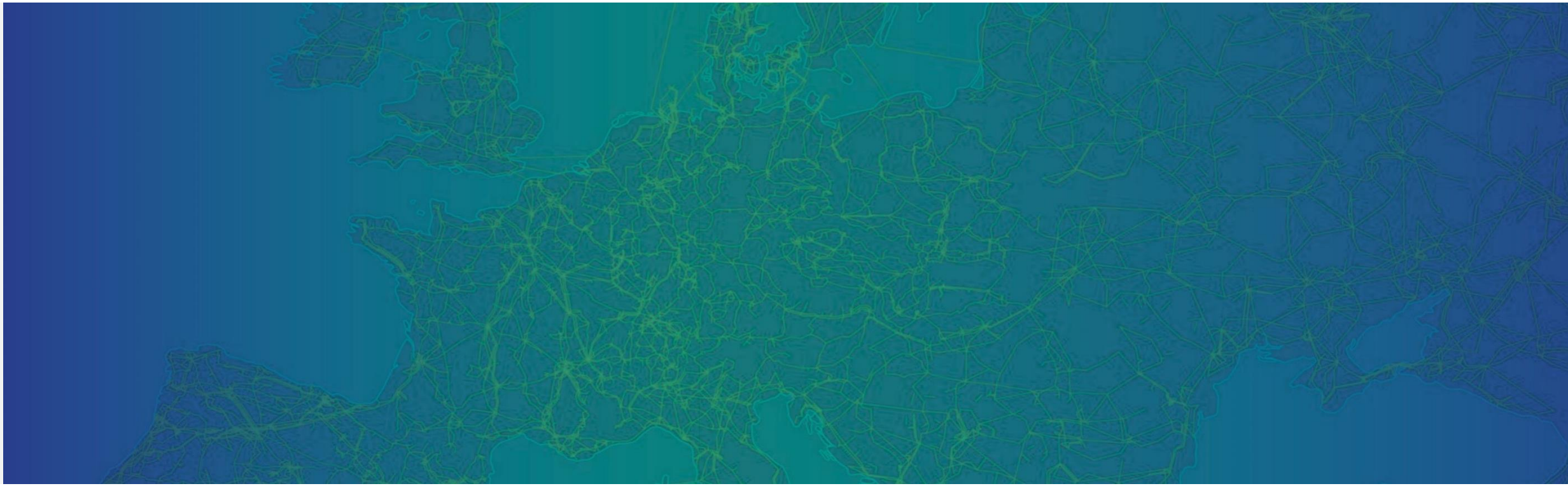
EB SG – Co-optimisation IIA Workshop

20 October 2021



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List of Abbreviations

aFRR	automatic Frequency Restoration Reserves
BC	Balancing Capacity
BCM	Balancing Capacity Market
CZC	Cross-Zonal Capacity
CZCAOF	Cross-Zonal Capacity Allocation Optimisation Function
CPOF	Capacity Procurement Optimisation Function
DA	Day-Ahead
DAM	Day-Ahead Market
IIA	Implementation Impact Assessment
mFRR	manually Frequency Restoration Reserves
RR	Restoration Reserves
SDAC	Single Day-Ahead Coupling
PTDF	Power Transfer Distribution Factor

Outline

1. Introduction on IIA status quo
2. Linking of bids
   a. Cross-product linking (the need and options)
   b. Quantification (welfare effects)
3. Implementation options
4. Feedback – Interaction with stakeholders

5. NEMOs: Implications of one-step co-optimisation
6. NEMOs: Feasibility of two-step co-optimisation

1. Introduction on IIA status quo

1. Introduction on IIA status quo

- Following article 40 EBGL, co-optimisation facilitates the allocation of cross-zonal capacities (CZCs) for Day Ahead Market purposes and for Balancing Capacity. Both markets will be cleared with the same Gate Closure in case regional initiatives want to start exchanging Balancing Capacity and/or sharing reserves. This requires the joint optimisation of CZC allocation, SDAC and Balancing Capacity procurement to reach highest European economic surplus from the allocation of CZCs in the concerned areas.
- TSOs are currently conducting an implementation impact assessment for the methodology of co-optimised allocation to be published by TSOs the latest 16 December 2021. TSOs have also invited NEMOs to support the analysis of technical feasibility of co-optimisation implementation options and to support the analysis of cost estimation, categorisation and sharing.

1. Introduction on IIA status quo

Following ACER's Decision on a Methodology for Co-Optimised Allocation from 17 June 2020, Article 13 (2), the implementation impact assessment shall cover the following 8 topics:

1. Governance of the CZCAOF
   - This topic address the placement and responsibility for the optimisation function and its integration with the SDAC and the capacity procurement optimisation functions (CPOFs)
2. Technical implementation feasibility of the CZCAOF
   - The technical implementation feasibility of options of the CZCAOF need to be assessed in a most open and unbiased way:
     - One-step implementation in an integrated CZC allocation with SDAC
     - Two-step implementation as an alternative with CZC allocation outside SDAC to make a fast CZC split and send revised PTDFs and order books to SDAC
3. Flow-based compatibility
   - The CZCAOF and/or, depending on the implementation option, EUPHEMIA need to consider flow-based parameters.
   - While DA bids relate to actual energy flows, BC bids need not result in flows which affects the flow-based domain.
4. Compatibility with price coupling algorithm methodology and continuous trading matching algorithm
   - The implementation options need to be compatible with Article 37 of the CACM regulation. This requires the compatibility with the price coupling algorithm as implemented for DA markets.

1. Introduction on IIA status quo

Following ACER‘s Decision on a Methodology for Co-Optimised Allocation from 17 June 2020, Article 13 (2), the implementation impact assessment shall cover the following topics:

5 Operational security impact analysis of interconnected transmission system

- The CZC split between BC and DAM energy determines the operational flexibility for TSOs’ XB exchange. The more CZC is allocated for DAM energy exchange, the more BC must be reserved locally. In contrast, the less CZC is allocated for DAM energy exchange, the higher are local DA and ID market price differences. Thus, the assessment of the CZC split needs to balance the economic and the technical value of operational system security impact.

6 Linking feasibility between BC bids and between BC bids and DA bids

- A higher level of integrated optimisation reduces the requirement for cross-product linking-of-bids options. Depending on the order of BCM and DAM optimisation, different linking-of-bids options might be supportive. The requirement of different linking-of-bids options and their feasibility have been assessed.

7 Reasoning for separate BCM procurement after CZC allocation

- Although the CZCAOF already provides the optimal distribution of BC procurement, there exist (governmental, regulatory, legal or technical) requirements to organize a CPOF after the CZC allocation.

8 Costs estimation, categorisation and sharing

- Besides implementability, costs for implementation, cost requirements for each implementation option and cost sharing are assessed.

2. Linking of bids

2a. Cross-product Linking

2a. Necessity of cross-product linking

Cross-product linking means the linking possibibilities of bids of different balancing capacity qualities and linking bids between balancing capacity and DAM bids.

In a most simple implementation, with cross-product linking, exclusive group linking is meant. In other words, if a certain bid in market A is not used, it can be used in market B, with a volume and price that is indicated upfront by the market participant.

- TSOs have acknowledged feedback from stakeholders 2019 regarding the need for cross-product linking.
- TSOs have included cross-product linking in 2019 as part of the IIA
- Assessments have been performed on the need of cross-product linking, its different options, and the welfare effect.
- First results of these assessments of need, options and welfare shall be presented
- Stakeholders feedback is welcome

2a. Cross-product linking

What is cross-product linking?

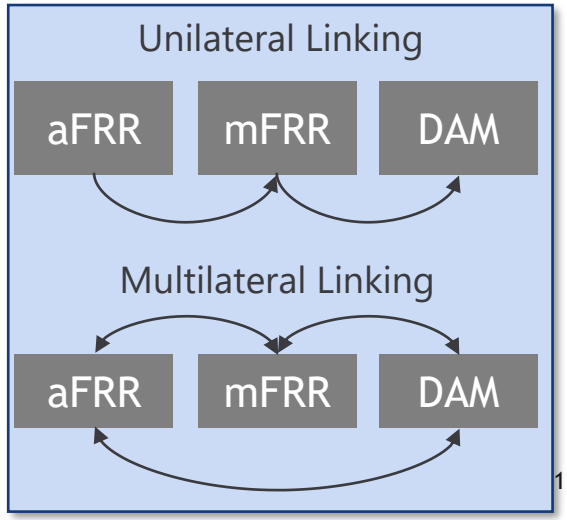
- Cross-product linking is an exclusive bid linking. That means that a bid can be taken into account for different markets (aFRR, mFRR, RR, DAM) but will only be awarded in one market.

Why do we need cross-product linking?

- The implementation of co-optimisation has consequences on:
  - The market: inefficient market bidding, reduced market diversity, drop of the total market liquidity
  - Compliancy: probability of unsatisfied demand, incompliancy to reserve availability → fewer / no applications of co-optimisation
  - Welfare: loss of explanatory power of market prices, potential risk of windfall-profits, unevenly distributed welfare

What kind of cross-product linking options are elaborated?

- Unilateral Linking:
  - Different market clearings are subject to a pre-defined prioritisation
  - A cross-product linked bid will be transferred from one market to the next one only if the bid was out of the money in the first market. In other words, bids are forwarded in case not used in a pre-defined setting.
- Multilateral Linking:
  - An algorithm (virtually) clears each market including bid placement according to a maximisation of the total surplus of all markets combined
  - If a cross-product linked bid is in the money for several markets it will be awarded to the market where it generates the higher total surplus



2a. Cross-product linking options

How can cross-product linking look like?

