



A novel smart grid architecture that facilitates high-RES penetration through innovative markets towards efficient interaction between advanced electricity grid management and intelligent stakeholders

Final e-Demo Day Event

Pitch: Automated Flexibility Aggregation Toolkit (AFAT)

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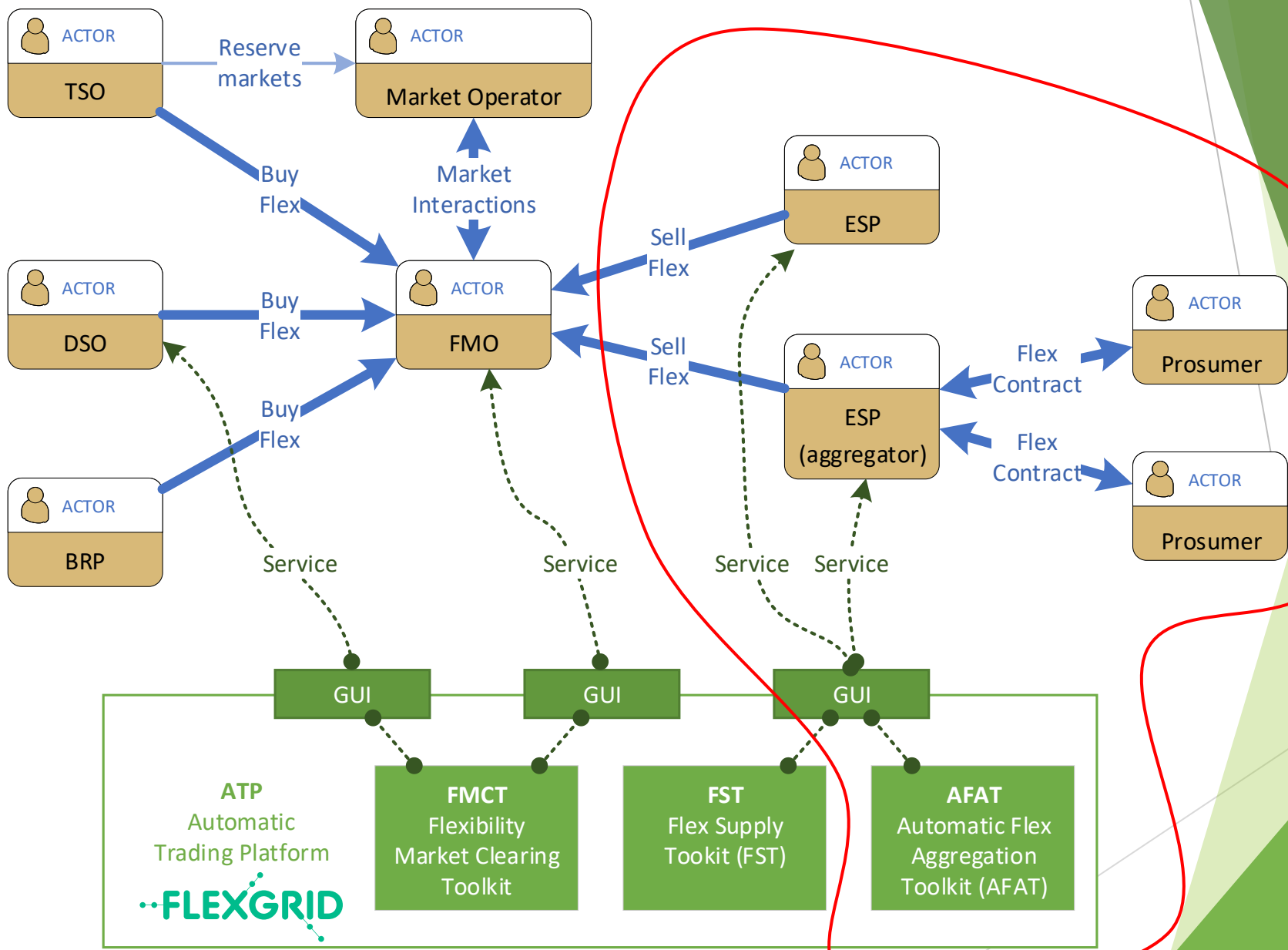
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Problem

