

Non-Uniform Pricing: Explanatory note



28 May 2023

1 Introduction

This document provides a high-level summary of the results of a series of Non-Uniform Pricing studies conducted in the framework of the SDAC MSD Euphemia Lab.

Disclaimer:

Through this work, SDAC MSD investigated the potential implementation of the Non-Uniform Pricing (NUP) as one of possible evolutions of the market coupling algorithm. The studies outlined some of key qualitative and quantitative indicators that may be seen if the non-uniform pricing would be taken into use. At this moment, the MCSC decision is to neither further continue the study, nor to provide an assessment on possible implementation of the NUP into SDAC market. There are further steps that are necessary to be completed should the solution be taken into operative use.

2 CONTEXT – EXECUTIVE SUMMARY

In 2020, SDAC MSD, as part of the Euphemia performance improvement work, decided to have N-Side investigate if the Non-Uniform Pricing could provide a much needed performance improvement of the calculation when the SDAC market transfers from 60min MTU to 15min MTU. At the start of the study, SDAC MSD in Euphemia Lab work (together with N-Side) had still a long way to go in order to get satisfactory performance improvements done prior the 15min MTU go live of the SDAC market. In parallel to the NUP study, several other performance improvements were developed, tested, and validated. As the non-uniform pricing is a disruptive change for market participants, the (potential) implementation (around the same time as the go-live of the original disruptive change from 60min MTU to 15min MTU) was considered premature and risky. This especially as other performance improvement initiatives were providing good results.

A proof-of-concept prototype was developed within the studies. It was progressively updated to reflect the last version of Euphemia release and related heuristics improvements, and to include features allowing computation of 15 min data. The topic of side-payments was also explored; different sources to those were identified, as well as projections performed on maximum side payment values. The performance indicators (as listed in **Objectives and Assumptions section**) were followed (during the study we extended to also scope the impacts to welfare/economic surplus and some quantitative KPIs). Finally, we discussed and investigated if NUP could be (mis)used for gaming by the market participants. The study items were identified, and first analysis performed. They need to be re-activated and completed in case the non-uniform pricing would be re-considered in the future.

Based on current simulation results the NUP improves the performance, increases the welfare, and lowers the number of PRBs (Paradoxically Rejected Blocks). The performance challenge of the algorithm in the future will not ease, so having a potential alternative approach available is a good asset for the coming years. The Non-Uniform Pricing productization would not be available at the time of go live of the 15min MTU due to amount of the work still to be done. The NUP would also be an additional disruption to the market at the time of market time unit change from 60 minutes to 15 minutes.

Final report material of the last study was provided during April 2023.

3 OBJECTIVE AND ASSUMPTIONS

The main objective of the study was to find out how much (if at all) the non-uniform pricing could improve the algorithm performance. The aim of the study was furthermore to get more information on:

- The impact on the Welfare
- The impact on PRBs (Paradoxically Rejected Block orders)
- How the side payments can be handled

It was, however, not the goal to perform a complete market assessment. The study was therefore limited to direct algorithmic aspects and did not assess implementation beyond this (e.g., on the process level).

The following basic assumptions were applied to the model used to obtain the results. Please mind there are some simplifications applied:

<p><i>Euphemia NUP prototype</i></p> <ul style="list-style-type: none"> - The (latest) Euphemia Lab version of the Euphemia and the standard simulation batches used for performance simulations for the 15min MTU
<p><i>Non-Uniform Pricing</i></p> <ul style="list-style-type: none"> - The non-uniform pricing concept implemented by N-Side (after analysis of different options, i.e. Convex Hull or IP pricing)
<p><i>Welfare optimization</i></p> <ul style="list-style-type: none"> - Initial target was to seek performance optimization, however we always validate the key KPIs, including the welfare (if NUP shall improve the performance, it shall not deteriorate the other indicators). - It was assumed that welfare may not be worse than with Uniform Pricing.
<p><i>MTU resolution</i></p> <ul style="list-style-type: none"> - Both 60 and 15 minute MTU

SCOPE

<ul style="list-style-type: none"> - Side payment options were considered but no final recommendation was made - Max side-payment quantities were outlined - Potential performance improvements to be identified - Analysis of the gaming options opened by NUP - Software was developed platform to enable quick modifications of the orders for a test re-run
<p><i>Order book scenarios</i></p> <ul style="list-style-type: none"> - Same simulation batches were used as for the 15min MTU performance simulations
<p><i>Key Performance Indicators</i></p> <ul style="list-style-type: none"> - Time To First Solution (TTFS) - Time to Volume problem - Number of PRB - Optimality gap - Welfare

OUTCOMES AND CONCLUSIONS

Observations on Non-Uniform Pricing studies and simulations

The Non-Uniform Pricing study have provided a thorough overview of the NUP concept and its impact. Certain results will need further analysis. In general, if an assessment about potential implementation in production shall be done, additional work would be needed both on algorithmic, as well as non-algorithmic issues.

The Euphemia performance improves if we use the NUP approach for SDAC data. If we use the Time To First Solution (TTFS) as an indicator, the performance improvement varies based on input data (i.e. daily market coupling data) between approx. 4% to 30%. For some cases the performance unfortunately also decreases. The calculation time is more dependent on input data than the uniform pricing.

Welfare is marginally improved, but the improvement itself does not justify taking the NUP into production.

Thirdly, the number of Paradoxically Rejected Blok orders (PRBs) are lower with NUP than with Uniform Pricing. Again, the improvement is modest.

Therefore, at this stage, despite positive results, the benefits are not strong enough to plead for an introduction in the SDAC in the near future.

