European Network of
Transmission System Operators
for Electricity

IMPLEMENTATION GUIDELINE FOR REDISPATCH ASSESSMENT

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1 INTRODUCTION AND PURPOSE OF REDISPATCH

Assessing projects by just focusing on the impact of transfer capacities across certain international borders can lead to an underestimation of the project specific benefits because most projects also show significant positive benefits that cannot be covered by only increasing the capacities of a certain border, i.e. the reduction of internal congestions. This effect is strongest but not limited to internal projects that do not necessarily aim for increasing the capacities across specific borders, which makes it difficult or even impossible to solely assess them by market simulations. In order to close this gap of incomplete benefit calculation for internal projects, within the 2nd CBA guideline the use of redispatch simulations has been introduced. The main aim of introducing this methodology was to get the best link to reality, as within some countries redispatch has already become a standard procedure of dealing with internal congestions.
Following its current application in reality, the redispatch simulations need to be based on detailed market and subsequent load flow simulations. As for the moment it is not possible to calculate the whole toolchain, especially the redispatch simulations itself, on a common tool and/or on ENTSO-E wide level this implementation guideline needs to focus on a detailed methodology description, its main principles and an alignment of the most important parameters.
In TNYDP 2020 redispatch simulations will not be applied for interconnectors. Only for internal projects with and/or without CB impact, where the respective project promoter can prove that the tool and methodology used is compliant with the 3rd CBA guideline and this implementation guideline, redispatch calculation can be performed.

Useful links for the Redispatch Process

2nd ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects (FINAL EC Approved 27.09.2018)

3rd ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects (Draft Version 28.01.2020)

TYNDP 2020 Implementation Guideline

TYNDP 2020 Scenario Report

Implementation guideline on Project-Level Benefits

Note with respect to the *Implementation Guideline on "Project Level Indicators Based on Promoters' Input"*:
Although the redispatch methodology will not be performed by ENTSO-E on a centralised level, it is not defined within the Project Level Indicators (PLI) guideline. Within the PLI guideline only specific indicators, as defined already in the 3rd CBA guideline, will be described, while the redispatch methodology is used to achieve the same indicators as by the use of market simulations. It is thus no description of how to assess specific indicators but instead on how the redispatch methodology to be applied in order to achieve the respective indicators.

2 MAIN OBJECTIVES OF THE IMPLEMENTATION GUIDELINE OF THE REDISPATCH ASSESSMENT

As it is not yet possible to perform the redispatch simulations on a centralized level this guideline aims for giving all necessary descriptions and definitions to allow project promoters to perform the redispatch simulations on their own (presupposed the respective tools are available). This guideline should thus give everything needed at hand for the modelers to be able to produce comparable results. The main goal should be to achieve the highest degree of comparability between the results achieved by the different tools and simulators.
It is therefore of major importance to define the **main parameters** and align them between the different tools and modelers. This is crucial, as all models need to be based on a comparable data foundation, but on the other side it might be the case that specific parameter needed for the one tool might not be used in another. To find the best possible alignment a detailed comparison between the different tools used for modelling the redispatch inside the ENTSO-E TSOs has been performed in the preparation of this guideline. The results of this exercise is given in the following chapters.

The definition of the **general principles** of the different tools was also part of the alignment process and will be presented here. This includes e.g. the determination of the sequence of generation units to be used for redispatch.

For this purpose, in chapter 3 an overview of the general process is given. After giving the minimal requirements on quality in chapter 4 that need to be met, the participating tools are presented in chapter 5 together with a description of the test case to find alignment between the tools. As the redispatch methodology is based on market and network simulations, the needed input data is described in chapter 6 including a description of model specific data per simulation tool. An overview of the overall CBA assessment framework for the redispatch simulations, such as the number of climate years, TOOT/PINT methodology etc. and the definition of the model perimeter is given in chapters 7 and 8. A detailed overview of the optimization measures such as the order of sequence of generation units used for redispatch, possible penalty costs, the objective function etc. is given in chapter 9, followed by the definition of the critical branches to be considered when performing the redispatch simulations in chapter 10. The final two chapters, 11 and 12 give an overview of the results needed for a full CBA assessment and its monetization.

In the end in best case, this implementation guideline might be seen as a step-by-step guideline for assessing projects using redispatch simulations, but at least it shall act as source giving all the needed information for simulators to perform the redispatch simulations in a consistent way.

Key drivers of the methodology:

1. Complementing the guidance as given in the 3rd CBA Guideline
2. Delivering the methodology for assessing projects without major impact on trading capacities
3. Alignment between results and tools in order to create comparable results
4. Transparency on the methods, assumptions and models used within the TYNDP

OVERVIEW OF THE SIMULATION PROCESS

All redispatch calculations need to follow the principles as laid out within the 3rd CBA guideline (section 6.21).

In this section a short overview of the general simulation process of redispatch calculations is given. This does not include the detailed specifics that might be considered as defined by the respective tools. An overview of the used tools is given in section 4.

Although no interconnectors will be assessed using redispatch calculations within TYNDP2020, both options as given in the 3rd CBA guideline (see also Figure 1) can be applied dependent of cross border contribution of the respective project:

- Option 1: Calculation of benefits using pure redispatch
- Option 2: Calculation of benefits using a combination of border-NTC-variation and redispatch

