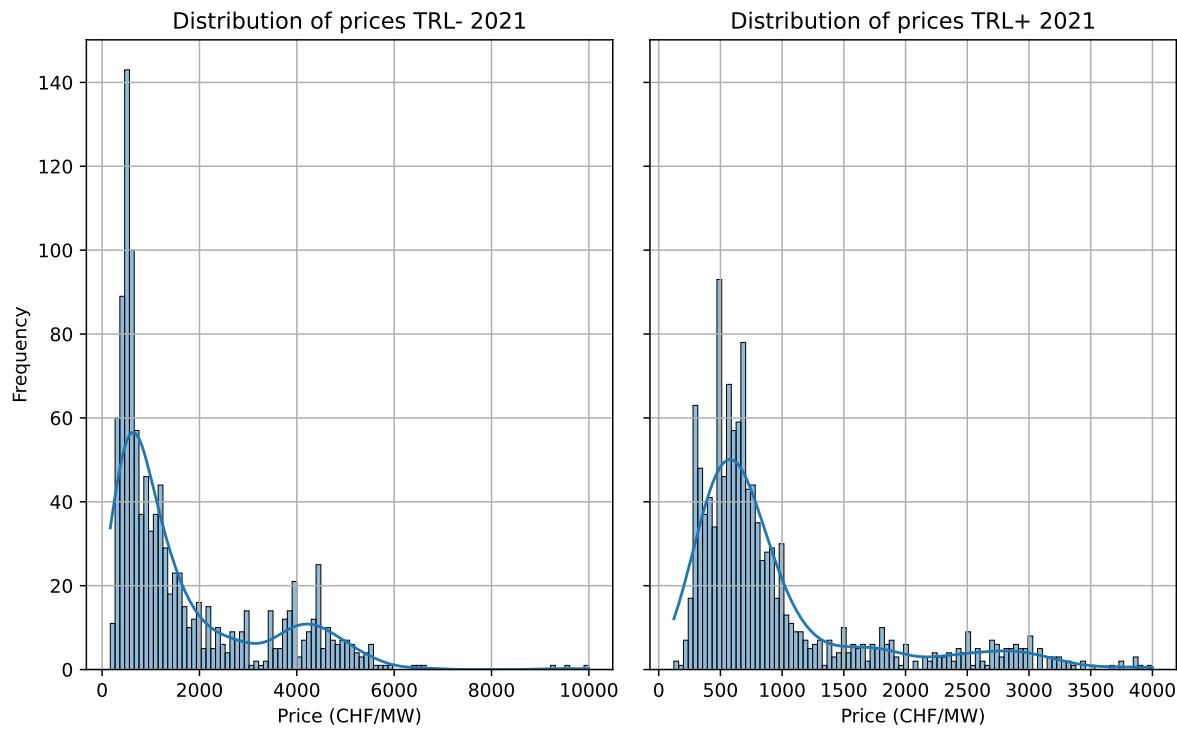


Figure 57: Distribution of TRL bid prices in 2021

Statistic	TRL- Prices	TRL+ Prices
Mean	1808.15	916.37
Std Dev	1480.36	702.29
Min	393.19	237.05
25%	650.00	506.76
50%	1146.52	658.39
75%	2428.80	953.86
Max	5198.26	3108.81

Table 30: Summary Statistics for weekly TRL- and TRL+ Prices in EUR/MW 2021

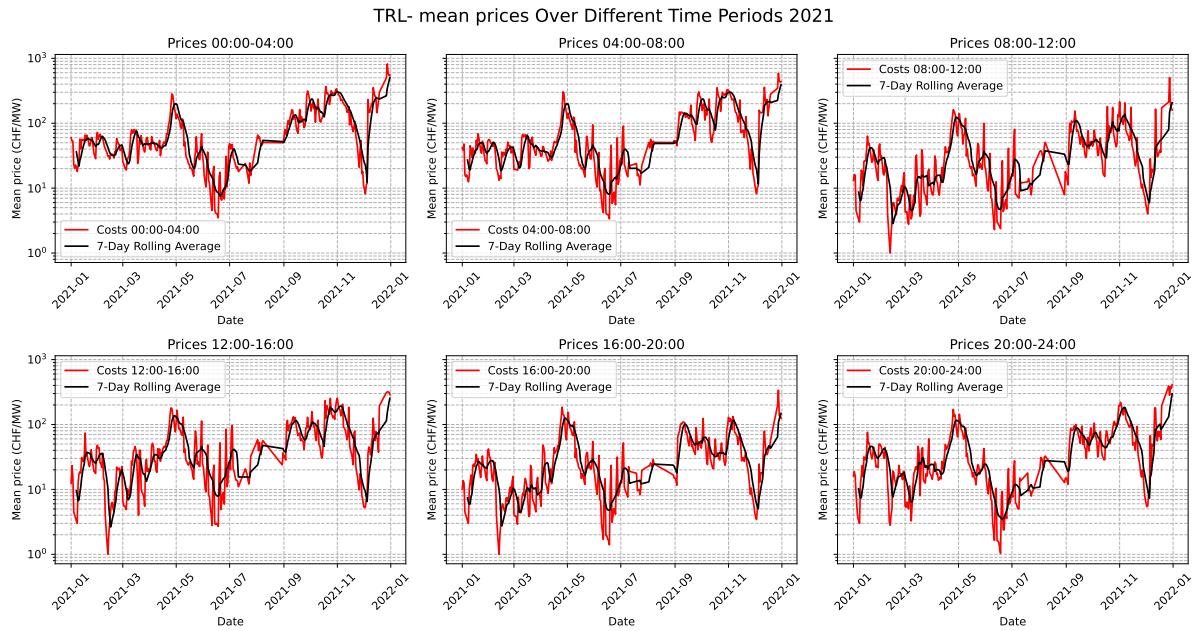


Figure 58: Mean prices per day of TRL- bids over the different four hours slots EUR/MW

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	94.82	86.29	40.17	54.99	34.84	47.29
Std Dev	104.65	92.49	49.75	59.61	38.76	57.88
Min	3.48	3.36	1.00	1.00	1.00	1.04
25%	30.10	25.96	9.83	16.51	9.88	14.15
50%	54.16	48.60	23.78	32.75	22.04	27.57
75%	121.30	123.30	49.02	75.26	45.02	63.44
Max	819.50	588.00	504.50	318.00	337.87	412.80

Table 31: Summary Statistics for TRL- daily mean price (EUR/MW) over different time windows in 2021

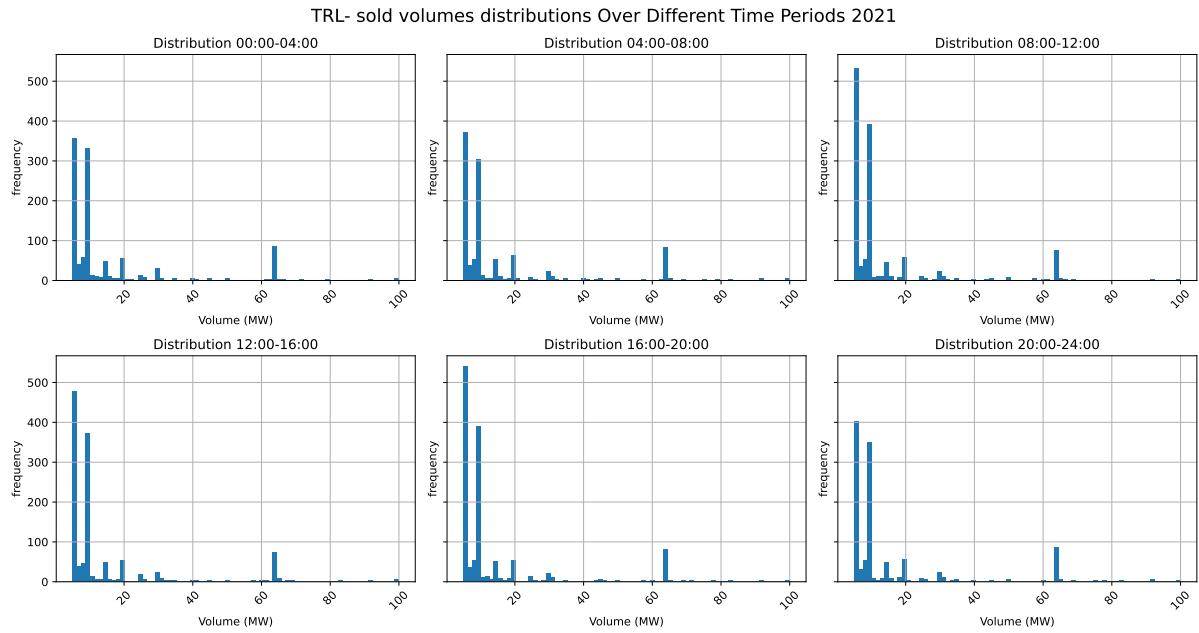


Figure 59: TRL- Distribution of bid volumes in a year over the different four hours slots

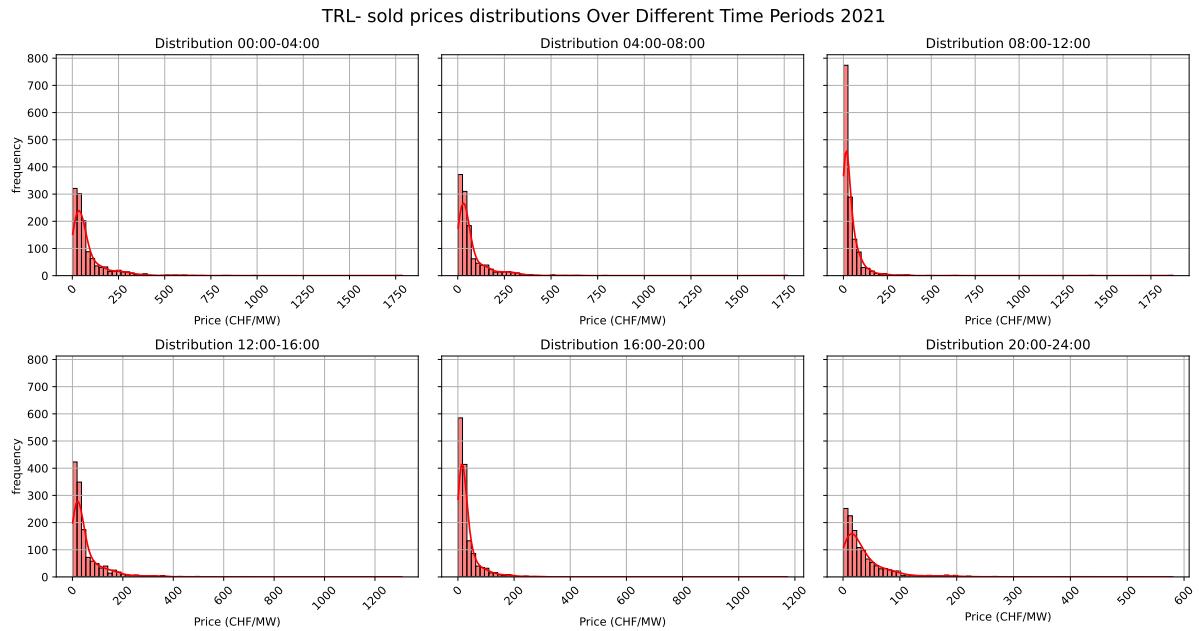


Figure 60: TRL- Distribution of 2021 bid prices in a year over the different four hours slots

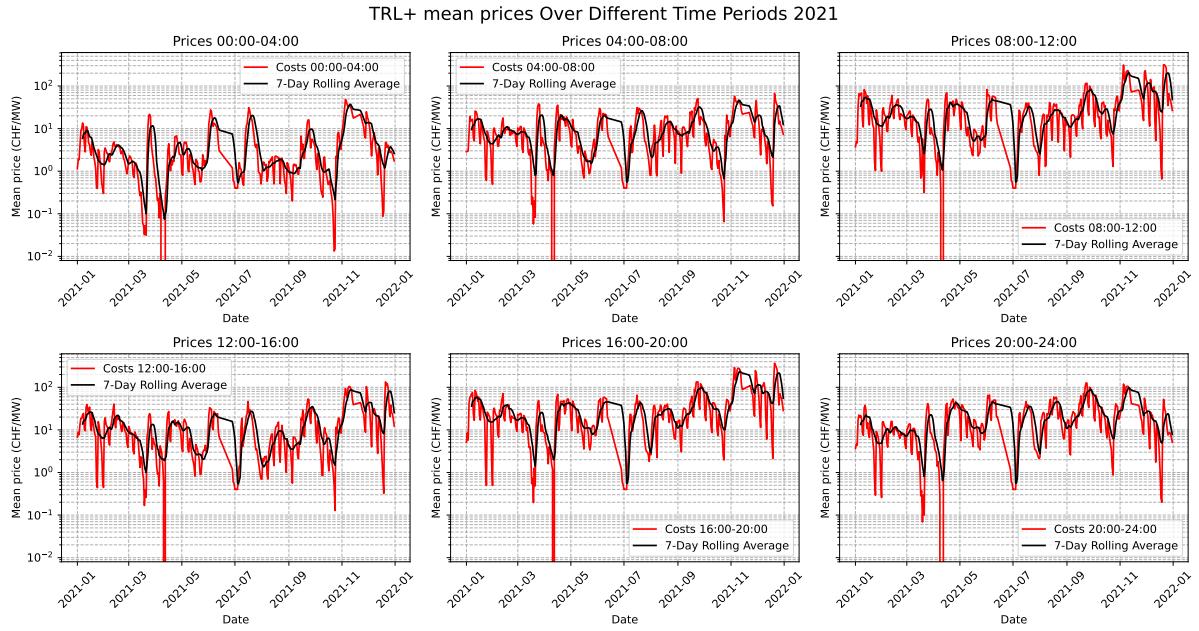


Figure 61: Mean prices per day of TRL+ bids over the different four hours slots EUR/MW

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	4.90	10.99	35.81	15.30	40.60	21.97
Std Dev	7.42	11.18	50.10	20.52	54.79	22.98
Min	0.00	0.00	0.00	0.00	0.00	0.00
25%	0.92	3.31	8.23	3.16	10.32	6.61
50%	2.04	7.59	20.22	8.71	23.06	14.88
75%	4.57	15.18	41.91	19.08	46.59	31.00
Max	48.34	66.63	316.63	134.10	367.31	127.43

Table 32: Summary Statistics for TRL+ daily mean price (EUR/MW) over different time windows in 2021

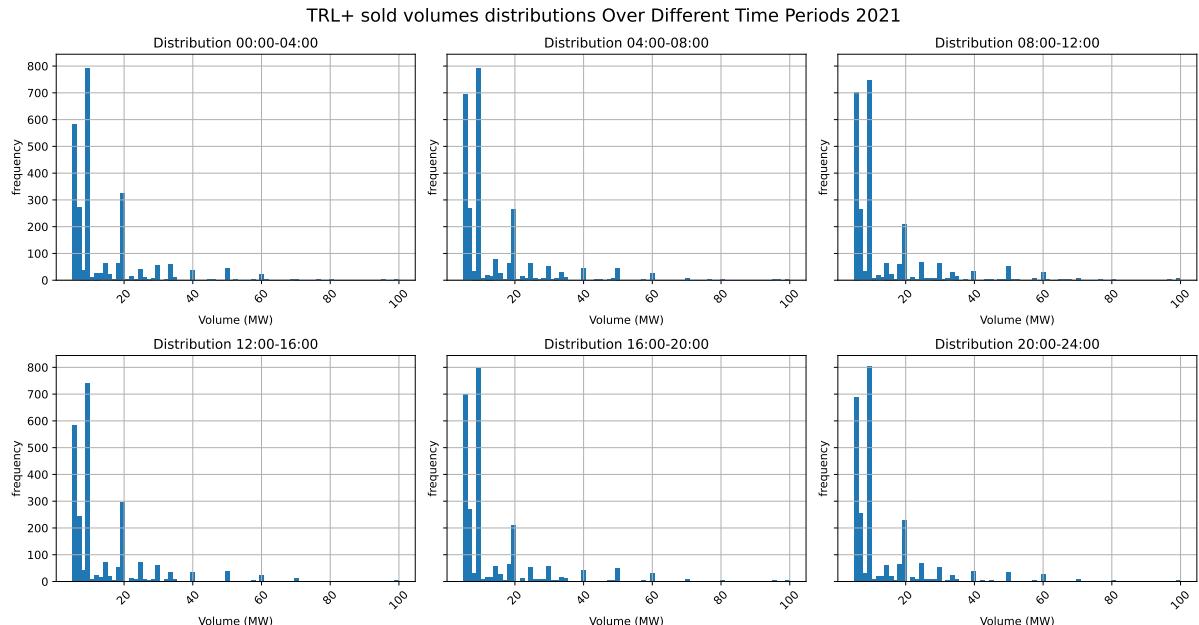


Figure 62: TRL+ Distribution of bid volumes in a year over the different four hours slots

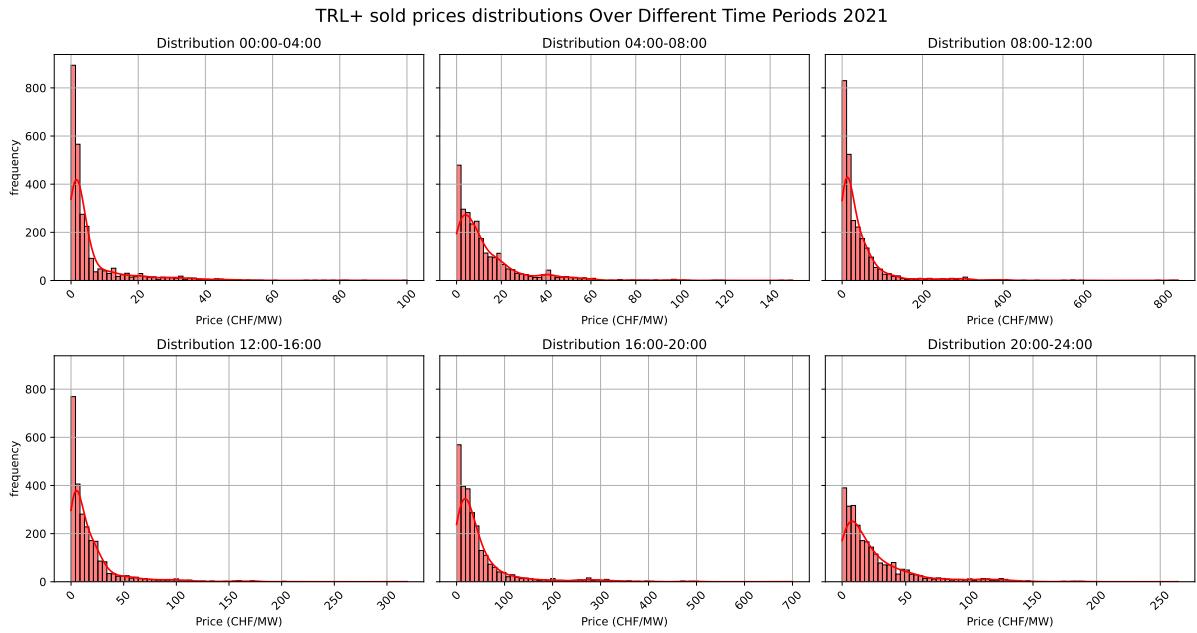


Figure 63: 2021 TRL+ Distribution of bid prices in a year over the different four hours slots