Business challenges of an independent aggregator company:

1. How to optimally schedule a portfolio of a vast number of Distributed Flexibility Assets (DFAs), while dealing with many sources of uncertainty? → **minimize OPEX**
2. How to operate a B2C flexibility market in order to incentivize end users' engagement? → **provide competitive and personalized flexibility contracts to end users**
3. How to dynamically and automatically create aggregated flexibility offers towards optimal market participation? → **maximize expected revenues & minimize portfolio's imbalances**

AFAT solution

FLEXGRID Automated Flexibility Aggregation Toolkit's (AFAT) services:

▶ **AFAT service #1 (Manage a FlexRequest):**

- ▶ Scheduling algorithm that takes into account uncertain real-time prices, RES, loads, etc.
- ▶ Minimize the cost of DFAs' operation and respect DFAs' real-time constraints

▶ **AFAT service #2 (Manage a B2C flexibility market):**

- ▶ Behavioral real-time pricing algorithms in order to incentivize end users (bottom up flexibility investors/operators) to participate in energy markets
- ▶ Run various “what-if” simulation scenarios to determine more beneficial FlexContracts with end energy prosumers in the future

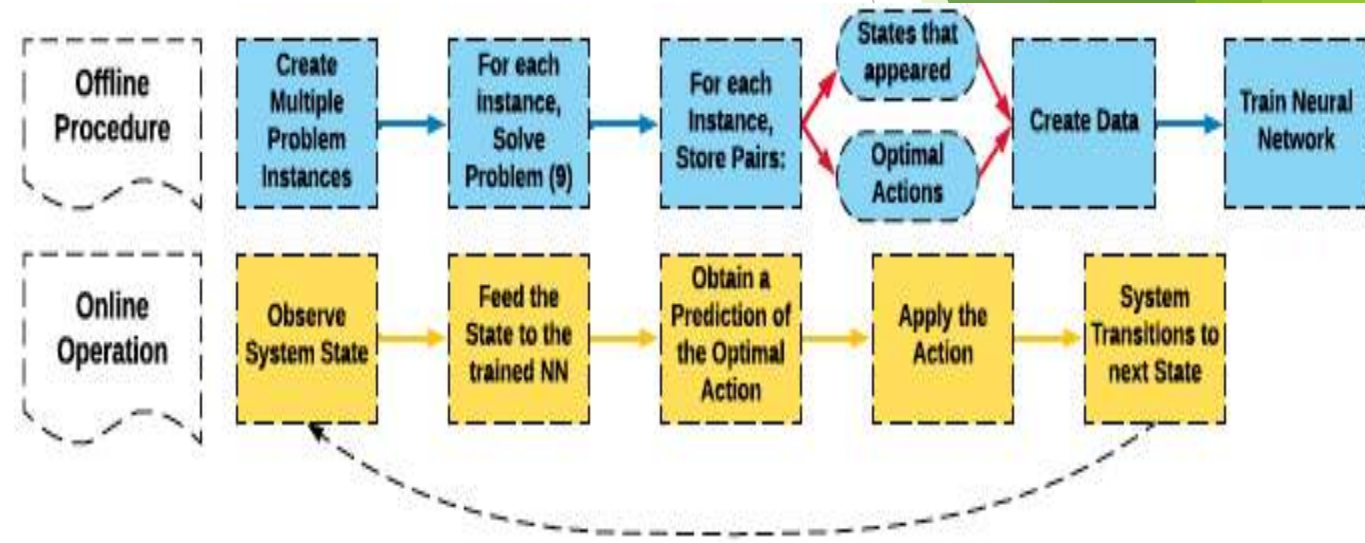
▶ **AFAT service #3 (Create an aggregated FlexOffer):**