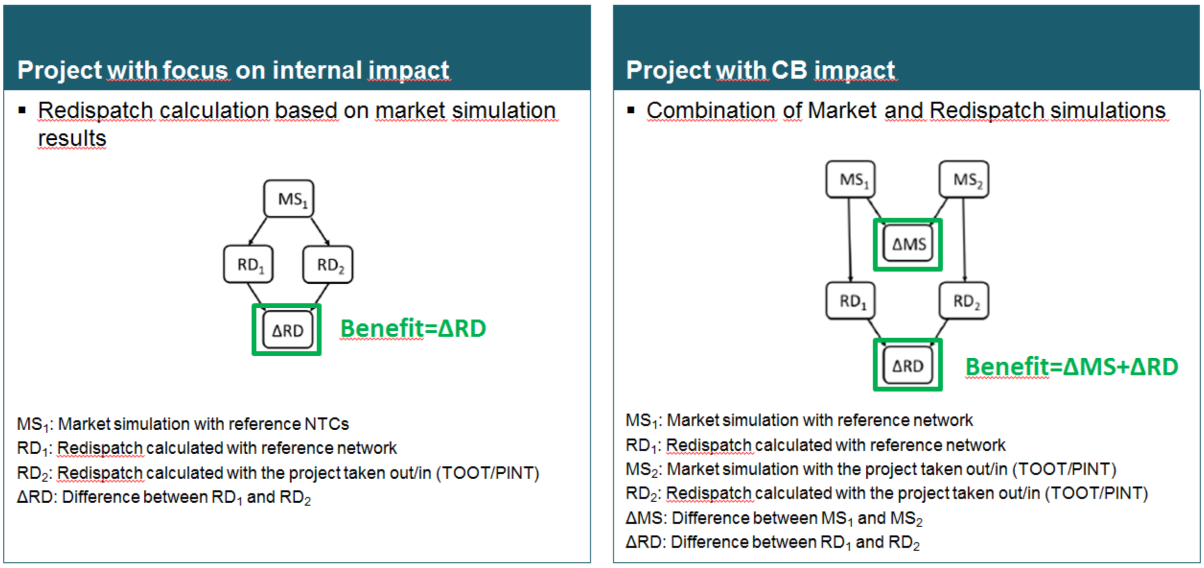


Figure 1: Simplified presentation of the two methods applied for projects with focus on internal impact only and those with internal and cross-border impact respectively.

Choice of respective methodology:

The choice of what method to be used is upon the project promoter. However, in the end, within the TYNDP project sheets the chosen method needs to be displayed together with a justification of the respective choice.

In general, project with no cross-border contribution will be assessed using Option 1, while those with cross-border impact are assessed using Option 2. However, also for the latter, project promoters might wish to only use redispatch calculations e.g. in order to reduce the complexity of the simulations, or as the focus relies on internal effects only. It needs to be noted, that in that case the cross-border part of the benefits will be lost and the results can be seen as a lower bound. On the other hand the application of Option 2 for projects with no cross border impact will deliver the same results as when using Option 1.

Overview of the simulation process:

1. **Market Simulations:** all subsequent simulations need to be based on the by ENTSO-E centrally performed market simulations. The respective data needs to be obtained by the TYNDP Study Team.
2. **Load Flow Calculations:** the following load flow simulation needs to be based on the grid models as prepared by the TYNDP Study Team.
3. **Redispatch Simulations:** the redispatch simulations need to be based on the principles and requirements as defined in this guideline and are executed by the respective project promoter.
    a. all grid models need to be based on the models prepared by the TYNDP Study Team
    b. all marked data needs to be in line with the data as used by TNYDP Study Team

***Note*:** As for the load flow and redispatch simulations a fuel type based resolution is not sufficient, the market simulation from step 1 needs to be broken down on a generator level – where the infeed of each single generator/power plant is given and not its aggregation per fuel type. The geographical scope for this disaggregation has to be the same as defined for the redispatch simulations in this guideline.

4 SANITY CHECK FOR MINIMUM MODELLING REQUIREMENTS

The project promoter has to perform the simulations for the calculation of the indicators based on the redispatch method. The TYNDP 2020 Study Team does not perform calculations for projects based on the redispatch method. However, compliance with the redispatch guideline and a minimum quality of the calculations should be granted.

For this reason, the project promoter is requested to participate in the sanity check by performing detailed redispatch calculations using a highly simplified network model with a strongly reduced number of artificial market simulation results. The project promoter submits the results at least together with the final project results to the TYNDP team. The TYNDP Study Team Expert Group compares the results of the project promoter regarding the simplified model. The submission of the Sanity Check results should take place before the submission of the final project results to the TYNDP team. This is a recommendation, as a recalculation may not be possible in given timeframe of the publication process of the TYNDP. The approval process of the redispatch results by the project promoter follows the approval process of the "Project-Level Benefits".

The following tables give the description of the input data for the sanity check in the Annex:

- Technical parameters
- Market Input Data
- Template for the results

The input data of the sanity check model covers all processes and methods necessary for the redispatch calculation. However, only minimal resources are required for the project promoter to generate it.

A Brief description of the model:

The sanity check model consists of six nodes (N=North, S=South, W=West & E=East). All nodes are connected by a 2-system 380 kV overhead line connection in ring topology. The phase shifter NW_NE_1 is located between the nodes NW and NE. There are two HVDC connections (HVDC1, HVDC 2) between node SW and SE. Four generation units or feeder and three load units are located in the model. Generation unit N_G is located in node N. Two generation units SW_G1 & SW_G2 and one load SW_L is located in node SW. Two load units SE_L1 & SE_L2 and one generation unit SE_G are located in node SE.

