# CRM Design Note:

# Derating factors

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ABOUT THE PUBLIC CONSULTATION

This design note is put for formal public consultation and any remark, comment or suggestion is welcome. It builds further on the discussions and proposals already made in the different TF CRM meetings gathering all relevant stakeholders and in the follow-up committee, the latter consisting of representatives of the CREG and Elia, under the presidency of the FPS Economy.

This public consultation runs in parallel with a public consultation on other design notes. Reactions to this public consultation can be provided to Elia via the specific submission form on Elia's website no later than **Wednesday 30 October 2019 at 6pm**.

On 13 September 2019 a first set of design notes has already been launched by Elia for public consultation[1].

Note that, in line with their roles and responsibilities and the foreseen governance in the Electricity Law, also the FPS Economy and the CREG will consult on aspects within their competence according to their procedures.

[1] https://www.elia.be/en/public-consultation/20190913_formal-public-consultation-on-the-crm-design-notes-part-i

# Introduction

This design note will serve as basis for Elia's proposal regarding the methodology, as referenced in Article 7undecies, §2 of the CRM Law[2]. In particular, the principles included at the end of each chapter of this note, will serve as guidance for Elia when preparing its proposal of methodology.

In accordance with Article 7undecies, §2 of the CRM Law, a yearly calibration for the parameters will take place. At the end, a yearly Ministerial Decision is taken in order to instruct the TSO to organize the auction and according to which parameters.

The purpose of this document is to present the methodology and the process that will be followed to determine the derating factors associated with every capacity, hence reflecting its expected contribution to adequacy. In addition, it will also provide the maximum cross-border contribution per border. The multiplication of the associated derating factor and the reference power upon prequalification results in the derated capacity, i.e. the maximum capacity that could take part in the auction.

An overview of the whole process is illustrated on Figure 1.

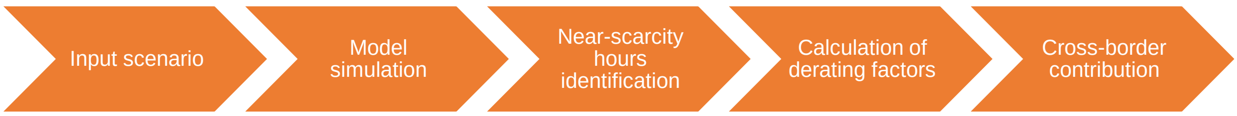



*Figure 1: Methodology overview*

**The first step** of the methodology is to select an input scenario on which the derating factors will be calculated. Such scenario must contain at least information about the expected hourly consumption profiles, thermal generation facilities, RES capacities, storage capacities, market response and cross-border market capacities between considered countries. In addition associated weather profiles, energy limitations and technology characteristics are also required.

**The second step** consists in performing a 'Monte-Carlo' probabilistic simulation to dispatch the different facilities to meet the electricity demand following a cost optimization approach. The output of the model will first provide all the data needed to calibrate the input scenario installed capacities to comply with the legal adequacy criteria, as referenced in Article 7undecies, §3 of the CRM Law. The model will also provide dispatch indicators necessary to calculate the contribution of each technology, like countries net position or the hourly generated energy per technology.

**The third step** consists of determining the near-scarcity hours. These hours represent the time periods which are critical for the Belgian electricity adequacy.

[2] http://www.ejustice.just.fgov.be/doc/rech_n.htm

Once this set of hours is known, **the fourth step** is to calculate model-based derating factors for all technologies. A derating factor is calculated as the ratio between the average contribution during near-scarcity hours (the contribution to security of supply) and the reference power of every technology.

Following the same methodology, the maximum entry capacity for cross-border participation for each border is calculated in **the last step**.

All these steps, and if applicable any other relevant input, will be provided for the determination of the capacity to be procured.

# 0 Legal framework

This design note is based on the CRM Law from 22nd of April 2019 that modifies the Electricity Law of 29th April 1999 on the organization of the electricity market.

The main articles concerning the derating factors are the following:

| **22 April 2019<br>Wet tot wijziging van de wet<br>van 29 april 1999 betreffende de organisatie<br>van de elektriciteitsmarkt, teneinde<br>een capaciteitsvergoedingsmechanisme<br>in te stellen** | **22 avril 2019<br>Loi modifiant la loi<br>du 29 avril 1999 relative à l'organisation<br>du marché de l'électricité portant<br>la mise en place d'un mécanisme<br>de rémunération de capacité** |
|---|---|
| **Ch.2, Art 2, §78** | |
| **"vraagcurve": de curve die de variatie weergeeft van het te contracteren capaciteitsvolume in functie van het prijsniveau van de capaciteit** | "courbe de demande": la courbe représentant la variation du volume de capacité à contracter en fonction du niveau de prix de la capacité |
| **Ch.2, Art 2, §83** | |
| **"reductiefactor": de wegingsfactor van een bepaalde capaciteit, die diens bijdrage aan de bevoorradingszekerheid bepaalt, teneinde het volume vast te leggen dat in aanmerking komt om deel te nemen aan de veiling** | "facteur de réduction": le facteur de pondération d'une capacité considérée, déterminant sa contribution à la sécurité d'approvisionnement afin de fixer le volume éligible à participer à la mise aux enchères |
| **Ch.2, Art 6, §2** | |
| **Op basis van een methode die wordt vastgesteld door de Koning, op voorstel van de netbeheerder, opgesteld na raadpleging van de marktspelers en na advies van de commissie, stelt de netbeheerder, na raadpleging van de marktspelers over met name de basishypotheses, de twee volgende verslagen op:**<br>**1° een eerste verslag […] dat de berekeningen bevat van het noodzakelijke capaciteitsvolume en het aantal uren tijdens dewelke deze capaciteit gebruikt zal worden ten behoeve van de toereikendheid, met het oog op het verzekeren van het vereiste niveau aan bevoorradingszekerheid zoals bepaald in paragraaf 3, voor de veilingen van één jaar en van vier jaar vóór de periode van capaciteitslevering. Dit verslag omvat eveneens een voorstel voor een minimaal te reserveren volume voor de veiling die één jaar voor de periode van capaciteitslevering plaatsvindt. Dit minimaal te reserveren volume is minstens gelijk aan de capaciteit die gemiddeld minder dan 200 draaiuren heeft per jaar teneinde de totale piekcapaciteit af te dekken; en**<br>**2° een tweede verslag dat een voorstel bevat van parameters, berekend op basis van het volume bedoeld in het 1°, die noodzakelijk zijn voor de organisatie van de veiling van vier jaar vóór de periode van capaciteitslevering, met name de vraagcurve, de prijslimiet(en), de referentieprijs, de uitoefenprijs en de reductiefactoren. Dit verslag bevat eveneens de noodzakelijke aanpassingen voor de veiling van één jaar vóór de periode van capaciteitslevering.**<br>Voorafgaand aan de opmaak van het verslag bedoeld in het | Sur la base d'une méthode fixée par le Roi, sur proposition du gestionnaire du réseau, formulée après consultation des acteurs du marché et après avis de la commission, le gestionnaire du réseau établit, après consultation des acteurs du marché notamment sur les hypothèses de base, les deux rapports suivants:<br>1° un premier rapport contenant un calcul du volume de capacité nécessaire et du nombre d'heures pendant lesquelles cette capacité sera utilisée à des fins d'adéquation, en vue d'assurer le niveau de sécurité d'approvisionnement requis conformément au paragraphe 3, pour les mises aux enchères quatre ans et un an avant la période de fourniture de capacité. Ce rapport contient également une proposition de volume minimal à réserver pour la mise aux enchères se déroulant un an avant la période de fourniture de capacité. Ce volume minimal à réserver est au moins égal à la capacité nécessaire, en moyenne, pour couvrir la capacité de pointe totale pendant moins de 200 heures de fonctionnement par an; et<br>2° un second rapport contenant une proposition des paramètres, calculés sur la base du volume visé au 1°, nécessaires à l'organisation de la mise aux enchères quatre ans avant la période de fourniture de capacité, notamment, la courbe de demande, le ou les plafond(s) de prix, le prix de référence, le prix d'exercice et les facteurs de réduction. Ce rapport contient également les ajustements nécessaires pour la mise aux enchères un an avant la période de fourniture de capacité.<br>Préalablement à l'établissement du rapport visé à |