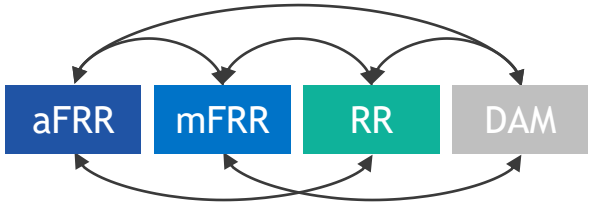
- There are 6 different options how cross-product linking can look like. They are illustrated below:

Option 1: No linking

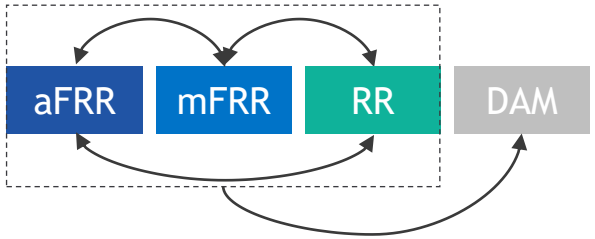
* DAM = Day-Ahead Market

Option 2: Unilateral

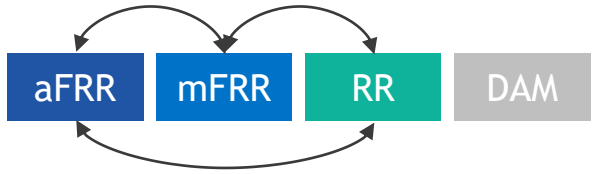
Option 3: Multilateral



Option 4: Multi- and unilateral



Option 5: multilateral and no linking



Option 6: Unilateral and no linking

What do we want to know from you?

- Can you identify yourself with the current content about cross-product linking?
- Are there aspects that still need to be addressed in your opinion?

2b. Quantification

2b. Objective

- The IIA report shall consist of a separate chapter elaborating on the welfare change and the distribution of surpluses subject to the different cross-product linking options.
- The assessment reveals that any decision on the applicability of a certain cross-product linking option shall have an effect on the total welfare that can be realised by co-optimisation and also how the increase of welfare is distributed across the market actors (sellers, buyers and network owners)

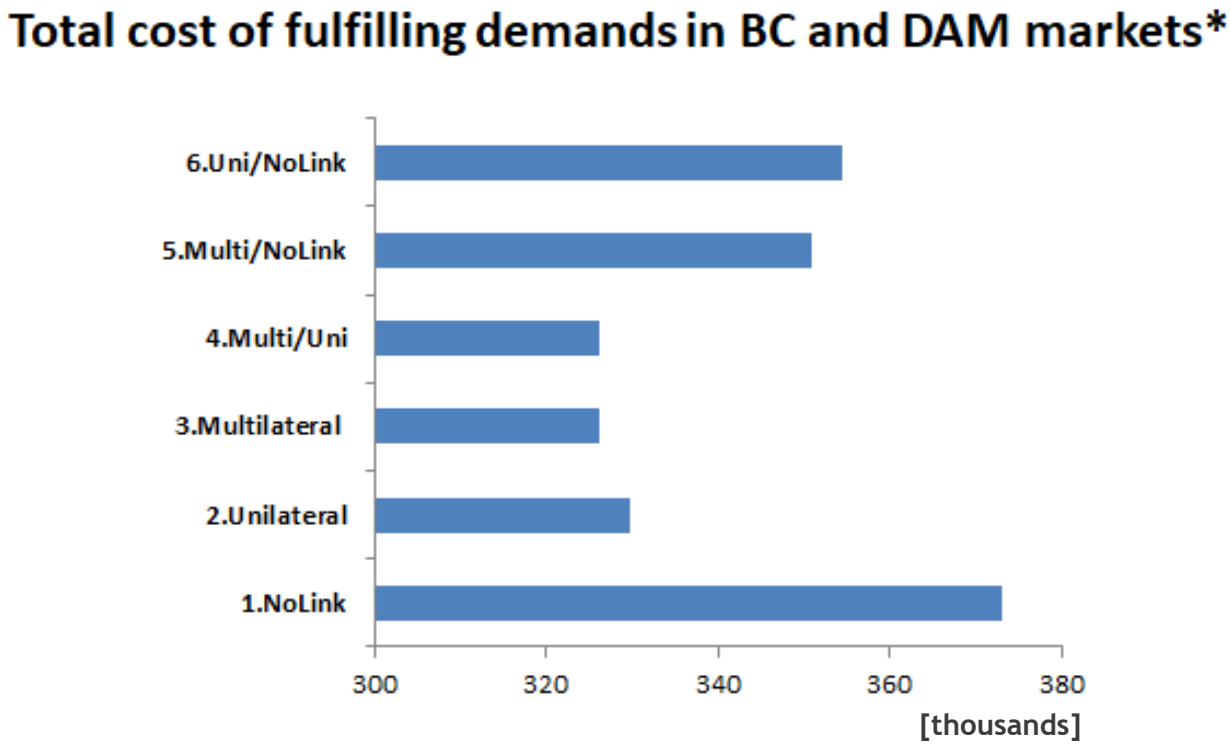
- The quantitative assessment, together with the technical feasibility study and necessity of cross-product linking shall be the basis for next year‘s decision on the updated set of requirements to be send by TSOs to NEMOs for the implementation of co-optimisation.

2b. Linking bid options in day-ahead energy and balancing capacity markets

Different cross-product linking bid options between aFRR and mFRR balancing capacity market and day-ahead energy market (DAM) are assessed:

1. aFRR, mFRR, DAM	**No-link**
2. aFRR -> mFRR -> DAM	**Unilateral cross-product linking between all bids**
3. aFRR & mFRR & DAM	**Multilateral cross-product linking between all bids**
4. (aFRR & mFRR) -> DAM	**Multilateral between aFRR and mFRR BC and unilateral between DAM and BC market**
5. (aFRR & mFRR) -> DAM	**Multilateral between aFRR and mFRR BC and no-link with DAM and BC market**
6. (aFRR -> mFRR) -> DAM	**Unilateral between aFRR and mFRR BC and no-link with DAM and BC market**

2b Total cost of fulfilling demands case study: Germany



Total cost of fulfilling demands = aFRR BC marginal price aFRR BC demand + mFRR BC marginal price* mFRR BC demand + DAM marginal price * DAM demand

2b. Observations and recommendations

- The qualitative cross-product linking study tries to give an overview of different linking-of-bid options and how they can lead to significant changes in welfare distribution and surpluses.
- The results of welfare gain and distribution depend on the data structure and market parameters, therefore, more analysis should be performed to get a better understanding of the full potential benefits of linking of bids between DAM and BC markets.
- For the performed assessment for case studies of DE and NL, we observed multilateral and unilateral cross-product linking of bids between BC and DAM, leading to a significantly lower total cost of fulfilling the demand, consequently maximising welfare (and a welfare re-distribution from seller to buyer).
- More extensive assessment should consider to perform:
  - More analysis with different data structure for bids in BC markets and DAM
  - Sensitivity analysis in terms of changing market framework and relevant market parameters
  - Simulation for EU market scale adding the flow-based market coupling.

3. Implementation Options

3. Implementation Options

The IIA identified alternative implementation options for co-optimisation:

1. **One step co-optimisation** [**CZCAOF & SDAC**]:
    1. Fully integrated optimization of CZCAOF and SDAC including capacity procurement requirements

    In this option multilateral linking between balancing capacity and DAM is possible with fully accurate CZC allocation and accurate bid selection per market.

2. Alternative **two step co-optimisation** [**CZCAOF →← SDAC**]:
    1. CZCAOF using a (standalone) algorithm based on simplified mathematical equations used in SDAC for a less complex process. The outcome of the CZCAOF is subsequent provision of revised PTDFs for DAM to EUPHEMIA. EUPHEMIA then clears DAM and provides back the SDAC outcome to CZCAOF.
    2. CZCAOF reoptimises based on SDAC (EUPHEMIA) results and provides revised PTDFs for BCM and revised BCM order books to the process that procures reserves

    It has been identified that this option can be accurate for unilateral cross-product linking between BCM and DAM.

    With multilateral linking there is the risk that bids in the money are selected by the CZCAOF but not taken by the CPOF, due to the imperfect allocation of CZC by the CZCAOF.

3. High level conditions of the two implementation options

Implementation option		Implementation feasibility	CZC allocation accuracy	Linking BC with DAM	Bid selection accuracy	Additional information
1	1-step **CZCAOF&SDAC**	worse	perfect	multilateral	Perfect, all bids in the money are cleared	
2	Alternative 2-step **CZCAOF→←SDAC**	better	weaker	unilateral	perfect for unilateral linking	For multilateral linking, risk that bids in the money are not cleared

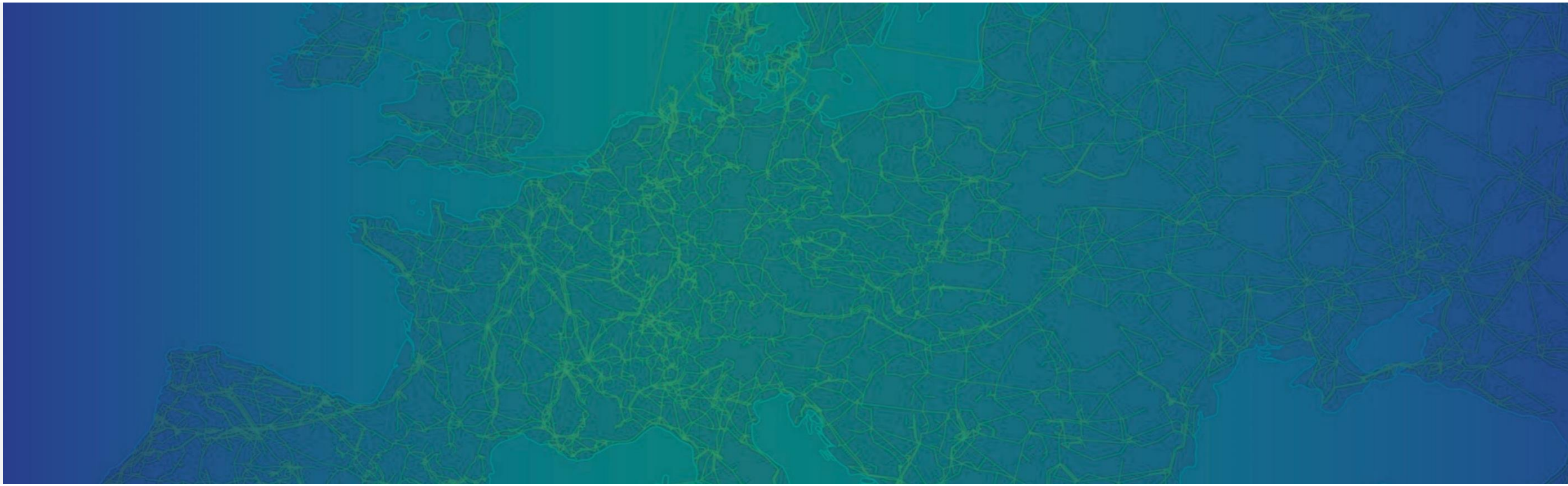
4. Feedback – Interaction with Stakeholders

4. Feedback – Questions to stakeholders

Stakeholders are asked to review these questions and prepare their views in advance of the EB SG meeting on 20 October (prior to 19 Oct)

1. **One single Gate Closure Time of Balancing Capacity Markets and Day Ahead Markets:**
   a. How will this affect your Balancing Capacity bids and your Day Ahead bids?
2. **Cross-product linking of bids (linking of different Balancing Capacity bids and with Day Ahead bids).**
   a. Are you active in both DAMs and in BCMs?
   b. Do you need cross-product linking, and if yes, unilateral or multilateral? Why?
3. **Implementation could be a big bang of one-step co-optimisation with full cross-product linking-of-bids possibilities or a multistep implementation of co-optimisation, starting with a two-step approach and increasing optimisation complexity over time.**
   a. Which advantages/ disadvantages do you expect from only a big bang implementation?
   b. Which advantages/ disadvantages do you expect from a multistep implementation of co-optimisation?