In addition, the current legislation does not allow to introduce the NUP – the latter is foreseen in the last version of CACM 2.0, which is not yet approved and might be amended before entering into force. It is not expected that CACM 2.0 would be in force, together with all related methodological updates, prior to the 15 min MTU implementation in January 2025. And even if the legal framework would be ready, as the NUP is a disruptive technology, its potential implementation at the time when the Day Ahead market has a significant change to undergo anyway, it would not be advisable to introduce another disruption at the same time.

Short conclusion on the outcomes of the study:

- NUP design is a good asset to have available for the future when SDAC needs yet another leap forward with performance.
- The side payments can be covered within the market. However, the exact side payment methodology is not decided yet.
- Therefore, at this stage, despite positive results, the benefits are not strong enough to plead for an introduction in the SDAC in the near future

The NUP may be reexplored in the future, as a possible solution to manage further market growth and addition of features into the algorithm. The prerequisite for the possible implementation is at the first place the regulatory compliance which is not the case today. The following steps needs to be taken if in case it is decided to further explore this topic:

- The side payment methodology needs to be agreed and validated by regulators and other stakeholders.
- The remaining work items (including gaming prevention study) needs to be completed prior to taking NUP into production to ensure that there will be no loopholes to manipulate the market, nor to misuse the trading opportunities.
- Non-algorithmic topics to be investigated (process, legislation, methodology...)

Final Observations with respect to Non-Uniform Pricing Performance Improvements on Time

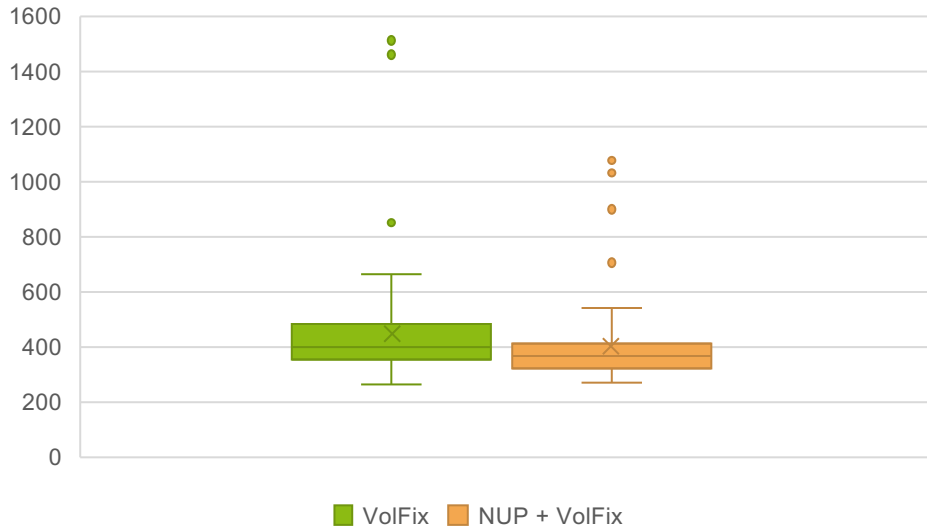
- Non-Uniform Pricing reduces the time to first solution (average, median and maximum) and the time to volume problems (average, median and maximum) with respect to Euphemia with the classic price requirements (no PAB, etc.)
- Observed performance improvements thanks to Non-Uniform Pricing are **strongly dependent on the considered batch**. Non-Uniform Pricing has more added value for more challenging batches for Euphemia. In this analysis:
 - **Y21B33***: Reduction of the average *time to first solution* of **10%** (up to about **15%** for the *time spent in the core of the algorithm (i.e. time spent until post-processing problems lifting volume indeterminacies = “volume problems”)*)
 - **Y20B35****: Reduction of the average *time to first solution* of **20%** (up to **more than 30%** for the *time spent in the core of the algorithm (i.e. time spent until post-processing problems lifting volume indeterminacies = “volume problems”)*)
- NB: In the current simulations, in the only session where NUP is less performant (in Y20B35), challenges are in the post-processing volume problems whose design is NOT impacted by using Non-Uniform Pricing (Non-Uniform Pricing only impacts the implementation of the main search). In that session, issues are purely numerical and could be addressed in Iteration 9 by further improving the numerical stability of volume problems.

*Y21B33: Big bang 15' MTU batch based on Y21 data, with 80% of 15' MTU products and 20% of 60' products, SCO & NO PUN (LTA activated)

**Y20B35: Big bang 15' MTU batch based on Y20 data, with 80% of 15' MTU products and 20% of 60' products, SCO & NO PUN (LTA activated) + a delay in a large BZ

Non-Uniform pricing improves the observed time to first solution (TTFS)

TTFS (sec.)



TTFS Main Statistics

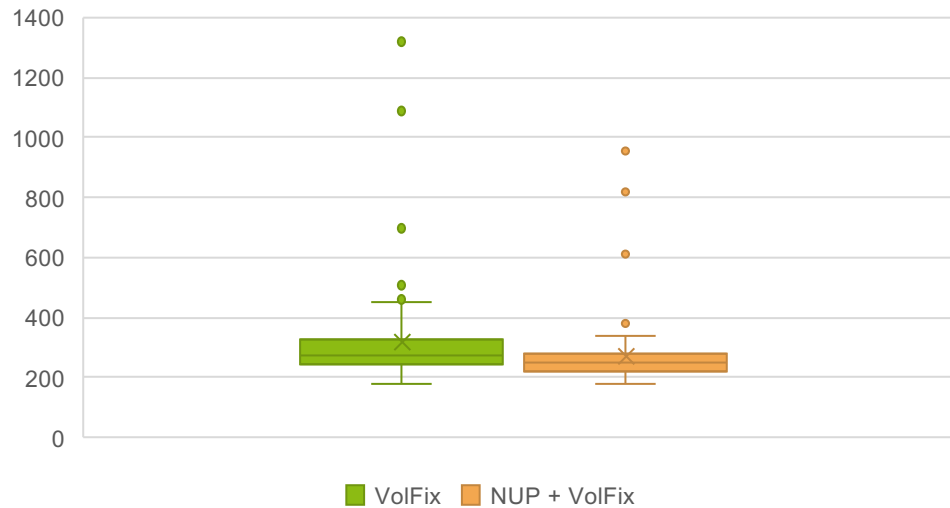
	Average (min:sec)	Median (min:sec)	Max (min:sec)	Nb. of sessions successful within 20 min	Nb. of sessions successful within 30 min
Euphemia with Volume Fixes	07:30	06:41	25:11	98%	100%
NUP with Volume Fixes	06:45	06:06	17:58	100%	100%
Performance Improvements (%)	10%	8.8%	28.6%	2%	0%