8 Data 2022

8.1 Primary control auction 2022

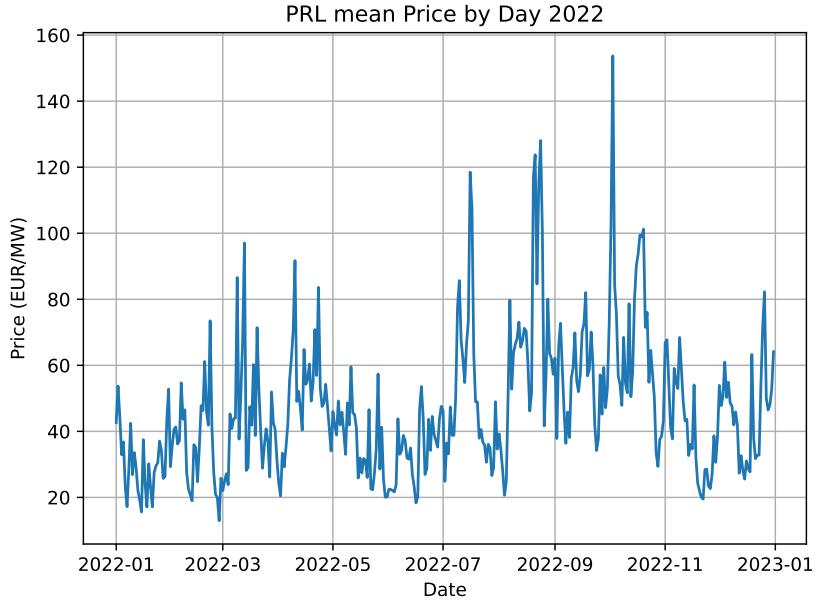


Figure 64: Mean prices per day of PRL bids EUR/MW 2022

mean	46.77
std	20.83
min	12.93
25%	31.98
50%	43.18
75%	56.71
max	153.71

Table 33: Statistics of PRL daily mean price in EUR/MW for 2022

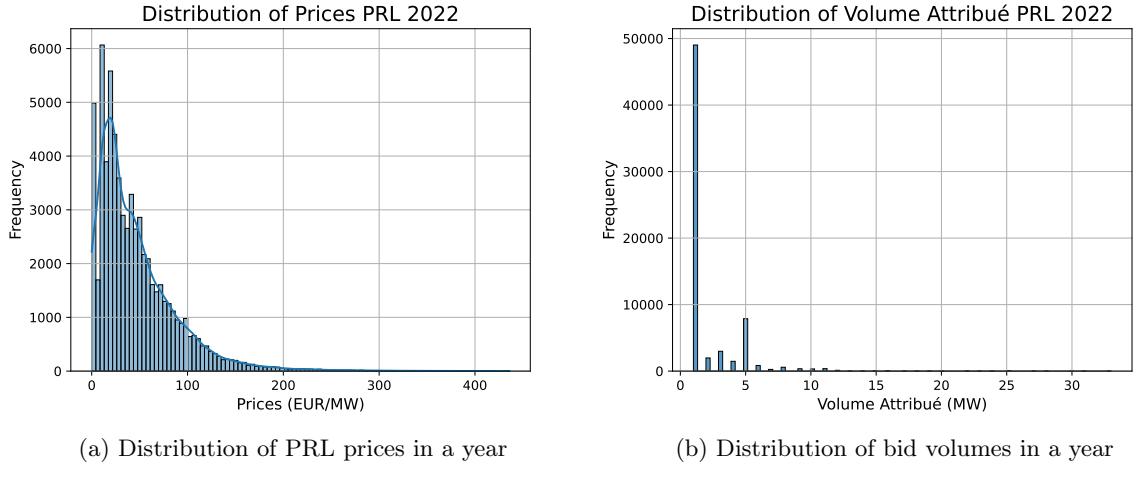


Figure 65: PRL 2022 distributions plots

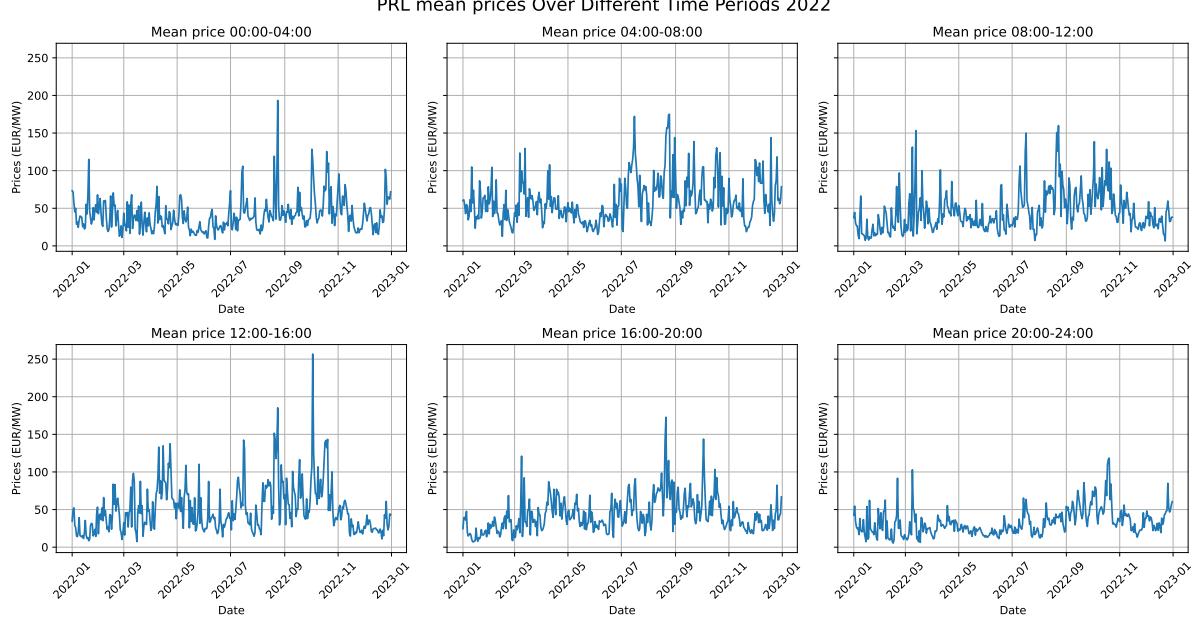


Figure 66: Mean prices per day of 2022 PRL bids over the different four hours slots EUR/MW

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	41.07	59.82	44.95	51.01	43.04	32.89
Std Dev	21.88	29.41	26.68	32.42	23.01	17.96
Min	8.57	12.66	6.62	7.35	7.05	5.37
25%	26.54	38.92	26.59	26.74	26.30	20.40
50%	37.09	53.75	39.03	43.41	37.95	28.89
75%	49.06	73.88	55.91	65.93	55.07	41.85
Max	193.44	175.10	159.90	256.79	172.71	118.39

Table 34: Summary Statistics for PRL daily mean price (EUR/MW) over different time windows in 2022

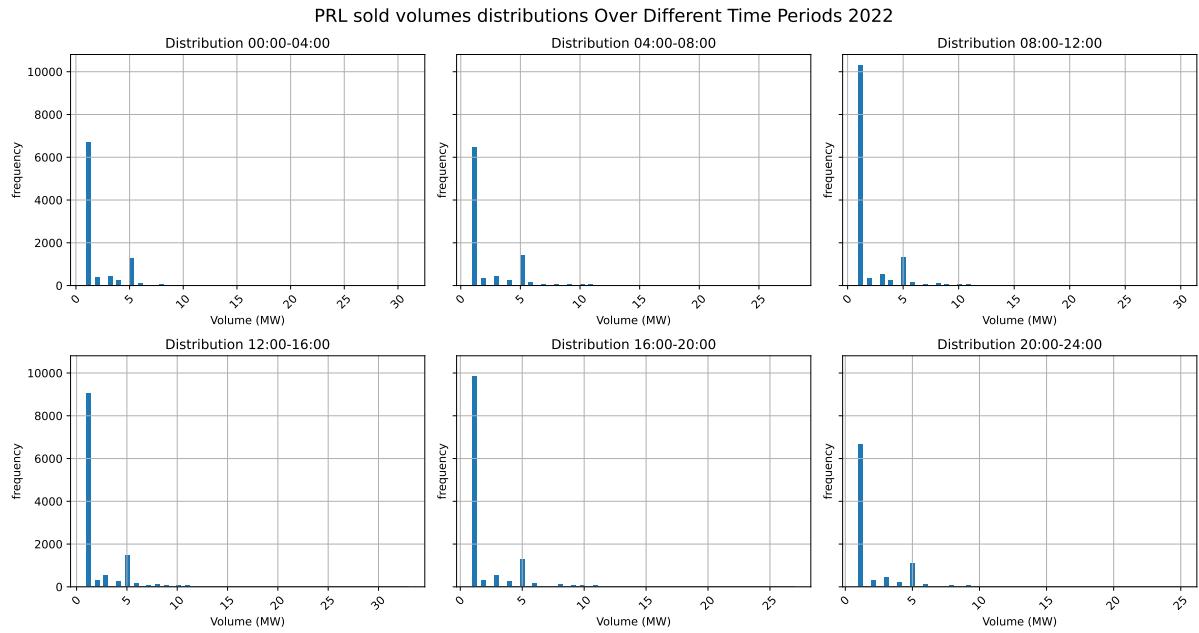


Figure 67: Distribution of 2022 bid volumes in a year over the different four hours slots

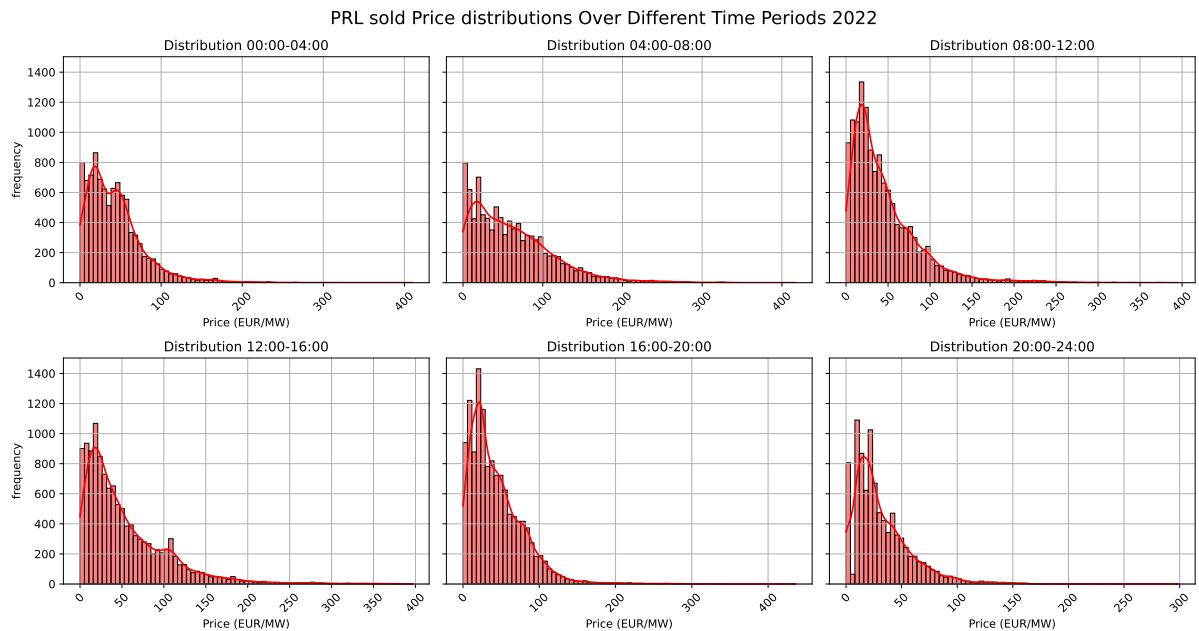


Figure 68: Distributions of PRL bid prices in a year over the different four hours slots

8.2 Secondary control auction 2022



Figure 69: Weekly mean prices of SRL in EUR/MW 2022

Table 35: Summary Statistics for SRL- and SRL+ Prices in EUR/MW 2022

Statistic	SRL- Prices	SRL+ Prices
Mean	9587.27	4638.29
Std	8169.10	3179.68
Min	2977.37	1346.88
25%	4120.63	2025.25
50%	5060.79	3127.72
75%	13568.31	8206.07
Max	30940.35	11239.03

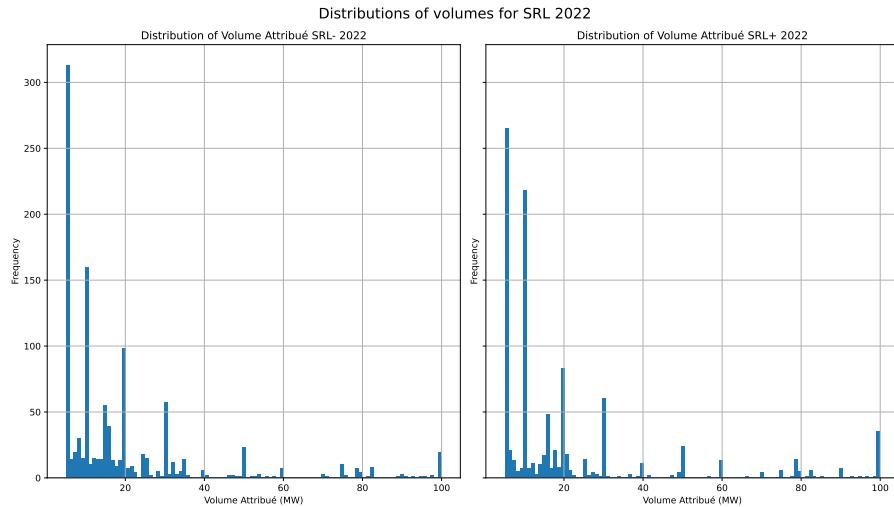


Figure 70: Distribution of SRL bid volumes in 2022

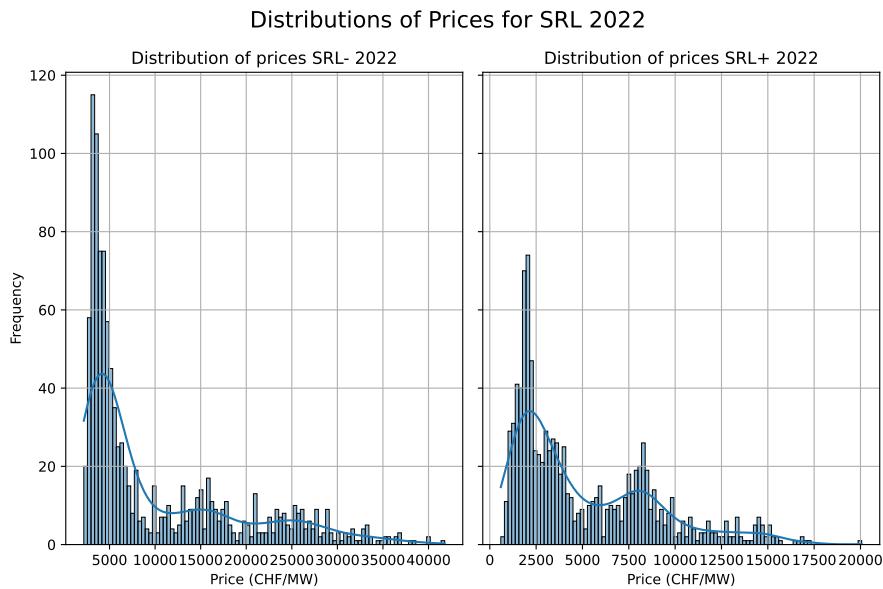


Figure 71: Distribution of SRL bid prices in 2022

8.3 Tertiary control auction 2022

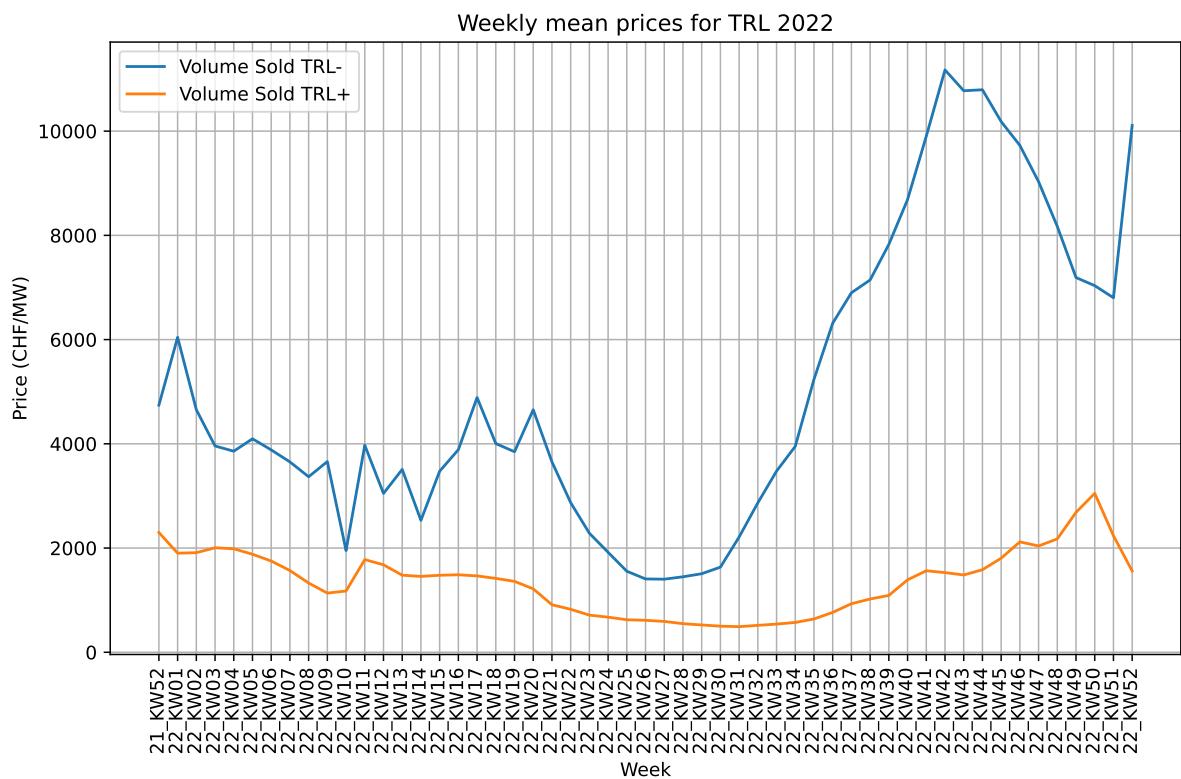


Figure 72: Weekly mean prices of TRL in EUR/MW 2022

Statistic	TRL- Prices	TRL+ Prices
Mean	5035.41	1360.03
Std Dev	2867.83	617.37
Min	1402.67	491.68
25%	3047.97	765.45
50%	3958.77	1456.07
75%	7034.83	1778.68
Max	11174.73	3049.27