Appendix



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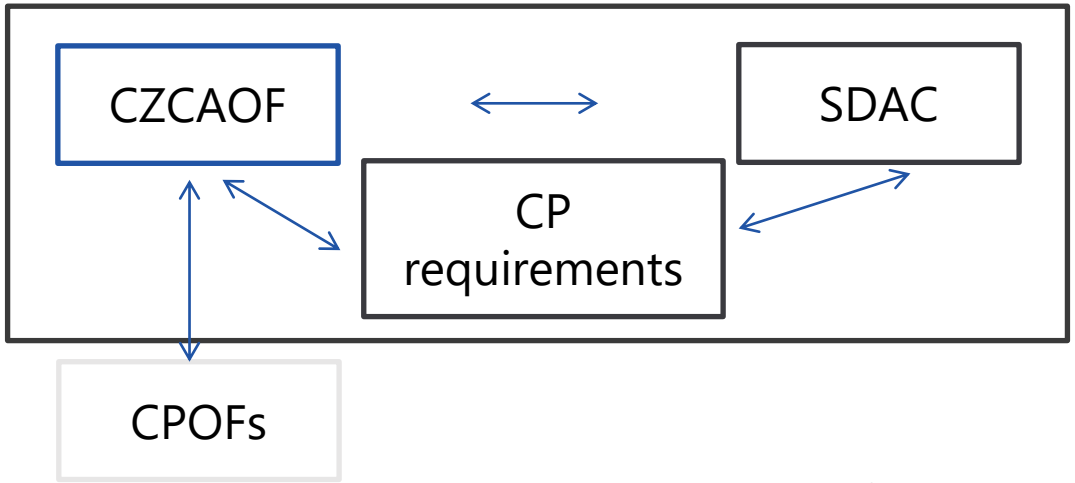
Appendix of co-optimisation implementation options

Implementation Options

1. One-step approach

- fully integrated optimization of CZCAOF and SDAC including capacity procurement requirements.



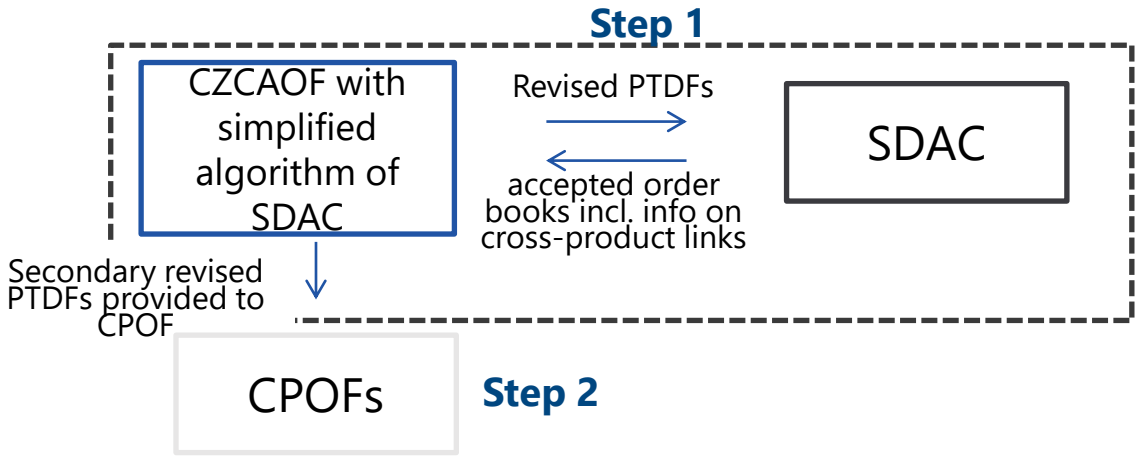
Integrated optimisation
- based on EUPHEMIA platform with newly developed modules or
- closely connected EUPHEMIA with external optimization tool

- Enables multilateral cross-product linking (exclusive group linking, linking families and combinations)
- Provides the first-best solution regarding the CZCA from a social welfare perspective
- Challenges:
  - Technically: Implementation complexity for a big bang introduction
  - Optimisation time might require a shift of subsequent procedure
  - Preparation for market participants: they can gain no experience beforehand
  - Optimisation could be seen as a black box → Intransparency

Implementation Options

2. Two-step approach: CZCAOF interacting with SDAC [CZCAOF→←SDAC]

- CZC allocation optimisation implemented together with the CPOF and subsequent provision of revised PTDFs to (current) EUPHEMIA for SDAC

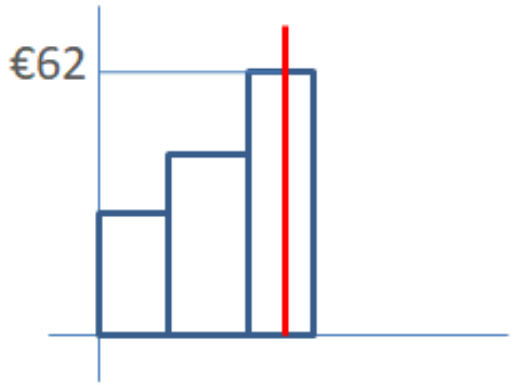


- The CZCAOF determines revised PTDFs for DAM by using a standalone simplified representation of the mathematical optimisation procedure of EUPHEMIA, and uses actual BC bids and DA bids. The revised order books and PTDFs decided by the CZCAOF are then provided to SDAC.
- The accepted DAM order book by SDAC is provided back to the CZCAOF which calculates secondary revised PTDFs for BC taking into account the SDAC outcome and the information of cross-product links from DA to BC bids before the CPOF is run.
- Enables only unilateral cross-product linking (exclusive group linking and linking families) between DAM and BCMs, and multilateral linking between BCMs.
- Optimisation time is expected to be decreased vis-à-vis the one-step approach but higher than in the two-step approach on the previous slides.
- EUPHEMIA procedures need not be changed but a simplified SDAC algorithm needs to be developed for the CZCAOF.
- No risk of unsatisfied demand as long as CZCAOF uses identical optimisation algorithm as CPOFs

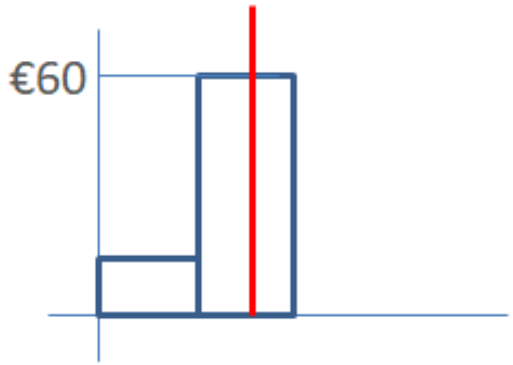
Appendix of quantification assessment on welfare effects of different type of cross-product linking options

