Industry4Redispatch (I4RD)

Deliverable 7.1

Cost-benefit analysis of the solutions developed in I4RD for the stakeholders and the system as a whole

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Document control information	
Title	D3.1 Cost-benefit analysis of the solutions developed in I4RD for the stakeholders and the system as a whole
Dissemination Level	☐ **CO** Confidential, only for members of the consortium ☐ **RE** Restricted to a group specified by the consortium ☐ **PP** Restricted to other programme participants (NEFI) ☒ **PU** Public
Status	☐ Draft ☒ WP Manager accepted ☒ Co-ordinator accepted
Action requested	☐ to be revised / added to by Partners ☐ to be reviewed by applicable Partners ☐ for approval of the WP Manager (EB) ☐ for approval of the Project Coordinator
Requested deadline for Action	

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GLOSSARY

CAPEX

Capital expenditures

CBA

Cost-benefit analysis

DA

Day-Ahead

DSO

Distribution system operator

EPEX

European Power Exchange

FSP

Flexibility service provider

OPEX

Operational expenditures

RD

Redispatch

TSO

Transmission system operator

UC

Use Case

WP

Work Package

1. Introduction

Cost-benefit analysis (CBA) is probably the most comprehensive method of economic evaluation available. In general, a CBA is conducted by systematically cataloguing the impacts of benefits and costs of two or more alternative scenarios. Usually, a CBA tries to consider all of the costs and benefits to society as a whole [1]. As for the project Industry4Redispatch, the main focus is on evaluating the impact of integrating industrial flexibility in the redispatch (RD) provision process, the aim of the conducted CBA is more on determining individual costs and benefits for providers of redispatch as well as the costs for the TSO.

The process of conducting a CBA can be broken down into the following steps [1]:

1. Explanation of the purpose of the CBA
2. Specification of base case and alternatives
3. Identification of monetizable impact categories
4. Discount benefits and costs (if applicable)
5. Computation of the net present value of each alternative (if applicable)
6. Make a recommendation

This deliverable deals with steps 1. to 3. and gives an outlook on the methods used for step 4.

Explanation of the purpose of the CBA

As already mentioned, the focus of the conducted CBA is on evaluating the impact of integrating industrial flexibility in the redispatch (RD) provision process. As the economic goals of the involved stakeholders differ significantly, it has been decided upon conducting an individual CBA for each of them.

Specification of base case and alternatives

As for the purpose of the CBA, the analyzed base cases and alternatives differ dependent on the stakeholder in focus. Therefore, case-specific baselines and alternatives have been designed, whereby one can roughly differentiate between the base case as "state of the art" (i.e., without involvement of industry in the RD process and without TSO-DSO interaction process) and the I4RD scenario (i.e., with RD provision from industry).

Identification of monetizable impact categories

In practice, there are numerous options for economic efficiency calculations and as the distinctive features of each involved stakeholder strongly differ, the selection of the best alternative, especially when it comes to complex investment processes, requires a detailed analysis of the different implications that each method has on the final results of the project. Therefore, defining the crucial factors for each stakeholder is key to the deduction of conclusive results. In general, defining criteria and respective metrics is very critical and controversial, since the whole conception of values needs to be considered, which is inherently subjective. Therefore, a special focus was on the involvement of the individual stakeholders. As the specific impact, e.g. amount and distribution of associated costs, revenues, etc. differ for the involved stakeholders, each conducted CBA has to take into account the respective requirements and framework conditions.

Monetization of impacts and framework conditions is to a large extent based on conducted calculations and simulations. The foundation for these calculations has been laid in previous work packages.

This deliverable contains the methodology for the CBA and the definition of corresponding scenarios that will be compared. The basis scenario for the CBA is Use Case (UC) 4, which is about TSO Redispatch (defined in D3.1). In UC 4, flexibility from the industrial sector is used to participate in the Day-Ahead market as well as to provide redispatch bids to a redispatch platform where bids can be accesses by the TSO.

Section 3 describes the different steps required to carry out the CBA, the specification of the examined base case and alternatives and the identification of impact categories for the industrial sector, aggregator, TSO and DSO. Grid simulations that result into the redispatch clearing process have been used to estimate redispatch demand and activation for various locations and participants. The corresponding methodology is described in Section 4.

2. Required processes for different stakeholders

As mentioned in the introduction, stakeholder needs and expectations are quite diverse. Therefore, it is necessary to analyse the profits and costs as well as the required processes for each stakeholder separately. This chapter provides an overview of the steps required for the CBA plus their specific assumptions for industry, TSO, aggregator, and DSO.

2.1. Industry perspective

For each of the industry sites participating in the project, an individual profitability calculation will be carried out. For the industry, the most important aspect is to find a calculation method for evaluating economic efficiency of investments in new equipment. It is important to note that, especially when it comes to investment decisions for industry that focusses on final product manufacturing, each industry site has its own distinctive criteria that must be considered.

The first step for conducting the CBA is to define a site-specific baseline scenario. The baseline scenario is based on historically measured (and eventually up-scaled for a representative period) consumption data. The consumed energy is assumed to be purchased at quarter hourly day-ahead spot market prices or produced on-site, e.g. in hydro power plants or thermal conversion units (e.g. turbines or gas engines). Beside the DA electricity costs, the total costs in the baseline scenario include natural gas prices (assumption for simplification: monthly changing gas prices) and certificate costs as well as taxes and fees for electricity and natural gas grids. For the case of industry sites that currently provide balancing energy, balancing energy prices are not included in the baseline scenario.

The actual revenue estimation for the industry sites is based on site-specific RD bids per day, that are generated through a specific optimization framework (derived in WP4). In a first step, the electricity consumption is optimized under the constraint of EPEX-Spot DA prices, under perfect foresight of prices, with the objective to minimize overall costs. Based on this cost-optimal schedule, the optimization framework takes an estimation of RD demand in form of call probabilities as an input (see WP 4) and calculates (the most likely) highest possible redispatch bids including their costs (RD bid price), which are then forwarded to the redispatch clearing process. To represent the competition of RD bids from industry with RD bids from conventional plants it is also necessary to include the bids from conventional power plants in the redispatch clearing. The calculation of redispatch demand is done by using a physical simulation of the transmission grid as well as historical production and consumption data. A clearing subject to power flow constraints is implemented using an optimization model that considers all available bids as well as available transmission capacities (see Section 3.3).