Table 36: Summary Statistics for weekly TRL- and TRL+ Prices in EUR/MW 2022

Distributions of weekly volumes for TRL 2022

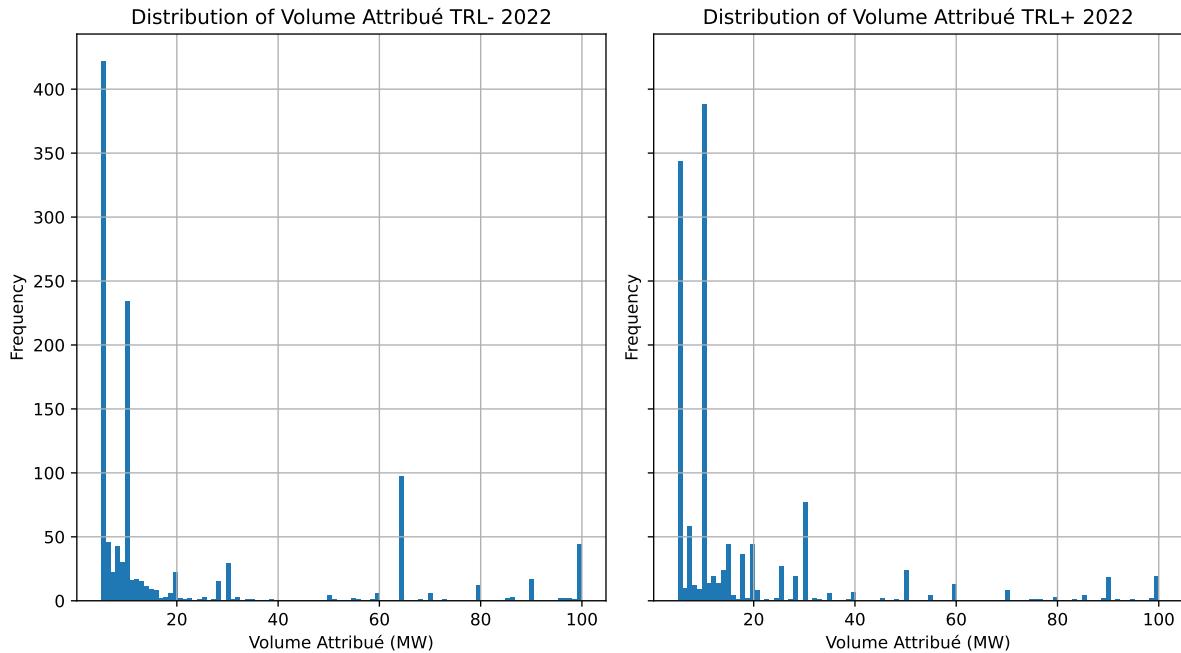


Figure 73: Distribution of TRL bid volumes in 2022

Distributions of Prices for TRL 2022

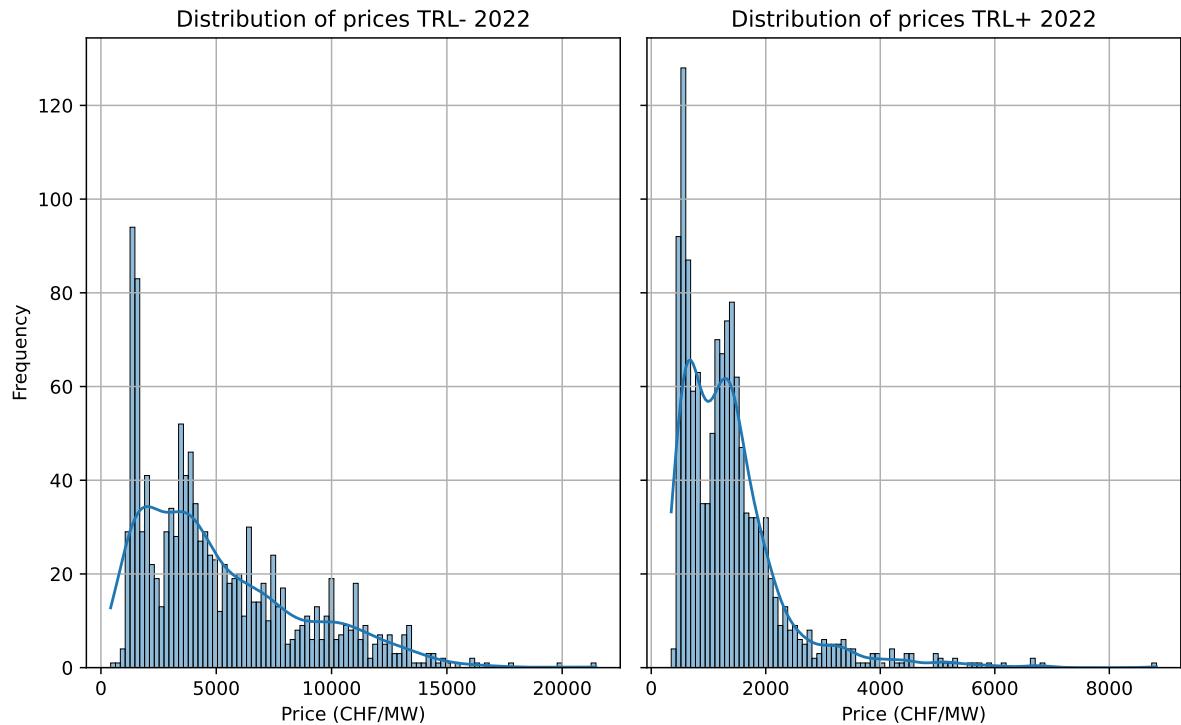


Figure 74: Distribution of TRL bid prices in 2022

TRL- mean prices Over Different Time Periods 2022

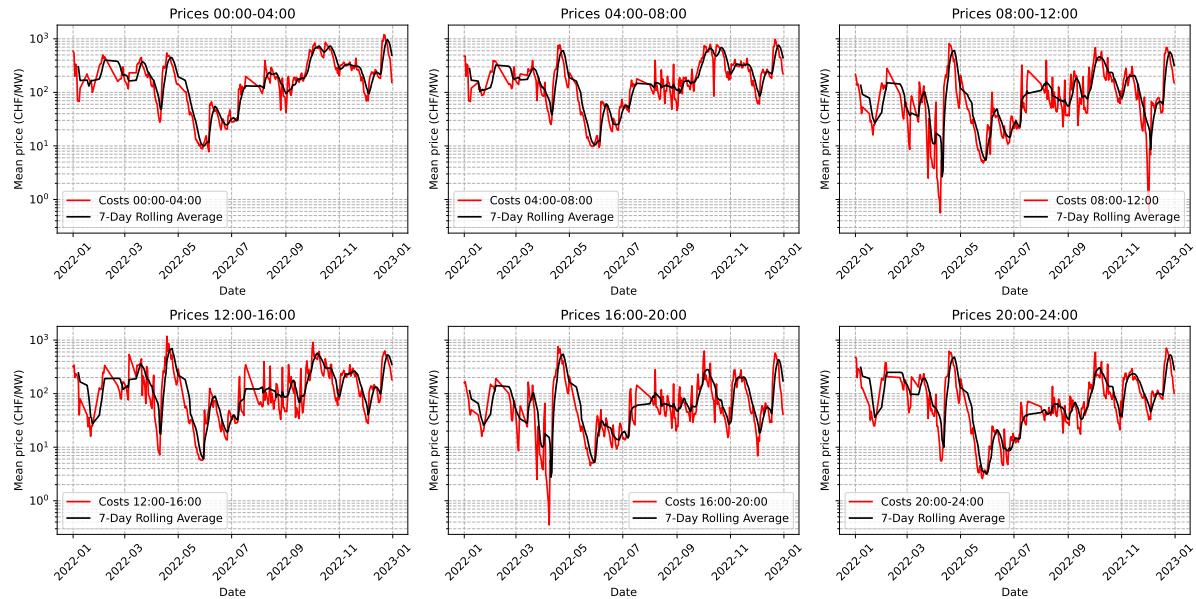


Figure 75: Mean prices per day of TRL- bids over the different four hours slots EUR/MW

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	242.09	219.20	122.93	168.30	92.12	113.30
Std Dev	215.55	196.25	149.87	169.30	117.93	128.10
Min	7.81	9.40	0.56	5.70	0.35	2.59
25%	85.00	71.35	28.00	46.00	23.60	27.41
50%	188.67	157.11	64.46	111.00	52.00	66.33
75%	316.00	300.00	166.00	239.00	119.25	169.60
Max	1202.67	982.00	820.64	1184.46	753.51	707.99

Table 37: Summary Statistics for TRL- daily mean price (CHF/MW) over different time windows in 2022

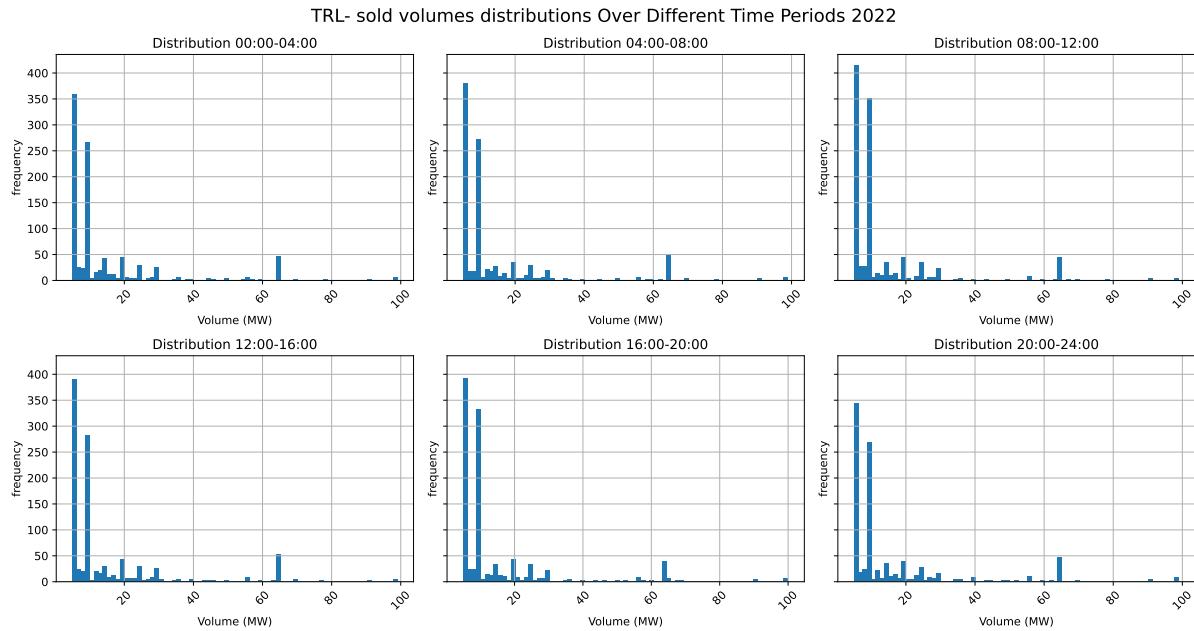


Figure 76: TRL- Distribution of bid volumes in a year over the different four hours slots

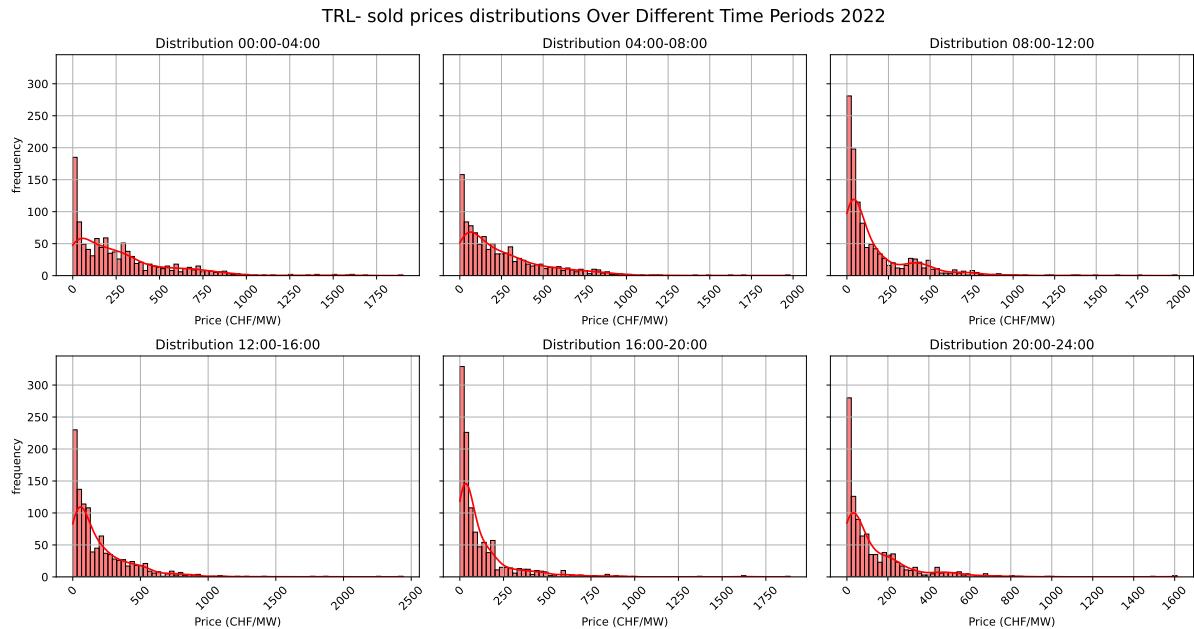


Figure 77: TRL- Distribution of 2022 bid prices in a year over the different four hours slots

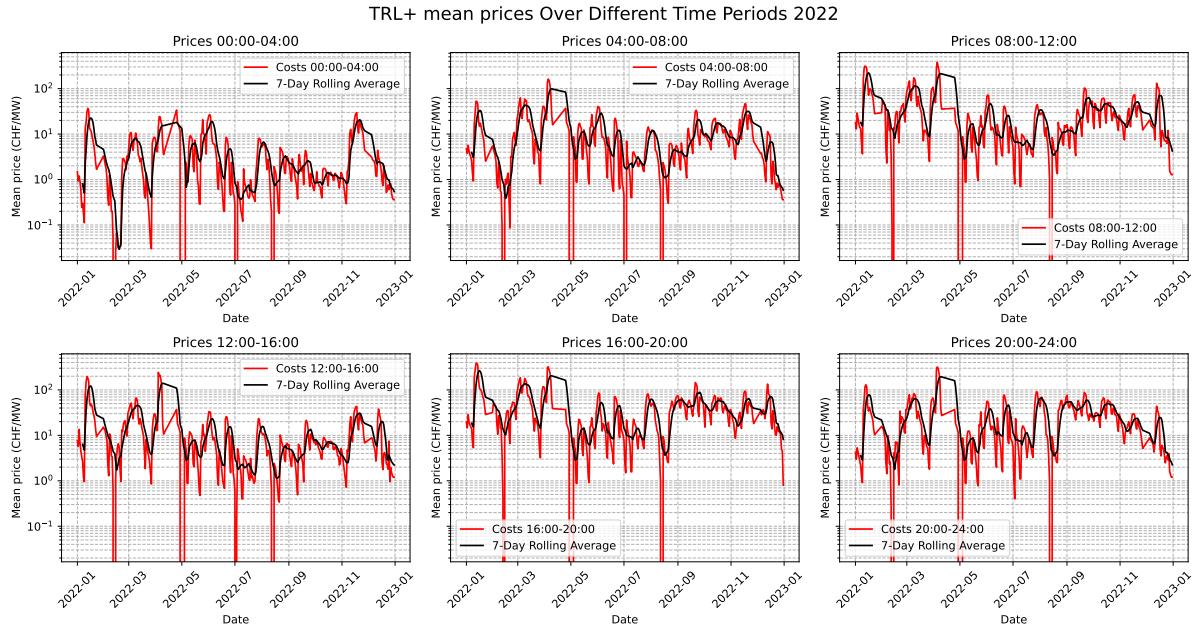


Figure 78: Mean prices per day of TRL+ bids over the different four hours slots EUR/MW

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	4.32	12.09	35.06	14.89	44.83	27.89
Std Dev	6.34	18.89	52.21	30.59	56.21	37.22
Min	0.00	0.00	0.00	0.00	0.00	0.00
25%	0.70	2.23	8.11	2.52	12.40	5.73
50%	1.65	6.49	16.65	6.37	30.99	16.20
75%	5.47	14.30	40.88	13.54	55.53	37.36
Max	36.67	162.73	379.54	243.03	386.25	320.47

Table 38: Summary Statistics for TRL+ daily mean price (EUR/MW) over different time windows in 2022