- ▶ Automated flexibility aggregation algorithm to determine/create an optimal FlexOffer that best represents aggregator's portfolio in near-real-time

AFAT service #1 (Manage a FlexRequest)



- Formulate the economic dispatch problem as a **multi-agent Markov Decision Process (MDP)**, which cannot be tackled by standard dynamic programming algorithms.
- Apply a **machine learning (ML) algorithm in the dual problem space** and take advantage of the fact that its dimension (number of variables) is **drastically smaller than the one of the primal problem**, while guaranteeing constraint satisfaction.
- A **NN is trained to perform energy management decisions in real-time**, upon receiving the information about the current system state. Instead of the primal problem, the **dual problem is used to train the NN**. With this technique, we reduce the NN's MAE and enhance the NN's reliability.
- Perform energy management in a rolling horizon fashion, so that the NN can **adapt its decisions based on new information about the system's state**
- The proposed method achieves a near-optimal performance and significantly **outperforms the conservative and offline constraint-satisfying benchmarks** (i.e. deterministic approach).

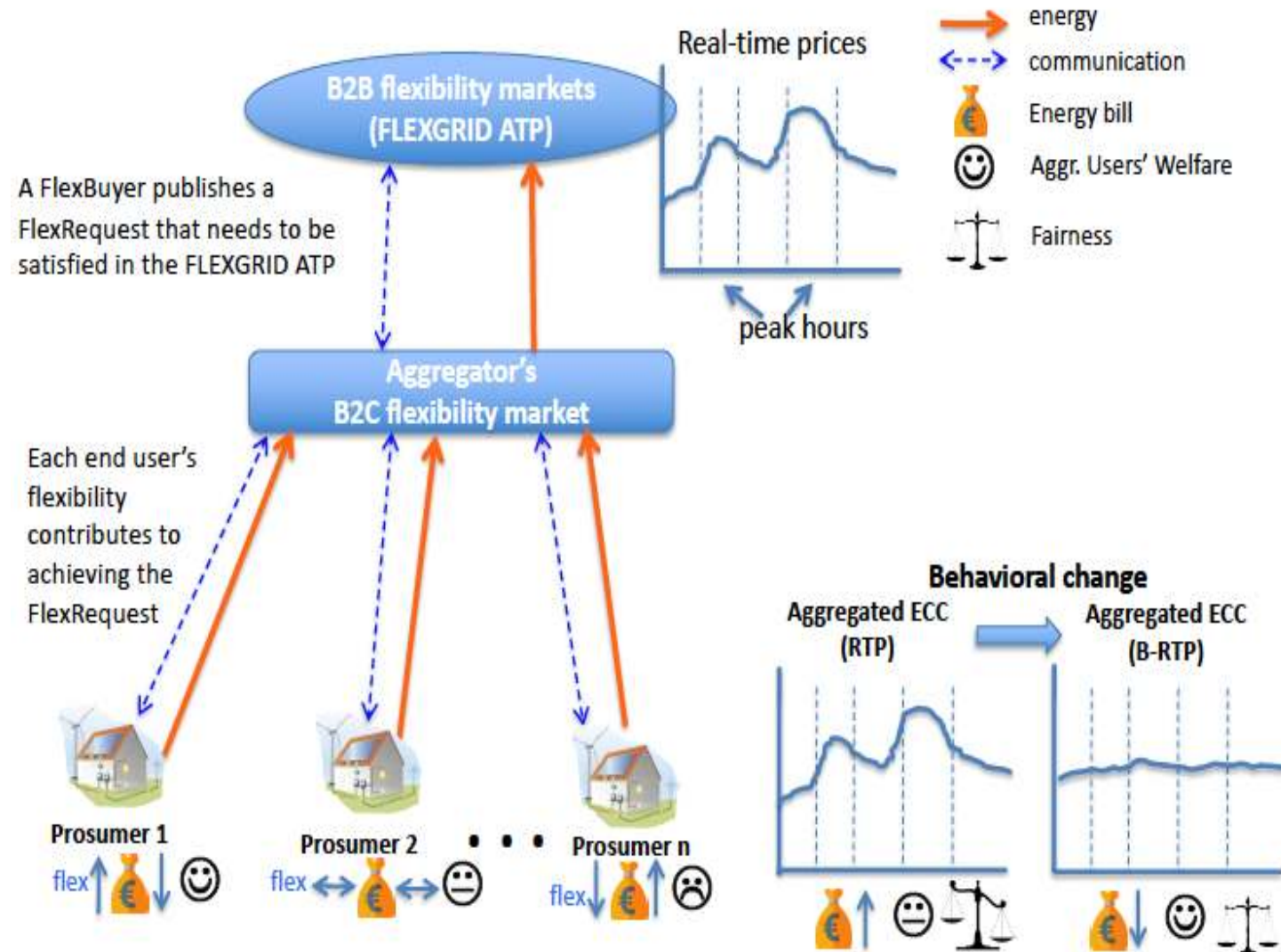


AFAT service #2 (Manage a B2C flex market)



KPIs:

- **“optimality/efficiency”** → achieve VCG outcome (social welfare)
- **“incentive guarantee/strategy proof”** → satisfy Dominant-Strategy-Incentive-Compatible (DSIC) Property
- **“privacy protecting”** → end users do not have to reveal their utility functions, but just respond to the B2C flexibility market price signals
- **“convergence/scalability”** → for a large number of end users that participate in the B2C flexibility market
- **“fairness”** → each flexible end user is rewarded based on its personalized contribution (NOT Real Time Pricing)
- **“Competitiveness”** → easily adjust the trade-off between aggregator’s profits and AUW
- **“Transparent”** to any type of FlexRequest that needs to be satisfied