| | |
|---|---|
| eerste lid, 1°, stelt de Algemene Directie Energie alle informatie die nuttig is voor die analyse en waarover het beschikt, ter beschikking van de netbeheerder.<br>Uiterlijk op 15 december van elk jaar worden de in het eerste lid bedoelde verslagen voor advies bezorgd aan de commissie en aan de Algemene Directie Energie.<br>De Algemene Directie Energie en de commissie maken uiterlijk op 15 februari hun respectieve adviezen met betrekking tot deze verslagen over aan de minister.<br>Uiterlijk op 31 maart van elk jaar, op basis van de verslagen en de adviezen bedoeld in het eerste en het vierde lid, met het oog op het verzekeren van het vereiste niveau aan bevoorradingszekerheid zoals bepaald in paragraaf 3, na overleg in de Ministerraad, geeft de minister instructie aan de netbeheerder om de veilingen te organiseren voor de onderzochte perioden van capaciteitslevering, stelt de parameters vast die nodig zijn voor hun organisatie en bepaalt het minimaal te reserveren volume voor de veiling die één jaar voor de periode van capaciteitslevering georganiseerd wordt. Dit minimaal te reserveren volume is minstens gelijk aan de capaciteit die gemiddeld minder dan 200 draaiuren heeft per jaar teneinde de totale piekcapaciteit af te dekken, vermeerderd met de onzekerheidsmarge vervat in de initiële volumeberekening uitgevoerd door de netbeheerder in het verslag bedoeld in het eerste lid, 1°. | l'alinéa 1er, 1°, la Direction générale de l'Énergie met à disposition du gestionnaire du réseau toute information utile pour cette analyse et dont elle dispose.<br>Au plus tard le 15 décembre de chaque année, les rapports visés à l'alinéa 1er sont transmis pour avis à la commission et à la Direction générale de l'Energie.<br>La Direction générale de l'Énergie et la commission transmettent leurs avis respectifs relatifs à ces rapports au ministre au plus tard le 15 février.<br>Au plus tard le 31 mars de chaque année, sur la base des rapports et des avis visés aux alinéas 1er et 4, afin d'assurer le niveau de sécurité d'approvisionnement requis conformément au paragraphe 3, après concertation en Conseil des ministres, le ministre donne instruction au gestionnaire du réseau d'organiser les mises aux enchères pour les périodes de fourniture de capacité considérées, fixe les paramètres nécessaires à leur organisation et détermine le volume minimal à réserver pour la mise aux enchères organisée un an avant la période de fourniture de capacité. Ce volume minimal à réserver est au moins égal à la capacité nécessaire, en moyenne, pour couvrir la capacité de pointe totale pendant moins de 200 heures de fonctionnement par an, augmentée de la marge d'incertitude prévue dans le calcul du volume initial effectué par le gestionnaire du réseau dans le rapport visé au 1° de l'alinéa 1er. |
| **Ch.2, Art 6, §3** | |
| **Het te bereiken niveau van bevoorradingszekerheid dat wordt vooropgesteld voor het capaciteitsvergoedingsmechanisme, komt overeen met de vraagcurve, die gekalibreerd wordt met als referentie:**<br>**1° desgevallend, de geharmoniseerde normen vastgesteld door de in deze aangelegenheid bevoegde Europese instellingen;**<br>**2° bij het ontbreken van geharmoniseerde normen op Europees niveau, desgevallend de geharmoniseerde normen vastgesteld op regionaal niveau, inzonderheid op het niveau van de Centraal-West-Europese elektriciteitsmarkt;**<br>**3° bij het ontbreken van zulke normen, een berekening van een LOLE van minder dan 3 uur en van een LOLE95 van minder dan 20 uur.** | Le niveau de sécurité d'approvisionnement à atteindre visé par le mécanisme de rémunération de capacité correspond à la courbe de demande calibrée avec comme référence:<br>1° le cas échéant, des normes harmonisées établies par les institutions européennes compétentes en la matière;<br>2° en l'absence de normes harmonisées au niveau européen, les normes harmonisées fixées le cas échéant au niveau régional, en particulier au niveau du marché de l'électricité du Centre Ouest de l'Europe;<br>3° en l'absence de telles normes, un calcul de LOLE inférieur à 3 heures et de LOLE95 inférieur à 20 heures. |

**Disclaimer:**

The above-mentioned legal framework is subject to evolution, in particular to align it with the European 'Clean Energy Package-legislation'. This could impact the process of the determination of the reliability standard for Belgium and the competences in the volume determination process. This design note already anticipates the possible future changes, to the best of knowledge of Elia, following discussion in a working group consisting of representatives of CREG, FPS Economy and Elia.

# 1 Input scenario


The derating factors shall always be calculated based on a given input scenario. To develop a coherent scenario, some information must be provided regarding on the one hand the national consumption and on the other hand the different capacity sources and their characteristics (volume, energy limitations…). These data should be available for Belgium but also for at least the electrically directly connected market zones included in the simulation perimeter. Moreover, the interconnection capacity between the different considered market zones must also be determined.

An example of input scenario to calculate the derating factors for Belgium could be the latest available 'central scenario' from the European Resource Adequacy Assessment (ERAA) defined at ENTSO-E level.

The input parameters that are required to determine derating factors are [I]:

- The consumption (growth) and hourly normalized consumption profiles;
- The installed capacity of thermal generation facilities with their associated availability parameters for per-unit modeled generators and hourly generation profiles for distributed thermal capacities;
- The installed solar, wind and hydroelectric capacity;
- The installed storage facilities with their associated efficiency and reservoir constraints;
- The installed demand flexibility/market response capacity with their associated energy or activation limits;
- The interconnection capacity between market zones (e.g. 'flow-based' domains, 'NTC' capacities).