- **Scenario simulated:** Y21/22 (first 3 months of 22) + 4Y market growth, no pun, 80% at 15MTU, 20% at 60MTU, LTA activated – Batch 33 with 91 business days.
- **Hardware setup:** Distributed Computing with 4xR5 machines
- **Euphemia version:** (i) Euphemia Lab Iteration 8 – March 2023 – “Volume Fixes”; (ii) Euphemia Lab Non-Uniform Pricing Prototype with “Volume Fixes” – March 2023

- Reduction of the average TTFS by 10% and maximum TTFS by 28%.
- All sessions solved with NUP in 20 minutes.
- NUP prototype and Euphemia version build on all past efforts in the Euphemia Lab + numerical stability improvements in the post-processing problems lifting volume indeterminacies.

Non-Uniform pricing improves the observed time in main search until post-processing volume problems (TTV)

TTV (sec.)



TTV Main Statistics

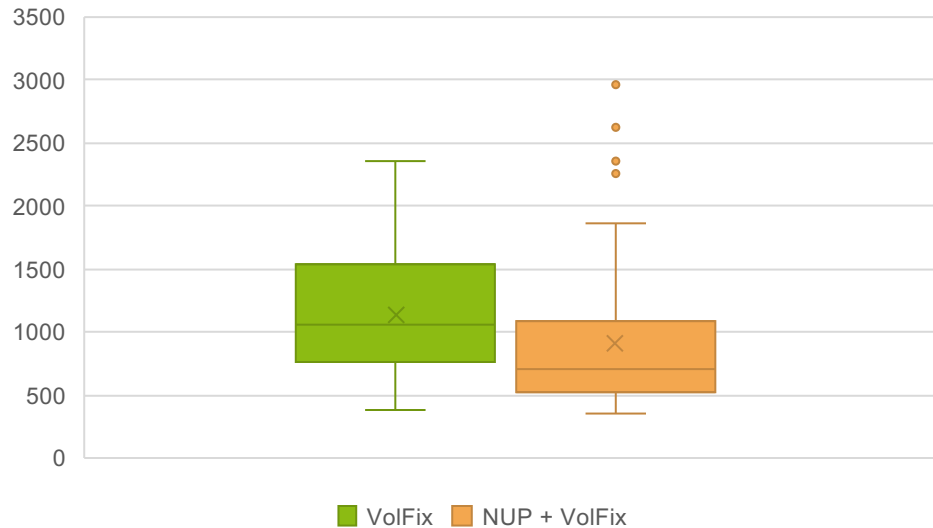
	Average (min:sec)	Median (min:sec)	Max (min:sec)	Nb. of sessions successful within 20 min	Nb. of sessions successful within 30 min
Euphemia with Volume Fixes	05:17	04:36	21:58	99%	100%
NUP with Volume Fixes	04:32	04:14	15:55	100%	100%
Performance Improvements (%)	14.2%	8.3%	27.6%	1%	0%

- **Scenario simulated:** Y21/22 (first 3 months of 22) + 4Y market growth, no pun, 80% at 15MTU, 20% at 60MTU, LTA activated – Batch 33 with 91 business days.
- **Hardware setup:** Distributed Computing with 4xR5 machines
- **Euphemia version:** (i) Euphemia Lab Iteration 8 – March 2023 – “Volume Fixes”; (ii) Euphemia Lab Non-Uniform Pricing Prototype with “Volume Fixes” – March 2023

- Time to volume problems allow to analyze the improvements provided by Non-uniform Pricing in the core of the algorithm.
- Non-Uniform Pricing improves the average time spent in the core of the algorithm by 14% and its maximum by 27%.
- NUP prototype and Euphemia version build on all past efforts in the Euphemia Lab + numerical stability improvements in the post-processing problems lifting volume indeterminacies.

Non-Uniform pricing improves the observed time to first solution (TTFS)

TTFS (sec.)