The bid clearing algorithm provides as an output the activated bids. The revenues from these activated bids are evaluated in the first post-processing step. In the second post-processing step, the revenues are adjusted by additional costs and revenues such as intraday electricity costs, e.g., covering catch-up effects and consideration of free emission certificates. An overview of the optimization as well as the post-processing steps is given in Figure 2.

The whole process is shown in Figure 1. The simulation steps which are closely related to the grid calculations, described in Section 3.3, are marked in blue. Input, that comes from industry simulation and optimization as part of WP4 is depicted in pink. The remaining steps, that are carried out specifically for the CBA are coloured in green. The process serves to gather all data, which is necessary to calculate for example amortisation times and suitable heights of a mark-up. Other KPIs that are evaluated based on the industry-CBA are[1]

- total revenues/ energy costs per industrial site
- cost reduction/ additional income per industrial site
- investment costs for flexibilization per industrial site

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[1] See also D3.1

- additional OPEX for flexibilization per industrial site

The CBA will be conducted under the following assumptions

- It is assumed that there are no special supplier tariffs for electricity for industry sites; for better comparison, the total electricity costs are calculated by using hourly EPEX spot prices.
- A final height of remuneration for redispatch bids will not be defined within the project. Therefore, a sensitivity analysis is carried out in the course of the CBA, where different mark-ups are evaluated.
- Other potential industry bids are not considered in the clearing process, therefore, there are no additional competitors compared to the status-quo.
- No minimum bid size is required, and no aggregation is simulated. The assumption is, that there are always other assets available to aggregate with to reach the minimum bid size.
- The exact location of the bid within the distribution grid is not considered. The impact of the bid (sensitivity) lies 100% at one defined grid node.
- No TSO-DSO interaction is considered for the CBA of a specific industry site since the real DSO grid topology is not available and is subject to change in the next years. Assumptions concerning this matter would highly influence the outcome of the CBA. This uncertainty factor was decided to be neglected, therefore blocking of bids by the DSO is neglected.
- The Redispatch forecast, which serves as input for the industry optimization, is assumed as the average of historical redispatch demand per hour at the corresponding grid node.
- The CBA is planned for at least one historical year (2019) and two future years (2030/2040). The methodology for the simulation of future redispatch demand is currently in development.

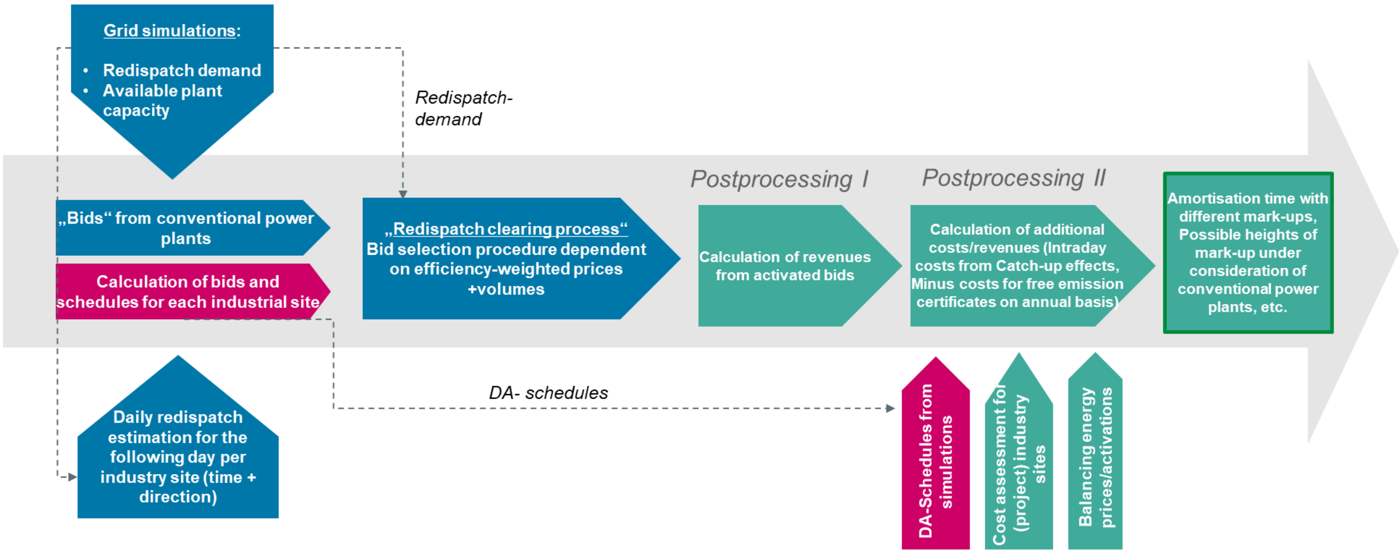
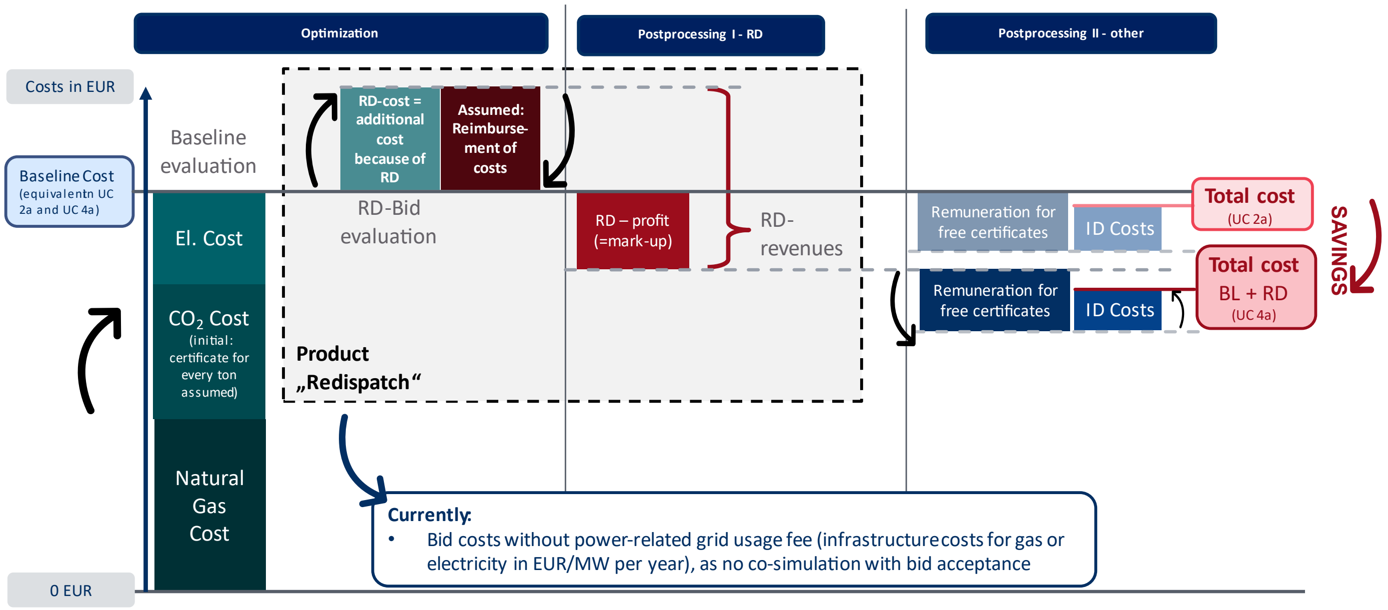