To correctly calibrate the derating factors and given that the CRM is designed to procure the needed capacity to be adequate, the input scenario has to be made adequate following the adequacy criteria defined for Belgium (cf. section on model simulation). It means that the defined reliability standard has to be respected, as referenced in Article 7undecies, §3 of the CRM Law.

*Example: Case study from the Adequacy & Flexibility study [I]*

*Throughout this note, an example is used to illustrate the different concepts and the process to be followed when calculating derating factors.*

*For this example a scenario is used from the latest 10 year Adequacy & Flexibility study [I]. The input scenario used is the 'CENTRAL/EU-BASE' scenario for 2025, which also takes into account the 'flow-based' model implemented for CWE countries (including the CEP min 70% rule) and the adequacy patch.*

*The main assumptions for Belgium of this example scenario are summarized on Figure 2.*

**Summary of assumptions for Belgium**

Key assumptions for Belgium

| | | 2018 | 2020 | 2023 | 2025 | 2028 | 2030 |
|---|---|---|---|---|---|---|---|
| | Energy efficiency<br>Economic growth | In line with WAM scenario from draft NECP submitted by Belgium to the EC | | | | | |
| | Amount of EV | 20k | 88k | 306k | 518k | 919k | 1310k |
| | HP (elec/hybrid) penetration | 1.3k | 5.5k | 25k | 68k | 170k | 249k |
| | Total Demand (incl. electrification) [TWh] | 85.5 | 86.2 | 86.4 | 86.9 | 87.8 | 88.8 |
| Market response | Shedding* [GW] | 1.2 | 1.4 | 1.5 | 1.6 | 2.2 | 2.6 |
| Market response | Shifting [GWh/day] | ≈0 | ≈0 | 0.3 | 0.5 | 1.1 | 1.5 |
| Storage | in pumped storage [GW] | 1.3 | 1.3 | 1.3 | 1.4 | 1.4 | 1.4 |
| Storage | in stationary batteries and EV [GW] | ≈0 | 0.1 | 0.6 | 1 | 1.4 | 1.6 |
| RES [GW] | | 3.9 | 5 | 6.9 | 8.3 | 9.9 | 11 |
| RES [GW] | | 2.3 | 2.8 | 3.3 | 3.6 | 4.1 | 4.5 |
| RES [GW] | | 1 | 1.6 | 2.3 | 2.3 | 4 | 4 |
| RES [GW] | Hydro RoR | 0.12 | 0.12 | 0.13 | 0.14 | 0.14 | 0.15 |
| RES [GW] | Biomass | 0.8 | 0.8 | 0.7 | 0.5 | 0.5 | 0.5 |
| Existing thermal [GW] | CHP + waste | 2.3 | 2.4 | | | | |
| Existing thermal [GW] | Nuclear | 5.9 | 5.9 | 3.9 | 0 | | |
| Existing thermal [GW] | Existing CCGT/OCGT | 4.4 | 4.0 | Economic viability check (all existing units are considered unless their closure has been announced) | | | |
| Existing thermal [GW] | Existing CCGT-CHP** | 0.5 | 0.5 | | | | |
| Existing thermal [GW] | Turbojets | 0.1 | 0.1 | | | | |
| Existing thermal [GW] | New capacity (DSM, Diesels, CCGT, OCGT, Storage,…) | | | Possibility to invest in any new capacity (if viable) | | | |

** including ancillary services volume*
*** Zandvliet and Inesco are categorised in CCGT-CHP to reflect their ability to operate in CHP mode*

Figure 2: Assumptions for Belgium for the illustrational example [I]

**Main principles which serve as input for the Royal Decree proposal**

1. The Minister shall determine on an annual basis and no later than 31 March of every year, the derating factors and cross-border entry capacity for every auction on the basis of a scenario.
2. The scenario shall include input parameters on consumption, supply and interconnection capacity for Belgium and at least electrically connected market zone.

# 2 Model simulation


Once the input scenario has been defined, a 'Monte-Carlo' simulation is performed with a unit commitment tool for the given year. The purpose of this tool is to optimally dispatch the different technologies on the market to meet the hourly consumption for each considered market zone. The simulation methodology that will be applied shall be in line with the relevant sections of the 'European Resource Adequacy Assessment' methodology, provided that such an approved methodology exists at the time of performing the calculations. The simulation shall apply the requirements described in this methodology, insofar they are implemented in the most recently published ENTSO-E ERAA report at the time of performing the calculations on derating factors. For the latter, the most recently published 'ENTSO-E Mid-Term Adequacy Forecast' report at the time of performing the calculations on derating factors is used as a benchmark.

A 'Monte-Carlo' method is used to perform simulation of the electricity market. This requires the construction of a large number of future states (called 'Monte-Carlo' years). The different variables which are needed to perform the simulations can be subdivided into two categories: weather variables and the availability of generation or interconnection facilities (more information can be found in Annex 1: Correlation of climatic conditions).

First, periodic values for wind energy generation, solar generation, hydro inflows and temperature-dependent electricity consumption are mutually correlated. These climatic variables are modelled on the basis of a representative number of historical years. The forecasts of installed capacity for each simulated market zone are combined with this historical data to obtain production time series for onshore wind, offshore wind, photovoltaic production and hydroelectric 'run-of-river' production. The temperatures of the historical years have an impact on the electricity consumption.

Second, parameters related to the availability of thermal generation or HDVC links (in a non-meshed grid) are assumed to be independent from climatic data and therefore not correlated to the others. Thermal generation can be subdivided in two categories. On the one hand, large thermal generation units, independent of their generation types, are modelled individually, with their specific technical characteristics. Their individual availability is determined by a probabilistic draw for each 'Monte Carlo' year based on historical availability rates. This way, a sequence of availabilities can be drawn for each unit to be used in the simulations. On the other hand, small thermal generation units are modelled in an aggregated way by using a fixed generation profile based on historical metering data. The availability of these smaller units is directly taken into account in the generation profile, and is therefore the same for all 'Monte Carlo' years.

The generation output of climate independent technologies is optimized by the simulator.

This category also contains flexible technologies such as storage or market response. Storage capacity is economically optimized, storing electricity in some form when prices are low and releasing electricity when those are higher. Market response is also introduced in the model with a certain number of constraints. The model optimizes their dispatch, taking their specific characteristics and limitations into account.

The above variables are combined into a number of 'Monte-Carlo' years so that the correlation between the various renewable energy sources (wind, solar, hydroelectric) and the temperature remains intact. Both geographical and time correlations are present. Consequently, the climatic data relating to a given variable for a specific year shall always be combined with data from the same climatic year for all other variables, with this applying to all market zones involved. In contrast, for power plant and HVDC link availability, random samples are taken by the model, by considering the parameters of probability and length of unavailability (in accordance with the 'Monte Carlo' method). Availability thus differs for each future state. Since each 'Monte Carlo' year carries the same weight in the assessment, the different availability samples have equal probability of occurrence.