TTFS Main Statistics

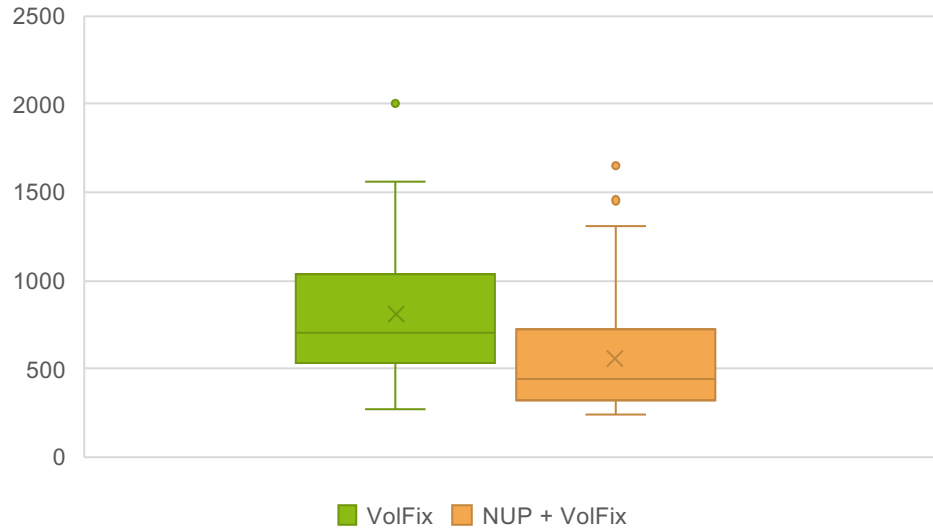
	Average (min:sec)	Median (min:sec)	Max (min:sec)	Nb. of sessions successful within 20 min	Nb. of sessions successful within 30 min
Euphemia with Volume Fixes	19:02	17:37	39:17	63%	91%
NUP with Volume Fixes	15:15	11:39	49:19	78%	93%
Performance Improvements (%)	19.9%	33.9%	-25.5%	15%	2%

- **Scenario simulated:** Y20 + 5Y market growth, no pun, no LTA, 80% at 15MTU, 20% at 60MTU, delay in FR – Old Batch 35 with 91 business days.
- **Hardware setup:** Distributed Computing with 4x R5 machines
- **Euphemia version:** (i) Euphemia Lab Iteration 8 – March 2023 – “Volume Fixes”; (ii) Euphemia Lab Non-Uniform Pricing Prototype with “Volume Fixes” – March 2023

- Old Batch 35 is more challenging for Euphemia to solve compared to new Batch 33.
- Non-Uniform Pricing improves the average TTFS by almost 20% and the number of sessions solved in 20 minutes by 15%.
- The maximum time in this case increases with Non-Uniform Pricing due to numerical challenges in the volume problems whose design is actually NOT impacted by NUP (NUP only impacts the design of the main search). The punctual numerical issues in the volume problem post-processing should be easily addressable in the short-term. This suggests that the numerical stability of volume problems should be studied in the Lab further in Iteration 9.
- NUP prototype and Euphemia version build on all past efforts in the Euphemia Lab + numerical stability improvements in the post-processing problems lifting volume indeterminacies.

Non-Uniform pricing improves the observed time in main search until post-processing volume problems (TTV)

TTV (sec.)



TTV Main Statistics

	Average (min:sec)	Median (min:sec)	Max (min:sec)	Nb. of sessions successful within 20 min	Nb. of sessions successful within 30 min
Euphemia with Volume Fixes	13:32	11:44	33:25	84%	99%
NUP with Volume Fixes	9:16	7:22	27:47	95%	100%
Performance Improvements (%)	31.5%	37.3%	16.9%	11%	1%

- **Scenario simulated:** Y20 + 5Y market growth, no pun, no LTA, 80% at 15MTU, 20% at 60MTU, delay in FR – Old Batch 35 with 91 business days.
- **Hardware setup:** Distributed Computing with 4x R5 machines
- **Euphemia version:** (i) Euphemia Lab Iteration 8 – March 2023 – “Volume Fixes”; (ii) Euphemia Lab Non-Uniform Pricing Prototype with “Volume Fixes” – March 2023

- Time to volume problems allow to analyze the improvements provided by Non-uniform Pricing in the core of the algorithm.
- Non-Uniform Pricing improves the average TTV by more than 30% and the number of sessions solved in 20minutes by 11%.
- The maximum TTV is improved by almost 17% with NUP which shows that the observation of previous slide with the maximum TTFS is related to volume problems post-processing in this case.
- NUP prototype and Euphemia version build on all past efforts in the Euphemia Lab + numerical stability improvements in the post-processing problems lifting volume indeterminacies.

Summary: Non-Uniform Pricing improves the observed time to first solution (TTFS)

Y21B33	Average (min:sec)	Median (min:sec)	Max (min:sec)
Euphemia with Volume Fixes	07:30	06:41	25:11
NUP with Volume Fixes	06:45	06:06	17:58
Performance Improvements (%)	10%	8.8%	28.6%

Y21B35	Average (min:sec)	Median (min:sec)	Max (min:sec)
Euphemia with Volume Fixes	7:38	5:49	48:08
NUP with Volume Fixes	7:06	5:44	32:55
Performance Improvements (%)	7%	1.6%	31.7%

Y21B38	Average (min:sec)	Median (min:sec)	Max (min:sec)
Euphemia with Volume Fixes	7:36	6:47	24:00
NUP with Volume Fixes	7:18	6:05	30:42
Performance Improvements (%)	4.1%	10.4%	-27.9%

Y20B35	Average (min:sec)	Median (min:sec)	Max (min:sec)
Euphemia with Volume Fixes	19:02	17:37	39:17
NUP with Volume Fixes	15:15	11:39	49:19
Performance Improvements (%)	19.9%	33.9%	-25.5%

- Improvement of observed time to first solution thanks to NUP is highly dependent of the batch considered (Range from 5 to 20% in average)
- For batch Y21B38 and Y20B35, the maximum time increases with Non-Uniform Pricing due to numerical challenges in the volume problems whose design is actually NOT impacted by NUP (NUP only impacts the design of the main search). This suggests that the numerical stability of volume problems should be studied in the Lab further in Iteration 9.
- NUP prototype and Euphemia version build on all past efforts in the Euphemia Lab + numerical stability improvements in the post-processing problems lifting volume indeterminacies.