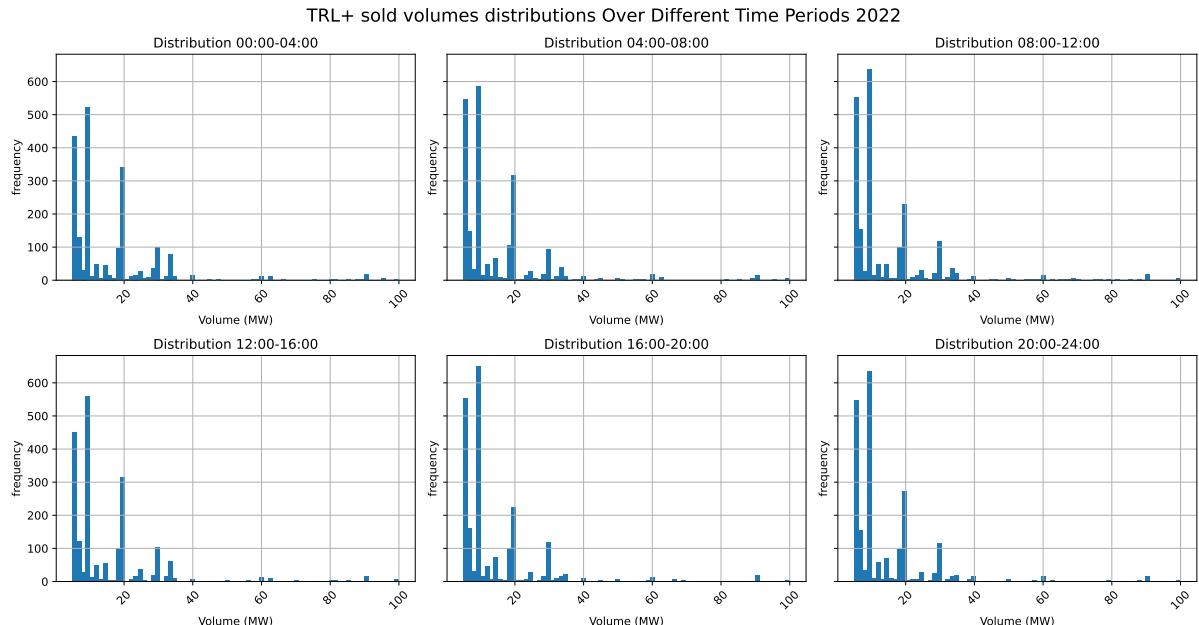


Figure 79: TRL+ Distribution of bid volumes in a year over the different four hours slots

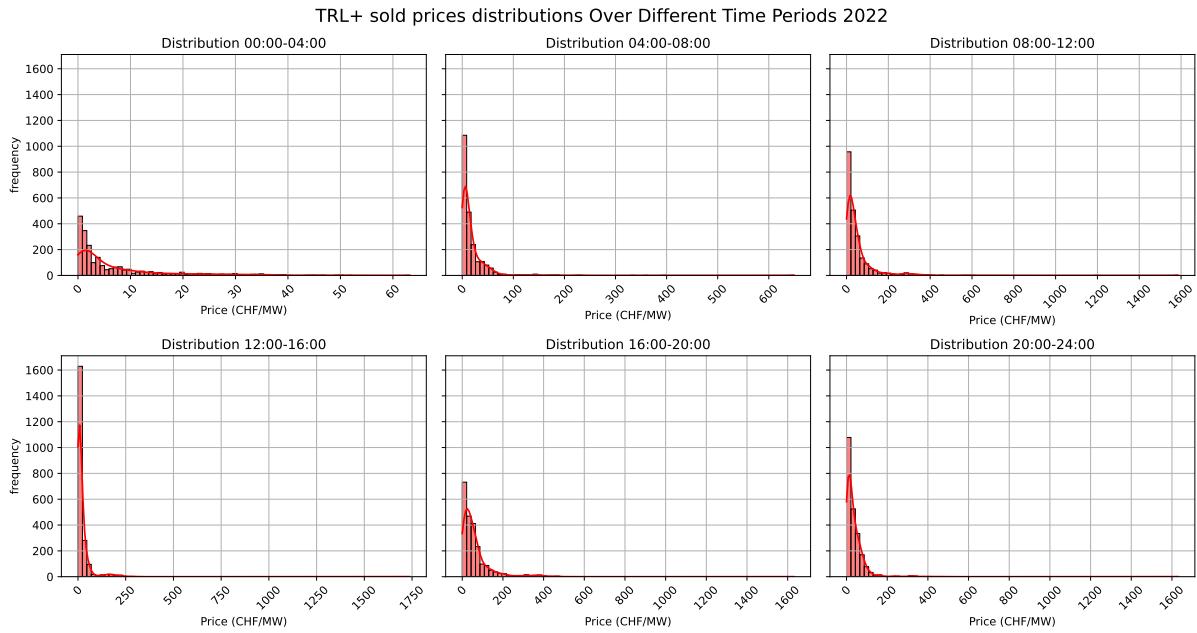


Figure 80: 2022 TRL+ Distribution of bid prices in a year over the different four hours slots

9 Data 2023

9.1 Primary control auction 2023

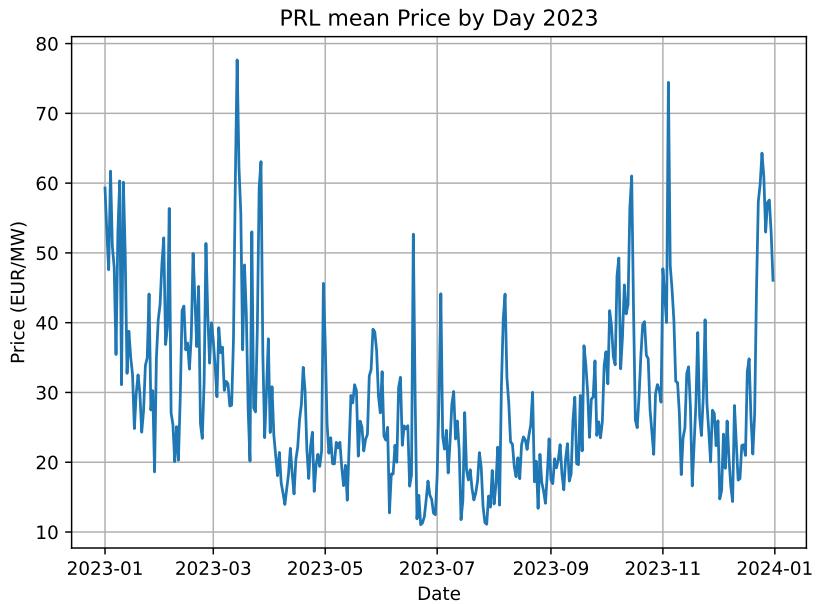


Figure 81: Mean prices per day of PRL bids EUR/MW 2023

mean	29.44
std	12.34
min	11.04
25%	20.50
50%	26.64
75%	35.56
max	77.66

Table 39: Statistics of PRL daily mean price in EUR/MW for 2023

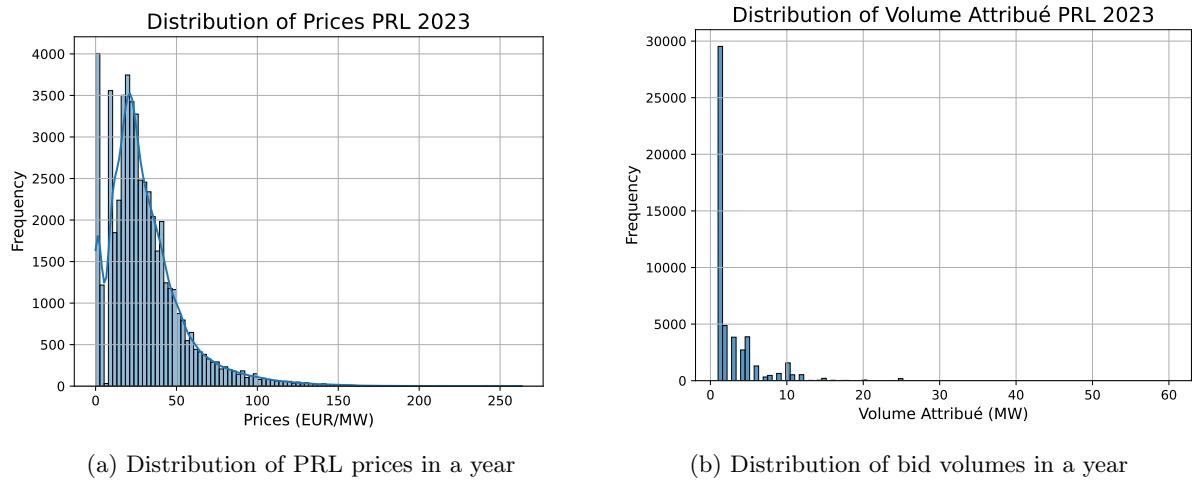


Figure 82: PRL 2023 distributions plots

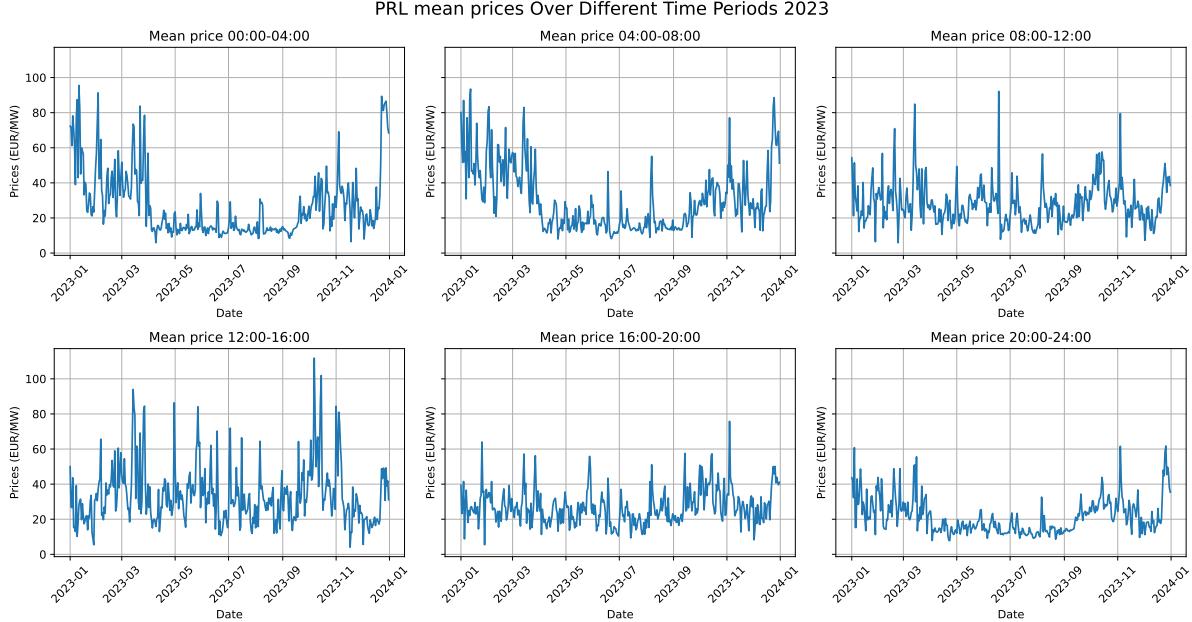


Figure 83: Mean prices per day of 2023 PRL bids over the different four hours slots EUR/MW

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	27.09	30.19	28.12	33.71	27.06	21.53
Std Dev	18.74	18.04	11.84	16.97	10.01	10.22
Min	5.85	7.98	5.85	4.08	5.45	7.83
25%	13.53	15.68	20.01	21.82	20.43	13.90
50%	20.68	25.31	26.57	30.66	25.59	18.94
75%	33.99	40.23	33.43	39.64	32.03	26.26
Max	95.52	93.47	92.12	111.83	75.78	61.74

Table 40: Summary Statistics for PRL daily mean price (EUR/MW) over different time windows in 2023

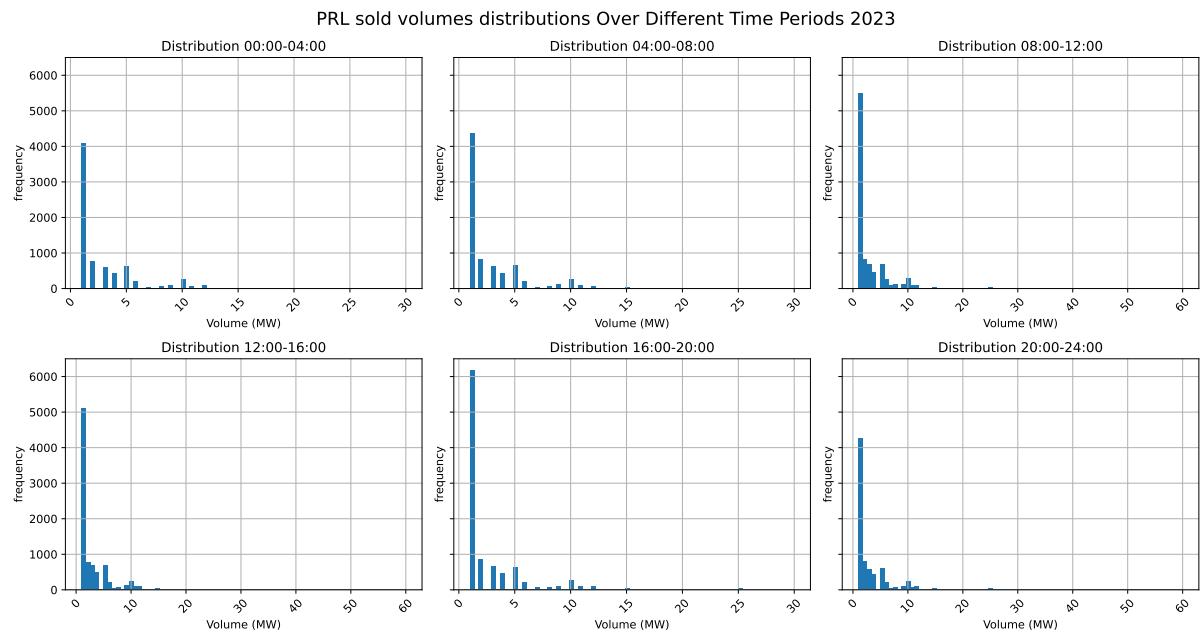


Figure 84: Distribution of 2023 bid volumes in a year over the different four hours slots

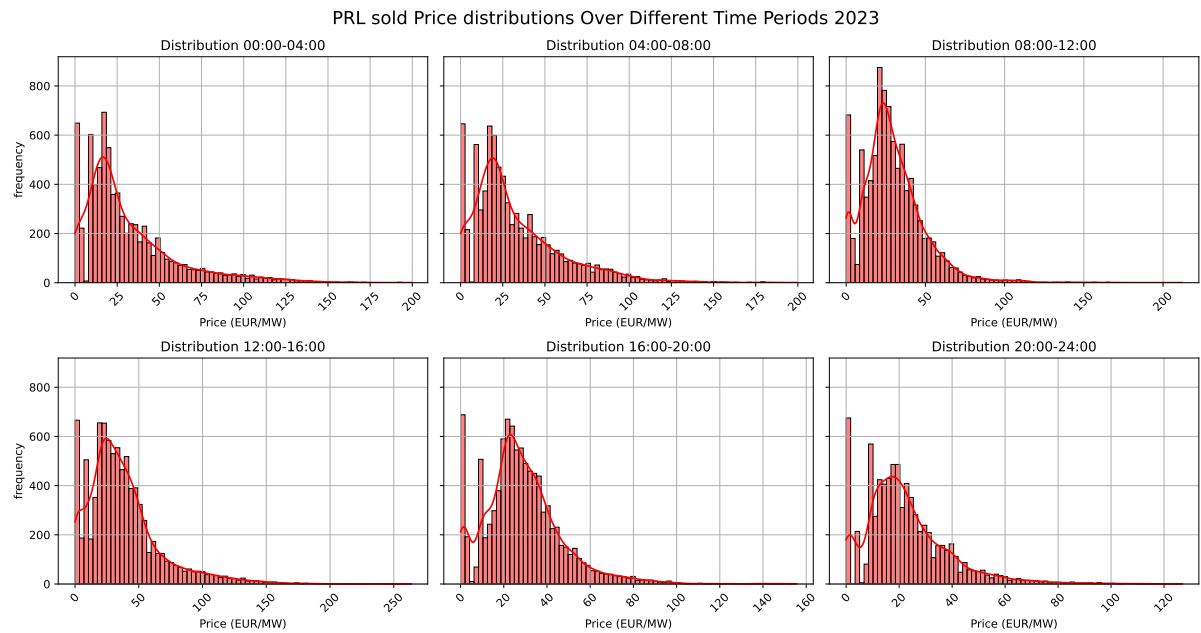


Figure 85: Distributions of PRL bid prices in a year over the different four hours slots

9.2 Secondary control auction 2023



Figure 86: Weekly mean prices of SRL in EUR/MW 2023

Table 41: Summary Statistics for SRL- and SRL+ Prices in EUR/MW 2023

Statistic	SRL- Prices	SRL+ Prices
Mean	11118.85	5920.10
Std	12144.85	5384.29
Min	1645.71	1018.85
25%	2313.26	1273.62
50%	4417.62	1927.64
75%	15869.39	10661.57
Max	44518.75	16427.24