Based on the defined inputs and parameters, the optimization problems are solved with an hourly time step and a weekly timeframe, making the assumption of perfect information at this weekly time horizon but assuming that the evolution of load and RES is not known beyond this weekly horizon. Fifty-two weekly optimization problems are therefore solved in a row for each 'Monte-Carlo' year. The simulation ends when it reaches a convergence criterion by combining the results of all these future states.

The optimal dispatch, minimizing overall ENS, is based on market bids reflecting the marginal costs of each unit (be it generation, storage or demand/market response) [€/MWh]. When this optimum is found, the following output can be analysed in order to derive the derating factors and cross border contribution:

- Hourly dispatch by technology (generation, storage or demand/market response);
- Hourly net position for all market zones within the 'flow-based' zone (only Belgium and electrically directly connected market zones data will be used);
- Hourly cross border exchanges on links modelled with 'net transfer capacities' (links between market zones inside the 'flow-based' zone and outside of this zone).

Following the simulations, the output data provided by the model enables a large range of indicators to be determined. In the framework of this design note, the main parameters of interest will be dispatch indicators:

- market exchanges between market zones;
- generated energy per fuel/technology.

Figure 3 summarizes the global process.

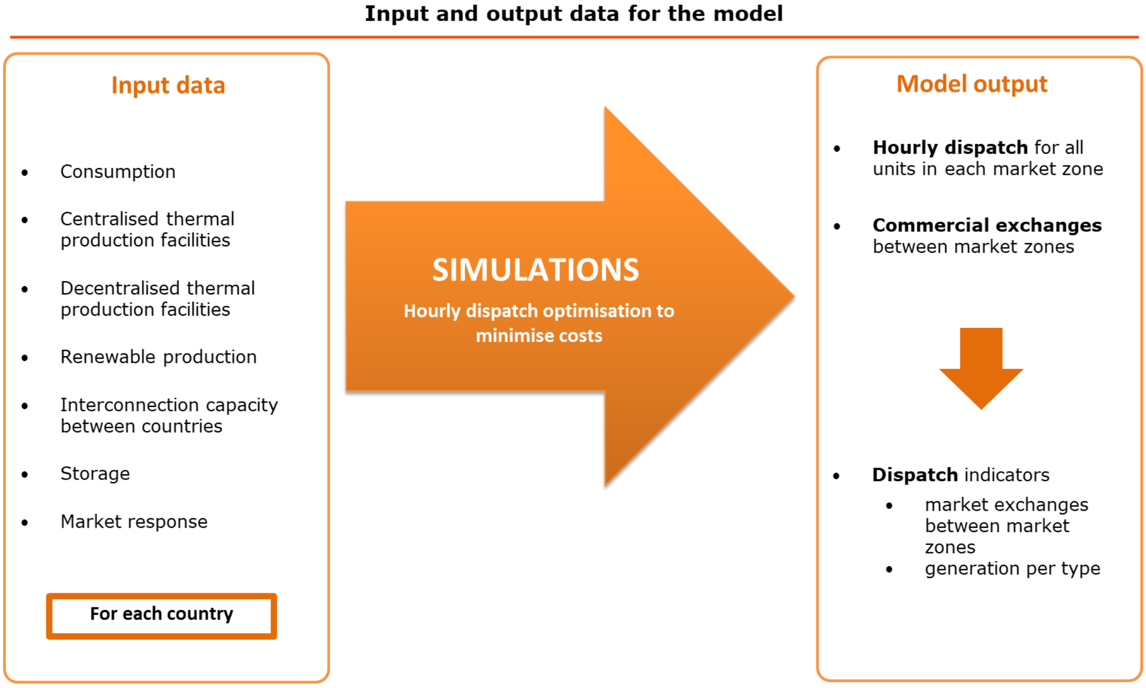


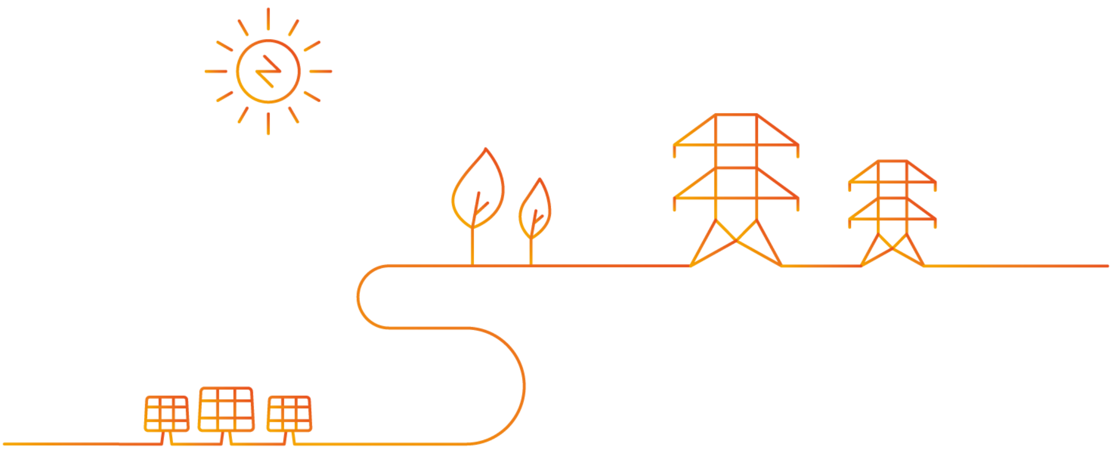

*Figure 3: Hourly electricity market model [I]*

The hourly generated energy per technology and the hourly imports/exports are furthermore required to calculate the derating factors and the maximum entry capacity for cross-border participation for each border.

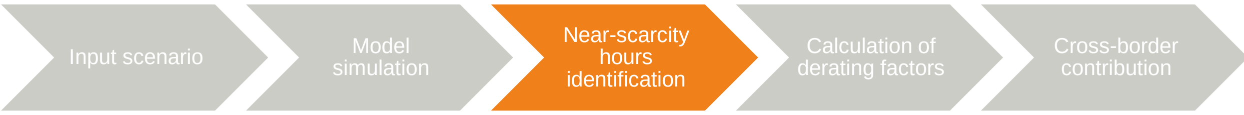
As mentioned before, the applicable adequacy criteria of Article 7undecies, §3 of the CRM Law needs to respected. If the input scenario already complies with the criterion, then it is assumed to be adequate and the analysis can continue. In contrast, if the criterion is not reached, a virtual capacity (100% available capacity) will be added, or vice-versa, if the scenario is 'over-adequate', a volume of assumed new capacity will be removed to the point where any additional removal would lead to a non-compliance with the criteria.