Summary: Non-Uniform Pricing improves the observed time in main search until post-processing volume problems (TTV)

Y21B33	Average (min:sec)	Median (min:sec)	Max (min:sec)
Euphemia with Volume Fixes	05:17	04:36	21:58
NUP with Volume Fixes	04:32	04:14	15:55
Performance Improvements (%)	14.2%	8.3%	27.6%

Y21B38	Average (min:sec)	Median (min:sec)	Max (min:sec)
Euphemia with Volume Fixes	5:11	4:41	21:44
NUP with Volume Fixes	4:29	3:59	17:11
Performance Improvements (%)	21.8%	17.2%	21%

Y21B35	Average (min:sec)	Median (min:sec)	Max (min:sec)
Euphemia with Volume Fixes	5:47	4:9	43:20
NUP with Volume Fixes	5:15	3:59	29:02
Performance Improvements (%)	9%	3.9%	33%

Y20B35	Average (min:sec)	Median (min:sec)	Max (min:sec)
Euphemia with Volume Fixes	13:32	11:44	33:25
NUP with Volume Fixes	9:16	7:22	27:47
Performance Improvements (%)	31.5%	37.3%	16.9%

- As for the TTFS, improvements of observed TTV thanks to NUP is highly dependent of the batch considered (Range from 10 to 30% in average)
- For batch Y21B38 and Y20B35, the maximum TTV is reduced with NUP. It confirms that the increase of the maximum TTFS with NUP in the previous slide is due to numerical challenges in the volume problems which indeed suggests that the numerical stability of volume problems should be studied in the Lab further in Iteration 9.
- NUP prototype and Euphemia version build on all past efforts in the Euphemia Lab + numerical stability improvements in the post-processing problems lifting volume indeterminacies.

Final Observations with respect to Non-Uniform Pricing Performance Improvements on Other KPIs

Improvements of performances with Non-Uniform Pricing were tested on other KPIs (welfare, gap, number of solutions, ...) for Batch Y21B33 with a maximum time limit of 30 minutes.

Key observations from this assessment:

- Non-Uniform Pricing **reduces the number of paradoxically rejected orders and their respective “PRBness”** compared to Euphemia with the classic price requirements (no PAB, etc.)
- Non-Uniform Pricing **improves** slightly in general the **welfare of the final solution** compared to Euphemia with the classic price requirements (no PAB, etc.)
- Non-Uniform Pricing **improves the observed gap** of the final solution compared to Euphemia with the classic price requirements (no PAB, etc.) meaning that the solution in that case is proven to be closer to optimality.
- Non-Uniform Pricing **increases slightly the number of valid solutions found** by the algorithm in 30 minutes with respect to Euphemia with the classic price requirements (no PAB, etc.)

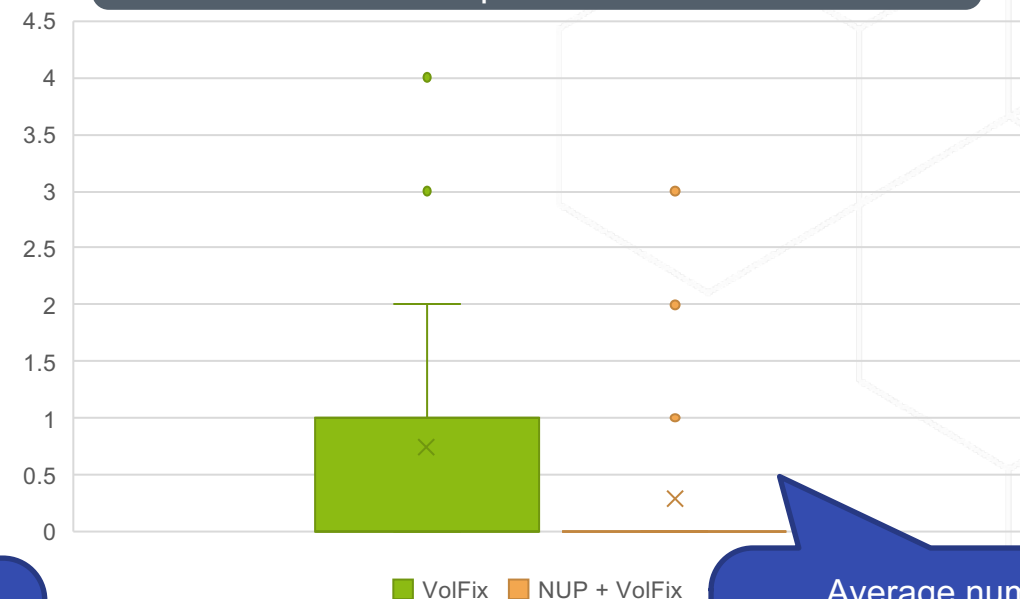
Non-Uniform Pricing reduces the observed number of paradoxically rejected orders

Number of Paradoxically Rejected Block Orders



Average number of paradoxically rejected block orders goes down from 11.9 with Euphemia Classic to 7.4 with NUP