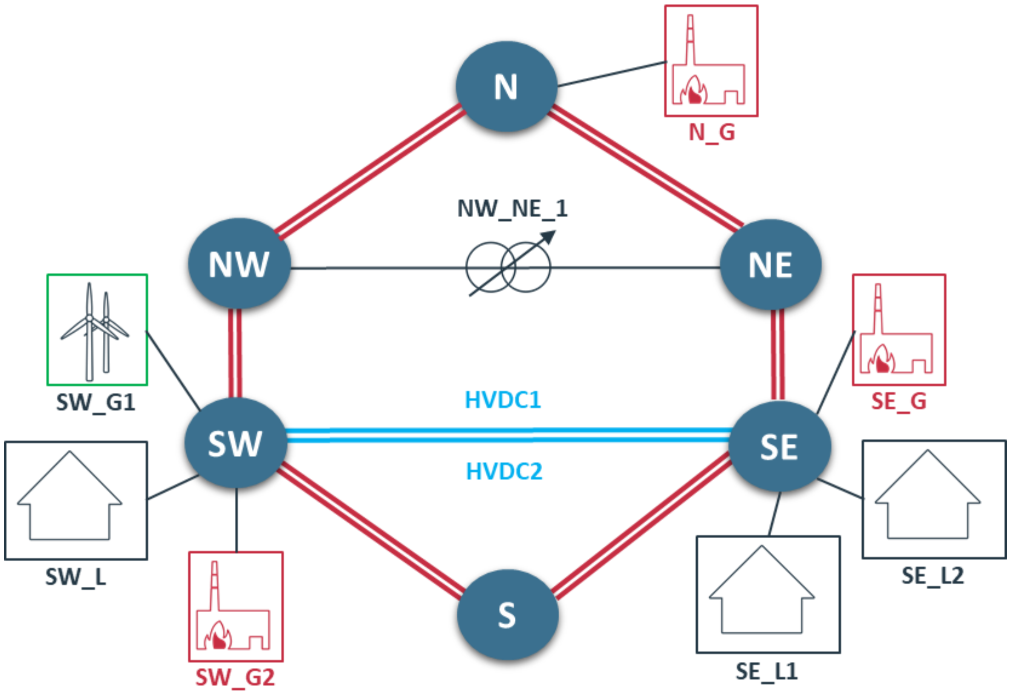


Figure 2 Illustration of the Sanity Check model.

The generator SW_G1 is an onshore wind turbine. All other generation units are thermal power plants of type CCGT new. The HVDC connections and the PST have default penalty/ marginal costs too, see Annex. Since the sanity check is a check of the detailed results for one day, only the order of the redispatch is important. All further input details can be taken from the guideline itself.

There are some requirements for the project promoter regarding the content of the disclaimer. Here again an overview as a kind of checklist for the project promoter.

The project promoter needs to give a written statement on:

- The compliance with the 3rd CBA Guideline and this TYNDP 2020 Implementation Guidelines for Redispatch calculations.
- The explanation of a deviation from the guidelines due to special national regulatory conditions. A submission of these regulations to the TYNDP Study Team for the authorization process (e.g. RES Monetisation; Consideration of the n-2 criterion – Line Ratings etc.).
- The compliance with the TYNDP 2020 Input Data (This also excludes the mixing of the data.)
- A description, which proposed options in the guidelines were chosen.
    - AC load flow/DC load flow

- Number of Scenarios and Climate Years
- Multiple TOOT/PINT
- Consider Branches Options (e.g.: 110 kV level)

5 PARTICIPATING TOOLS IN THE REDISPATCH-ASSESSMENT

The use of redispatch calculations to assess projects is still relatively new and very resource intensive. An extensive software and hardware environment is necessary for this but currently not yet available on ENTSO-E level with purpose of centrally coordinated computations. Within the framework of this guideline, we strive to achieve a high standard by defining the main principles, but the implementation of this assessment method leads to different approaches and focuses in the details. Not only because of different national requirements and regulations, but also because of the different tools used by different promoters. Therefore, in this chapter we would like to clarify the generally accepted approach, but also address the specifics of individual project promoters' tools and country.

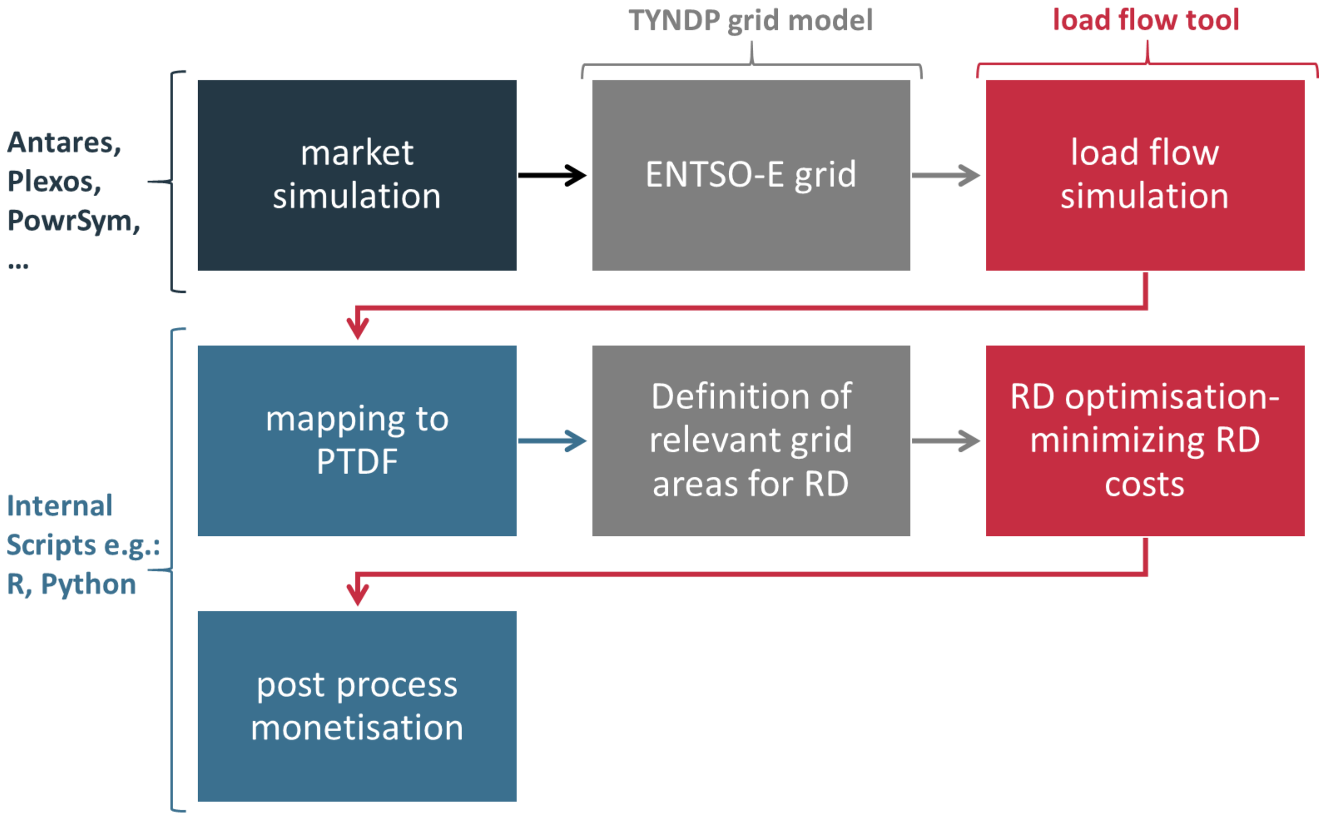
General approach:

To perform the redispatch simulation a market simulation is the first step. Based on the output of market simulation with the resulting cost optimal power plant dispatch a load flow analysis is to perform on the grid model to determine the utilizations of network elements in base case and (n-1) case. The line utilizations while respecting the security criteria (e.g. n-1) resulting from the load flow analysis are evaluated within the redispatch simulation and possible bottlenecks are identified. The power flows, which exceed in the (n-1) case the thermal limits of respective network element (utilization over 100%) represent the reason for redispatch interventions of generating units in order to ensure the (n-1) security criteria of the electricity grid. Their effect on the power flow on the lines is determined by linear sensitivity factors $PTDF$, so-called "Power Transfer Distribution Factors". The nodal PTDF matrix does offer such a possibility as it translates nodal injections into individual line flows by explicitly stating the contributions of each nodal injection to a given line flow. Assuming a DC approach, PTDFs can be calculated directly from line parameters.

In the next step the grid data will be reduced to all relevant grid areas and elements that have to be considered in the redispatch simulations (see Chapters 8 and 9). Further the cost-optimal redispatch optimisation will be performed to solve all respective congestions in the electrical grid.

The final step will be the monetization of the redispatch outcomes.

Redispatch Implementation



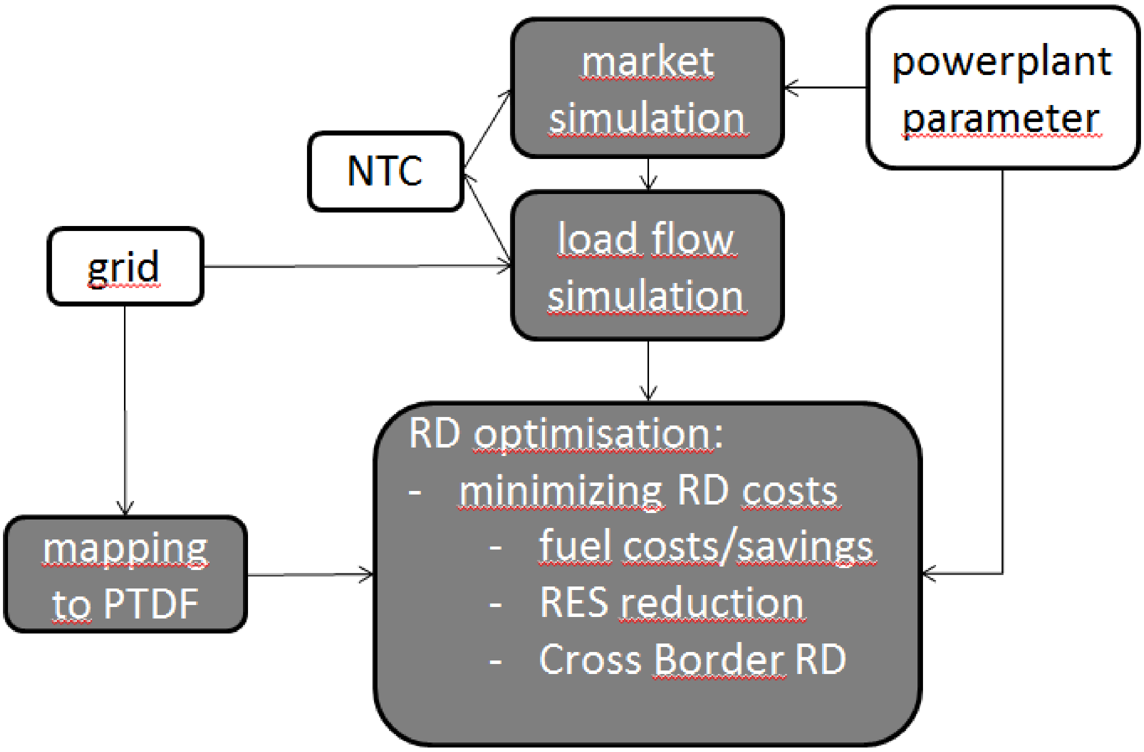
<u>Specific differences and software used by project promoter compared to the general approach:</u>

Project promoter APG:

- ➔ Market tool independent - process based on the ENTSO-E Market Modelling standard output template and internal Matlab scripts for ENTSOE-E load flow calculation conversion input. (Same standard as for the Losses Assessment)
- ➔ The load flow and redispatch calculation will be done with the software FGH Integral (no time coupling)
- ➔ For all other steps APG uses R

Project promoter German TSOs (50Hertz, Amprion, TenneT, TransnetBW):

- ➔ Mixed-integer linear optimisation problem (MILP) which uses DC-approach for modelling of network constraints (PTDF, PSDF, LODF sensitivities)
- ➔ Optimization of power flow controlling devices (PST, HVDC) in the redispatch simulation.
- ➔ Time coupling constraints for all generating units (gradient ramps, min. up- downtime etc.) are taken into account in the redispatch optimisation
- ➔ Additional penalty costs for "initial call" of the power plant for redispatch and for changing the redispatch performance to ensure more realistic, less dynamic redispatch pattern
- ➔ Definition of nodes where virtual generation units are placed to perform cross-border redispatch