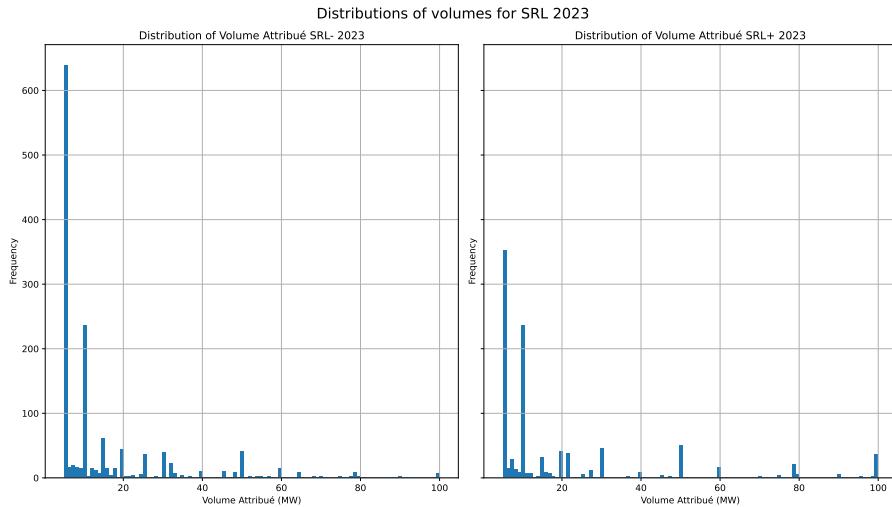


Figure 87: Distribution of SRL bid volumes in 2023

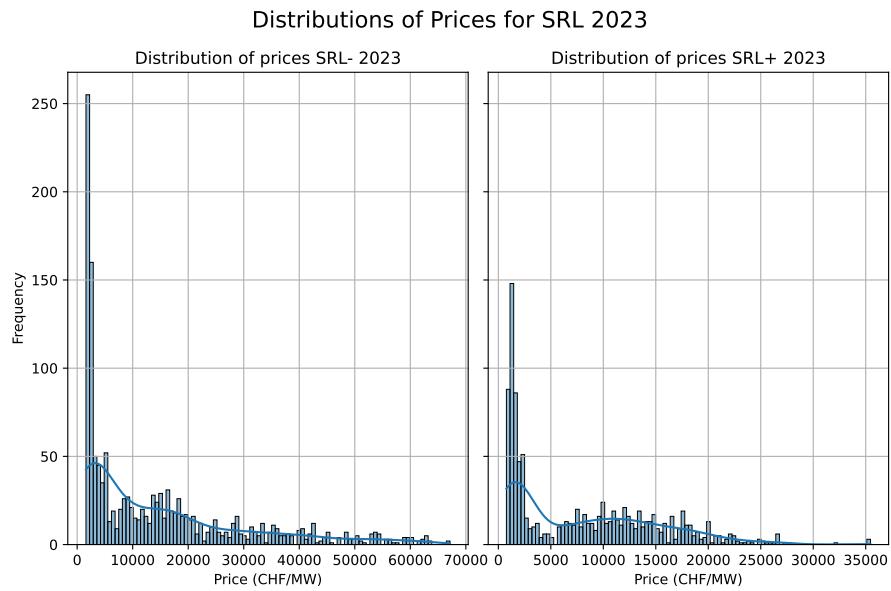


Figure 88: Distribution of SRL bid prices in 2023

9.3 Tertiary control auction 2023

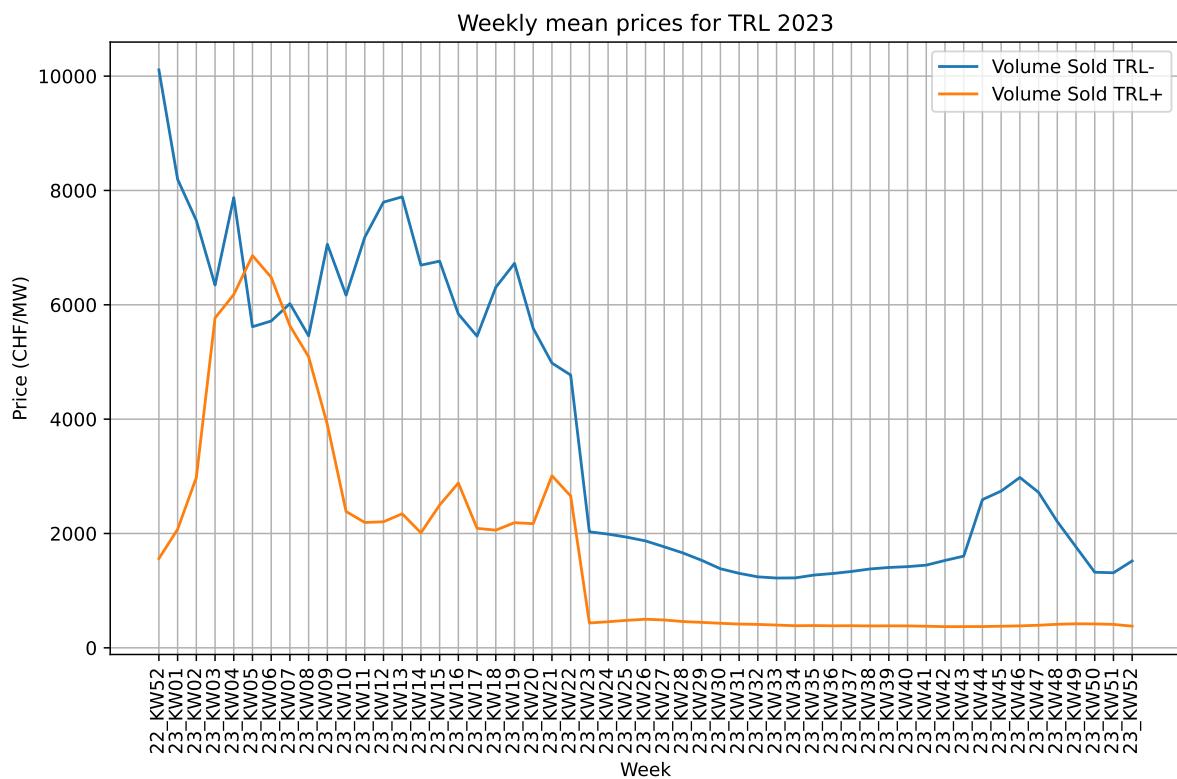


Figure 89: Weekly mean prices of TRL in EUR/MW 2023

Statistic	TRL- Prices	TRL+ Prices
Mean	3830.71	1689.36
Std Dev	2611.26	1842.71
Min	1220.80	370.46
25%	1446.58	389.23
50%	2592.13	459.50
75%	6168.15	2344.98
Max	10108.54	6860.42

Table 42: Summary Statistics for weekly TRL- and TRL+ Prices in EUR/MW 2023

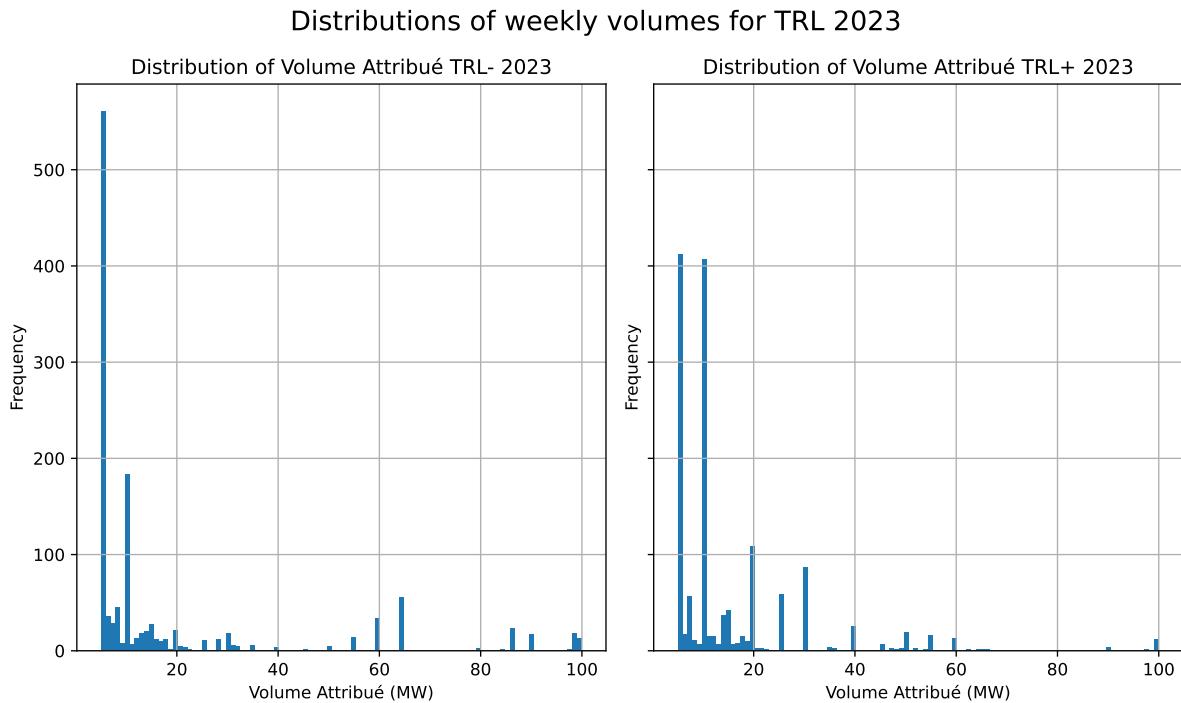


Figure 90: Distribution of TRL bid volumes in 2023

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	49.64	48.93	30.65	57.50	26.63	28.78
Std Dev	46.09	41.91	33.95	61.42	26.10	28.64
Min	5.88	5.74	0.50	1.80	0.80	0.00
25%	18.00	20.15	10.29	16.53	10.81	10.99
50%	32.90	38.00	21.00	36.53	19.09	19.00
75%	66.75	57.75	35.77	76.16	32.99	34.11
Max	251.52	248.26	256.00	354.00	163.31	214.12

Table 43: Summary Statistics for TRL- daily mean price (EUR/MW) over different time windows in 2023

Distributions of Prices for TRL 2023

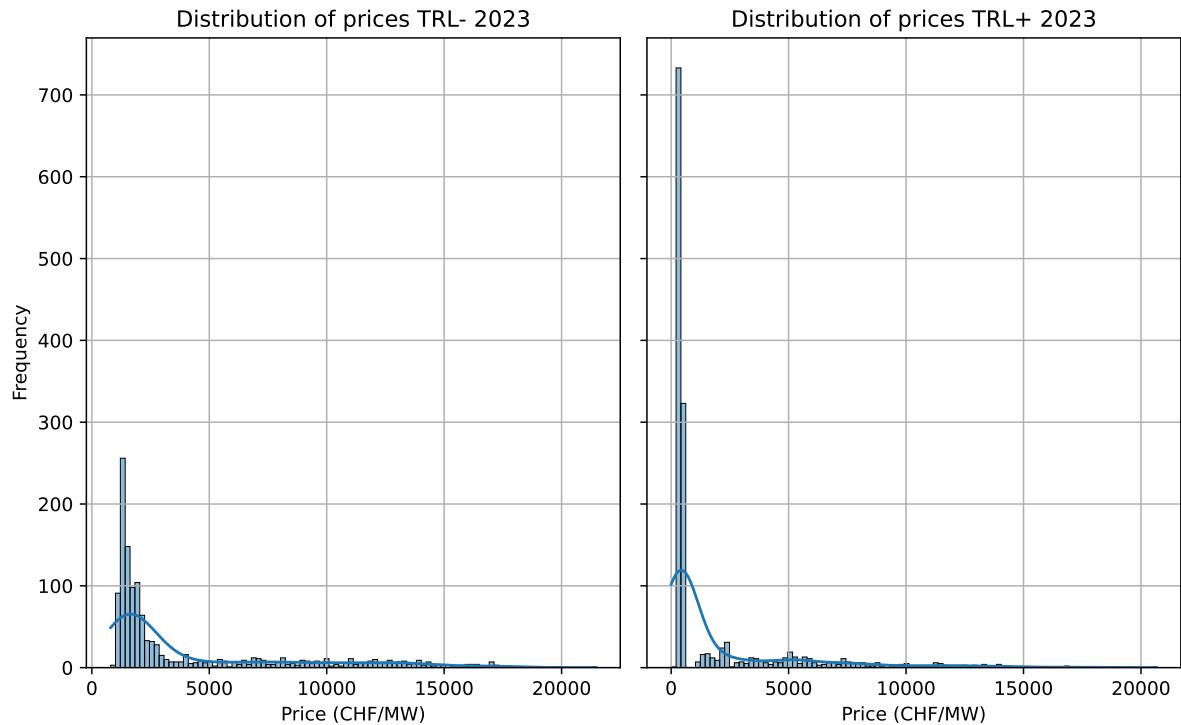


Figure 91: Distribution of TRL bid prices in 2023

TRL- mean prices Over Different Time Periods 2023

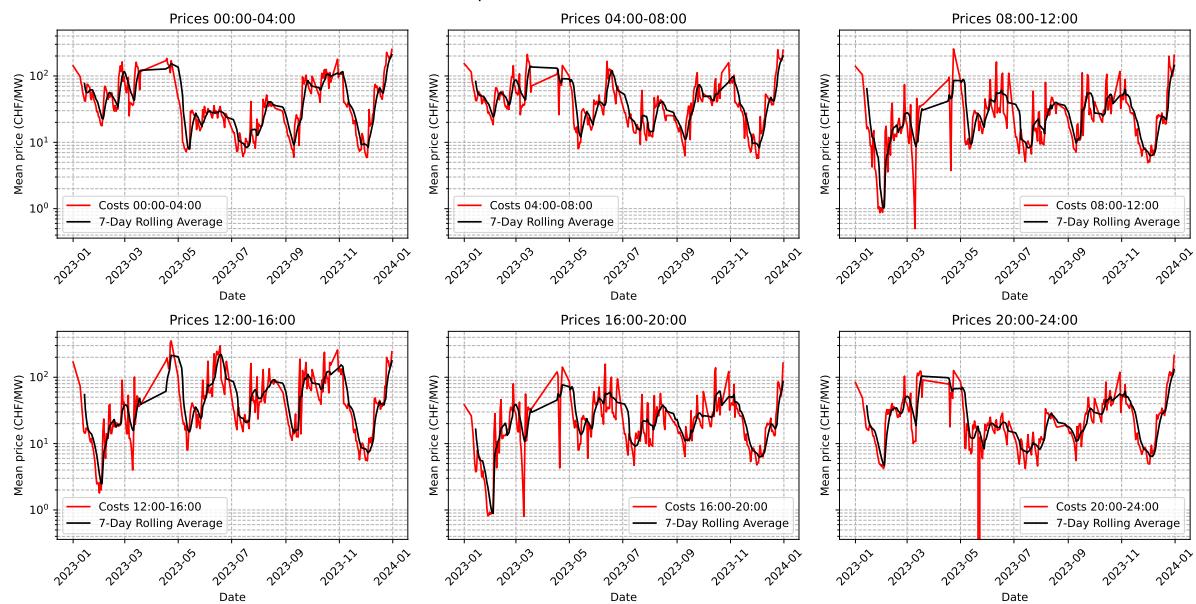


Figure 92: Mean prices per day of TRL- bids over the different four hours slots EUR/MW

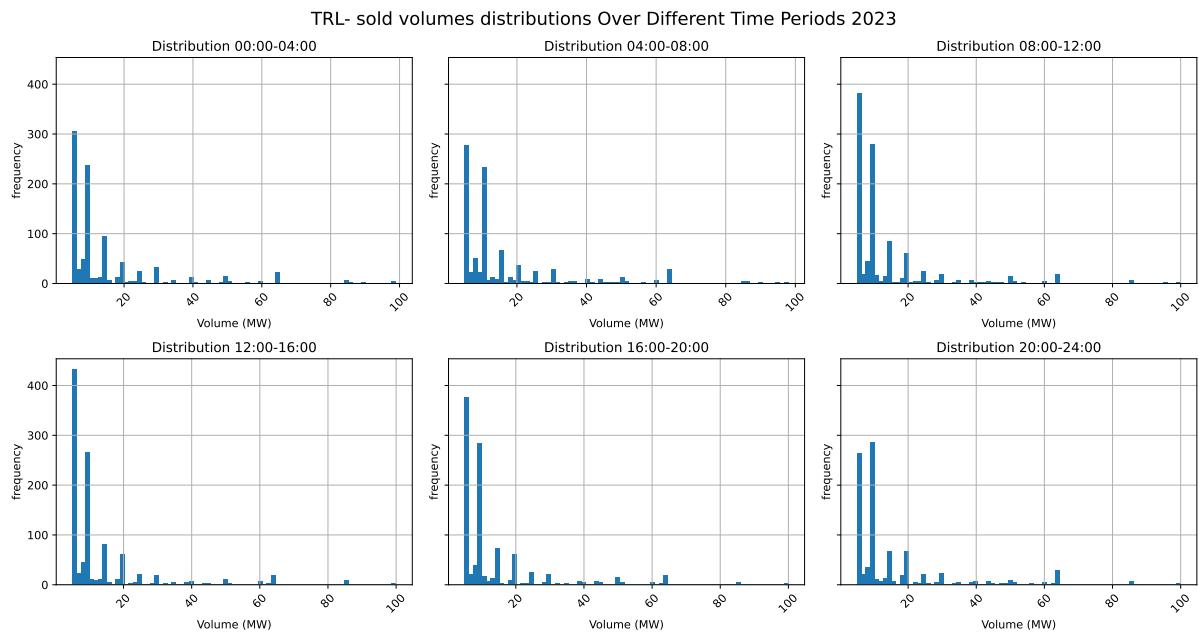


Figure 93: TRL- Distribution of bid volumes in a year over the different four hours slots

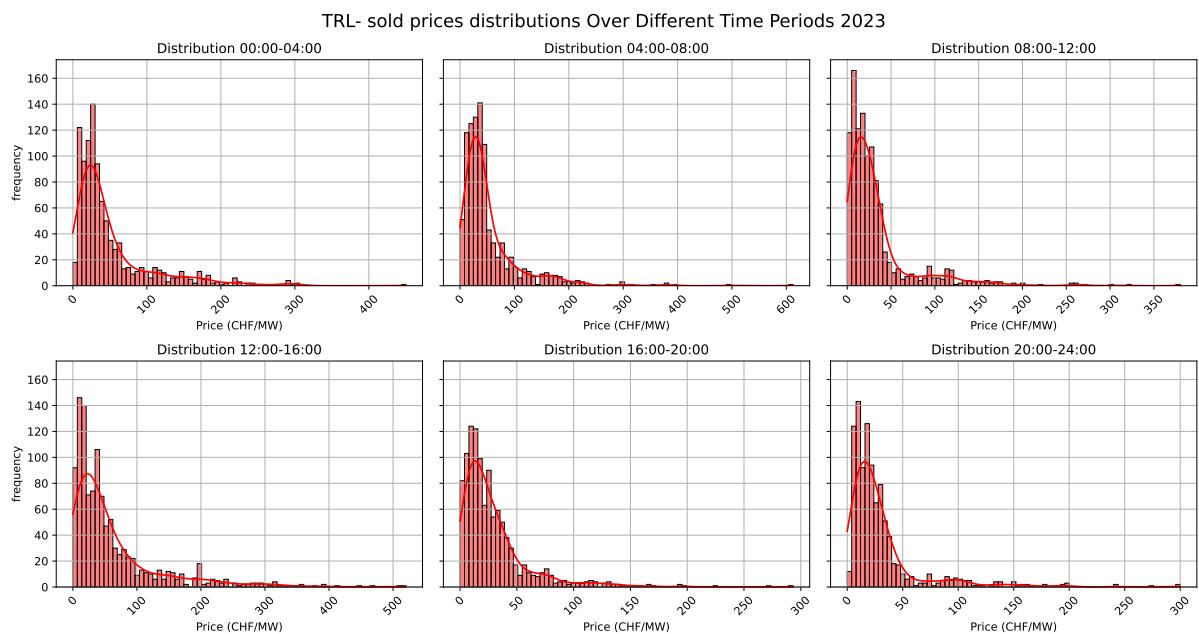


Figure 94: TRL- Distribution of 2023 bid prices in a year over the different four hours slots