Number of Paradoxically Rejected Scalable Complex Orders

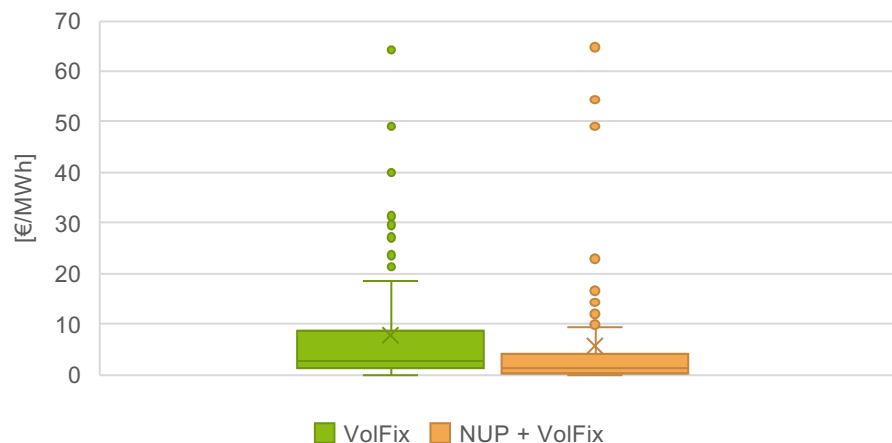


Average number of paradoxically rejected scalable complex orders goes down from 0.8 with Euphemia Classic to 0.3 with NUP

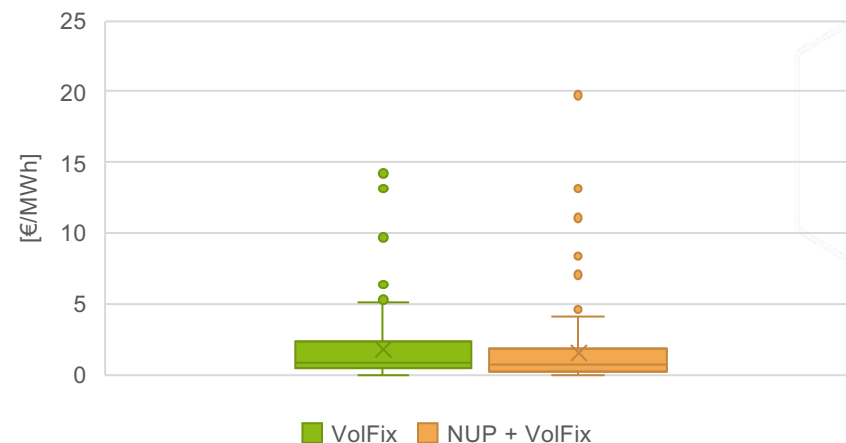
- **Assessment realized on batch Y21B33 (Big bang 15' MTU batch based on Y21 data, with 80% of 15' MTU products and 20% of 60' products, SCO & NO PUN (LTA activated) with 91 business days).**
- **Global decrease in the number of paradoxically rejected block and scalable complex orders by using NUP.**

Non-Uniform Pricing reduces the “PRBness” of paradoxically rejected orders

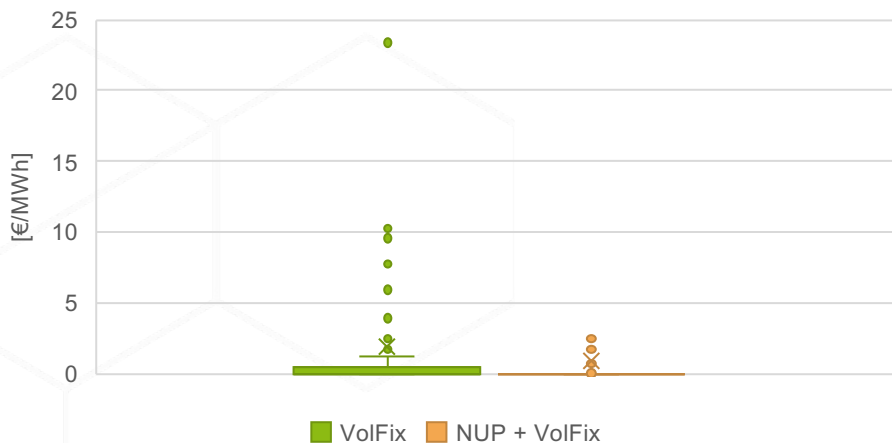
Maximum Δp of Paradoxically Rejected Block Orders



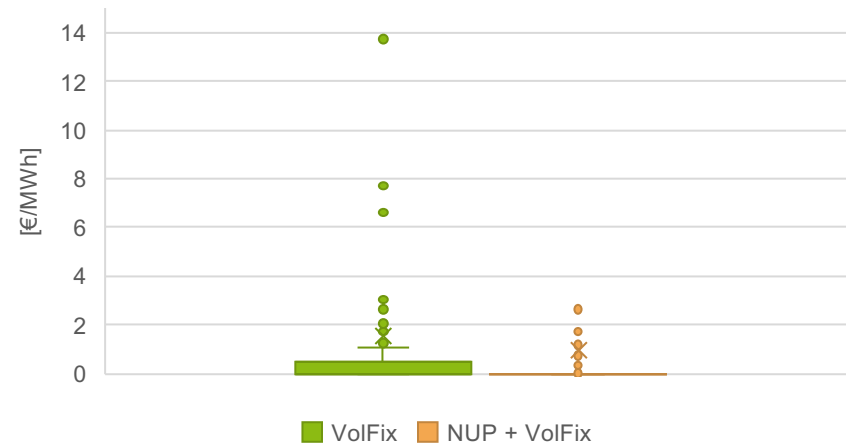
Average Δp of Paradoxically Rejected Block Orders



Maximum Δp of Paradoxically Rejected SCOs



Average Δp of Paradoxically Rejected SCOs



- Global reduction of the observed average and maximum “PRBness” of paradoxically rejected block and scalable complex orders by using Non-Uniform Pricing.
- Assessment realized on batch Y21B33 (Big bang 15' MTU batch based on Y21 data, with 80% of 15' MTU products and 20% of 60' products, SCO & NO PUN (LTA activated) with 91 business days).