Project promoter ELIA:

- ➔ Market tool independent. Modelling of load and generation profiles, as well as HVDC flows, is done across the continental European model. Only the main power plants in Belgium are modelled individually:
- ➔ The minimum required number of generators per type is determined for each hour. Generators are chosen randomly, and power is distributed proportionally to their Pnom across this minimal number of generators. This does mean no time coupling with start-up and shut-down times is considered; this would require a market model with individual generator output. Loadflow tool: PowerFactory.
    - o Redispatch is calculated by the built-in UnitCommitment module, i.e. not by external scripting with PTDF.
    - o N and N-1 considered, with seasonal line capacity. Observed area for congestion: Belgium 400 kV lines + first line across borders in France and The Netherlands.
    - o Preventive redispatch for N-1. No temporary overloads considered.
    - o Using penalty costs on generator redispatch by merit order. No time coupling.
- ➔ Post-processing of delta MWh for monetisation.

6 REQUIREMENTS FOR INPUT DATA

In order to perform redispatch calculation the set of network and market data is needed. Since the results of the redispatch calculations are very sensitive to the input data used, the essential requirements for the content of the input data are defined in this chapter. Compliance with the defined requirements can ensure the consistency of the redispatch assessment runs and the comparability of results from different tools and promoters. Three data categories can be defined dependent on its confidentiality level:

1. Data publicly available
2. Data only available on request (Due to data size)
3. Data for which an NDA is necessary

6.1. MARKET DATA

Redispatch simulations have to be aligned to the market studies that were performed on the scenarios used in TYNDP20. In order to meet this requirement, the market model input data as well as market model simulation results have to be included in the dataset for the redispatch assessment [CBA 3].

The main datasets to be used from the market input are (the colour code denotes the confidentiality category as defined above):

•price assumptions (fuel prices, CO2 price and the marginal costs of thermal generation types calculated from these)
•net generating capacities for all generating types
•demand time series
•must-run values of thermal generation types
•availabilities of thermal units
•inflow profiles for Run-of-Rivers and pump storages
•DSR capacities
•crossborder capacities (NTC values)
•fixed exchanges with non-modelled countries

This data is based on the PEMMDB package per scenario per country and have to be coherent with the input that was used for market simulations.

The market model simulation results, which are used as input for the power flow computations, also have to be included in the input dataset for the redispatch calculations. This should include:

•Utilisation (hourly time-series) of thermal generation types, DSR, and hydro categories
•dumped energy time series
•hourly marginal costs on market nodes
•ENS (energy not served) time series

The market simulation results are covered with standard market modelling output file provided by the TYNDP Study Team per scenario and climate year.

The methodology for mapping the market results to the grid model depends on the modelling-specific features of the individual grid models. In general, the mapping is based on the distribution of market hourly time-series proportional to the installed capacity of network element with corresponding fuel type code. The technical restrictions of the network elements defined in the network model must be kept (e.g. Pmax, Pmin etc.). Demand side response is subtracted from the demand time-series. Dumped Energy and Energy not Served are primarily subtracted from renewable energies and the demand.

6.2. NETWORK DATA

Grid Model:

The grid model for the redispatch assessment have to be aligned with the CGMES grid model submitted for network analysis as a part of TYNDP20. So that the installed capacities in the grid model are the same with market input data and the power flow results are consistent with other grid studies (e.g., the delta NTC, losses calculations).

Any new changes in grid model after official grid model collection process have to be aligned with TYNDP Grid modelling guidelines and communicated with Working Group Data and Models and TYNDP Study Team.

Power flow analysis:

To determine the utilizations of the lines in grid model in base case and under contingencies (N-1 case) the power flow analysis should be performed on the grid model. The power flow simulations should be based either on DC- or on AC- load flow approach. As far as AC load flow approach cannot be applied by project promoters due to its complexity and missing comparability between different tools, the usage of DC approach is allowed. The network analysis should be made on a year-round basis. If this is not possible, representative points in time can be analysed following the principles as layed dow in the the 3rd CBA Guideline.

Special input data provided by the TSO as part of the grid model:

Due to special national requirements and regulations, it is possible to deviate from the original TYNDP line ratings (and ratings depending on seasonal parameter) in the grid model and the n-1 principle based on them. The need to take account of these exceptions such as Dynamic Line Rating or curative mitigation measures must be regulatory required and is provided by the respective national TSO. Due to the immense influence on the results, this approach must at least be described in the disclaimer.

7 MINIMUM REQUIREMENTS DEFINITION FOR THE CBA ASSESSMENT

Compared to the TYNDP standard methodology, the assessment of projects with indicators determined using the Redispatch method is very computationally intensive. Nevertheless, a comparable minimum standard should be ensured. This chapter therefore deals with the question of the minimum level of detail and number of simulations required to calculate the indicators. However, the project promoter is free to carry out a greater number of simulations within the framework of the guideline or to increase the level of detail of the methods. (e.g.: more climate years or additional TYNDP Scenarios). However, this must always strictly follow the assumptions of the TYNDP and the 3rd CBA Guideline. It is not allowed to change any input data or mix scenario data. Otherwise, the comparability of the results would no longer be possible.

Minimum number of TYNDP Scenarios and Time Horizons:

As a minimum requirement, the central policy scenario **National Trends** with the time horizons **2025** and **2030** must be used for project evaluation.

Minimum number of Climate Years:

The minimum requirement for project assessment is to use the most representative climate year of the three climate years represents the three climate groups (1982, 1984 & 2007). In the case of TYNDP 2020, the climate year **2007** is the most representative climate year.