Figure 1 CBA Process from industrial perspective: Simulation steps closely related to the grid calculations in blue. Input from industry simulation and optimization (WP4) in pink. The remaining steps, that are carried out specifically for the CBA are coloured i



Currently:

- Bid costs without power-related grid usage fee (infrastructure costs for gas or electricity in EUR/MW per year), as no co-simulation with bid acceptance

Figure 2 Visualization of considered cost-components for positive flexibility for Redispatch (RD) with bid costs (for the TSO > 0 in general). Here total costs for Use Case 2a and 4a are shown and compared, definition of costs for redispatch bids derived by the optimization, visualization of savings in Use Case 4a compared to Use Case 2a – open question is the definition of the Redispatch profit in the post-processing step 1 (=mark-up)

For the economic assessment the following definitions are introduced:

Table 2-1 Definition of cost, profit and revenue from an industrial perspective for Redispatch (RD) provision

German Term	English Term	Definition
RD-Erlös	RD-revenues	Financial consideration the company receives from the TSO for providing redispatch, case distinction. ➔ Positive flexibility: additional costs are covered + Mark-up ➔ Negative flexibility: Mark-up - fuel savings
RD-Kosten	RD-costs	Costs incurred by a company in delivering a bid, Case distinction: ➔ Positive bid price – industrial site has costs e.g. for energy sources (other than electricity) that have to be procured, usually: positive flexibility ➔ Negative bid price – industrial site has costs for "electricity post-purchase" when the bid is awarded.
RD-Gewinn	RD-profit	Difference between RD costs and RD revenues, regardless of positive or negative flexibility ➔ Profit = Mark-up

2.2. TSO perspective

The CBA for the TSO aims at reflecting the total redispatch costs from a whole Austrian perspective.

In this case the baseline scenario is the status-quo, which means redispatch costs without industry participating in flexibility provision. First, redispatch demand is calculated and bids from conventional power plants are generated. With this input, a redispatch clearing algorithm is applied, resulting in activated redispatch bids and the respective costs for redispatch provision. This scenario will be verified with actual redispatch costs in the corresponding year. This methods for grid simulation and redispatch optimization are described in further detail in Section 4.

To quantify the influence of industry participating in the redispatch process, available flexibility potential per industry sector is used, which has been deduced in work package 3. Typical bid patterns as well as load profiles per industry sector will be derived from this analysis. These industry bids will be geographically distributed in the Austrian electricity network according to available statistical data and additional available information about the location of large industrial plants.

In terms of compensation, different remuneration options have been discussed in deliverable D3.2. The conclusion was that the bid costs inevitably need to cover at least the amount of actual costs for the industry's redispatch provision. Furthermore, some additional incentive for industry is required, as without any regulatory obligation, the relating effort of flexibility provision is way too high as for the industry to be profitable. Further, it could be shown in WP3 that a potential market, including the additional flexibility potential of industry, does not provide enough liquidity to function optimally and therefore is not a viable solution at the moment. A final remuneration scheme will not be decided on within the project, but there are some options which could be conceivable and therefore will be, potentially among others, investigated in the further course of the CBA:

a) **Mark-up for all bidders:** A specific mark-up could be defined per MWh of energy provided for redispatch, which every bidder receives independent of their actual costs (industry sites as well as conventional plants). The costs of the total redispatch considering only conventional power plants without any mark-up will be compared with the costs of total redispatch including industry and a mark-up for all bidders. There will be an intersection, where the total costs with mark-up and industry will be the same as without mark-up and without industry. This point will define the maximum mark-up, suitable mark-ups will likely lie between this mark-up and zero. If the maximum mark-up turns out to be zero, a qualitative analysis will be carried out.

b) **Mark-up only for industry:** A specific mark-up could be defined per MWh of energy provided for redispatch, which all industrial/decentralized bidders receive independent of their actual costs. The assumption is, that conventional power plants are part of the grid reserve and therefore remunerated as they are used to (without mark-up). The mark-up could range from (slightly-above) zero up to a mark-up, where no industry plants will be activated anymore, because conventional plants are always cheaper. The real mark-up will likely lie again somewhere in between these two limits and is target of the investigation. If the range of the mark-up turns out to be zero (industry is never activated), a qualitative analysis will be carried out. Additionally, a sensitivity analysis on how much of the flexibility potential will be used by the TSO with which markup is planned.

c) **Investment support:** The bids are remunerated cost-based, but there is an incentive for investment provided by the TSO. This means for the CBA, that only the actual costs for redispatch provision are considered in the clearing-process. The savings for redispatch provision can be calculated and compared to the assumed costs for investments by industry. A qualitative analysis could be carried out, whether support in investment would be a viable solution compared to the mark-up.

d) **Separate (and sequential) market for industry:** Another option is to procure a certain volume of redispatch from distributed flexible resources in a separate market, that is cleared before the activation of conventional power plants for redispatch. However, the modelling of realistic (strategic) bidding behavior of market participants in new market systems requires agent-based models and is not foreseen within the scope of the project I4RD. Therefore, a uniform pricing mechanism will be assumed for all industrial bidders, where industrial market participants bid their marginal costs, analogical to the day-ahead market. It will be investigated, how many industrial bids can be activated in this way until the overall costs exceed the current costs, as well as the optimal resulting volume of procured industry bids. This volume will be compared to the overall available and suitable flexibility volume of industry bids in each timestep. In this way, it can be evaluated, which amount could be ideally procured in a potential upstream market for smaller and distributed bidders and which percentage of total available bids this amount makes up.