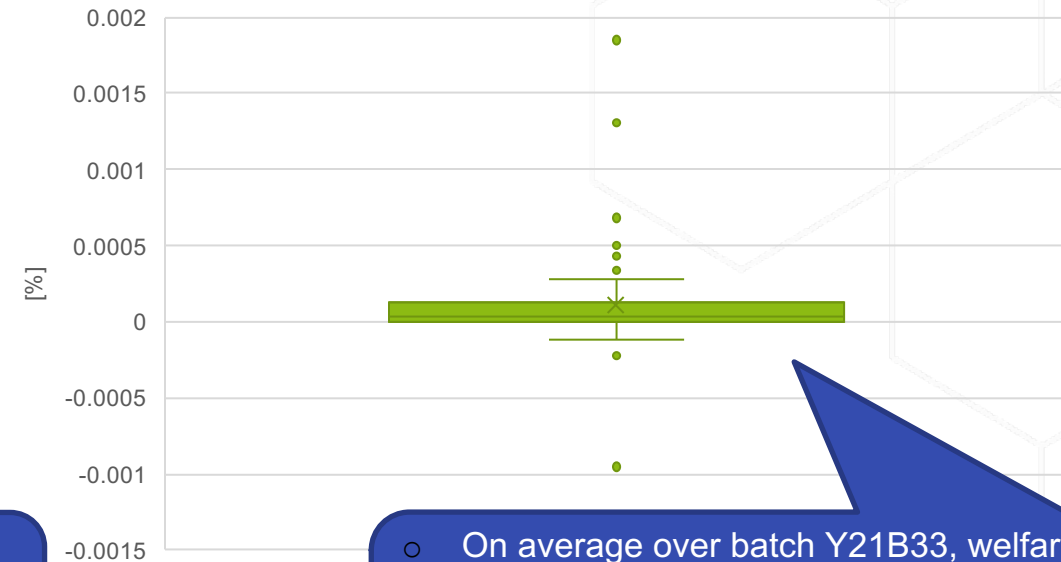
Non-Uniform pricing generally improves the welfare of the final solution

Difference in € between the welfare obtained with NUP and the one obtained with Euphemia using classic price requirements



- On average over batch Y21B33, welfare is increased by 10194 € when using NUP over Euphemia with classic price requirements.
- At maximum, this gain amounts to 160 233 €.

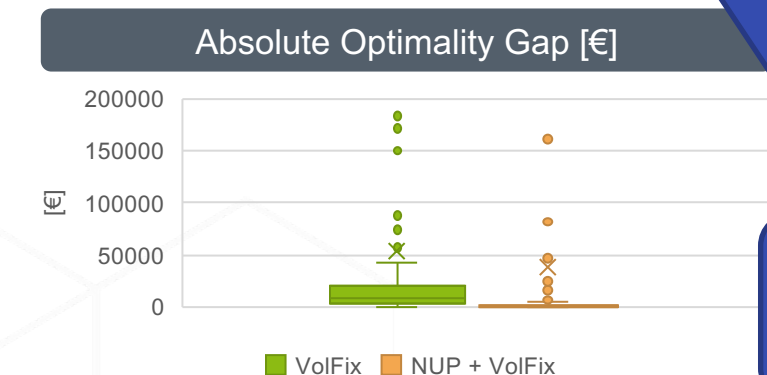
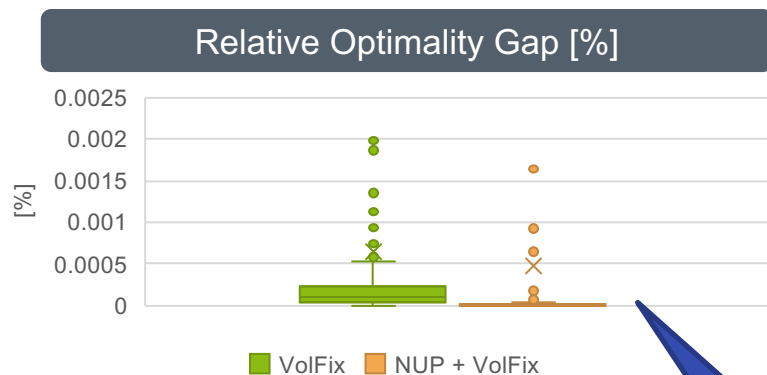
Difference in % between the welfare obtained with NUP and the one obtained with Euphemia using classic price requirements



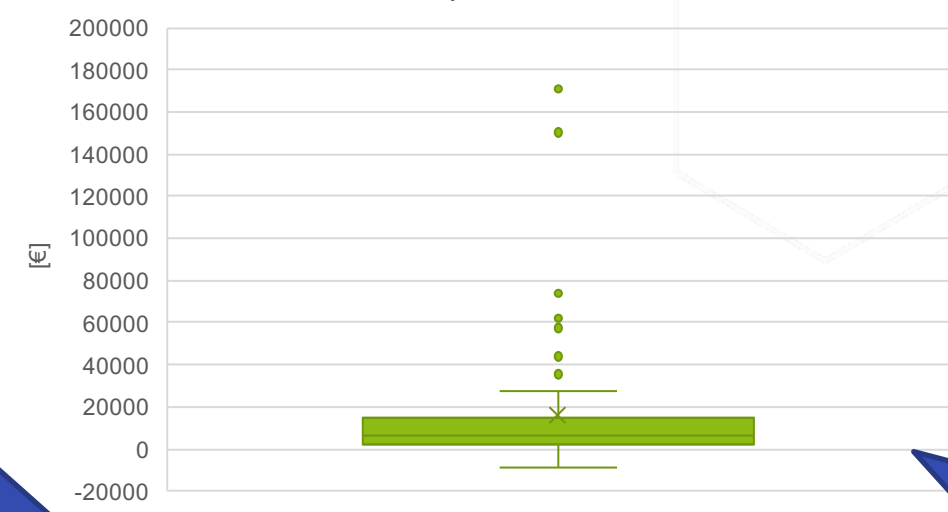
- On average over batch Y21B33, welfare is increased by 0.0001% when using NUP over Euphemia with classic price requirements.
- At maximum, this gain amounts to almost 0.002%.