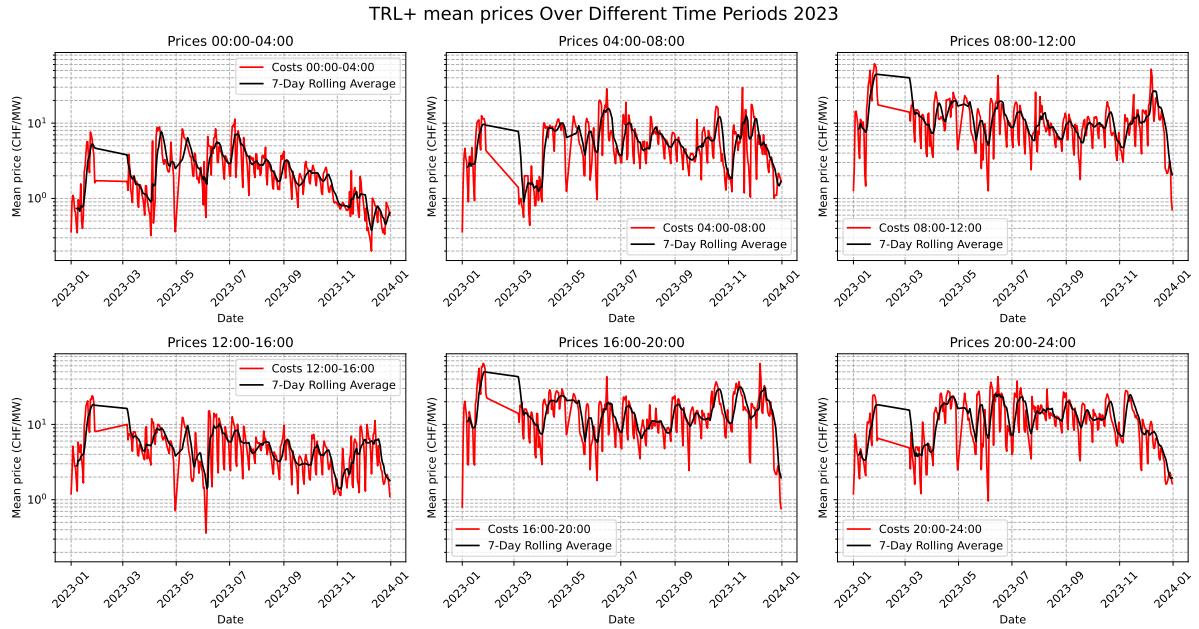


Figure 95: Mean prices per day of TRL+ bids over the different four hours slots EUR/MW

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	2.48	6.01	11.94	5.39	15.32	12.34
Std Dev	2.03	4.46	8.93	3.87	10.41	8.10
Min	0.20	0.36	0.71	0.36	0.76	0.96
25%	0.93	2.93	6.59	2.71	8.30	5.50
50%	1.92	4.72	10.22	4.41	13.95	10.80
75%	3.21	8.02	14.93	6.90	19.40	17.49
Max	11.32	29.63	61.64	24.03	64.92	43.00

Table 44: Summary Statistics for TRL+ daily mean price (EUR/MW) over different time windows in 2023

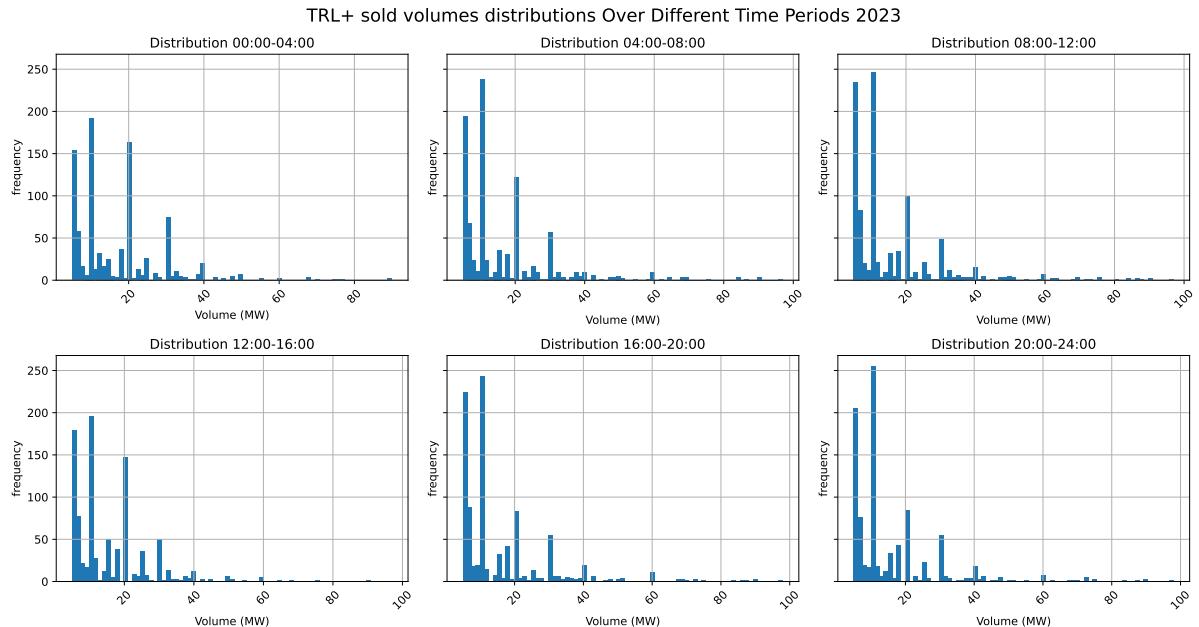


Figure 96: TRL+ Distribution of bid volumes in a year over the different four hours slots

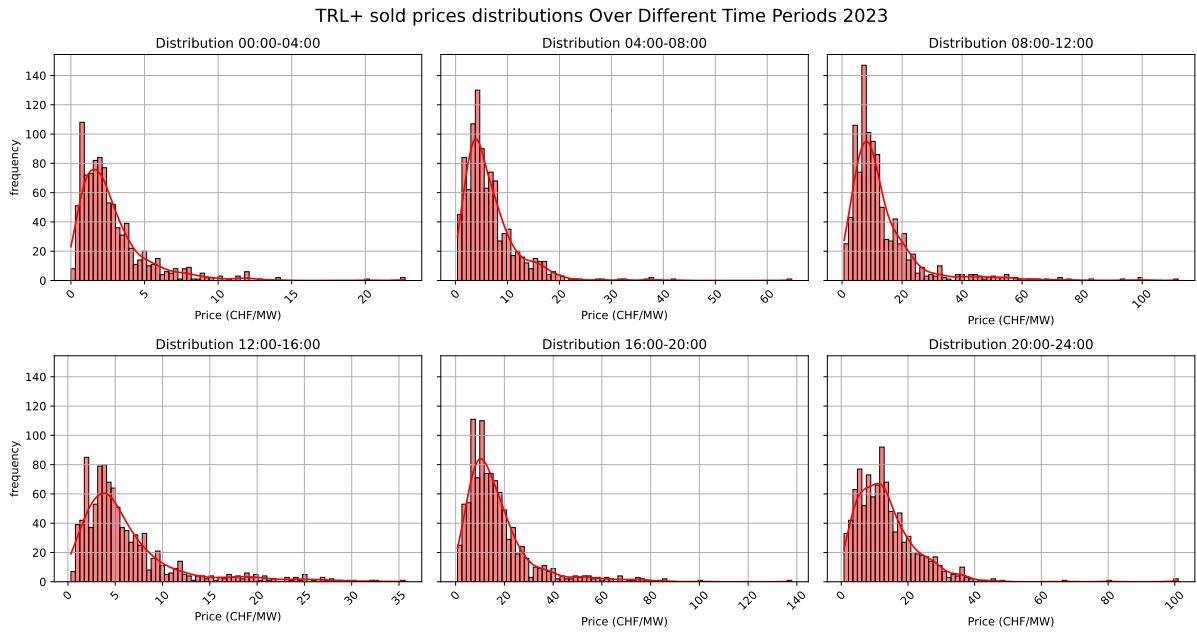


Figure 97: 2023 TRL+ Distribution of bid prices in a year over the different four hours slots

10 Data 2024

10.1 Primary control auction 2024

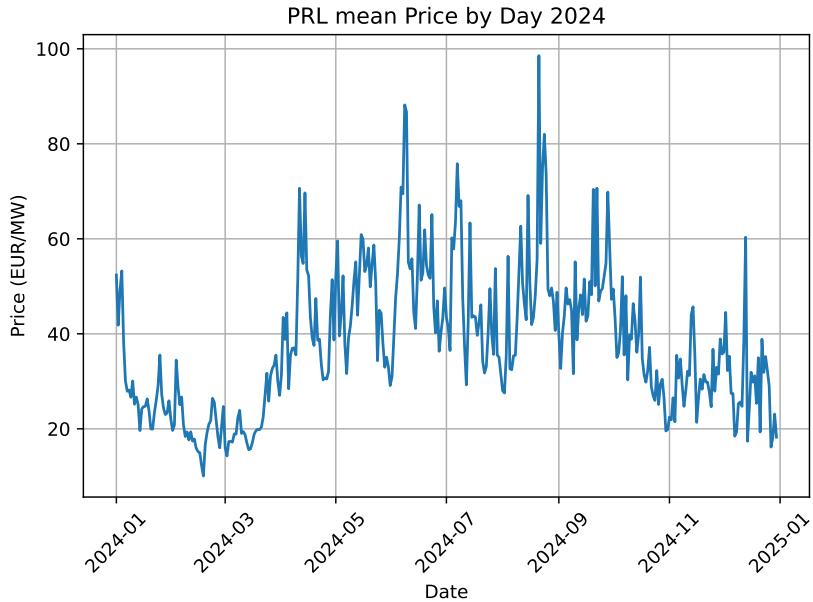


Figure 98: Mean prices per day of PRL bids EUR/MW 2024

mean	37.95
std	14.83
min	10.06
25%	26.66
50%	35.55
75%	47.79
max	98.56

Table 45: Statistics of PRL daily mean price in EUR/MW for 2024

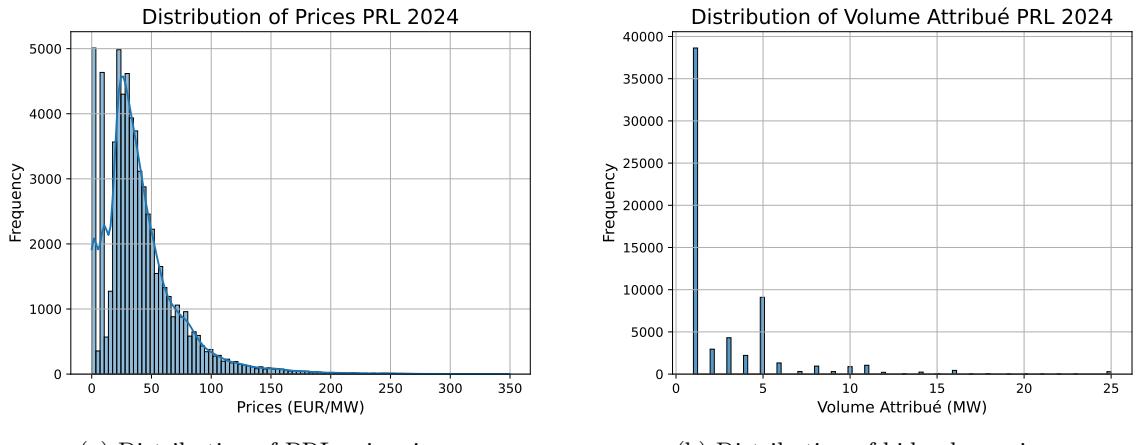


Figure 99: PRL 2024 distributions plots

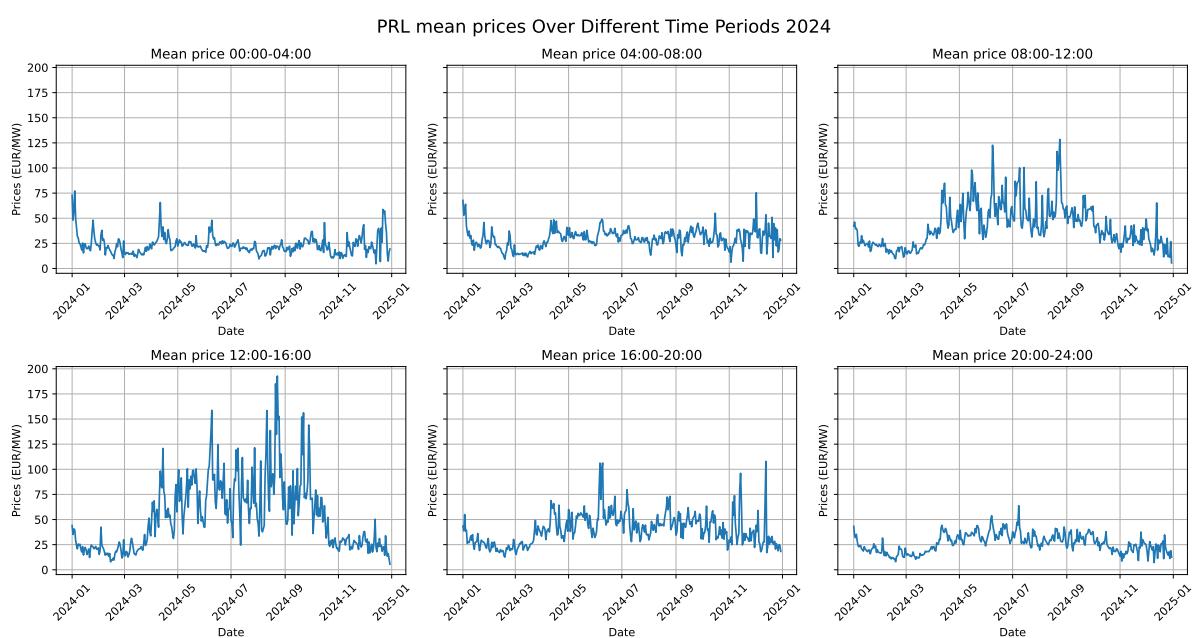


Figure 100: Mean prices per day of 2024 PRL bids over the different four hours slots EUR/MW

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	23.34	29.63	42.02	52.97	40.22	26.42
Std Dev	9.47	9.59	21.30	34.56	15.69	9.27
Min	4.62	6.25	9.77	7.85	12.55	7.18
25%	17.73	23.43	24.96	23.87	27.91	19.02
50%	22.00	30.03	38.76	45.89	38.33	25.93
75%	26.36	35.39	54.81	74.59	49.07	33.27
Max	77.18	75.49	128.48	192.82	107.91	63.72

Table 46: Summary Statistics for PRL daily mean price (EUR/MW) over different time windows in 2024

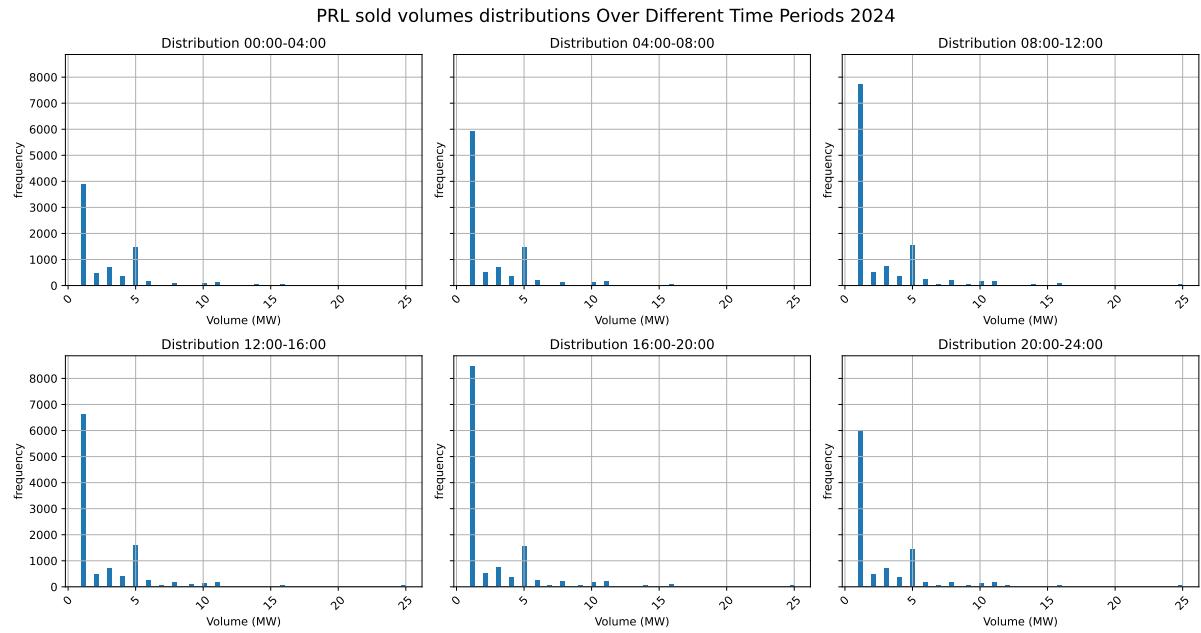


Figure 101: Distribution of 2024 bid volumes in a year over the different four hours slots