2b. No cross-product linking
aFRR , mFRR , DAM

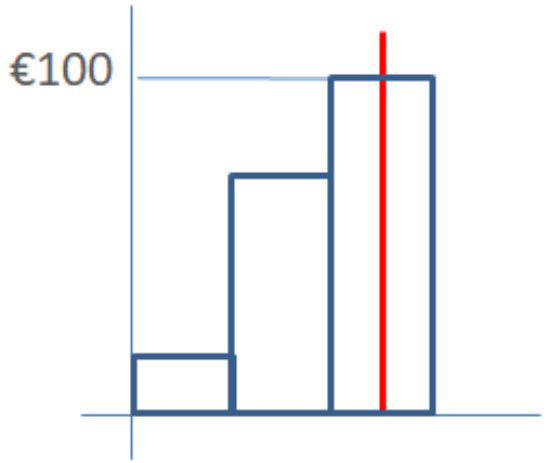
aFRR BC market



mFRR BC market

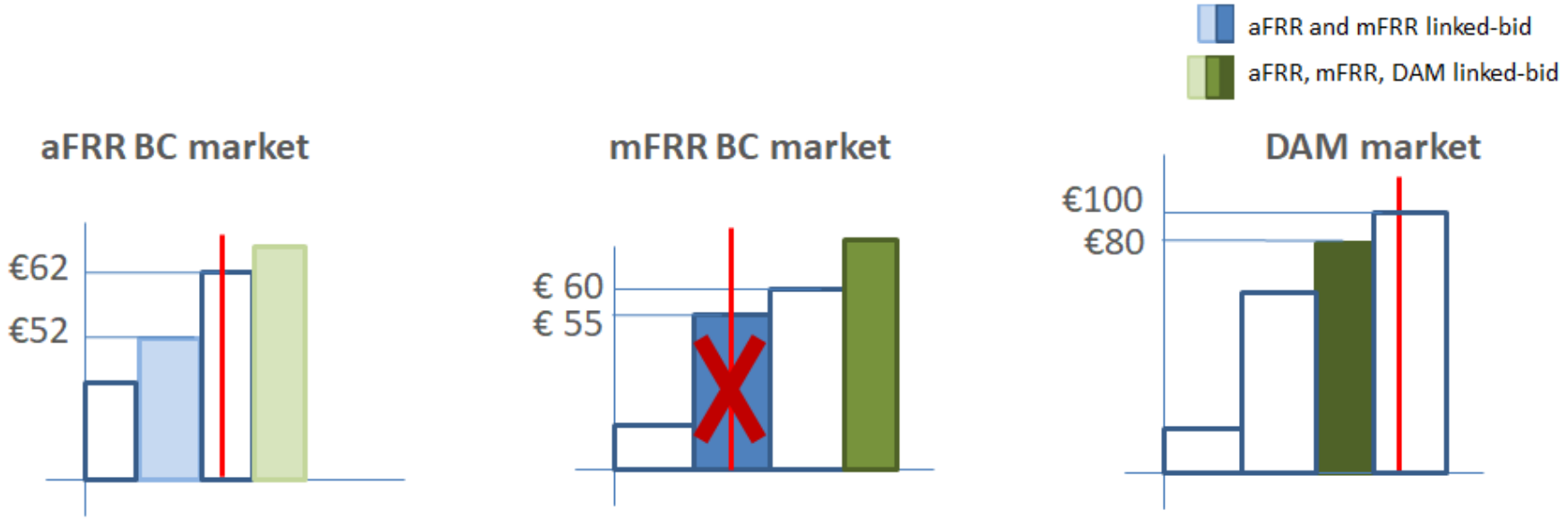


DAM market



aFRR BC marginal price	62 €
mFRR BC marginal price	60 €
DAM marginal price	100 €

2b. Unilateral cross-product linking
aFRR -> mFRR -> DA

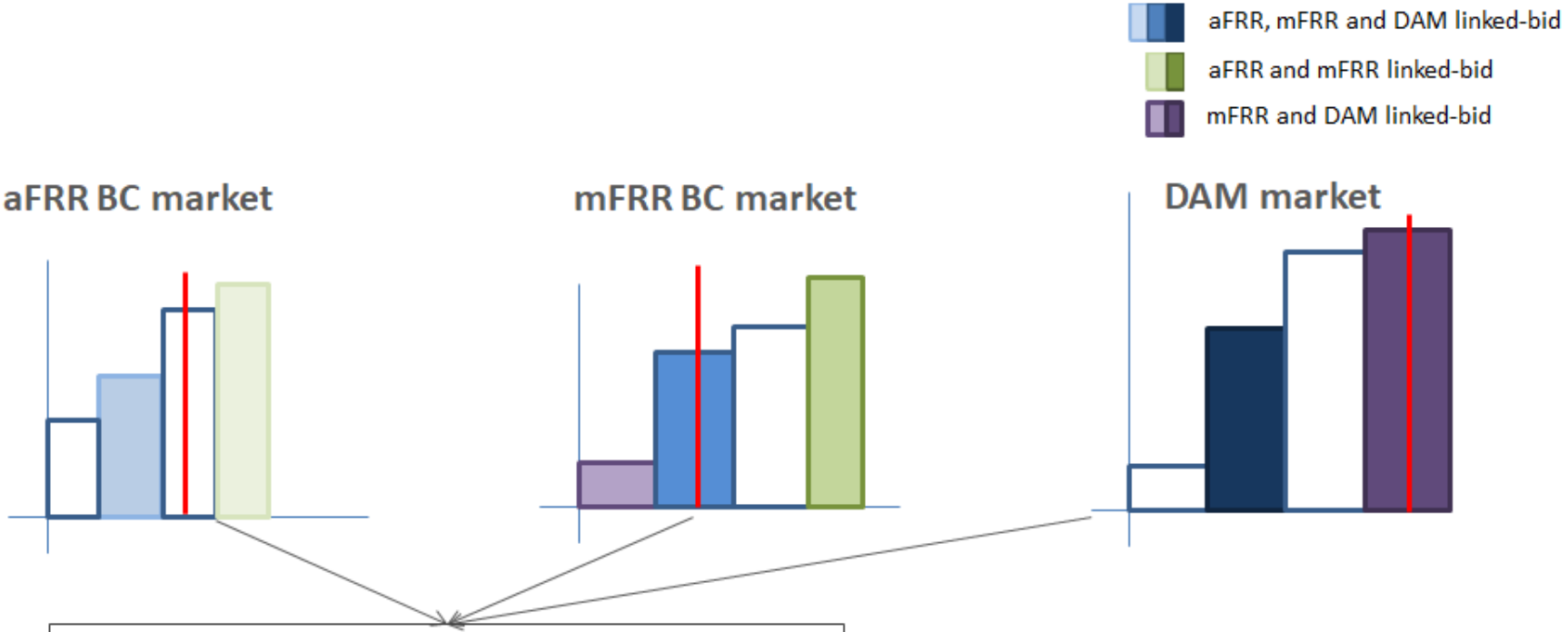


Blue Linked-bid is accepted in aFRR market and therefore will not be present in **mFRR and DA market**

Green Linked-bid which is not accepted in aFRR market will go to **mFRR and is not accepted in mFRR too, then will be present in DA market**

aFRR BC marginal price	**62 €**
mFRR BC marginal price	**60 €**
DAM marginal price	**100 €**

2b. Multilateral cross-product linking
aFRR & mFRR & DAM



Objective function:

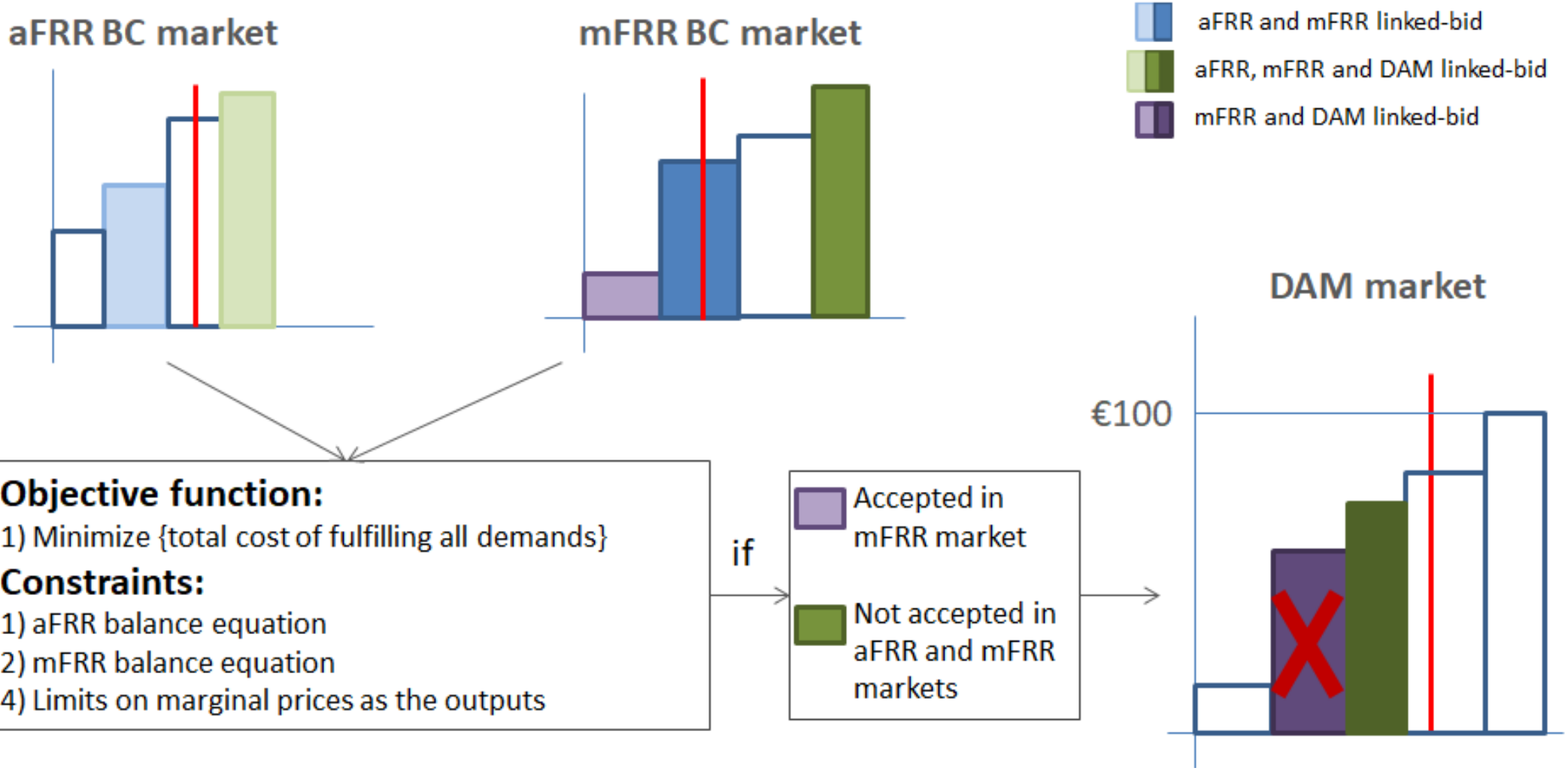
1) Minimize {total cost of fulfilling all demands}

Constraints:

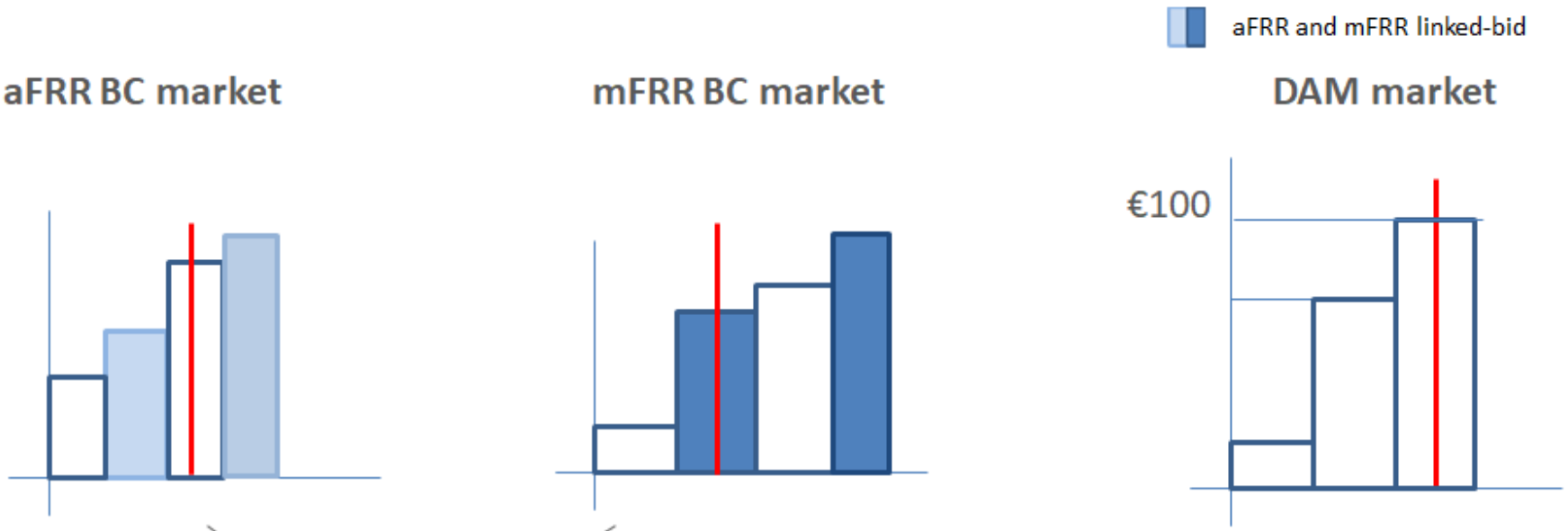
1) aFRR balance equation
2) mFRR balance equation
3) DAM balance equation
4) Limits on marginal prices as the outputs

aFRR BC marginal price	**A €**
mFRR BC marginal price	**B €**
DAM marginal price	**C €**

2b. Multilateral and Unilateral linking (aFRR & mFRR) -> DA



2b. Multilateral and no-link (aFRR & mFRR) , DA



Objective function:

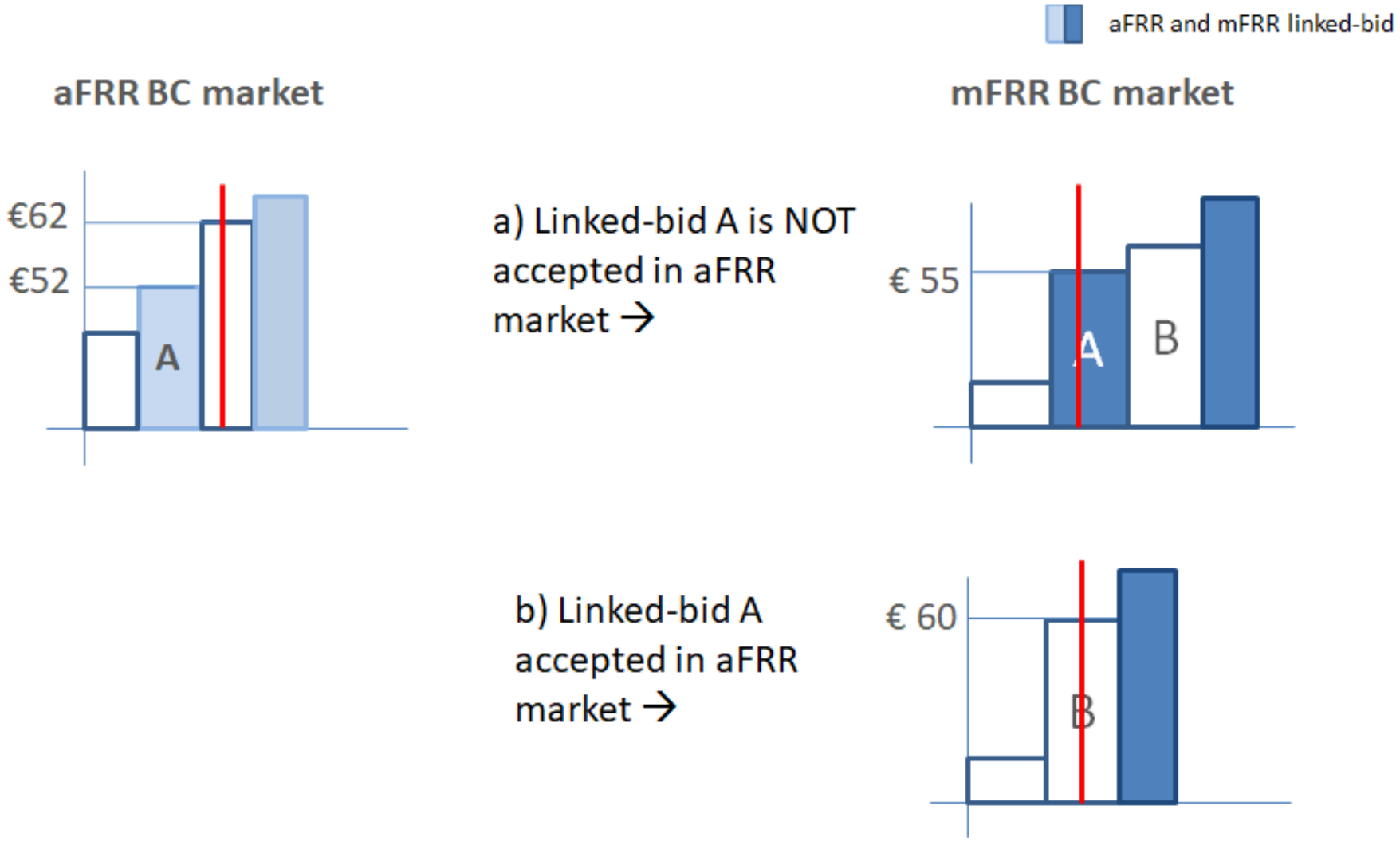
1) Minimize {The total cost of fulfilling all demands}

Constraints:

1) aFRR balance equation
2) mFRR balance equation
4) Limits on marginal prices as the outputs

aFRR BC marginal price	**A €**
mFRR BC marginal price	**B €**

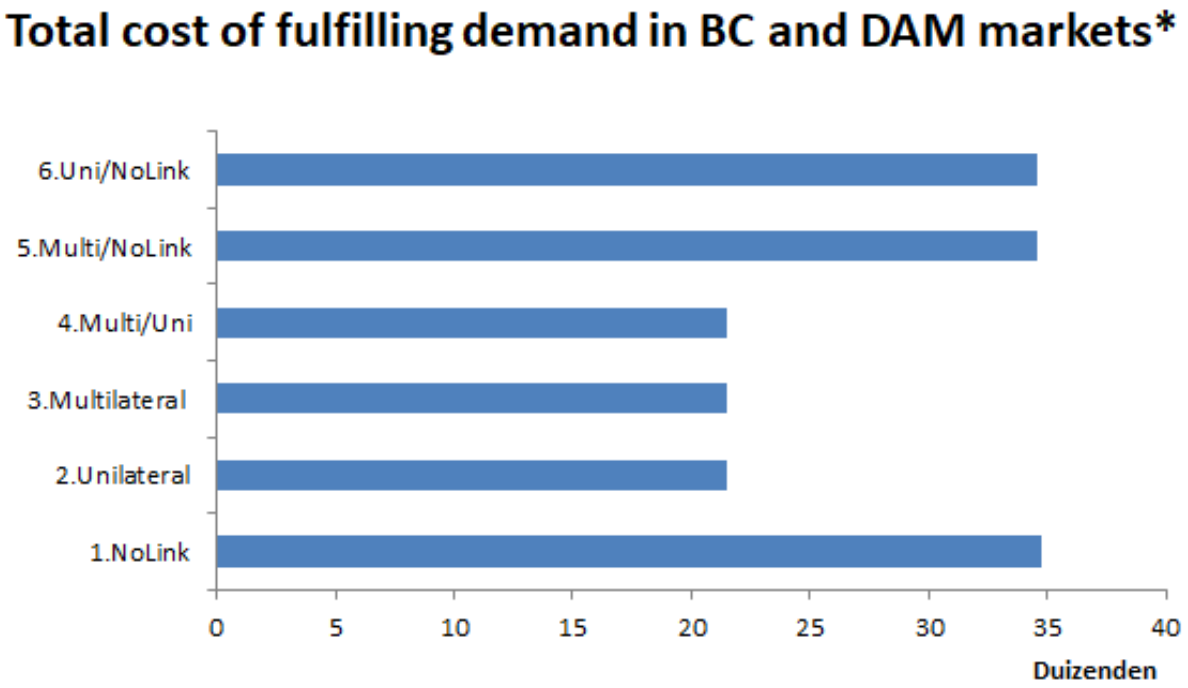
2b. Unilateral and no-link (aFRR -> mFRR) , DA