For the CBA process from the TSO perspective the bid clearing process described in Section 4.3 is used. As output, the algorithm provides the activated bids from conventional power plants as well as from industry. These costs can be then compared with the baseline scenario. Furthermore, different KPIs will be calculated, such as

- the number of hours in which redispatch was activated
- the total amount of energy activated for RD or typical duration of congestions

The most project-critical outcome of the CBA will be the cost savings for redispatch including bids from industry compared to conventional redispatch and amounts of conventional RD that can be prevented by using the concept of I4RD.

The CBA will be conducted under the following assumptions:

- All bids (industrial as well as conventional) are considered within one common Merit-Order. No sequential clearing scheme is considered, since the design of such a concept would require a lot of assumptions.
- Aggregation is not considered. Therefore, no minimum bid size is required, and no aggregation is simulated. The assumption is, that there are always other assets available to aggregate with to reach the minimum bid size.
- The exact location of the bid within the distribution grid is not considered. The bid has an impact of 100% (sensitivity) on one defined grid node.
- No TSO-DSO interaction is considered for the CBA since DSO grid topology is not available and is subject to changes in the next years. Assumptions concerning this matter would highly influence the outcome of the CBA. This uncertainty factor was decided to be neglected, therefore no blocking of bids by the DSO is considered here.
- The final remuneration for redispatch bids will not be defined within the project. Therefore, different mark-ups will be evaluated in the course of the CBA. A market-based approach, where bidders are allowed to choose their price, will not be subject of this investigation.
- The redispatch forecast is based on an average of historical redispatch demand per hour at each grid node.
- The CBA is planned for at least one historical year (2019) and two future years (2030/2040). The methodology for the simulation of future redispatch demand is currently under development.

An overview of the described process is given in Figure 3.

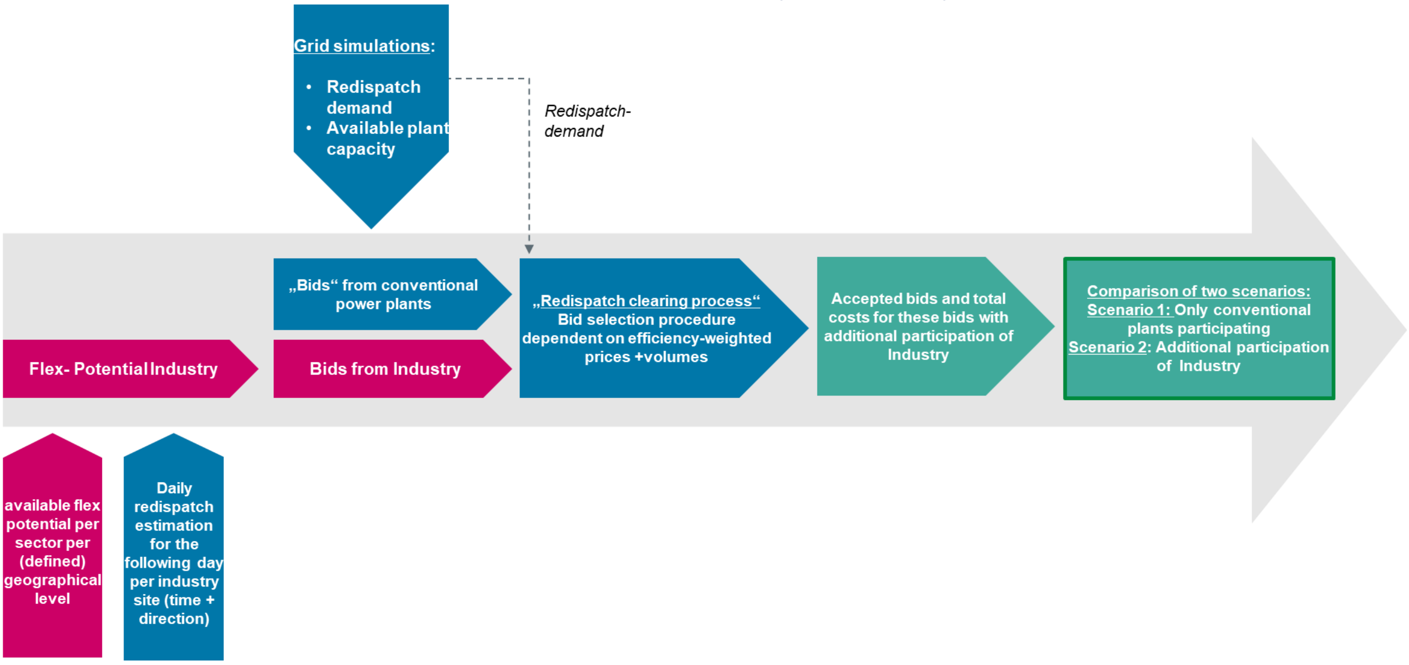


Figure 3 CBA Process from TSO perspective

2.3. Flexibility service provider (FSP) perspective

Main goal of the CBA conducted from an FSP’s point of view is to evaluate the possible revenue potential for the FSP. It needs to be noted that the cost-benefit analysis for FSPs is highly dependent on the selected business cases and chosen fee for the provided aggregation service. Generally spoken, if the outcome of the industry and TSO CBA is positive, there are possible rentable business cases for FSPs. There exists a high co-dependence.

The initial process of determining flex bids from industry as well as the clearing of redispatch, will be the same as the one for the TSO described in Section 2.2. It is assumed that there is no further aggregation step between the creation of industry bids and the actual bidding at the market, since the outcome is highly dependent on a lot of factors:

- Are there enough bids available for aggregation to reach the minimum bid size within one allowed aggregation area?
- By combining which assets does the FSP reach the minimum bid size?
- Which individual costs do the single assets have, are their costs quite similar? Is the distribution of costs in one potential aggregated bid rather wide or very narrow?
- Will the FSP be able to provide any kind of forecast which changes the bidding behaviour of single plants and therefore the aggregation possibilities?
- If there are enough assets available: What will be the aggregation strategy? It could be e.g. to mix cheap and expensive bids for aggregation, aggregate only bids with similar prices, etc.
- How are the plants located within and in between the 110 kV grids? Some areas could be more useful for aggregation than others, but there is only a limited amount of information about the distribution grids available.
- The suitability of business models, also depends on other currently available business and marketing models, such as the provision of balancing reserve. How are the business models for balancing reserve currently designed? Is there a “flat-rate” fee for marketing the full potential or is it remunerated per marketed MW of accepted capacity/energy? Or is it a percentage of the achieved revenues?
- How do the probabilities of activation for redispatch change the business case?

- Will there be several active FSPs participating? This would again have impact on liquidity, cost distribution etc.

A partly qualitative, partly quantitative analysis is planned to figure out some of the answers to the questions above.