**Main principles which serve as input for the Royal Decree proposal**

3. Elia shall perform a simulation of the electricity market. The simulation shall be based on the relevant sections as determined by the TSO of the European Resource Adequacy Assessment methodology referenced in Article 23 of Regulation (EU) 2019/943, provided such methodology has been adopted at the time of the simulation. The simulation shall apply the requirements described in this methodology, insofar they are implemented in the most recently published ENTSO-E ERAA report at the time of performing the calculations on derating factors.
4. The simulation shall provide the hourly dispatch per technology and net positions of Belgium and at least electrically connected market zone.
5. In case the simulation demonstrates that the scenario does not comply with the applicable adequacy criteria for Belgium, the Belgian installed capacity in the scenario shall be recalibrated as follows:
    i. if one or more of the applicable adequacy criteria of Article 7undecies, §3 of the CRM Law are not reached, an additional virtual capacity shall be added until the criteria is reached;
    ii. if one or more of the applicable adequacy criteria of Article 7undecies, §3 of the CRM Law are exceeded, a volume of assumed new capacity shall be removed to the point where any additional removal would lead to a non-compliance with the criteria.



# 3 Identification of near-scarcity hours




The purpose of this step is to select from the simulation output the critical hours for the Belgian adequacy. These hours correspond to situations where the sum of the available capacity on the market and the imports from electrically directly connected market zones is insufficient to meet the domestic consumption or close to the limit.

In the remainder of this note, the term ‘near-scarcity hours’ refers to both those hours with ENS (scarcity) and those hours that are close to a situation of scarcity (near-scarcity). Near-scarcity refers to situations where any additional increase of the load will lead to energy not served.

## 3.1 Choice of a criterion

The criterion used for the determination of the near-scarcity hours is a situation where any additional load in Belgium would not be served and would therefore lead to ENS. This criterion leads to an identification of hours where a scarcity situation with ENS exists, as well as hours with a near-scarcity situation where no margin is left.

## 3.2 Justification

The consideration of near-scarcity hours while calculating the derating factors is deemed necessary as relying only on the hours with ENS would not take into account situations where the system is close to its limits. As these situations are also critical for the adequacy of Belgium, the contribution of each technology to system adequacy should also account for such near-scarcity hours.

Basing the criterion on a given threshold (in [€]) for the marginal price introduces the difficulty of fixing this threshold value. It is very difficult to objectively select such a threshold, also given that simulated prices will depend on assumptions taken in the scenario regarding generation mix in Belgium and abroad, economic parameters, etc.

Therefore, an approach is proposed where the identification of near-scarcity situations is based on the appearance of ENS when for the given hour any additional consumption would be introduced in Belgium. This approach does not require setting a specific threshold value on simulated prices while allowing to capture the critical time periods from different ‘Monte-Carlo’ years.

**Main principles which serve as input for the Royal Decree proposal**

6. Near-scarcity hours shall mean hours in which there is simulated Energy Not Served and in which no more margin is left in Belgium, meaning that any additional load would not be served.

# 4 Calculation of derating factors


The purpose of derating factors is to evaluate the contribution of different technologies (generation/demand flexibility/storage facilities) to the Belgian adequacy for a particular input scenario. In the framework of the CRM, this contribution is evaluated in situations where Belgium is facing near-scarcity, as defined in §3. In such situations, the total generation combined with imports are insufficient to cover either the actual load (scarcity) or any additional load (near-scarcity).

The derating factors are technology specific and expressed as the percentage of the reference power that contributes to adequacy. It represents the fact that technologies are not assumed to be available to generate 100% of the time at 100% of their reference power during near-scarcity hours, due to breakdowns, maintenance cycles, economical constraints, technical constraints or weather conditions. In order to determine the contribution to adequacy of each unit, the capacity within each technology category is derated.

In the framework of the CRM, 4 main categories of contribution to adequacy are considered (Figure 4). The different technologies taken into account for the derating factors are divided into these 4 categories. They are based on the currently available technologies and could evolve in the future. The maximum entry capacity for cross-border participation for each border forms a particular case since their contribution is expressed in [MW] rather than in [%]. Cross-border contribution is therefore not represented in this figure and is presented in chapter 5.

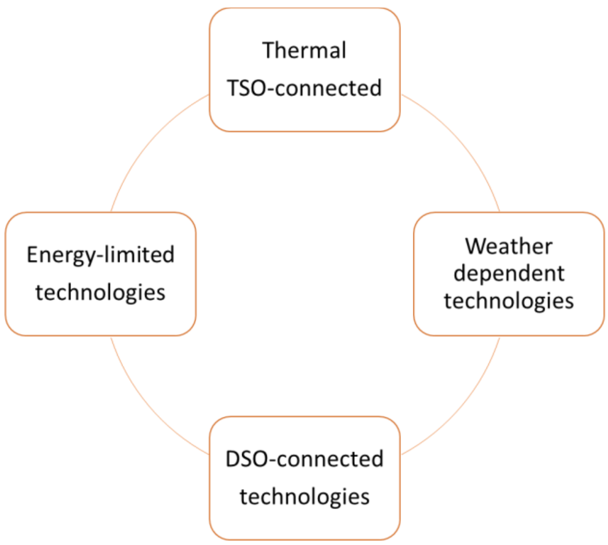



*Figure 4: Derating factors categories*

## 4.1 Thermal TSO-connected technologies

### 4.1.1 Concept

The first category takes into consideration technologies that contribute to adequacy independently from the weather conditions and without energy limitations. In the framework of the CRM, this category mostly refers to thermal units.

Thermal units consist in fossil fuel generation including TSO-connected combined heat and power (CHP), biomass and waste units, CCGT and OCGT. Turbojets, gas engines or diesel generators are also considered in this category. The main parameters impacting these units are their planned and unplanned unavailabilities (Figure 5). On the one hand, for planned outages, it is assumed that no maintenance is applied during winter months (or more specifically when near-scarcity situations occur). Therefore, planned outages will have no impact on the derating factors since no planned outage are assumed during near-scarcity periods. On the other hand, forced outage events are, within the probabilistic approach, assumed independent from the specific climate conditions occurring within the set of near-scarcity hours identified.

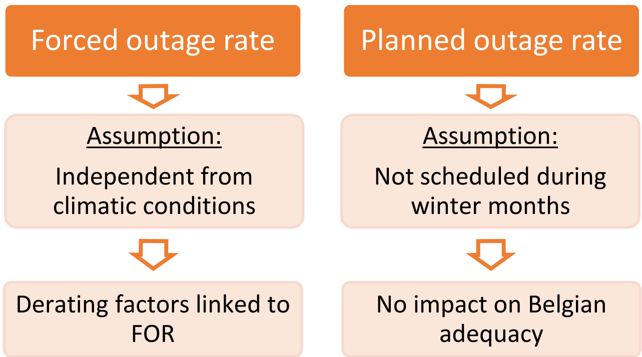



*Figure 5: Thermal units' parameters*

For the thermal generation, the assumed yearly average forced-outage rates (FORs) are provided as input to the model (combined with an average duration of such FORs). Given their independence from climatic variables and that these technologies are not constrained by activation limitations, the model-based approach will lead to the result that the average contribution of each thermal technology during the near-scarcity hours is equal to its reference power reduced by the given FOR percentage. The associated derating factors of these technologies can therefore simple be inferred from the input parameters provided to the model (i.e. historical FO data).