2b. Welfare impact of cross-product linking of bids

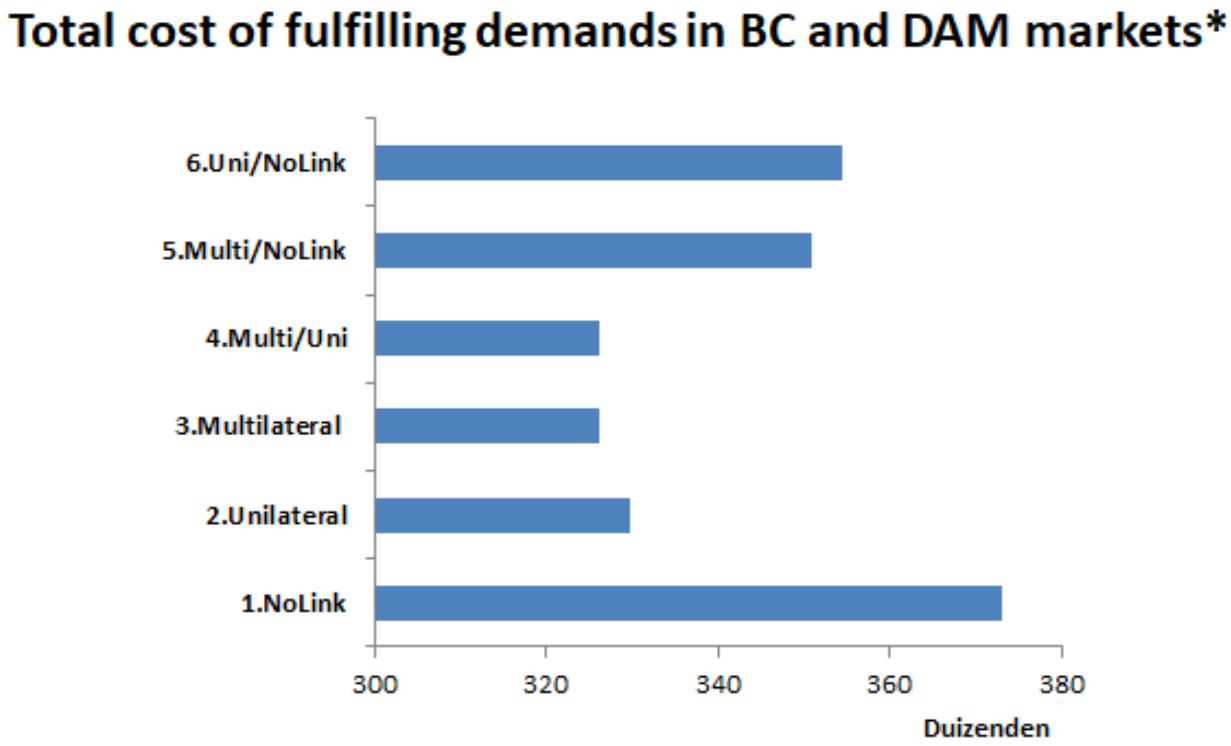
1. Welfare impact of cross-product linking of bids in a national market

2b. Total cost of fulfilling demands case study: the Netherlands



Total cost of fulfilling demands = aFRR BC marginal price aFRR BC demand + mFRR BC marginal price* mFRR BC demand + DAM marginal price * DAM demand

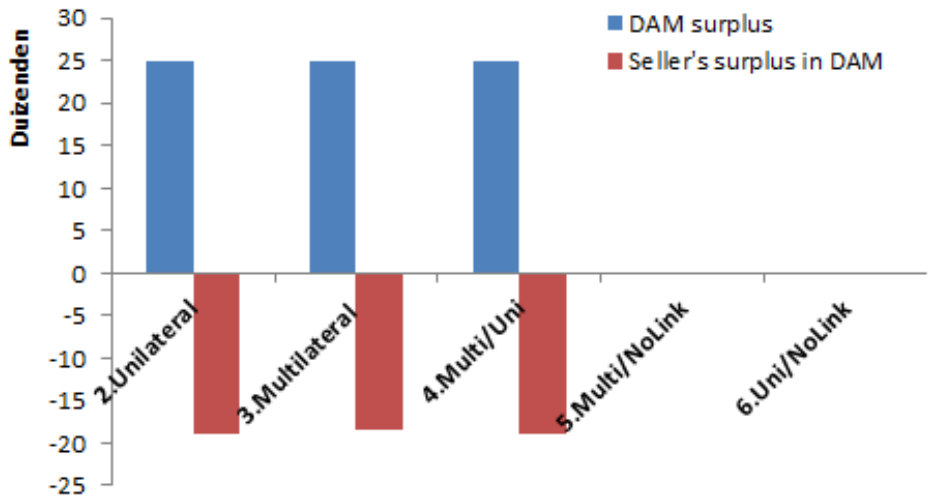
2b Total cost of fulfilling demands case study: Germany

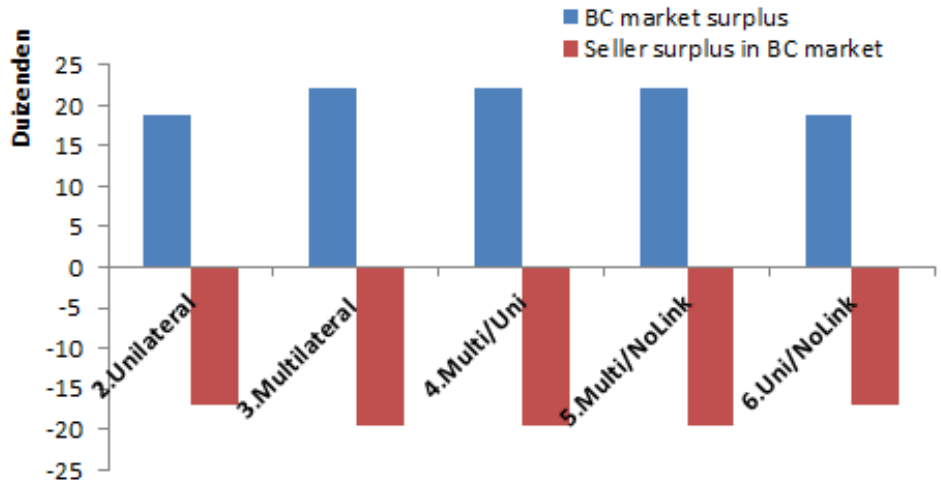


Total cost of fulfilling demands = aFRR BC marginal price aFRR BC demand + mFRR BC marginal price* mFRR BC demand + DAM marginal price * DAM demand

2b. Buyer and Seller surplus
case study: Germany

Total buyer and seller surpluses in DAM and BC market*





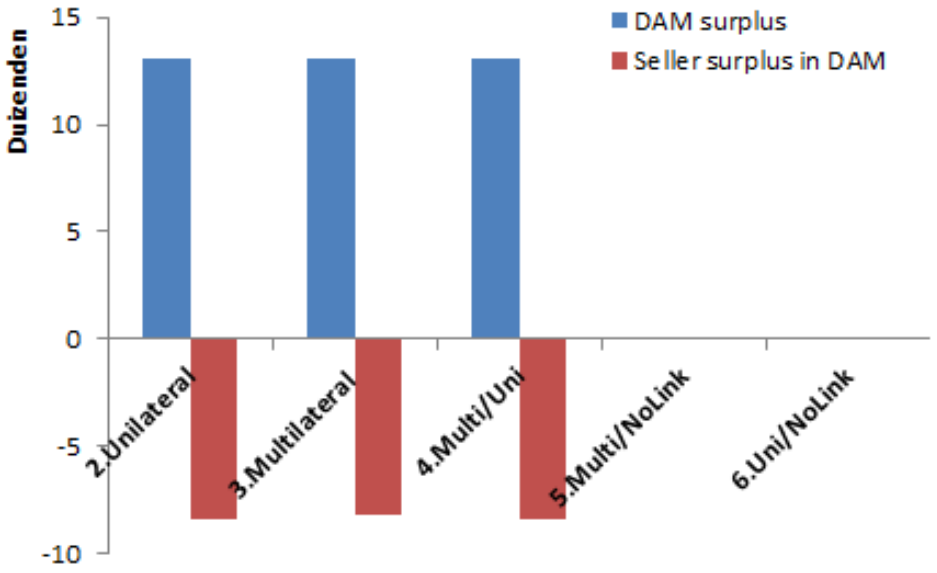
There are three kinds of sellers which can be affected differently by linking bids:

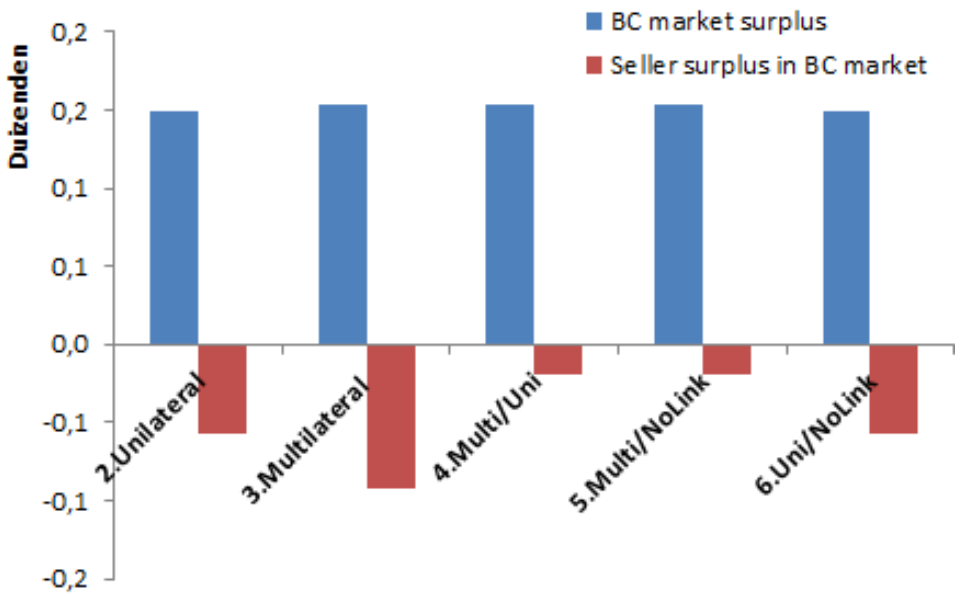
1. Sellers who are very cheap and in any case they always stay in the market→ **their surpluses decrease**
2. Sellers who stay out of the market due to the linking bids → **their surpluses decrease**
3. Sellers who stay in the market due to the linking bids → **their surpluses increase**

*This figure shows the relative surpluses of different linking bid options to the surpluses in the option "No Link".