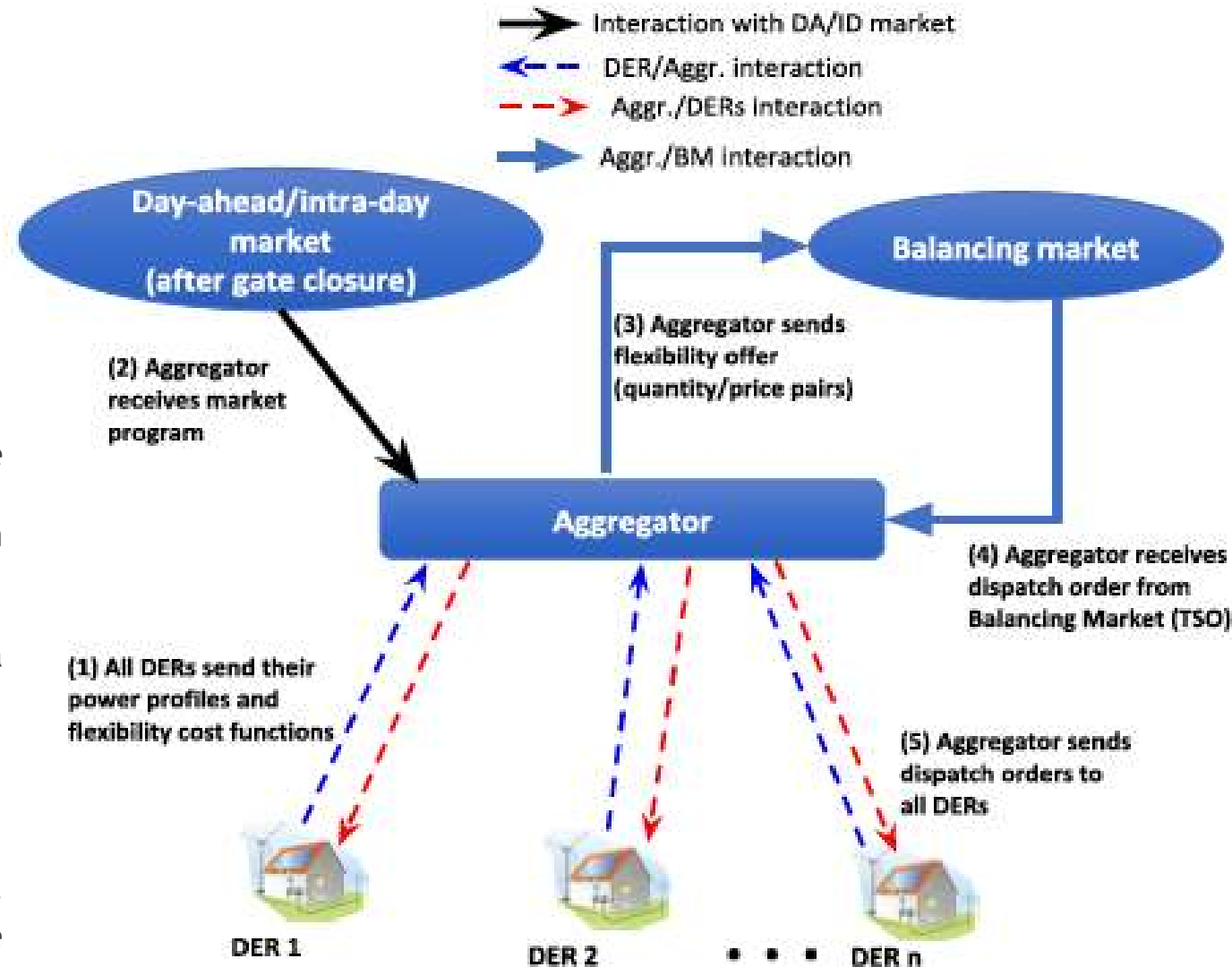


AFAT service #3 (Create an aggregated FlexOffer)



KPIs:

- **FlexOffer should be concise** → impossible to communicate precise information about every FlexAsset → However, need for aggregate flexibility feedback to be a concise summary of a system's constraints
- **FlexOffer should be privacy-preserving** → information conveyed to the system operator must limit the leakage about specific FlexAsset constraints
- **FlexOffer should be informative** → so that it allows the system operator to achieve its operational objectives, e.g., minimize cost and guarantee the feasibility of the whole system w.r.t. the private FlexAsset constraints
- **FlexOffer should be general enough** → to be applicable for a wide variety of controllable loads, e.g., electric vehicles (EVs), heating, ventilation, and air conditioning (HVAC) systems, energy storage units, thermostatically controlled loads, residential loads, heat pumps, etc.
- **FlexOffer should be real-time** → it is crucial that (nearly) real-time feedback can be defined and approximated if it is to be used in online FlexOffers made by the aggregator