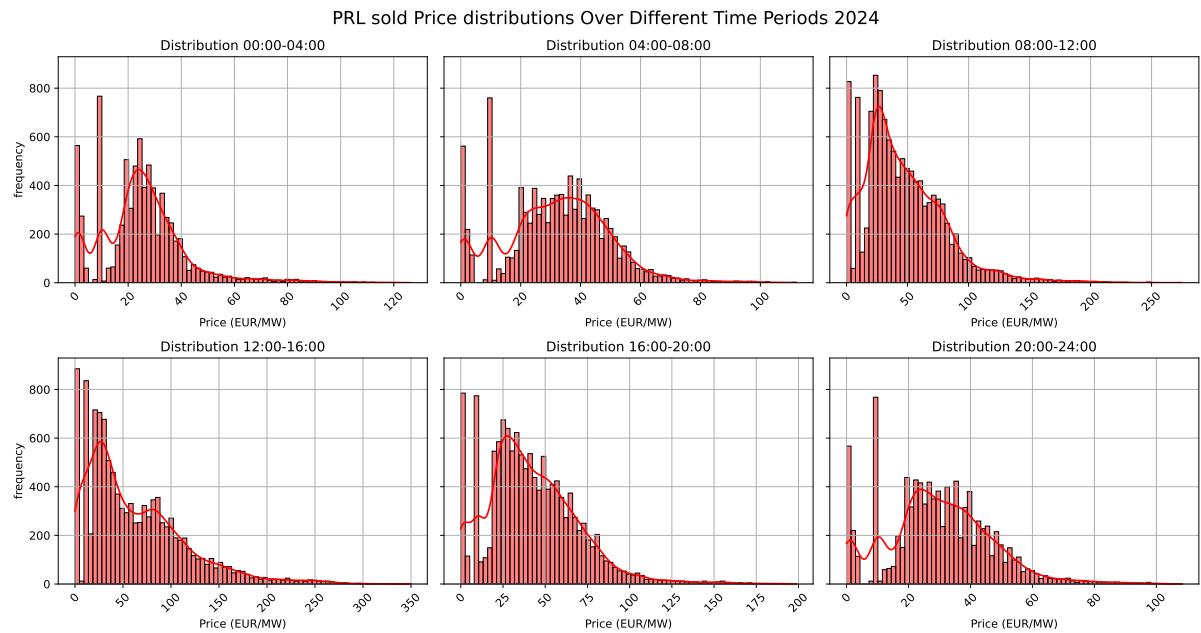


Figure 102: Distributions of PRL bid prices in a year over the different four hours slots

10.2 Secondary control auction 2024

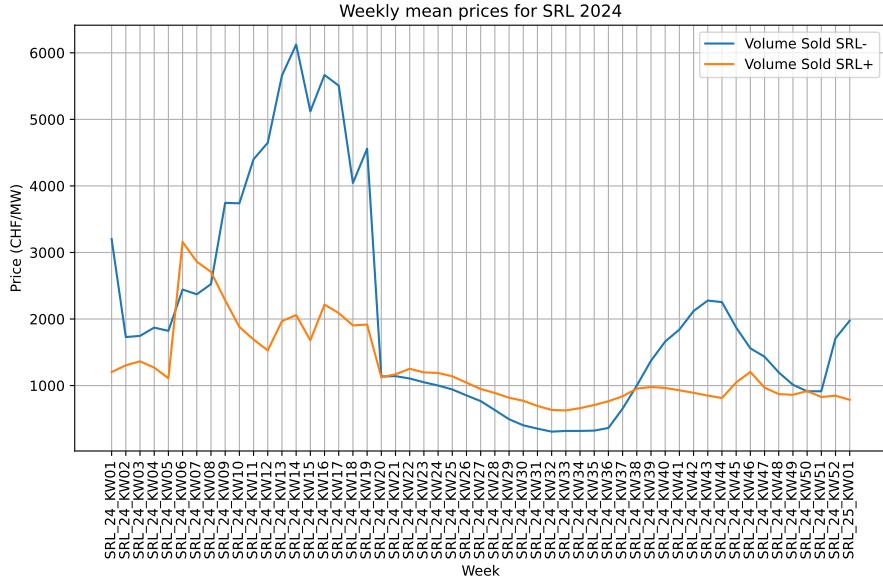


Figure 103: Weekly mean prices of SRL in EUR/MW 2024

Statistic	SRL- Prices	SRL+ Prices
Mean	2041.49	1271.38
Std	1624.78	600.37
Min	307.68	626.70
25%	914.23	848.79
50%	1661.81	1047.22
75%	2442.83	1528.65
Max	6124.48	3158.18

Table 47: Summary Statistics for SRL- and SRL+ Prices in EUR/MW 2024

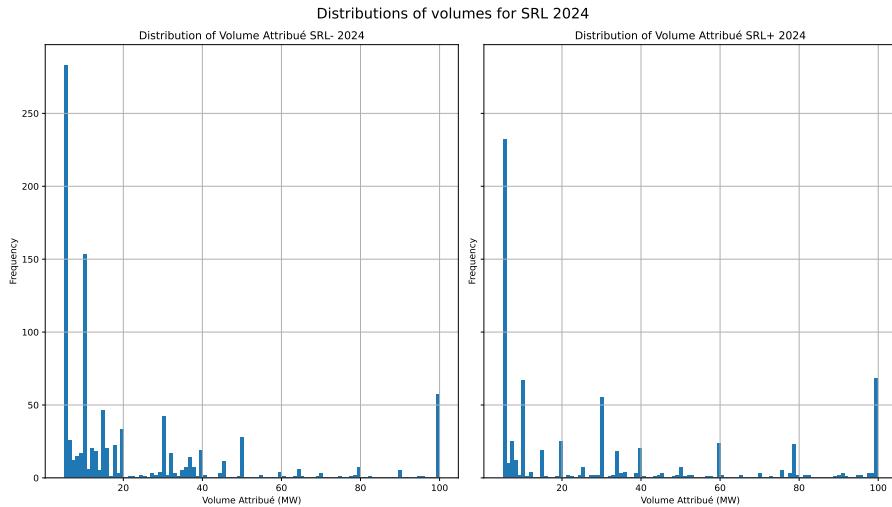


Figure 104: Distribution of SRL bid volumes in 2024

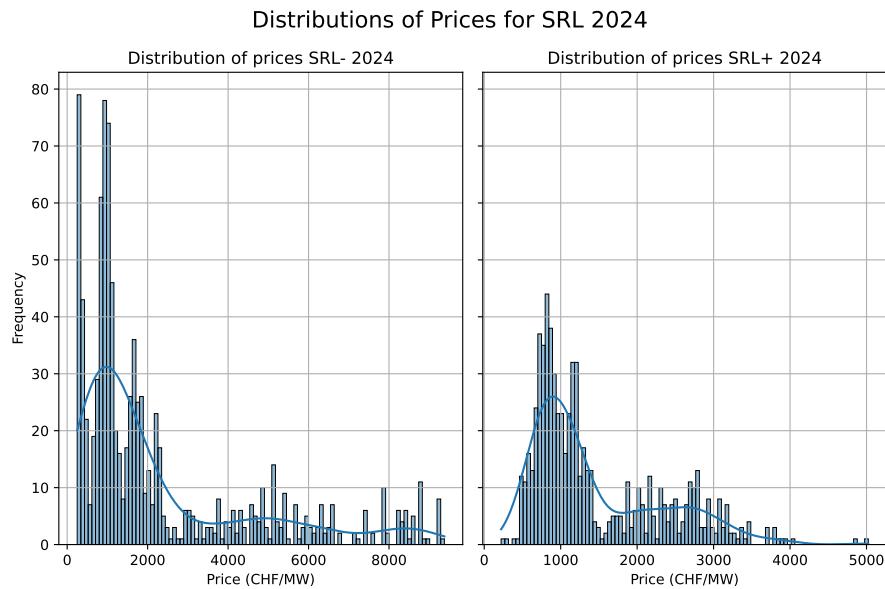


Figure 105: Distribution of SRL bid prices in 2024

10.3 Tertiary control auction 2024

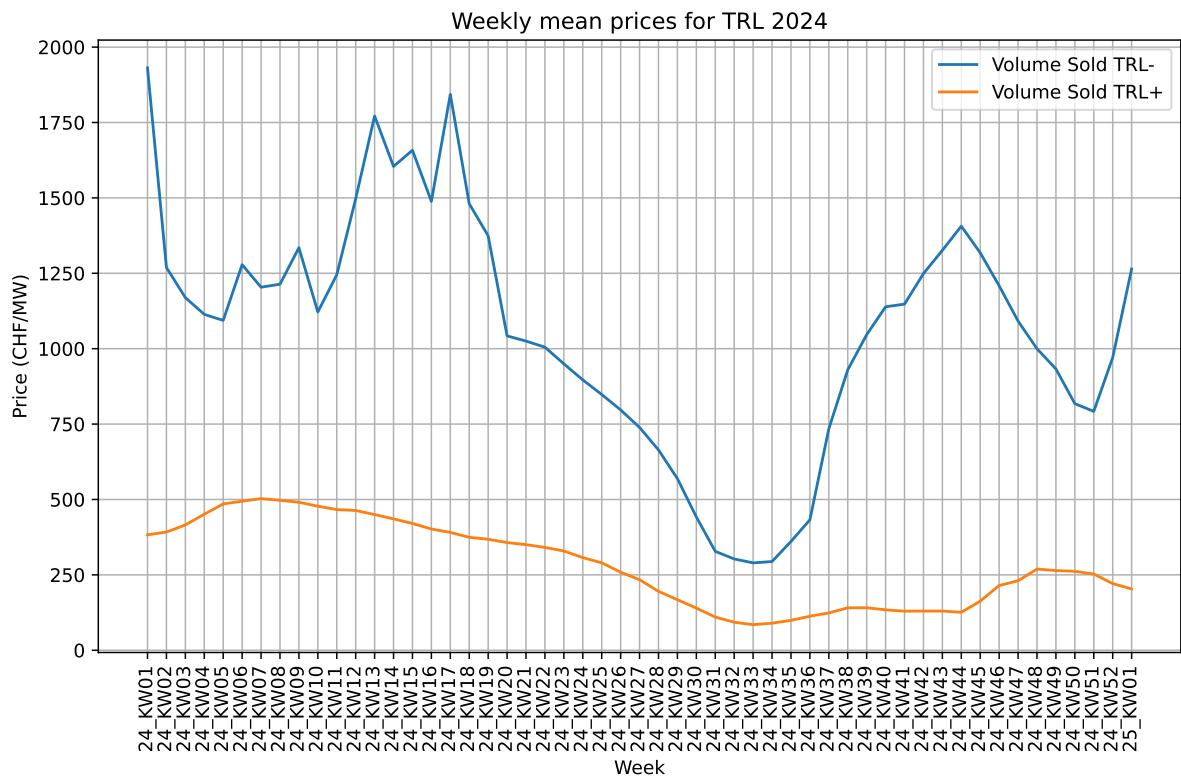


Figure 106: Weekly mean prices of TRL in EUR/MW 2024

Statistic	TRL- Prices	TRL+ Prices
Mean	1057.58	284.08
Std Dev	399.84	137.91
Min	289.65	84.91
25%	817.74	140.70
50%	1093.75	264.33
75%	1278.59	402.06
Max	1931.01	502.87

Table 48: Summary Statistics for weekly TRL- and TRL+ Prices in EUR/MW 2024

Distributions of Prices for TRL 2024

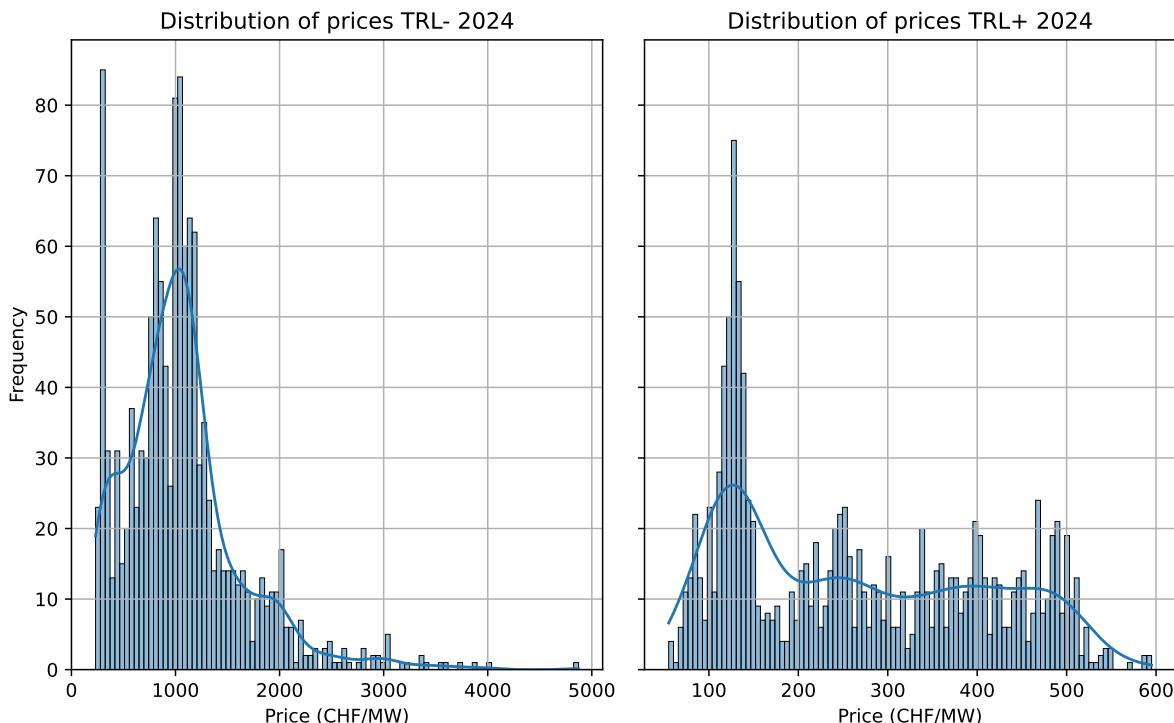


Figure 107: Distribution of TRL bid prices in 2024

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	134.88	147.51	103.09	120.74	108.83	117.94
Std Dev	190.26	204.79	157.87	174.18	171.05	189.60
Min	10.60	6.40	3.35	4.33	1.80	6.47
25%	20.21	18.73	7.83	14.33	7.33	8.84
50%	29.65	27.17	17.05	25.36	13.94	14.12
75%	156.46	280.77	135.66	151.66	140.74	89.36
Max	606.98	606.98	497.18	500.35	497.18	500.00

Table 49: Summary Statistics for TRL- daily mean price (EUR/MW) over different time windows in 2024

Distributions of weekly volumes for TRL 2024

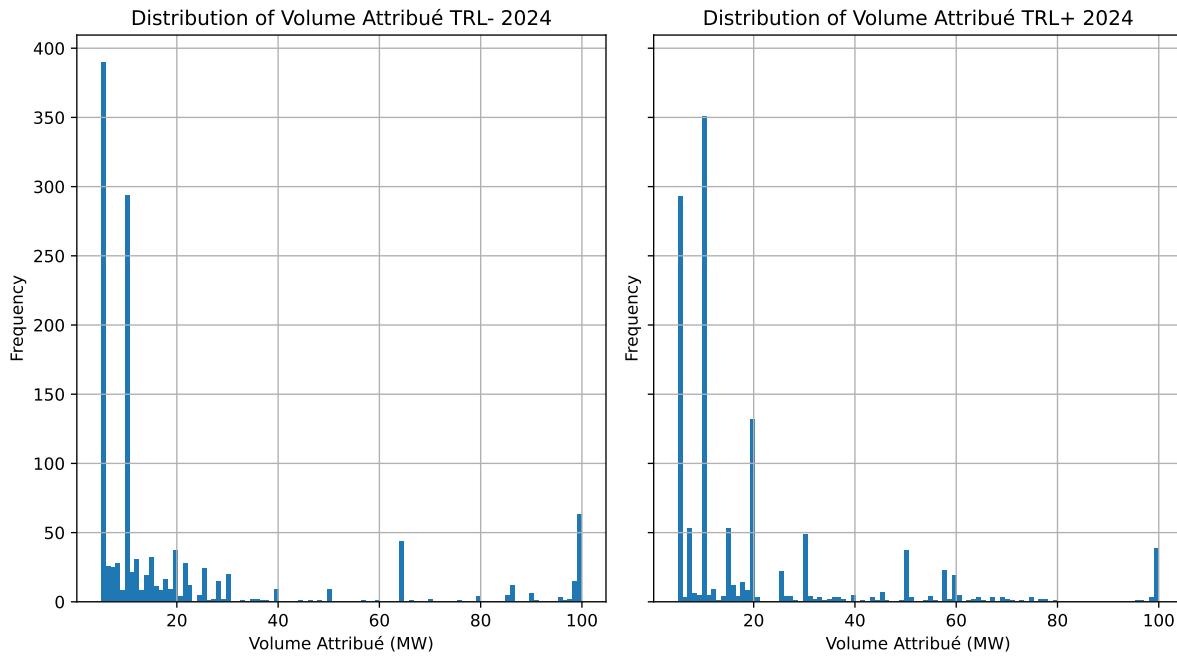


Figure 108: Distribution of TRL bid volumes in 2024

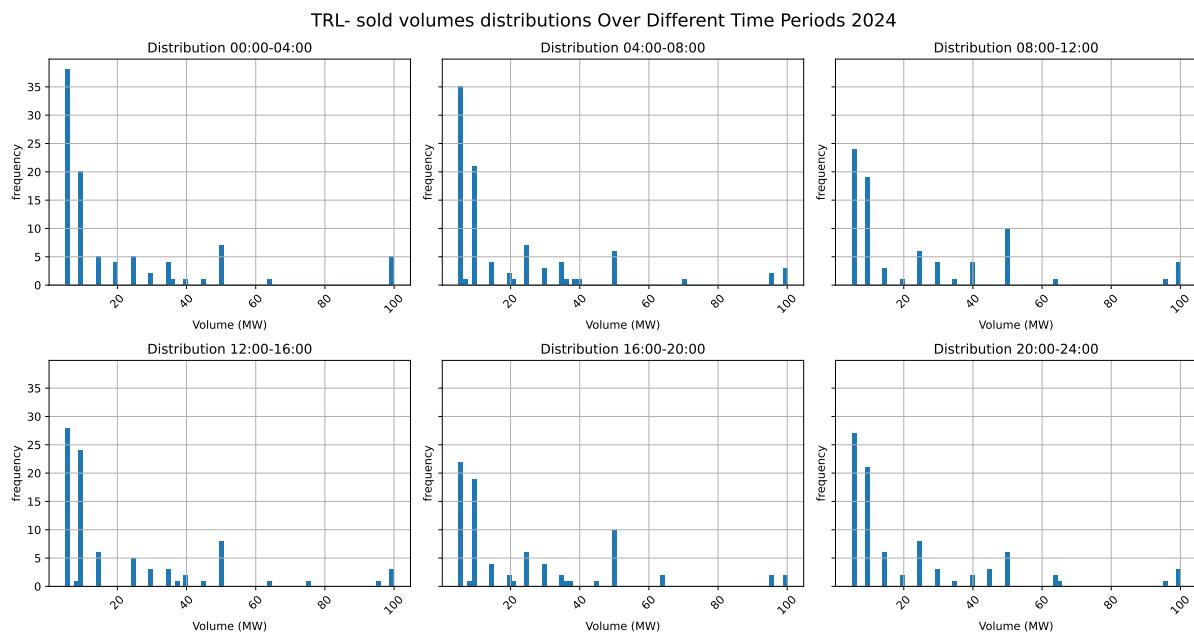


Figure 110: TRL- Distribution of bid volumes in a year over the different four hours slots