2b. Buyer and Seller surplus case study: the Netherlands

Total buyer and seller surpluses in DAM and BC market*



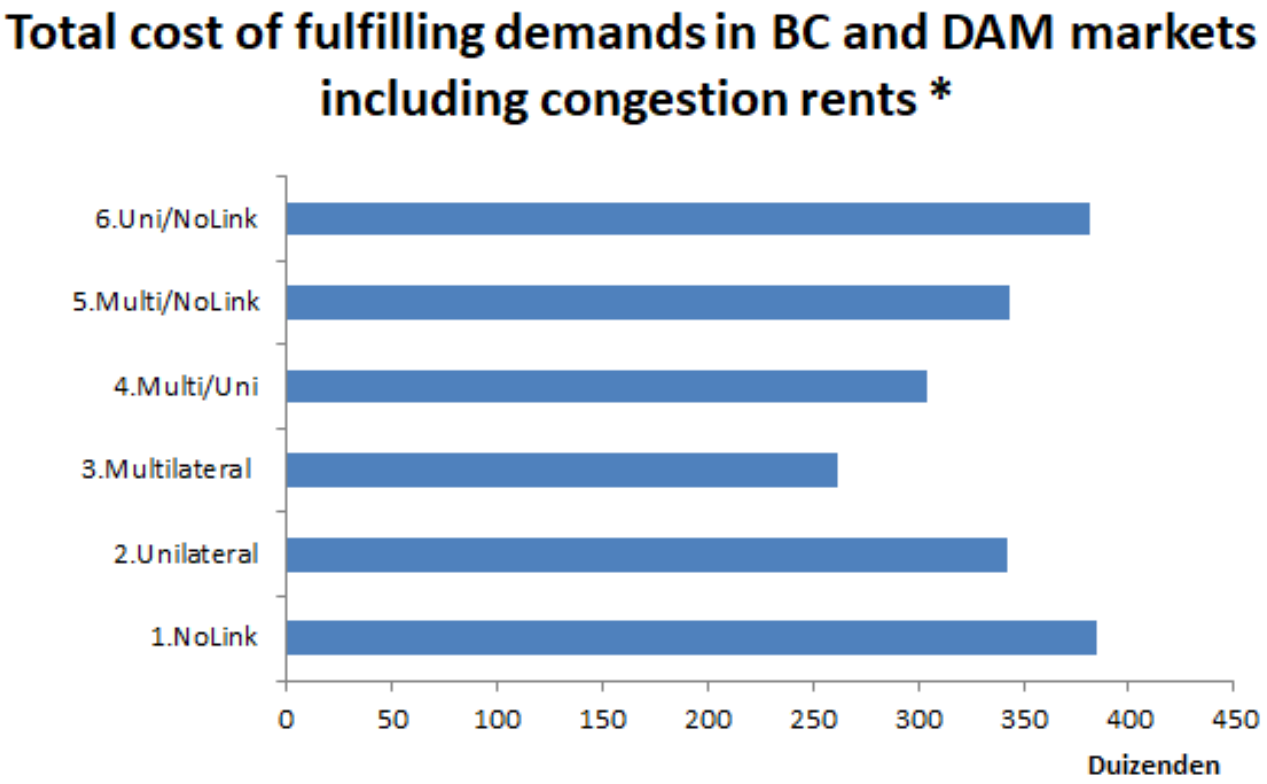


*This figure shows the relative surpluses of different linking bid options to the surpluses in the option "No Link".

2b. Welfare impact of cross-product linking of bids

2. Welfare impact of cross-product linking of bids with cross-zonal capacity

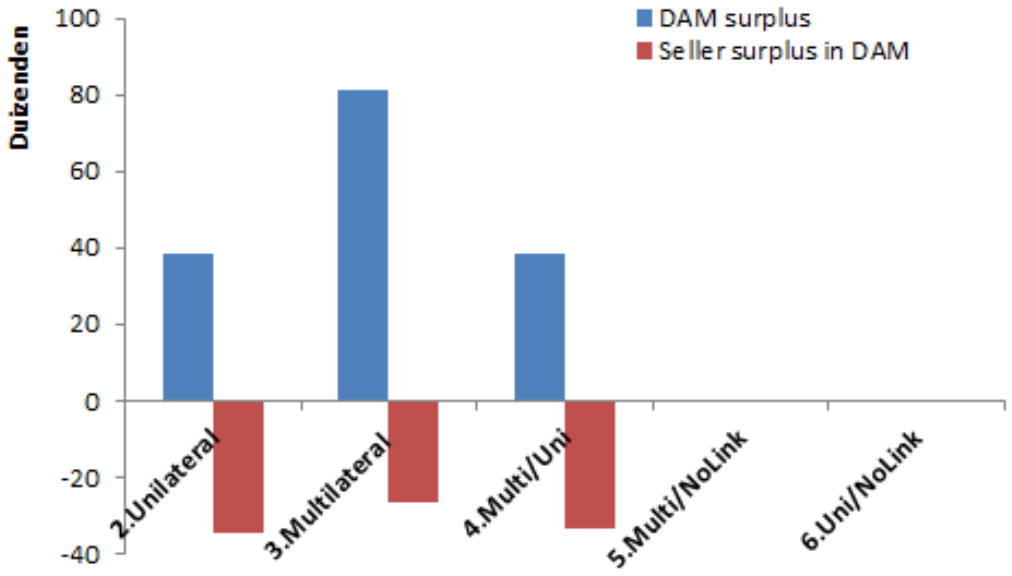
2b. Total cost of fulfilling demands
Congested cross-zonal border

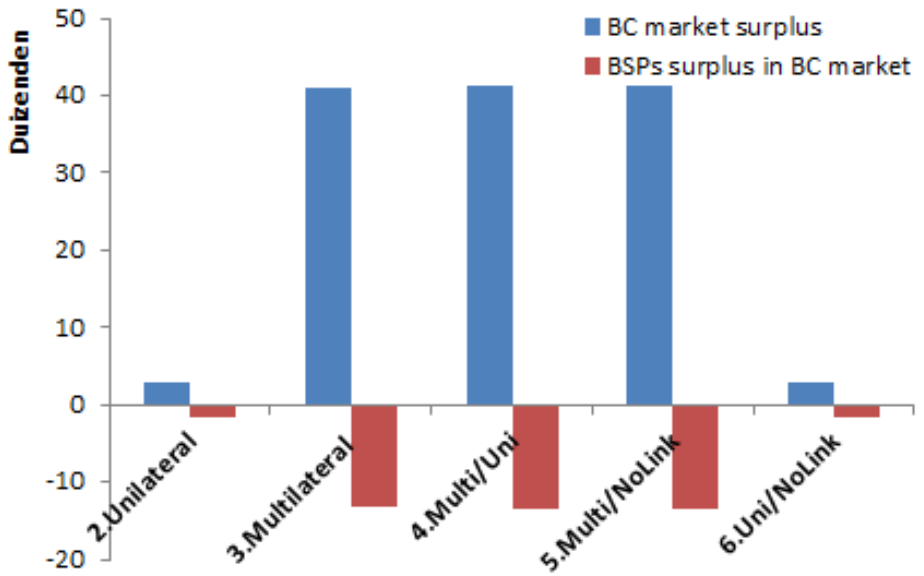


Total cost of fulfilling demands = aFRR BC marginal price aFRR BC demand + mFRR BC marginal price* mFRR BC demand + DAM marginal price * DAM demand

2b. Total Buyer and Seller surplus
Congested cross-zonal border

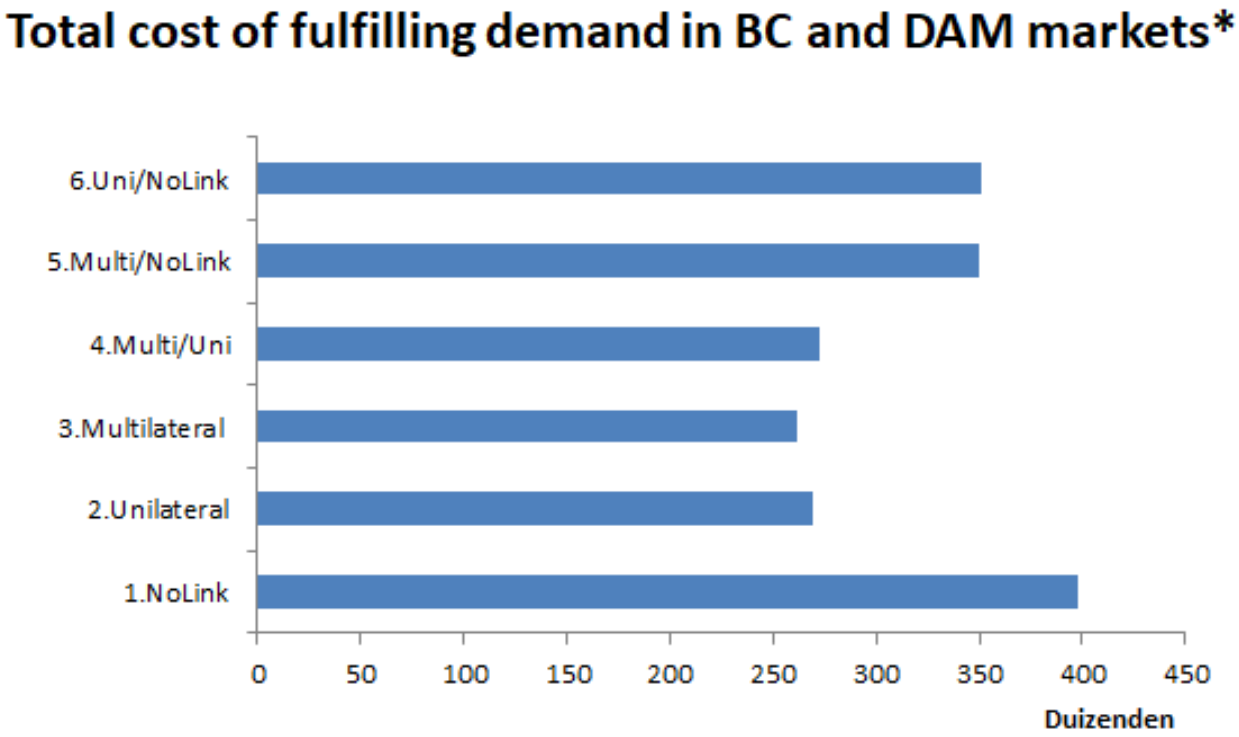
Total buyer and seller surpluses in DAM and BC market*





*This figure shows the relative surpluses of different linking bid options to the surpluses in the option "No Link".