AFAT Service #2 DEMO

The screenshot displays the UCS4.2 Retail pricing optimization interface. The browser address bar shows the URL: <https://afat.flexgrid.flexatrade.com/afat2>. The page title is "UCS4.2. Retail pricing optimization". Below the title, there are tabs for "CONFIGURATION", "RESULTS", and "HISTORICAL". The "RESULTS" tab is active, showing a table with the following columns: Status, Last change, Health icon, Price, % change, Price reason, Products, Algorithm, Profit, and Gamma.

Status	Last change	Health icon	Price	%	Price reason	Products	Algorithm	Profit	Gamma
✓	2020/02/08 19:41	🔴	0.1110001	0.1110001	See reason: 1, Low	item_1_Low, item_2_Low, item_3_Low	Enhanced RFP (ytd)	0	0.0
✓	2020/02/08 19:42	🟢	0.1110001	0.1110001	See reason: 1, High	item_1_Low, item_2_Low, item_3_Low	Enhanced RFP (ytd)	0	0.0
🕒	2020/02/08 19:43	🟢	0.1110001	0.1110001	See reason: 1, High	item_1_Low, item_2_Low, item_3_Low	Enhanced RFP (ytd)	0	0.0
✓	2020/02/08 19:50	🟢	0.1110001	0.1110001	See reason: 1, Low	item_1_Low, item_2_Low, item_3_Low	Enhanced RFP (ytd)	0	0.0