Minimum number of different Market tool results:

The minimum requirement is to use the results as input for the redispatch assessment of at least **one** market tool that participated in the TYNDP2020 CBA process. It is recommended that the same set of market tool input be always used for all projects within a bidding zone. This should increase the comparability of CBA redispatch results.

Minimum number of Point in Times:

It is recommended to calculate a complete year in hourly time steps. The selection of the minimum number and representativeness of the PiT's are described in the 3rd CBA Guideline and in the Implementation Guideline.

General:

Multiple TOOT/PINT approach is permitted under the 3rd CBA Guideline and is not restricted by this guideline. When the multiple TOOT/PINT method or a combination of both is applied, a detailed description of the sequence of projects must be given in a disclaimer. To ensure comparability, the project assessment approach regarding Multiple TOOT/PINT should correspond to the approach chosen in the CBA.

These specifications apply to all project types (overhead line, HVDC, storages...). The description of the selection of input data must be communicated in the project sheet in a disclaimer.

8 DEFINITION OF THE PERIMETER

The minimum perimeter considered in the calculation has to be chosen to cover all relevant grid areas influenced by the project, which depends on whether the projects contribution is considered as mainly internal or also contains a major cross-border part. (see chapter 10)

Internal projects (without significant CB impact)

The minimum perimeter for internal projects without significant cross-border impact to be monitored during the redispatch calculations is typically the country that includes the project. However, as the European grid is generally highly meshed, it is recommended to include at least the neighbouring countries. In any case, the border flows to the non-modelled countries should be mapped from a full grid model covering the entire synchronous area that the country of the project is part of.

Internal projects (with significant CB impact)

The minimum perimeter for internal projects (with significant CB impact) to be monitored during the redispatch calculations is typically the two or more countries that affected by the project on their common border, but the considerations described for internal projects are also valid in this case: it is recommended to also include at least the neighbours of the countries hosting the project.

Typically, the grid model used for the calculations should be the same full European merged grid model that is used for other calculations in the CBA process. If the full model cannot be utilized in the tool used for redispatch, the smaller perimeters defined above can be used, but the effects of the excluded network parts must be demonstrated (e.g. by showing that all LODF factors in the excluded part to the critical branches are below a certain limit, e.g. 3%).

9 ORDER OF OPTIMIZATION MEASURES – PENALTY COSTS

The order or selection of the measures taken by the tool to resolve the bottlenecks on the critical elements depends essentially on two factors:

- Effectiveness of the measure
- The cost of the measure

To define the effectiveness of different measures on the bottleneck in the electrical grid the PSDF/PTDF sensitivity factors are calculated using a DC load flow assumptions. These factors describe the change of utilization of each line by adjustment of initial setpoint of controllable units in the electrical grid (powerplants, storages, PSTs, HVDCs etc.).

The costs of the individual measures are insufficiently defined by the scenario and market data. On the one hand, the marginal costs, such as renewable energy is per definition 0, on the other hand, there are measures for grid optimization that cannot be captured by the market. Furthermore, there is the possibility that regulatory restrictions may specify a certain sequence of redispatch measures. For reasons of security of supply, certain measures are also kept in reserve so that they can be made available in the event of an emergency. All these additional artificial costs are described here as "Penalty Costs".

The corresponding costs of redispatch consist of the costs for up/ down regulation of all units K involved in the redispatch across all time steps T. The objective function of the underlying optimization problem is shown below:

$$\min f = \sum_{t=1}^{T} \left(\sum_{k=1}^{K} c(k,t) \cdot \Delta p(k,t) \right)$$

The above formula only applies to the time coupled approach. Without time coupling, the minimum costs for each hour are defined as a target function.

Basically, the costs c(k,t) picture the coefficients in the objective function of the optimization problem and depends on the technology/ fuel type of each measure. They determine how and in which sequence the conventional power plants, renewable energy, storages, foreign generation units and power flow controllable devices (PST, HVDC etc.) can be used to cure line bottlenecks. If the costs of the individual units (ex. conventional power plants) are defined by market data, they have to be used as costs coefficient of this units in the optimization for the redispatch calculation.

Due to this methodically necessary intervention, the sequence of the measures and thus the reduced redispatch quantity (e.g.: GWh or CO_2 tons) corresponds to the operational experience of the TSOs, but the Penalty Costs of these measures cannot be used for the project assessment. For this reason, a post-monetization must be implemented (see also chapter 12).

Furthermore, it must be ensured that in the case of a positive redispatch (power increase), the cheapest measure is always taken first, and in the case of a negative redispatch (power decrease), the most expensive measure is always taken first. This can already be determined by the tool itself or also by suitable penalty costs.

In principle, the following sequence must be ensured – driven by the two types of costs: the "real" costs also referred to as generation costs defining the marginal costs of the conventional power plants; and the Penalty Costs that can be interpreted as model parameter in order to ensure the desired order of sequence within the redispatch. No country specific differences to this approach have yet been identified. If these are identified, they must be taken into account.

1. network-side measures
    a. topological actions
    b. power flow controllable devices (PST, HVDC, FACTS)
2. weather-dependent line operation curative actions (generating units decrease) included in the ratings (see above)
3. Thermal Power plants based on the dispatch costs of each generator
4. Storages (Hydro, Batteries, P2G)
5. RES (only decrease)
6. Cross Border Power plants and Cross Border HVDC's (depending on the perimeter)
7. Very Last Step: (2 Possibilities with very high penalty cost)
    1. Load Shedding (ENS)
    2. Remaining Overloading (Branch Slack)

10 CONSIDERED BRANCHES

The planning and operation of electrical transmission networks takes into account the so-called (n-1)-criteria. The (n-1)-criteria ensures that the operating limits of the lines in system are not violated even in the case of single failures of circuits and transformer (busbars overloading's not taken into account). Using the market related measures, such as redispatch, TSOs adjust the feed-in of power plants in order to shift the power flow from the overloaded branches and therefore ensure the (n-1) security of the system. Hence, monitoring and identification of relevant branch overloadings has a huge impact on the redispatch results.