Evaluation of revenue potential:

As a result of the TSO analysis, a certain range that a mark-up could have will be figured out. In the case that only industry plants get remunerated with this mark-up, it could range from a mark-up of zero, to a specific mark-up where no industry plants will be activated anymore, because conventional plants are always cheaper. The real mark-up will likely be somewhere in between these two limits. If all participating plants receive the mark-up, there will be an intersection, where the current redispatch procurement would be cheaper than the proposed scheme including industry and rewarding a mark-up to all the plants.

The FSP very likely will get a share of this markup unless the costs for aggregation will be included in the fixed costs. Therefore, one important aspect to consider is that the determined maximum mark-up has to already include the share that is reserved for the FSP. This reduces the actual revenue for the industry but also predicates the revenues of the FSPs on the amount of actually activated bids and the respective bid volumes.

Based on the possible mark-ups, the range of the possible revenue potential for the FSP can be determined. In terms of entry barriers, additional costs for equipment and/or personnel are very hard to determine, since it varies a lot for each industry site (i.e., if the industry site is already offering its flexibility for balancing services) and also depends on the design of the redispatch module.

Profitability for the FSP also depends on the activation probability of redispatch for each individual industry site. If some sites are never activated for redispatch and cannot provide other flexibility services, such as balancing reserve as well, then it might not be profitable to connect these sites to the FSP. But also other factors can contribute to whether to connect an asset or not, i.e., such as strategical reasons for important customers.

Also, the design of the redispatch platform is highly important, whether an FSP will decide to provide his service or not. If it will be the same interface as for balancing reserve, which FSPs are already used to, then the effort to connect would be quite low. If there is a new interface developed, then the profitability needs to be evaluated individually.

Possible business models:

The contracts between flexibility service providers and industry are currently quite diverse. The remuneration for the FSP could for example be designed as 1) a flat-rate or as 2) a percentagewise share of revenues. Option 2) would provide an inventive for both stakeholders to maximize the revenues and market flexibility in the most profitable way, which is not given necessarily for the FSP in option 1). For the FSP, the connection of a larger asset might not be more (or even less) effort than the connection of a small asset. From this perspective, option 1) might seem again as the fairer option, since the revenues in option 2) would be much higher for the FSP. From experience it can be said that the preferences of customers are very individual and therefore the business models and contracts do highly vary individually for each industry site. Therefore, it is not possible to conclude general statements for rentability.

Other aspects that influence aggregation:

Another aspect that can be investigated is the price distribution of assets within one area. A question is, what possibilities are thinkable for aggregation, e.g. aggregation of similar prices, aggregation of different prices and the resulting price of the final aggregated bid.

The DSOs ability to block bids is also highly relevant for the FSP, in particular the bid blocking mechanism. Especially, the involved data flow is crucial as the FSP would benefit from information on why certain bids have been blocked.

If a plant is unlikely to be activated in a certain area, it might not be profitable for the FSP to connect it to the pool. If there is a possibility to know beforehand, how likely it is in a certain location to be activated for redispatch (e.g. a request to the TSO with a likelihood of activation rating between 1-10), it would clearly ease effort for providing aggregation services.

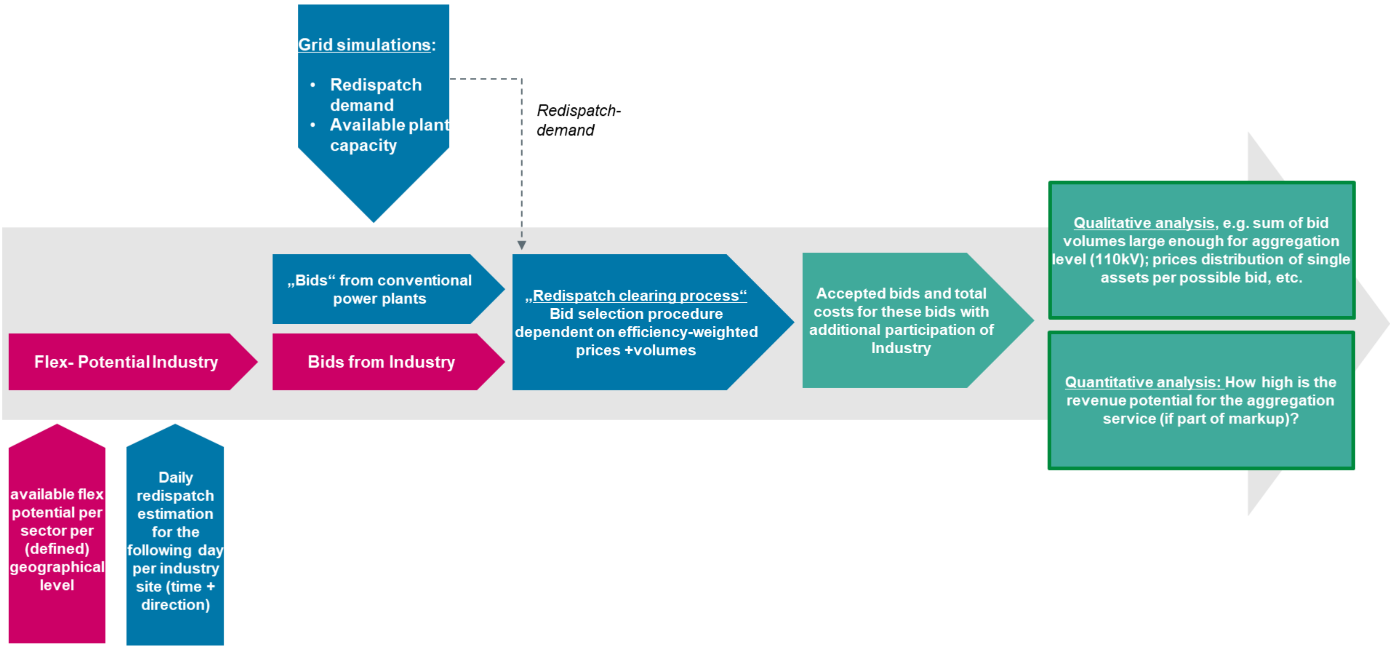


Figure 4 CBA Process from FSP's perspective

2.4. DSO perspective

Distribution networks were traditionally planned based on the estimated peak demand and annual demand increase, and by assuming concurrency factors below 100%. Using distributed flexibilities to provide ancillary services to the TSO was not considered in the planning of distribution networks. Consequently, the simultaneous activation of redispatch bids (whose providers are connected at the distribution level) may provoke much higher concurrency factors and thus violations of the operational distribution network limits. This issue can be addressed by conventional network reinforcement or by integrating the DSOs into the redispatch process. The interaction process specified in D5.1 allows the DSO to

a) block bid combinations (activated for redispatch at the transmission level) that provoke limit violations, and
b) activate bid combinations that mitigate existing limit violations (conduct redispatch at the distribution level).