The thermal derating factors are thus computed from forced outage rates through the following formula:

$$\mathrm{DRF}\ [\%] = \frac{\text{Average contribution during near} - \text{scarcity hours [MW]}}{\text{Reference power [MW]}}$$

which is equivalent to:

[1]   DRF [%] = 100 [%] - Forced Outage Rate [%]

### 4.1.2 Categories

This methodology is applied for the technologies for which the historical FO data are sufficient, trustworthy and assumed independent from the weather/seasonal conditions.

In the framework of the CRM, it will therefore be applied for the technologies defined on Figure 6.

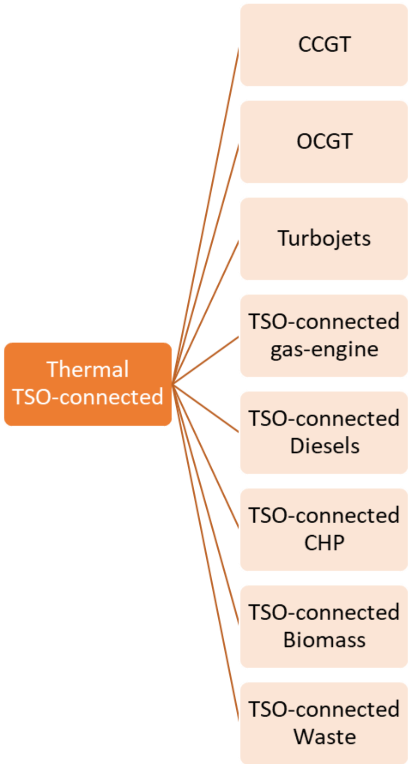



*Figure 6: Thermal TSO-connected categories*

*Example: Derating factors for thermal TSO-connected technologies*

*As an illustration, the input data from the Adequacy and Flexibility report* [I] *can be used. The different forced outage rates are determined and formula* [1] *is applied. The results are presented in Table 1.*

| Technologies | Forced outage rate [%] | Derating factors [%] |
|---|---|---|
| **CCGT** | 8,9 | 91,1 |
| **OCGT** | 12,3 | 87,7 |
| **TJ** | 4,3 | 95,7 |
| **TSO-connected CHP** | 6,4 | 93,6 |
| **TSO-connected Biomass** | 6,4 | 93,6 |
| **TSO-connected Waste** | 1,5 | 98,5 |

*Table 1: Example of historical-based derating factors*

## 4.2 Weather dependent technologies

### 4.2.1 Concept

For weather dependent technologies, the derating factors are calculated after analysis of the results of the model-based approach (Figure 7). Their contribution cannot be easily inferred from the input provided to the model. In this case, the contribution comes from the output of an associated 'Monte-Carlo' simulation including all technologies as input data. In the context of the CRM, the derating factors for these technologies are calculated on their contribution (from the simulation output) on near-scarcity hours, as defined in §3.

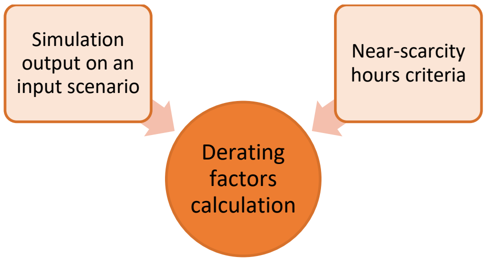



*Figure 7: Derating factors calculation – required data*

The derating factors are determined by dividing the average contribution of a particular technology during near-scarcity hours by its reference power.

The derating factors for weather independent technologies are computed through the following formula:

$$[2] \qquad \text{DRF [\%]} = \frac{\text{Average contribution during near-scarcity hours [MW]}}{\text{Reference power [MW]}}$$

### 4.2.2 Categories

In the framework of the CRM, this approach shall be applied for the technologies presented on Figure 8.

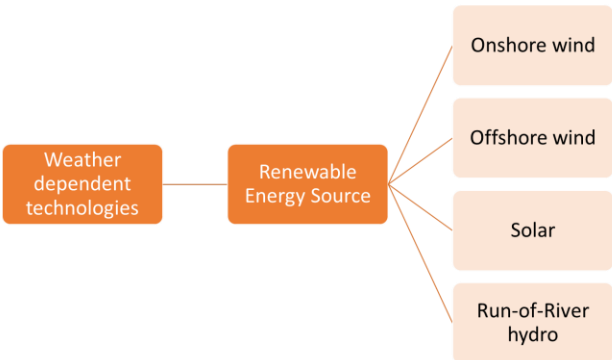



*Figure 8: Weather dependent technologies categories*

## 4.3 Energy-limited technologies

### 4.3.1 Concept

For energy-limited technologies, the derating factors are calculated by applying the same approach as for weather dependent technologies. Their derating factors are determined by dividing the average contribution of a particular technology during near-scarcity hours by its total reference power [2].

### 4.3.2 Categories

In the framework of the CRM, this approach shall be applied for categories defined on Figure 9.

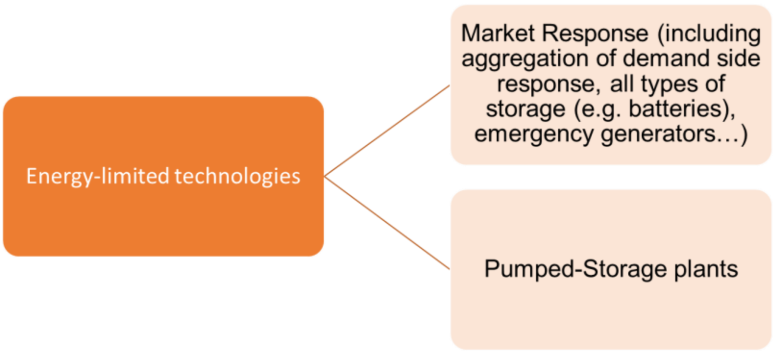



*Figure 9: Energy-limited technologies categories*

For flexible technologies (pumped-storage plants (PSP), market response, batteries or any other storage technology), the model optimizes their use so that they can maximally contribute to adequacy in near-scarcity hours when the price is the highest (and as such lead to the lowest overall ENS). Flexible sources are cost-optimized so that the pumping/loading cost is lower than the turbining/unloading revenue. Therefore, the optimization considers that pumping/loading can be interesting because there is a possibility to turbine/unload later at a higher price.

The contribution of market response and storage with high round trip efficiency (above 90%) subject to activation or reservoir constraints can be considered as equal as long as their availability duration is similar.

From the latest '10 year adequacy and flexibility study' performed by Elia [I], it can be shown that both a Market Response (MR) and a battery category with the same duration constraint have the same energy-constrained derating factor. Any aggregation of x% of MR and y% of battery (x% MR + y% battery) will qualify in principle under the same aggregation category.

A list of 'SLA categories' is therefore defined. Categories can be composed of any mix of MR (= DSR + generation +…), batteries or any other storage technology subject to similar activation constraints. For each 'aggregation category' a given activation limit is defined (Table 2). The derating factors for 'aggregation categories' can be therefore presented as so-called different 'service level agreements' (SLAs) based on hourly activation constraints (as most constraining limits). Moreover, every aggregation category is assumed to be available once a day.