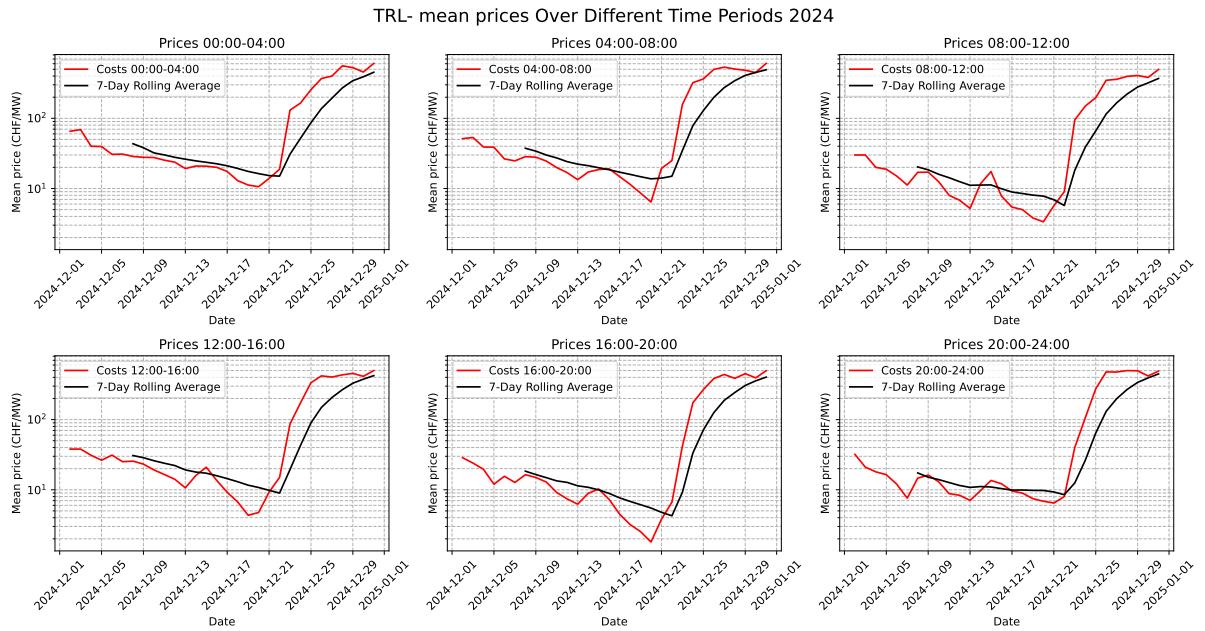


Figure 109: Mean prices per day of TRL- bids over the different four hours slots EUR/MW

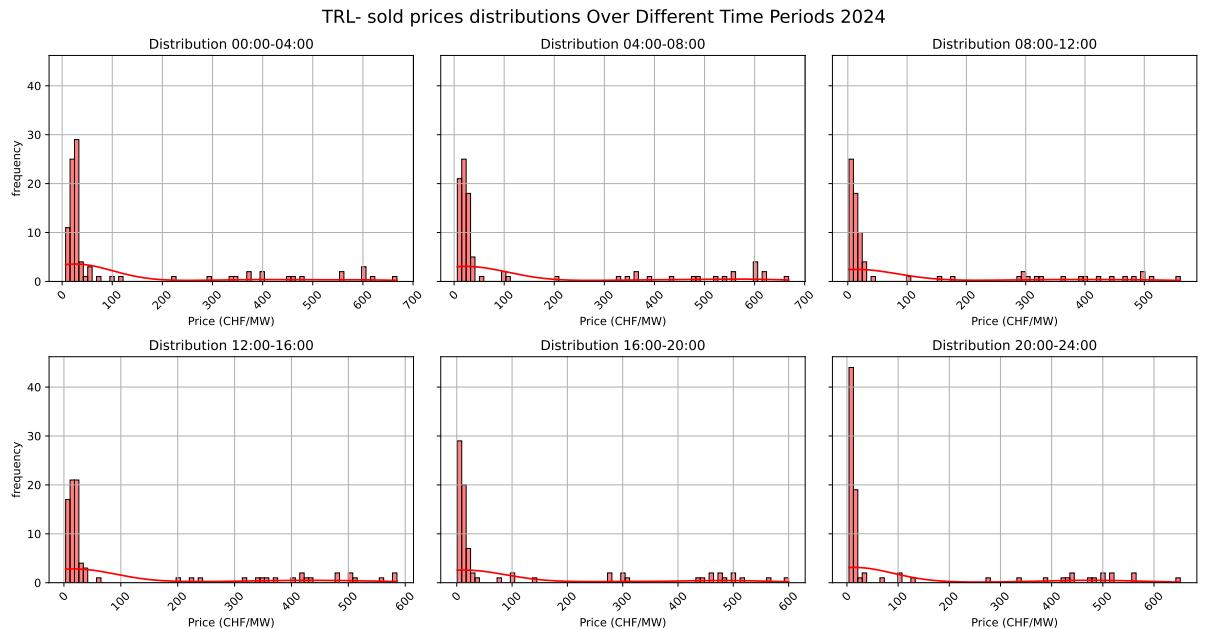


Figure 111: TRL- Distribution of 2024 bid prices in a year over the different four hours slots

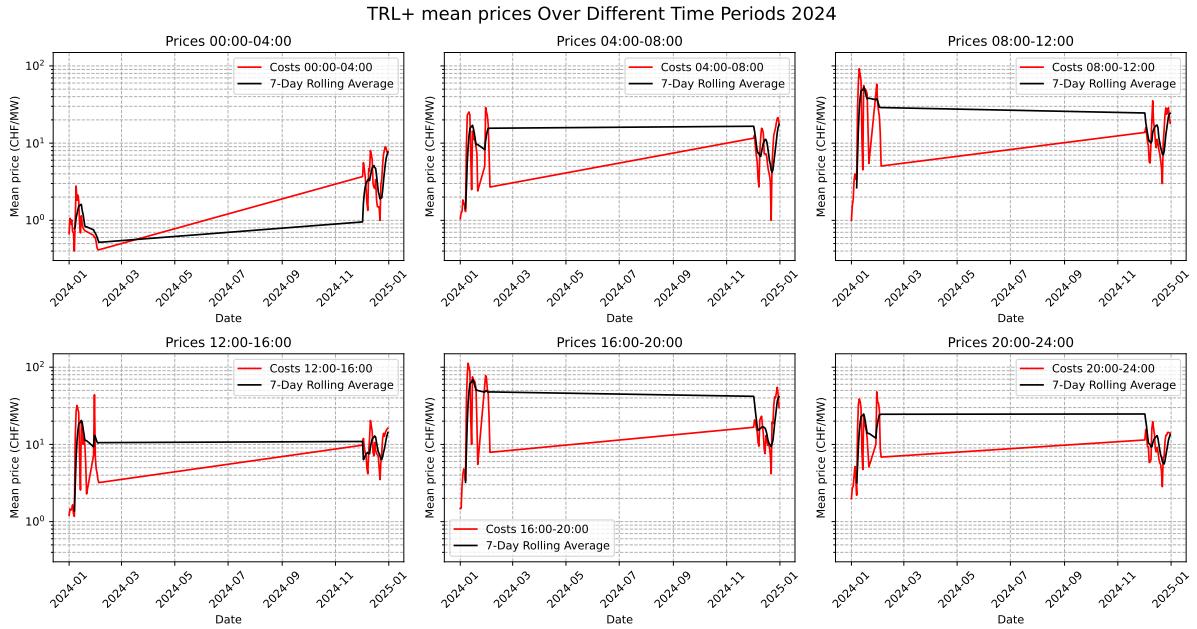


Figure 112: Mean prices per day of TRL+ bids over the different four hours slots EUR/MW

Statistic	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
Mean	2.73	10.30	21.84	10.39	30.51	13.21
Std Dev	2.54	7.59	20.71	8.45	27.80	10.37
Min	0.40	1.00	1.00	1.17	1.48	1.98
25%	0.74	4.00	6.39	4.84	9.55	6.06
50%	1.60	8.21	14.19	7.90	20.16	9.71
75%	3.69	14.83	28.54	13.62	46.70	15.82
Max	8.98	29.00	91.88	44.00	112.56	48.00

Table 50: Summary Statistics for TRL+ daily mean price (EUR/MW) over different time windows in 2024

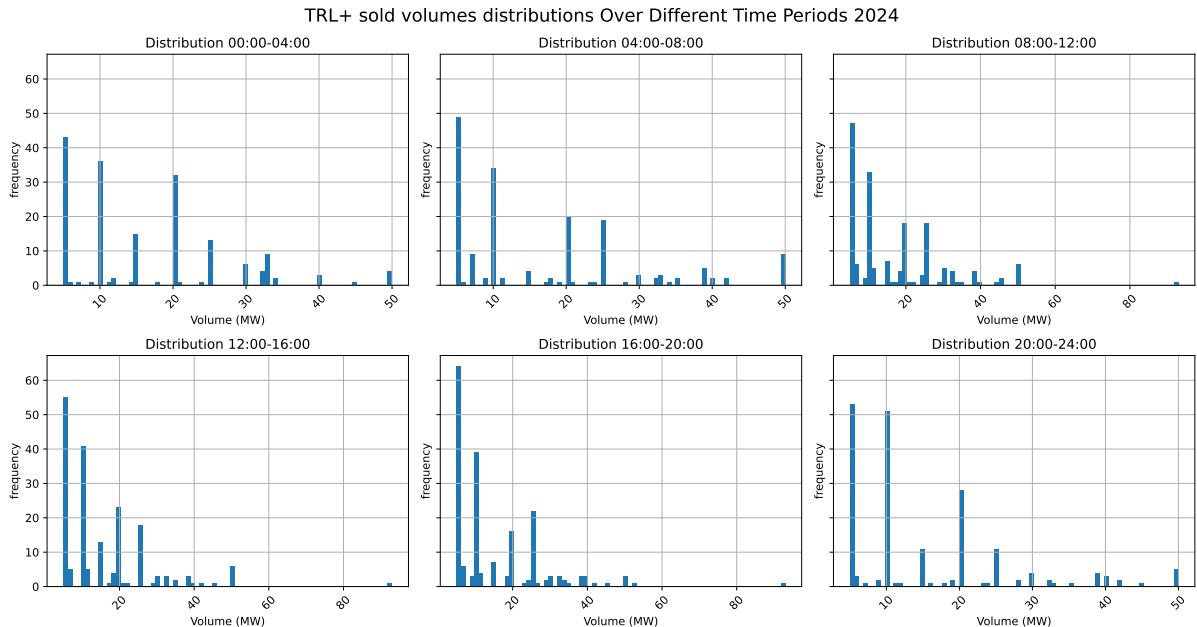


Figure 113: TRL+ Distribution of bid volumes in a year over the different four hours slots

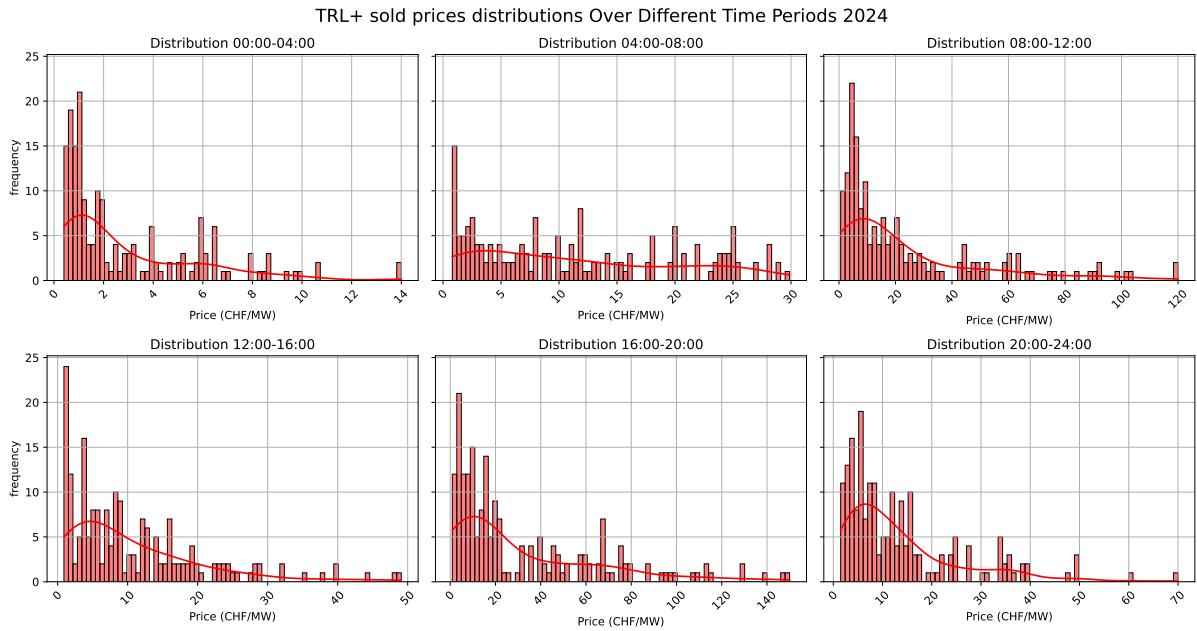


Figure 114: 2024 TRL+ Distribution of bid prices in a year over the different four hours slots

11 Conclusion

The analysis of Swissgrid's ancillary services PRL, SRL-, SRL+, TRL-, and TRL+ revealed key insights into market dynamics, pricing trends, and operational behavior. These findings answer the research problematic: evaluating the economic viability of 10 MW battery storage systems and identifying trends in the ancillary services market.

1. Pricing Trends and Market Dynamics:

- Negative energy services (SRL- and TRL-) consistently displayed significantly better prices compared to their positive counterparts (SRL+ and TRL+). Prices for negative services were sometimes ten times higher, underscoring their critical role in grid balancing.
- SRL services emerged as the most lucrative, with SRL- exhibiting the highest seasonal prices, particularly in spring. This highlights SRL's importance for market participants seeking higher revenue streams.

2. Seasonal Influences and Variability:

- Seasonal patterns were prominent, with spring and winter typically experiencing higher prices due to increased demand for balancing reserves during these periods.
- Summer consistently showed lower prices and variability, reflecting a period of grid stability and reduced stress.

3. Volume-Price Relationship:

- Across most services, a negative correlation between volume and price was observed, particularly for PRL and SRL, emphasizing the impact of market competition.
- TRL- demonstrated a unique positive volume-price relationship, indicating differing dynamics for this service.

4. Market Maturity and Stability:

- From 2019 onward, a gradual stabilization of prices was evident, reflecting regulatory advancements and the maturity of platforms like MARI and PICASSO.
- Early years were characterized by high volatility and extreme values, indicative of an evolving market structure.

5. Economic Viability of 10 MW Battery Systems:

- The analysis supports the economic viability of 10 MW battery systems in the ancillary services market, particularly in SRL services, where higher prices can lead to greater profitability.

- Investments in such systems could benefit from targeting negative energy services (e.g., SRL-) due to their superior pricing.

Key Takeaways

Swissgrid's ancillary services market demonstrates distinct patterns of price variability, seasonal trends, and service-specific behaviors. These findings underscore:

- The critical economic potential of SRL services, particularly SRL-, for stakeholders.
- The importance of tailored bidding strategies that account for seasonal and service-specific trends.
- The necessity of regulatory frameworks and innovations like battery storage to enhance grid flexibility and stability.

Final Remarks

Swissgrid's services have evolved into a more stable and predictable market, reflecting advancements in energy balancing systems. This analysis provides a foundation for future investments and strategies, particularly in the context of increasing renewable energy integration and cross-border collaborations. Market participants are encouraged to leverage these insights to optimize their participation and revenue in Switzerland's ancillary services auctions.

For further discussions about this report or access to the code used in the analysis, please feel free to contact me at: yassinuaimee@gmail.com

References

- [1] *MARI and PICASSO - European balancing platforms.* Swissgrid Ltd. Bleichemattstrasse 31, P.O. Box, 5001 Aarau, Switzerland, 2022. URL: <https://www.swissgrid.ch/dam/swissgrid/about-us/newsroom/positions/221005-factsheet-MARI-PICASSO-en.pdf>.
- [2] Dimitrios Nousios and Stefanie Aebi. *Overview of ancillary services.* Version 1.2, 06.04.2022. Swissgrid Ltd. Bleichemattstrasse 31, P.O. Box, 5001 Aarau, Switzerland, 2020. URL: <https://www.swissgrid.ch/content/dam/swissgrid/customers/topics/ancillary-services/as-documents/D200406-AS-Overview-V1-2-en.pdf>.
- [3] Dimitrios Nousios and Stefanie Aebi. *Principles of Ancillary Services Products.* Version 19, valid from 24.08.2022. Swissgrid Ltd. Bleichemattstrasse 31, P.O. Box, 5001 Aarau, Switzerland, Aug. 2022. URL: <https://www.swissgrid.ch/content/dam/swissgrid/customers/topics/ancillary-services/as-documents/D220824-AS-Products-V19-en.pdf>.