The DSO CBA presented in this deliverable focuses on option a), since it is prioritized by the involved DSOs, as option b) is currently not needed. In the case of option a), the DSOs can support redispatch at the transmission level in two distinct ways: by conventional network reinforcement that makes all bid sets feasible; or by providing the data that is necessary to filter the infeasible bid sets out.

Consequently, the DSO CBA should compare the costs of network reinforcements with the costs of establishing and operating a system that generates and communicates the data required by the bid set filter. Such a system contains distributed measurement devices and advanced distribution management system functionalities, whose costs are not quantified within this project. To overcome this issue, the DSO CBA conducted in this project takes a different path: it analyses the impact of distribution network reinforcement on the TSO's redispatch costs as follows:

To calculate the base case, which are the costs for network reinforcement for flexibility usage, the flexibility potential of the industry (again see D3.4) serves as a basis for RD bids from the industry located in the distribution network. After the RD bid selection procedure, including bids from the industrial sector as well as conventional power plants, it is analyzed which of the offered bids from the industry in a specific distribution network would be chosen by the clearing algorithm (see 3.3). It is then assessed to which extent network reinforcement would be necessary to allow for full utilization of those bids.

In a second scenario, a bid set filter is applied on the redispatch platform. Now, only a limited amount of network reinforcement is required, since the flexibility activation happens in a coordinated way and infeasible bid sets, i.e., bid sets whose activations provoke limit violations at the distribution level, are avoided. An overview of the described process is given in Figure 5 .

The outcome will highly depend on the selected grid, available flexibility, and industrial plant distribution within the network. Therefore, the DSO analysis serves as a case study that cannot be extrapolated to whole Austria. The CBA will be conducted under the following assumptions:

- Case study: An exemplary distribution grid is used, since only limited field data is available. The flexibility bids are assumed to be distributed equally.
- Aggregation is not considered. Therefore, no minimum bid size is required, and no aggregation is simulated. The assumption is, that there are always other assets available to aggregate with to reach the minimum bid size.
- A future scenario needs to be simulated, since historically there were not a lot of limitations in the distribution grid.
- Redispatch forecast is an average of historical redispatch demand per hour at each distribution grid area.

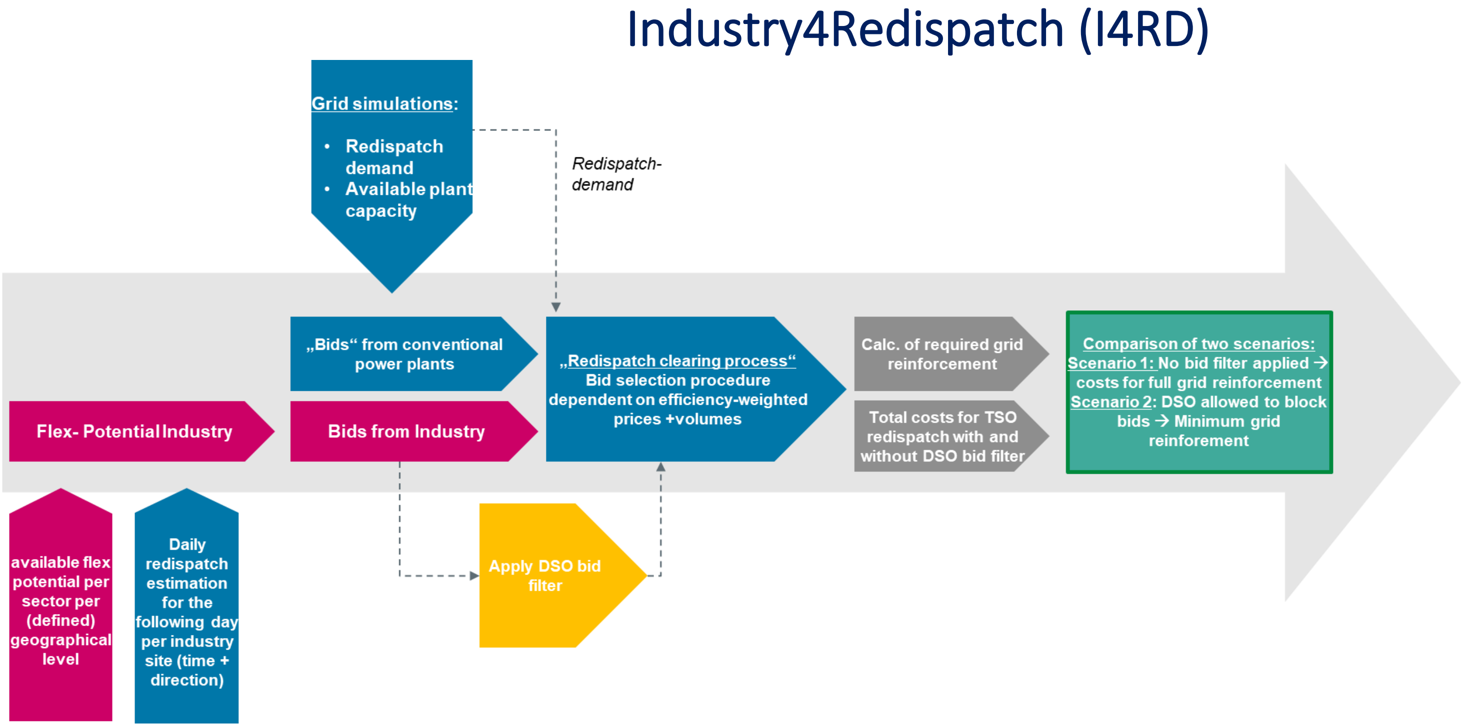


Figure 5 CBA Process from DSO perspective

3. Simulation of clearing process for redispatch

The grid simulations are used to estimate redispatch demands and activations for various locations and participants, which are subsequently used to perform the CBA from different points of view. The most important foundation to realistically model redispatch activations are the underlying power flows in the transmission grid. Therefore, the overall grid simulation follows a stepwise procedure:

1. transform and/or create hourly input data in high spatial resolution for the whole modelling region
2. assign and/or aggregate the input data based on information about how distribution grids are connected to the transmission grid
3. perform power flow calculations for each hour
4. determine location-to-line sensitivities for potential redispatch suppliers
5. find a cost-optimal redispatch activation that ensures a feasible grid state

A high-level overview is given in Figure **6**. The previously mentioned steps are detailed in the following sections. Currently, the modelling region consists of Austria including all cross-border connections. Grid simulations as well as redispatch calculations that fully include grid states of neighboring countries as well as properly depict cross-border redispatch are subject to further implementations. Power flow calculations, sensitivity estimates as well as the final redispatch optimization currently do not consider N-1 security as an additional limiting constraint[2]. The possibility to fully include these will be considered in the future course of the project.