Youtube link: <https://youtu.be/nII8HP7j008>

Competitive advantages of AFAT

- AFAT service #1 achieves a near-optimal performance and significantly **outperforms the conservative and offline constraint-satisfying benchmarks** (i.e. deterministic approach).
- AFAT service #2 provides a novel **B2C flexibility market as a service** offering, in which each end user gets a **personalized real-time price** according to its individual flexibility contribution to the system.
- AFAT service #3 offers a **model-free method for constructing aggregated FlexOffers** that best represent the aggregator portfolio's actual flexibility costs, **while accounting for uncertainty in future timeslots** towards minimizing the aggregator's imbalances.

Exploitation pathway

- ▶ Perform real-life pilots at a higher TRL → [look for mature pilot testing sites](#)
- ▶ Each one of the 3 AFAT service offerings can be [exploited as a standalone service or any other combination](#) → modular-by-design S/W architecture
- ▶ [Detailed user manual in FLEXGRID Github area](#) in order for any interested S/W developer/ researcher/ business analyst to be able to [deploy each AFAT service, run it in its localhost and reproduce FLEXGRID results.](#)
 - ▶ <https://github.com/FlexGrid/AFAT-service-2-manage-b2c-flexibility-market>
 - ▶ <https://github.com/FlexGrid/AFAT-service-3-flex-offer-creation>
- ▶ Detailed [Cost-Benefit Analysis](#) for each individual AFAT service and AFAT offering as a whole is available → ready to start discussion with commercial partners about further exploitation



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Scientific publications:

AFAT service #1: G. Tsaousoglou, K. Mitropoulou, K. Steriotis, N. G. Paterakis, P. Pinson and E. Varvarigos, "Managing Distributed Flexibility Under Uncertainty by Combining Deep Learning With Duality," in *IEEE Transactions on Sustainable Energy*, vol. 12, no. 4, pp. 2195-2204, Oct. 2021, doi: 10.1109/TSTE.2021.3086846. Available online: <https://ieeexplore.ieee.org/document/9447957>

AFAT service #1: G. Tsaousoglou, N. Efthymiopoulos, P. Makris and E. Varvarigos, "Multistage Energy Management of Coordinated Smart Buildings: A Multi-Agent Markov Decision Process Approach," in *IEEE Transactions on Smart Grid*, vol. 13, no. 4, pp. 2788-2797, July 2022, <https://ieeexplore.ieee.org/abstract/document/9744105>

AFAT service #2: G. Tsaousoglou, K. Steriotis, N. Efthymiopoulos, P. Makris, E. Varvarigos, "Truthful, Practical and Privacy-aware Demand Response in the Smart Grid via a Distributed and Optimal Mechanism", *IEEE Transactions on Smart Grid*, January 2020, [10.1109/TSG.2020.2965221](https://doi.org/10.1109/TSG.2020.2965221)

AFAT service #2: G. Tsaousoglou, P. Soumplis, N. Efthymiopoulos, K. Steriotis, A. Kretsis, P. Makris, P. Kokkinos, E. Varvarigos, "Demand Response as a Service: Clearing Multiple Distribution-Level Markets," *IEEE Transactions on Cloud Computing*, vol. 10, no. 1, pp. 82-96, 1 Jan.-March 2022, doi: 10.1109/TCC.2021.3117598, <https://ieeexplore.ieee.org/document/9557809>.

AFAT service #3: G. Tsaousoglou, I. Sartzetakis, P. Makris, N. Efthymiopoulos, E. Varvarigos and N. G. Paterakis, "Flexibility Aggregation and of Temporally Coupled Resources in Real Time Balancing Markets Using Machine Learning," *IEEE Transactions on Industrial Informatics*, December 2021, <https://ieeexplore.ieee.org/document/9633146>

Questions?

Visit our website!

<https://flexgrid-project.eu/>

YouTube channel:

<https://www.youtube.com/channel/UCEpdrFhiltkGTi7dmNL--yg>

GitHub area:

<https://github.com/FlexGrid>