Using AC or DC load flow approach a set of single outages are simulated on the grid model and the power flow of other branches in the system in each considered (n-1) case is calculated. A branch is said to be overloaded when the actual power flow post contingency exceeds the operational line limit that depends on the protection relay settings and weather conditions. Some TSOs investigate not only single failures, but also certain failure combinations, i.e. "(n-2)"-outages or exceptional contingencies.

Generally, the (n-1)-utilization of all branches in the grid should be considered in the redispatch analysis, but in the context of network development studies, some assumptions are made. The exception of certain elements from the optimization problem helps to avoid an overestimation of redispatch values and to obtain more robust and realistic results. Moreover, it can simplify an optimization problem and reduce the calculation time. Thus, a reasonable and consistent approach to the monitoring of relevant elements is necessary.

Like the generating units, the considered branches have to be reduced to the relevant grid area influenced by the project (see chapter 8). It means that only the branches within the defined perimeter as well as the corresponding interconnectors have to be considered in the (n-1)-calculation and redispatch simulation. Since the focus of the TYNDP is on the analyses of transmission network, the monitored branches can be filtered per se based on the voltage level (e.g. only 220-/380-kV). The possible reasons for this are simplified or uncompleted modelling of the distribution network in the grid model or regulatory restrictions for redispatch use in certain countries. Generally assumed, that failures and overloading of transformers are not considered in the redispatch analysis, but the decision whether transformers should be taken into account is optional and is up to project promoters.

Due to necessary simplifications in the model and the network reductions made, artificial overloads and thus artificially high redispatch needs can occur. If such cases are identified, the affected branches should be removed from the observation. Whereas the outages of HVDC lines have a big impact and can seriously increase the utilization of AC network, it is necessary to include them into analysis.

11 DEFINITION OF THE RESULTS FOR CBA OUT OF THE REDISPACH ASSESSMENT

In general, the indicators assessed using the redispatch methodology are the same as when using market simulations as both simulation methods deliver the power plant dispatch which is the driver for most of the CBA indicators. Below is a list with all CBA indicators as defined in the 3rd CBA Guideline that can be achieved by using the redispatch methodology applying the (multiple) TOOT/PINT approach (all other indicators are not foreseen to be calculated using redispatch):

- **B1 - SEW:** can be achieved by the generation cost approach the same way as for market simulations (including cross border costs and start-up and shot-down costs
- **B2 - Societal costs of CO_2**: can be achieved the same way as for market simulations as post process
- **B3 - RES integration**: can be achieved the same way as for market simulations by the change in needed reduction in RES generation due to redispatch
- **B4 - Non-direct greenhouse emissions:** can be achieved the same way as for market simulations as post process
- **B5 – Losses**: can be calculated the same way as for market simulations using the dispatch taken from the redispatch calculations as input for the losses calculations

- **B10 – Reduction of Redispatch Reserves:** the only way to calculate this indicator is by nature the use of redispatch simulations

The presentation of the results within the project sheets needs to be follow the definitions and requirements as defined within the Implementation Guideline the same way as when using market simulations.

12 MONETISATION AND QUANTIFICATION OF THE REDISPATCH RESULTS

In principle the monetisation of the redispatch results can be carried out directly by the simulation tool – using the generation cost approach as applied also within the market simulations, as each re-dispatch of conventional power plants is accompanied by a change in fuel consumption, which naturally will impact the system costs. This difference in costs then delivers the benefits (which might also be negative) of the assessed projects.

If this automated monetisation is not available by the respective tool. The final step of the redispatch assessment will be the monetisation of the simulation results. This step is a post process calculation. The redisptach results are added to the standard CBA results. (In line with the 3rd CBA Guideline)

First of all a clarification is needed for the energy amount differences per type of power plant between the calculations with/ without the project. For each type of power plant:

$$\text{for TOOT:}\quad \Delta\, energy = energy_{ref.\ case\, -\, project} - energy_{ref.\ case}$$

$$\text{for PINT:}\quad \Delta\, energy = energy_{ref.\ case} - energy_{ref.\ case\, +\, project}$$

B1: SEW – Social Economic Welfare

In case the monetisation needs to be performed by post-process: The Social Economic Welfare is defined as the yearly energy amount per power plant type times the power plant specific marginal costs.

$$\text{SEW } [€/\text{yr}] \;=\; \sum_{type} \Delta\, energy_{type}\ [\text{MWh/yr}] * marginal\ cost_{type}\ [€/\text{MWh}]$$

B2: Societal costs of CO2

In case the CO_2 emission are not directly reported by the tool: To calculate the yearly CO_2 emissions, the energy of the emitting power plant times the specific emissions per energy (see Annex 2) is used.

$$\text{CO}_2\ [\text{t/yr}] \;=\; \sum_{type} \Delta\, energy_{type}\ [\text{MWh/yr}] * \text{CO}_2\ emissions_{type}\ [\text{t/MWh}]$$

A monetization is done accordingly the descriptions in the Implementation Guideline and the 3rd CBA Guideline.

B3: RES integration

The RES integration indicator is not monetised.

B4: Non-direct greenhouse emissions

The yearly non-CO_2 emissions are not monetised.

B5: Losses

This indicator will be calculated with the same procedure as for transmission projects, as descripted in the Implementation Guideline and the 3rd CBA Guideline.

B10 – Reduction of Redispatch Reserves:

This indicator describes the impact of contracted redispatch reserve power plants by assessing the maximum power of redispatch with and without the project.

The quantification of the benefit is relative to the reduction of the maximum amount of necessary redispatch in MW and can be monetised using statistical analysis of the costs of reserve from power plants, i.e., from changing capacity constraint payments. The project promoter must carry out such an analysis. A short description in the disclaimer is required (for more guidance see the Implementation Guideline).