In order for the aggregator or individual demand/market response provider to select the SLA category that best fits its portfolio/profile, the choice of SLA is left open and left to the aggregator/individual demand/market response provider.

| 'SLA category' | Duration | Limits |
|---|---|---|
| **SLA #1** | 1h | 1 activation / day |
| **SLA #2** | 2h | |
| **SLA #3** | 3h | |
| **SLA #4** | 4h | |
| **SLA #5** | 8h | |
| **SLA #6** | No Limit | NA |

*Table 2: MR categories*

The derating factors associated with each aggregation category is to be considered as a maximum threshold. Its value is associated with the contribution of the SLA category to the Belgian adequacy. Furthermore, it is up to the aggregator to define the level of the reference power of each aggregated CMU, according to the principles set up in the prequalification and availability monitoring parts of the design.

Pumped-storage cannot be associated to a SLA category, even if both energy-limited technologies can be in principle activated with the same duration[3] because the derating factors are different. This is explained by two main parameters:

- a pumping/turbining efficiency ratio of around 75% (value for Coo power plant in Belgium);
- a forced outage rate in the same logic as for thermal units.

These parameters lead to the definition of a specific derating factor for pumped-storage units.

[3] For PSP, the duration of activation is linked to the size of the reservoir and to the turbining capacity.

## 4.4 DSO-connected technologies

### 4.4.1 Concept

For DSO-connected units, available historical metering datasets are used as input in the simulation. Due to a lack of information[4], it is not feasible to model the exact behaviour of such units. One of the main characteristics of these technologies is that their generation is not always linked to the electricity price only because it has frequently other purposes as well (e.g. the production of heat or steam). Nevertheless, it is assumed that these units will maximize their electricity generation in case of high electricity prices. The derating factors are consequently obtained by dividing the maximum contribution of a particular technology during near-scarcity hours by its total installed capacity.

Since it is assumed that those units are able to maximally produce electricity in case of high electricity prices, their derating factors shall be computed by taking the maximum contribution of the technology during near-scarcity hours from the simulation output through the following formula:

$$[3] \qquad \mathrm{DRF}\ [\%] = \frac{\text{Maximum contribution during near–scarcity hours [MW]}}{\text{Total installed capacity [MW]}}$$

Nevertheless, if relevant and sufficient metering data are available in the future, the calculation of derating factors for DSO-connected units could evolve to be closer to reality. These derating factors will then be determined by the ratio of their average contribution during near-scarcity hours to the reference power [2].

### 4.4.2 Categories

For the DSO-connected units, a detailed analysis has been performed to compare the contribution to adequacy of different categories. On the one hand, the units can be divided by fuel type:

- waste,
- biomass, and
- gas-fired.

From applying the first categorization it could be concluded that the data for waste were not representative due to a too small number of units in this category.

[4] E.g. all DSO-connected are not metered, the TSO does not have access to the metering data … Only relevant available metering are used but it only represent a part of the capacity.

On the other hand, they can be divided by the contract type that has been awarded:

- Gtrad[5]
- Gflex[6]
- Gint[7]

When applying the second categorization, most units have a Gtrad contract. The number of units with Gflex and Gint contracts is not large enough and the available data are not sufficient to be representative[8].

Therefore, two main categories of derating factors have been taken into account for DSO-connected technologies (that are not weather dependent): RES and non-RES (Figure 10). These categories could be subject to evolution in case of additional available information or data in the future.

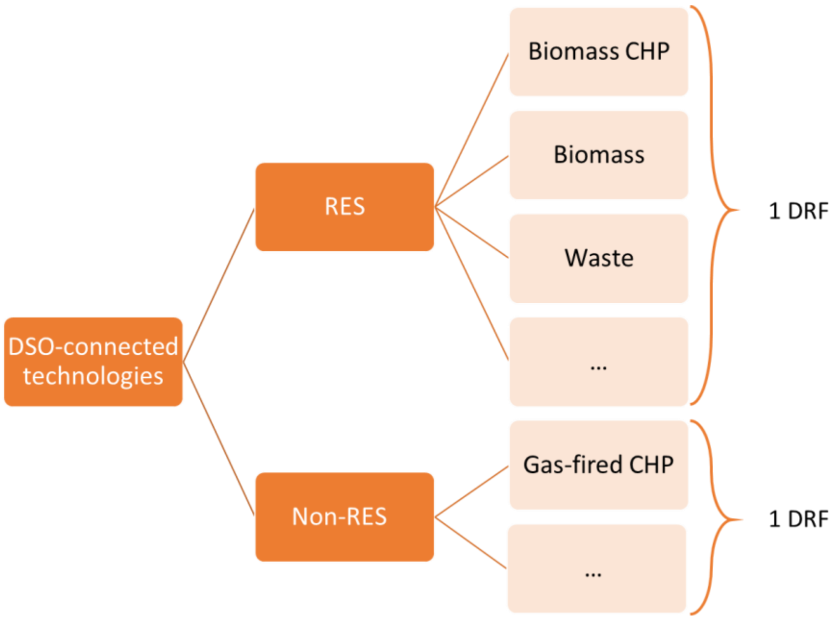



*Figure 10: DSO-connected technologies categories*

[5] Possibility to produce without any grid constraint.
[6] Possibility to produce subject to grid constraints. In case of planned or unplanned constraints on the grid, there can be a necessity to reduce the production.
[7] Interruptible production. The unit is connected through only one grid element to the transmission system (non-redundant connection). An interruptible unit can have either a Flex or a Trad contract.
[8] TSO-connected also have that kind of contract but the categorization does not apply since derating factors are determined based on forced outage rates.

## 4.5 Synthesis

Table 3 presents a synthesis of each category of derating factors and the formula used to determine those. Every technology taking part to the CRM has to be classified into one of these categories and the appropriate derating factor shall be applied to its reference power. These categories are based on the current available technologies and could evolve in the future.

<table>
<tr><th>Categories</th><th>Formulation</th><th>Sub-category</th><th>Technology</th><th>SLA Duration</th></tr>
<tr><td rowspan="4">Weather-dependent technologies</td><td rowspan="11">Average contribution during near-scarcity<br>/<br>Maximum capacity [%]</td><td rowspan="4">RES</td><td>Onshore wind</td><td>/</td></tr>
<tr><td>Offshore wind</td><td>/</td></tr>
<tr><td>Solar</td><td>/</td></tr>
<tr><td>Run-of-River</td><td>/</td></tr>
<tr><td rowspan="7">Energy-limited technologies</td><td rowspan="6">Market Response</td><td rowspan="6">Aggregation (MR + small-scale storage)</td><td>1h</td></tr>
<tr><td>2h</td></tr>
<tr><td>3h</td></tr>
<tr><td>4h</td></tr>
<tr><td>8h</td></tr>
<tr><td>No Limit</td></tr>
<tr><td>Large-scale storage</td><td>PSP</td><td>/</td></tr>
<tr><td rowspan="2">DSO-connected technologies</td><td rowspan="2">Maximum contribution during near-scarcity<br>/<br>Maximum capacity [%]</td><td>RES</td><td>DSO-connected RES</td><td>/</td></tr>
<tr><td>Thermal</td><td>DSO-connected non-RES</td><td>/</td></tr>
<tr><td rowspan="8">Thermal TSO-connected technologies</td><td rowspan="8">100 - Forced Outage Rate [%]</td><td rowspan="8">/</td><td>CCGT</td><td>/</td></tr>
<tr><td>OCGT</td><td>/</td></tr>
<tr><td>TJ</td><td>/</td></tr>
<tr><td>TSO-connected gas-engines</td><td>/</td></tr>
<tr><td>TSO-connected Diesels</td><td>/</td></tr>
<tr><td>TSO-connected CHP</td><td>/</td></tr>
<tr><td>TSO-connected Biomass</td><td>/</td></tr>
<tr><td>TSO-connected Waste</td><td>/</td></tr>
</table>