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[2] Currently, a configurable threshold (defaulting to 70%) as approximation of usable line capacity under N-1 constraints is used.

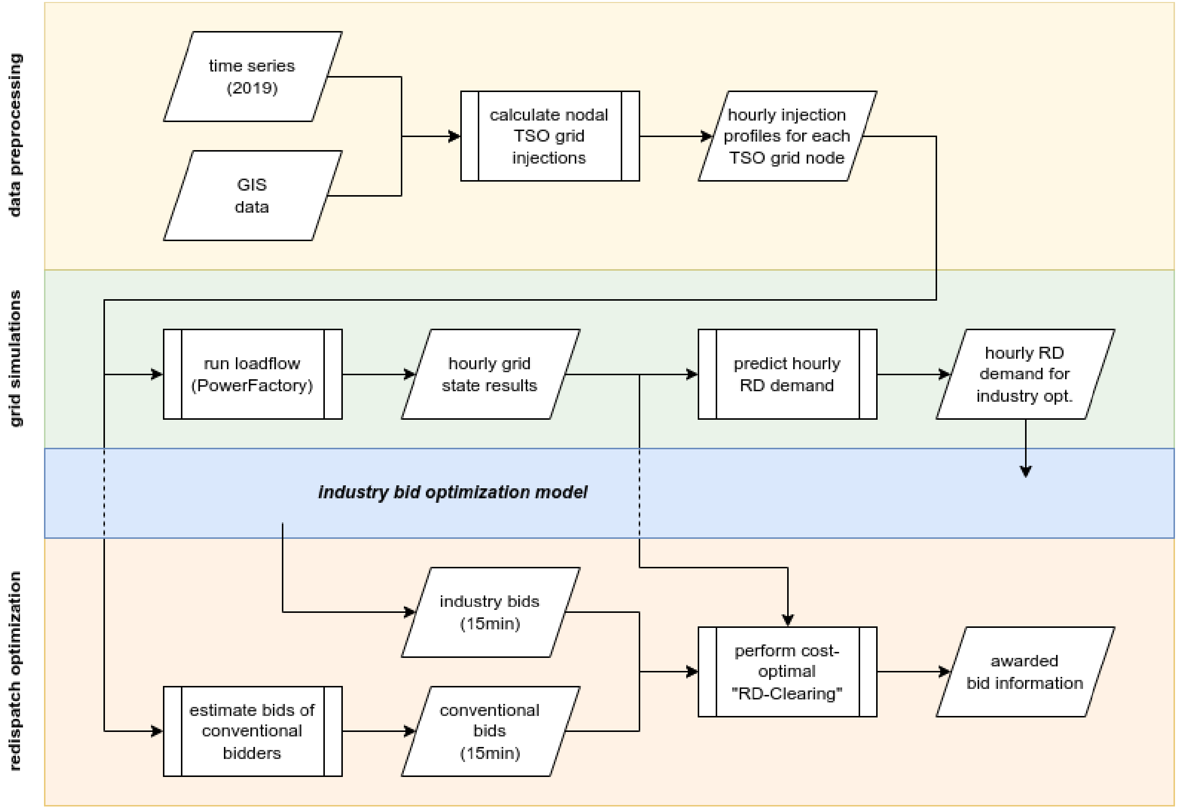

Figure 6: High-level overview of the grid simulation process including the redispatch optimization based on industry bids, based on the steps "data preprocessing", "grid simulations", and "redispatch optimization", which are described in more detail in the following sections.

3.1. Data pre-processing

Creating the spatially distributed data builds on the following main topics:

1. hourly generation data for the modelling region
2. power plant information
3. hourly renewable generation information
4. hourly demand data
5. municipality to distribution grid to transmission grid mapping
6. cross-border flows

Data is prepared for each hour (8760 timesteps per simulation year) as well as based on information available on municipality level and above.

1. Hourly generation data for the model region. This data is based on information published on the ENTSO-E transparency site [2]. Where applicable, data that was published and relevant before eventual remedial actions is being used (e.g. cross-border exchanges). However, generation data split into technologies is only available based on actual operation; this may skew the results partially, because it is based on generation schedules after the application of remedial actions (however, it is still the best publicly available basis for the calculations[3]).

2. Power plant information. The exact location of all reasonably large (≥10MW) power plants in the modelling region, as well as their relevant technical limitations (e.g. capacity) are based on an internal power plant database, that merges publicly available information with commercial data sources as well as manual corrections. For the use case of simulating 2019, the – now decommissioned – power plants at Dürnrohr and Mellach have been added. This list also includes whether a plant feeds into a specific transmission grid node or is considered to be feeding in at a lower voltage level and therefore being aggregated based on affiliation to a distribution grid.

3. Hourly renewable generation information. Since generation values for renewable sources are given only as total values across a single bidding zone, the distribution across the modelling region can be refined. This is based on:

- a commercial wind turbine database, explicitly listing exact location and capacity
- publicly available (see Statistik Austria [3]) installed capacity sums per municipality for photovoltaic
- spatially distributed capacity factors for each hour based on renewables.ninja [4]

Using this information, as well as the assumption that renewable energy sources do not feed directly into the transmission grid, the hourly generation for wind and photovoltaic is calculated per distribution grid.

4. Hourly demand data. Total demand (including transmission losses and accounting for import/export) is assumed to equal generation during all hours. In order to create a representative distribution of the hourly demand across the modelling region, data from Energiemosaik ([5]) is used. The energy usage belonging to the “Motoren / Elektrogeräte” category is used to derive a distribution factor for each municipality, mapping the total hourly demand to a regional percentage. The limitation of that approach – the fact that this distribution is static and not variable across different hours – shall be mentioned here. However, there is no publicly available data that allows a complete depiction of demand-distribution seasonalities.

5. Municipality to distribution grid to transmission grid mapping. In order to run grid simulations, hourly injection and load profiles for each transmission grid node need to be calculated. This is done by first aggregating all municipalities belonging to a distribution grid (based on rough geographical shapes of the distribution grids), and then connecting the aggregated values (generation/demand) based on connection points between distribution and transmission grid. Both steps are heavily based on information available on page 6 in the Systemschutzplan [6].