ANNEX 1: DATA FOR THE QUALITY CHECK FOR MINIMUM MODELLING REQUIREMENTS

Table of technical parameters

		Feeder				Load		
Unit name	**Unit**	**N_G**	**SW_G1**	**SW_G2**	**SE_G**	**SW_L**	**SE_L1**	**SE_L2**
U	kV	380	380	380	380	380	380	380
Q	MVar	7.48158	2.35231	2.35231	6.45498	4.8	4.8	4.8

Lines							
Unit name	**Unit**	**L_SW_NW**	**L_SW_S**	**L_S_SE**	**L_NE_SE**	**L_NW_N**	**L_NE_N**
Un	kV	380	380	380	380	380	380
R1	Ohm	0.01	0.01	0.01	0.01	0.01	0.01
X1	Ohm	1	1	1	1	1	1
Ir	A	600	500	500	600	600	600

HVDC			
Unit name	**Unit**	**HVDC1**	**HVDC2**
Ur	kV	400	400
Pr	MW	500	500
rdc	Ω	1	1
voltage-angle-control:			
headend station (SE)			
AC-angle control	MW/degree	-1260	-1260
AC-voltage control		OFF	OFF
DC-voltage control		ON	ON
Udc	kV	400	400
headend station (SO)			
AC-angle control	MW/degree	0	0
AC-voltage control		ON	ON
Usetpoint	kV	380	380
DC-voltage control		OFF	OFF

Phase-shifting transformer		
Unit name	**Unit**	**PST_NE_NE_1**
Ur1 (NO)	kV	380
Ur2 (NE)	kV	380
Sr	MVar	263.272
ukr	%	0.18233
Pk	kW	4.80001
Poc	kW	100
io	%	0.1
vektor group		DD4
tap changer		
max.		11
main		6
min.		1
additional voltage		
max. position	%	0.17453
min. position	%	-0.17453
angle	°	90

Table of Market Input

	Feeder				Load		
PIT	N_G	SW_G1	SW_G2	SE_G	SW_L	SE_L1	SE_L2
	P [MW]	P [MW]	P [MW]	P [MW]	P [MW]	P [MW]	P [MW]
1	0	-960	0	0	0	0	960
2	0	-800	-100	0	450	0	450
3	0	-600	-200	0	400	0	400
4	-600	0	0	-600	1200	0	0
5	0	-600	-600	0	600	0	600
6	-600	-2000	-2000	0	0	2000	2600
7	0	-800	-800	0	800	0	800
8	0	-2000	-2000	-600	0	2000	2600
9	-600	-1000	-1000	-600	1000	1200	1000
10	0	-900	-900	0	900	0	900
11	0	-1000	-1000	0	1000	0	1000
12	0	-1100	-1100	0	1100	0	1100
13	-600	0	0	0	0	600	0
14	-600	-2000	-2000	-600	0	2600	2600
15	-600	-2000	-2000	0	0	2000	2600
16	-600	0	-1000	-600	1100	0	1100
17	0	-1200	-1200	0	1200	0	1200
18	0	-2000	-2000	0	0	2000	2000
19	0	-1400	-1400	0	1400	0	1400
20	0	-1300	-1300	0	1300	0	1300
21	0	-1100	-1100	0	1100	0	1100
22	0	-900	-900	0	900	0	900
23	0	-700	-700	0	700	0	700
24	0	-500	-500	0	500	0	500

Template of Table of Results

	Feeder				Phase-shifting transformer		HVDC	
PIT	N_G	SW_G1	SW_G2	SE_G	PST_NW_NE_1	PST_NW_NE_1	HVDC1	HVDC2
	dP [MW]	dP [MW]	dP [MW]	dP [MW]	dSteps[]	dAngle[°]	dP [MW]	dP [MW]
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
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21								
22								
23								
24								

ANNEX 2: DATA FOR THE MONETIZATION

CO2 emission per type

Category #	Fuel	Type	Efficiency range in NCV terms %	Standard efficiency in NCV terms %	CO_2 emission factor kg / Net GJ	CO_2 emission factor t / Net MWh	CO_2 emission factor t / MWh
1	Nuclear	-	30% - 35%	33%	0	0.00	0.00
2	Hard coal	old 1	30% - 37%	35%	94	0.34	0.97
3	Hard coal	old 2	38% - 43%	40%	94	0.34	0.85
4	Hard coal	new	44% - 46%	46%	94	0.34	0.74
5	Hard coal	CCS	30% - 40%	38%	9.4	0.03	0.09
6	Lignite	old 1	30% - 37%	35%	101	0.36	1.04
7	Lignite	old 2	38% - 43%	40%	101	0.36	0.91
8	Lignite	new	44% - 46%	46%	101	0.36	0.79
9	Lignite	CCS	30% - 40%	38%	10.1	0.04	0.10
10	Gas	conventional old 1	25% - 38%	36%	57	0.21	0.57
11	Gas	conventional old 2	39% - 42%	41%	57	0.21	0.50
12	Gas	CCGT old 1	33% - 44%	40%	57	0.21	0.51
13	Gas	CCGT old 2	45% - 52%	48%	57	0.21	0.43
14	Gas	CCGT present 1	53% - 60%	56%	57	0.21	0.37
15	Gas	CCGT present 2	53% - 60%	58%	57	0.21	0.35
16	Gas	CCGT new	53% - 60%	60%	57	0.21	0.34
17	Gas	CCGT CCS	43% - 52%	51%	5.70	0.02	0.04
18	Gas	OCGT old	35% - 38%	35%	57	0.21	0.59
19	Gas	OCGT new	39% - 44%	42%	57	0.21	0.49

20	Light oil	-	32% - 38%	35%	78	0.28	0.80
21	Heavy oil	old 1	25% - 37%	35%	78	0.28	0.80
22	Heavy oil	old 2	38% - 43%	40%	78	0.28	0.70
23	Oil shale	old	28% - 33%	29%	100	0.36	1.24
24	Oil shale	new	34% - 39%	39%	100	0.36	0.92