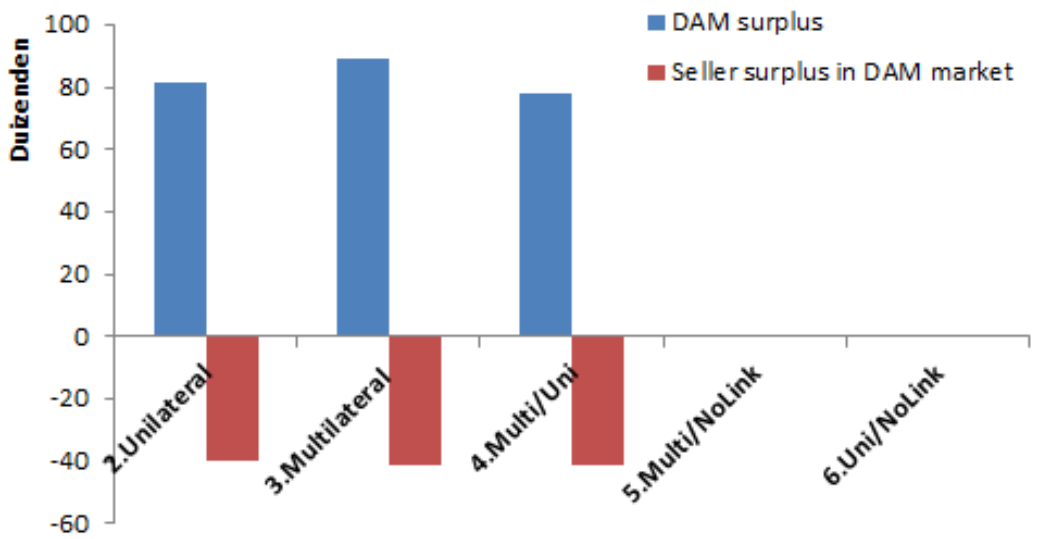
2b. Total cost of fulfilling demand
Uncongested cross-zonal border

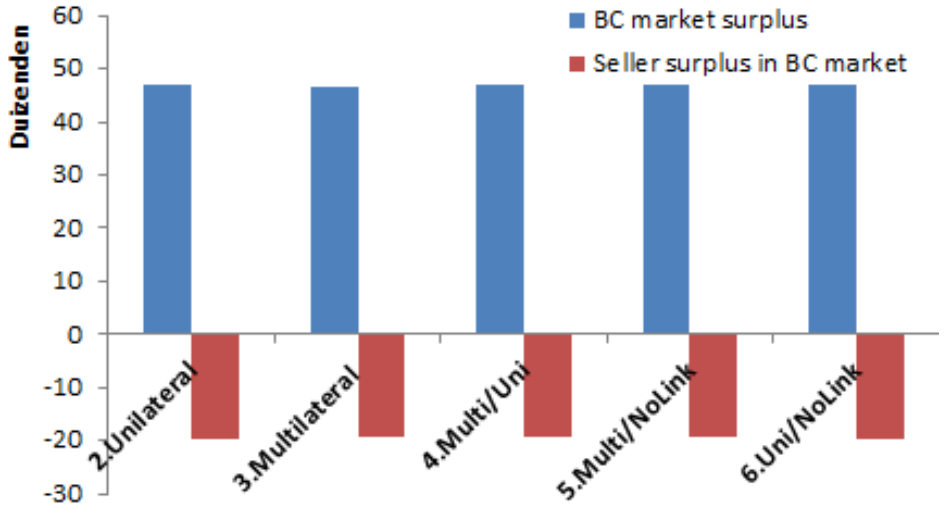


Total cost of fulfilling demands = aFRR BC marginal price aFRR BC demand + mFRR BC marginal price* mFRR BC demand + DAM marginal price * DAM demand

2b. Total Buyer and Seller surplus
Uncongested cross-zonal border

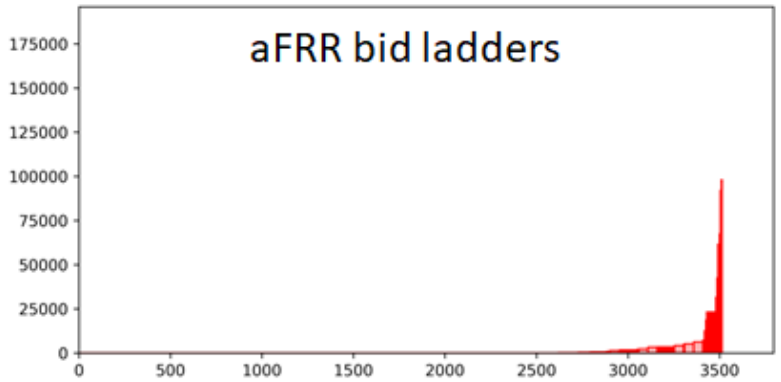
Total buyer and seller surpluses in DAM and BC market*



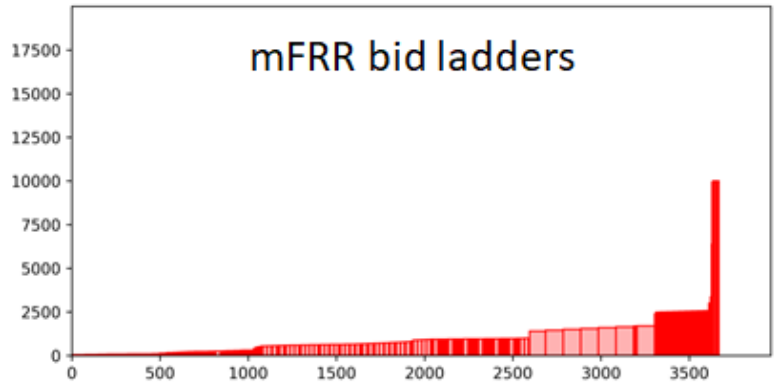


*This figure shows the relative surpluses of different linking bid options to the surpluses in the option "No Link".

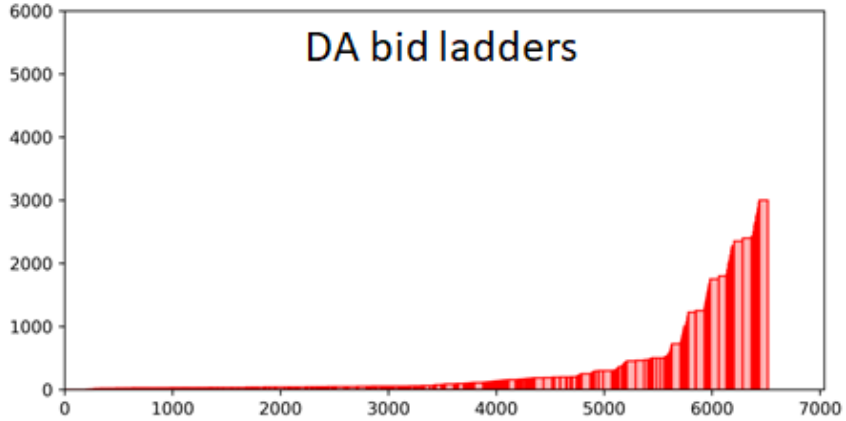
Input data for Germany



Demand: 900
Price cap: 3000

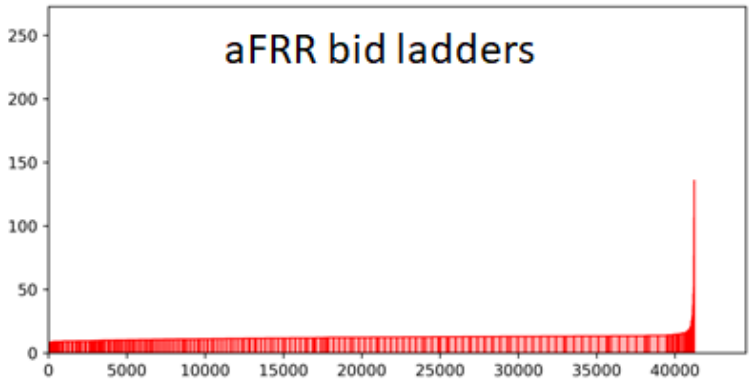


Demand: 400
Price cap: 3000

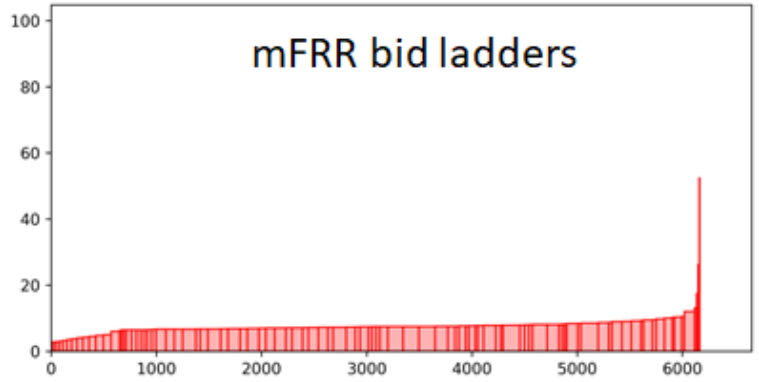


Demand: 4000
Price cap: 3000

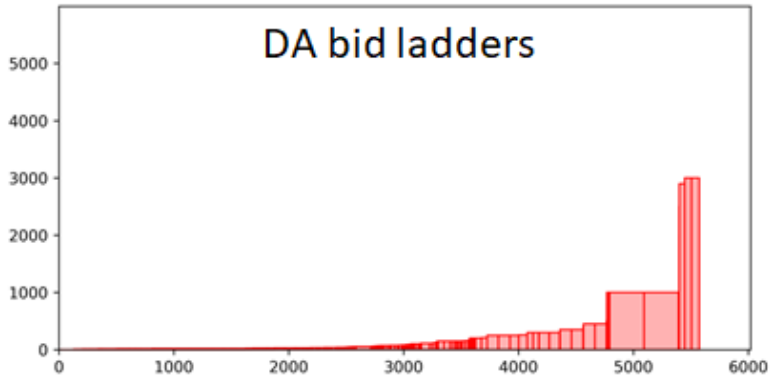
Input data for the Netherlands



Demand: 150
Price cap: 3000



Demand: 50
Price cap: 3000



Demand: 1100
Price cap: 3000