- On average, welfare is increased by 10194€ or 0.0001% when using NUP over Euphemia with classic price requirements. At maximum, over batch Y21B33, this increase amounts to 160233€ which represents almost 0.002%.
- Assessment realized on batch Y21B33 (Big bang 15' MTU batch based on Y21 data, with 80% of 15' MTU products and 20% of 60' products, SCO & NO PUN (LTA activated) with 91 business days).

Non-Uniform pricing improves the observed optimality gap of the final solution



Difference in € between the optimality gap obtained with NUP and the one obtained with Euphemia using classic price requirements



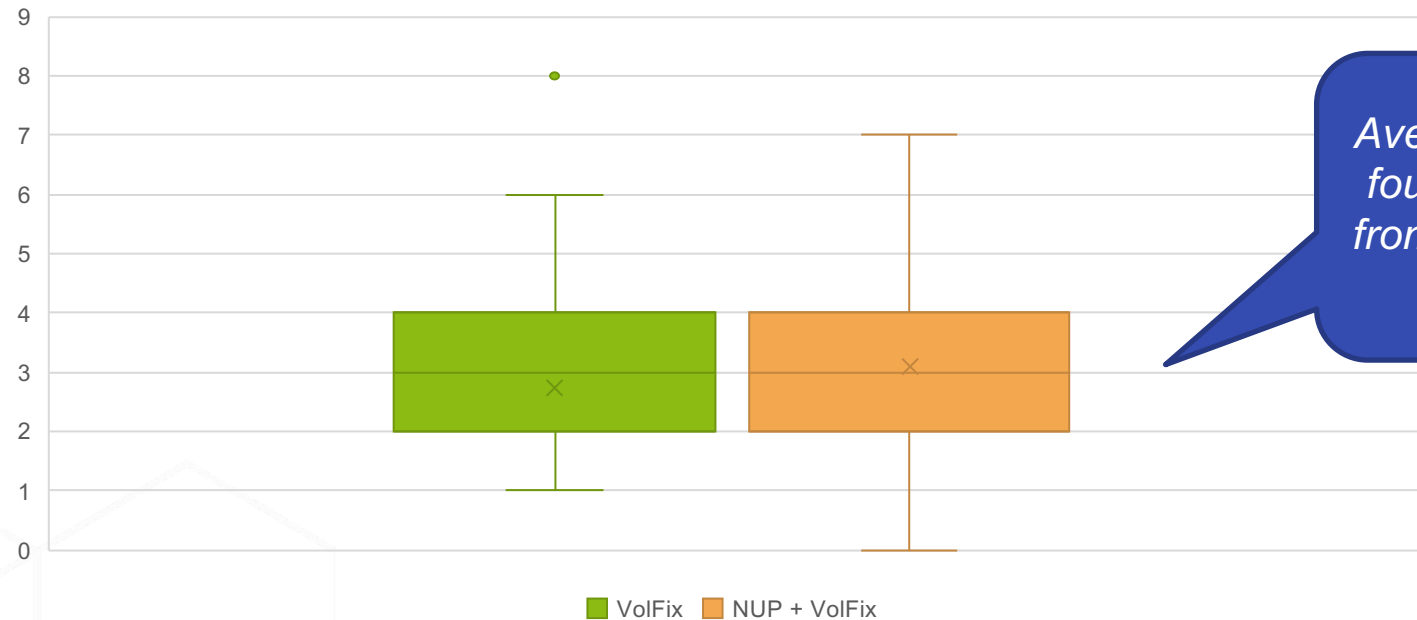
The average optimality gap goes from 0.00064% with Euphemia using the classic price requirements to 0.00047% when using NUP.

The optimality gap increases with NUP only in 5 sessions over the entire batch. The average improvement in optimality gap with NUP amounts to 15919€.

- Using NUP improves the observed optimality gap and therefore proves that the found solution is closer to optimality than the one found by Euphemia with classic price requirements.
- Assessment realized on batch Y21B33 (Big bang 15' MTU batch based on Y21 data, with 80% of 15' MTU products and 20% of 60' products, SCO & NO PUN (LTA activated) with 91 business days).

Non-Uniform pricing improves slightly the number of valid solutions found by the algorithm

Number of Valid Solutions Found by the Algorithm

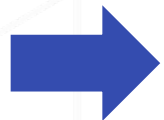


Average number of valid solutions found by the algorithm increases from 2.7 with Euphemia Classic to 3.1 with NUP

- The number of solutions found by the algorithm slightly increases in practice with NUP.
- Assessment realized on batch Y21B33 (Big bang 15' MTU batch based on Y21 data, with 80% of 15' MTU products and 20% of 60' products, SCO & NO PUN (LTA activated) with 91 business days).

Conclusions

- ***Time Performances:*** Non-uniform Pricing reduces *the time to first solution* with respect to Euphemia with classic price requirements even if *the reduction depends on the used batch*.
- ***Market & Performances Indicators:*** Non-uniform Pricing allows to improve several *market and performance indicators* such as the number of solution found after 30minutes, the welfare, the gap and the number of PRBs.



SDAC MSD may still gain from keeping Non-Uniform Pricing in mind to as a solution to manage future market growth and the addition of new features to the algorithm (such as other types of orders, ...)