6. Cross-border flows. Cross-border flows are considered to be fixed, and are based on the data published by ENTSO-E. For countries with more than one direct connection to Austria, flows are distributed onto tie-lines. This was roughly estimated as correcting factor after comparing congestion results with historic data; this will be replaced by exact per-line flow calculations after the inclusion of all neighbouring countries in the modelling region.

3.2. Grid simulations

After obtaining hourly injection and load profiles for each transmission grid node, these are used to perform exact power flow calculations. Those are based on a detailed transmission grid model (for Austria using a detailed

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[3] Estimating power plant states and schedules before the application of remedial actions may be possible based on combining different data sets and will be more closely examined in the further course of the project.

confidential grid model; for upcoming calculations for other countries based on the static grid models published by JAO [7]) and performed using PowerFactory. To account for energy lost due to transmission, the mismatch in the non-linear power flow between total generation and total demand is distributed onto all load elements, which are allowed to slightly reduce their setpoints. This ensures that final generation values correspond to published information, while still properly depicting transmission losses. Reactive power injections and loads are – due to no available information – loosely coupled to active power setpoints. No reactive power regulating devices are present.

The grid simulations result in the following outcomes for each hour:

- line loading factors for each line (therefore the possibility to determine congested lines based on arbitrary overloading-threshold; e.g. 70%)
- linearized sensitivities for each injection point (= each transmission grid node) onto each line (represented as PTDF matrices) based on the current grid state

In order to reduce overall simulation run times, the PTDF matrices (which calculation can take upwards of 30s per simulated hour) can be approximated using a matrix based on one or multiple representative grid states. Assuming that the known net injection values (injection minus load) at each transmission grid node form an n-dimensional vector, the PTDF matrix corresponding to the representative grid state whose net injection vector has the smallest Euclidean distance to the given net injection vector can be chosen.

3.2.1. Hourly redispatch forecast

The industry simulation and optimization (WP4) relies on estimates of upcoming redispatch demands. Those estimates are generated from grid simulations for the whole year and indicate whether a given hour is likely to require redispatch activations. Activations are based on a simplified system without any industry partaking in redispatch, and an estimated forecast is given for any time and date as average redispatch activation over:

- the current time-range, starting two hours before the current timestamp, and ending two hours after
- redispatch activations for this time-range during the last 14 days

This takes into account a pre-defined location that the forecast should be valid for as well as the assumption that bid prices are strictly based on opportunity costs (related to the day-ahead prices). Therefore, this does not represent the expected change to be activated given a specific bid price, but more generally the estimate whether a demand for redispatch capacity at a given location – and in which direction – can be expected.

3.3. Redispatch optimization

The redispatch optimization is tasked with finding a cost-optimal redispatch activation (that can be comprised of one or multiple accepted bids) that solves any occurring congestions and ensures a feasible grid state (= not creating new congestions). It makes use of:

- bids obtained from the industry simulation and optimization (WP4)
- bids from conventional (thermal) power plants (positive bid costs = min(50 EUR, day ahead price), negative bid costs = (- day ahead price) / 2)
- bids from pumped hydro storages (positive bid costs = day ahead price, negative bid costs = (- average day ahead price over the last three days) / 2)
- information about the setpoints of each conventional power plant / pumped hydro storage, to determine the available capacity for both positive as well as negative redispatch

Remark: Redispatch capacities in foreign countries (that are activated for Austria) as well as minimum up- and down-time constraints of Austrian power plants are currently not considered for the optimization. This will be examined in the further course of WP7.

Other generating units (wind, photovoltaic, run-of-river, biomass, waste) are currently considered to not offer any capacity for redispatch. The actual optimization utilizes the energy system model AIT-MarketFlow. It can directly base the underlying linearized power flow equations on the PTDF matrices calculated by PowerFactory, and allows freely adjusting the available capacity for each connection (which can be used to quickly estimate results under N-1 constraints by allowing only e.g. 70% of each line's capacity to actually be used). Positive and negative flexibilities for both power plants as well as industry are considered to be limiting constraints. Due to not explicitly modelling the transmission grid outside Austria, necessary cross-border redispatch is based on historic values (published by the APG [8]). While this serves as a rough estimate for the current Austria-only case, it will be based on actual simulation results after the integration of neighboring countries. The outcome of the redispatch optimization – the information which bid was accepted during which hour – is then passed onto the CBA calculation.

4. Conclusion

This deliverable contains the methodology for the CBA and the definition of corresponding scenarios that will be compared. It turns out that the differences in basic prerequisites, objectives, data availability as well as costs and benefits for the different stakeholders are quite versatile. Often, they are also highly co-dependent, DSOs costs for grid reinforcement are TSOs benefits and the other way around, and the possibility of a business case for the aggregator depends on the rentability of redispatch provision for industry. This implies the necessity of a detailed analysis of each sector to generate a deeper understanding of its individual requirements and relevant CBA scenarios.

The deliverable presents a step-by-step approach on how the CBA for the industrial sector, FSPs, DSOs and the TSO can be conducted. Furthermore, it describes the identified impact factors for each stakeholder, that are expected to have influence on the CBA results and the respective baseline scenarios.

For the industrial sector, the base scenario has been defined as the calculation of costs for conventionally consumed energy, purchased at the day-ahead spot market. The scenario also accounts for natural gas prices and certificates. This scenario is compared to the scenario, where industry participates in TSO redispatch provision. The consumption is optimized based on DA-prices, and additional revenues occur, that depend on the activated site-specific RD bids per day.

As TSO baseline scenario the current status-quo is defined, meaning the RD costs without industry participation. The I4RD scenario will then contain RD bids from the industrial sector and the trade-off between the two scenarios will give an idea of the actual added value that the inclusion of the industrial sector into the RD process can bring.

For FSPs, the definition of a CBA scenario is not that straightforward, as the costs and benefits of FSPs are highly dependent on the selected business cases and chosen fee for the provided aggregation service. Therefore, for the I4RD scenario for FSPs it has been decided to use a mostly qualitative analysis in order to determine potential business cases.

The DSO CBA analyses the impact of distribution network reinforcement on the TSO's redispatch costs. It compares the costs of distribution network reinforcements with the costs caused by the blocking of infeasible but highly economic bid sets.

The CBA for all stakeholders will be carried out in the further course of the project and the profitability as well as further qualitative aspects will be analysed according to the described methodology.

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