*Table 3: Synthesis of derating factors categories*

*Example: Derating factors calculation*

*The Adequacy and Flexibility study [I] presents (Figure 11) some global results of derating factors that would be obtained by applying the explained methodology to each technology (note that the derating factors depend on the scenario applied, and will therefore vary depending on the chosen scenario).*

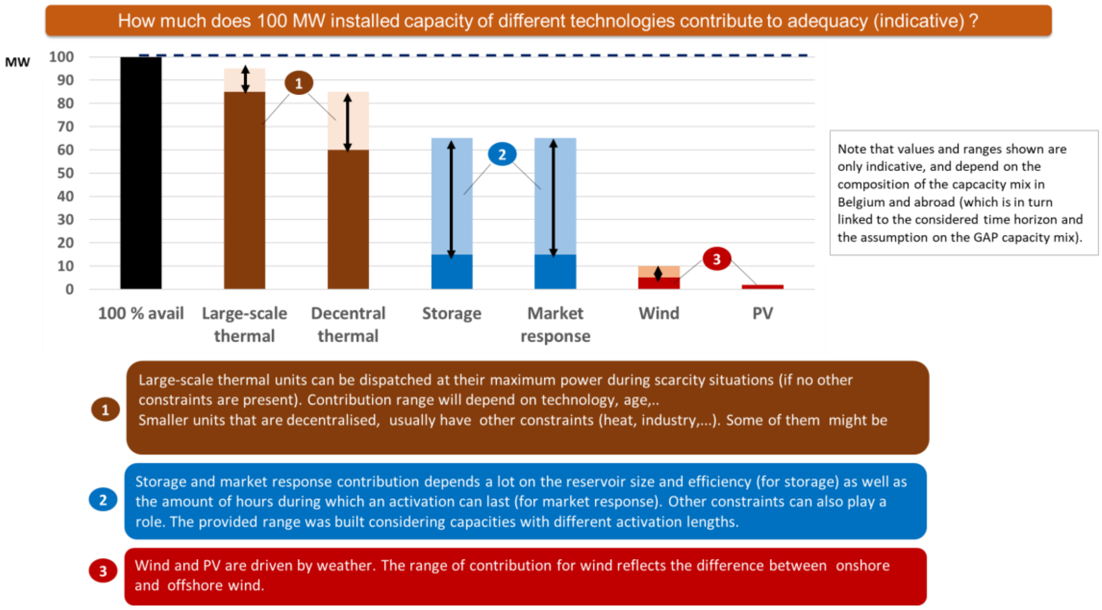
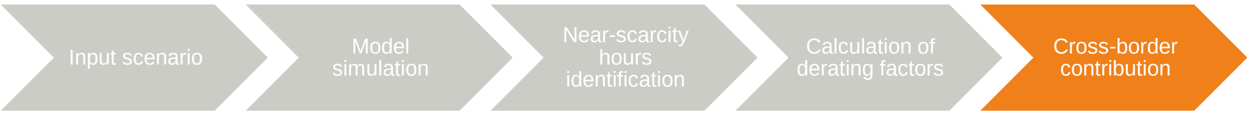



*Figure 11: Results from the Adequacy and Flexibility report [I]*

Main principles which serve as input for the Royal Decree proposal

7. For the purpose of calculating the derating factor applicable to each technology, the different technologies shall be divided into 4 different categories as follows:
   i. The category of thermal TSO-connected technologies shall comprise ”CCGT”, ”OCGT”, ”Turbojets”, “TSO-connected gas-engine”, ”TSO-connected Diesels”, ”TSO-connected CHP”, “TSO-connected Biomass” and “TSO-connected Waste”.
   ii. The category of weather-dependent technologies shall comprise “Onshore wind”, “Offshore wind”, “Solar” and “Run-of-river hydro”.
   iii. The category of energy-limited technologies shall comprise “Market Response”, including at least aggregation of demand side response, all type of small-scale storage technologies and emergency generators, and “Pumped-Storage plants”.
   iv. The category of DSO-connected technologies shall comprise “renewable energy sources”, including at least biomass CHP, biomass and waste, and “non-renewable energy sources”, including at least gas-fired CHP.
8. Derating factors for thermal TSO-connected units shall be calculated by subtracting the forced outage rate, based on historical data, and expressed in [%], from 100 [%].
9. Derating factors for weather dependent technologies shall be calculated by dividing their average contribution during near-scarcity hours from the simulation output by the relevant technology’s reference power.
10. Derating factors for energy-limited technologies shall be calculated by dividing their average contribution during near-scarcity hours from the simulation output by the relevant technology’s reference power, it being understood that, for “Market Response” the input data for the simulation shall first be divided into aggregation categories, represented by different “service levels” (SLAs), on the basis of hourly activation constraints or any other relevant technical constraint, as shall be proposed by the TSO in the yearly parameter report prior to the auction.
11. Derating factors for DSO-connected technologies shall be calculated based on available metering data. Derating factors for DSO-connected units shall be determined by the ratio of their average contribution during near-scarcity hours from the simulation output to the reference power. If insufficient relevant metering data are available as determined by the TSO, these derating factors shall be determined by the ratio of the technologies’ maximal contribution during near-scarcity hours from the simulation output to the reference power.

# 5 Cross-border contribution




Belgium is very dependent on imports to ensure its adequacy. Additionally, when scarcity situations occur in Belgium, they are mostly linked to scarcity in at least one electrically directly connected market zone. In the future, this interaction of scarcity situations between countries will further increase (see [I], Figure 4-12).

The contribution of interconnections is based on the simulation output. A post-processing methodology is implemented to determine the maximum entry capacity for cross-border participation in the context of adequacy, as the most relevant parameter for estimating the contribution to adequacy via interconnections with electrically directly connected market zones is the amount of energy that can be imported rather than the available interconnection capacity. Therefore, the contribution of other market zones to the Belgian adequacy shall be expressed in [MW].

The net position of Belgium during near-scarcity hours will be determined and the capability of electrically directly connected market zones (France, Germany [9], Netherlands and United Kingdom)[10] to export energy during those moments will be used to determine the average contribution of each electrically directly connected market zone to Belgian adequacy.

For interconnections, the different categories shall therefore be related to the contribution of these market zones, as presented on Figure 12.

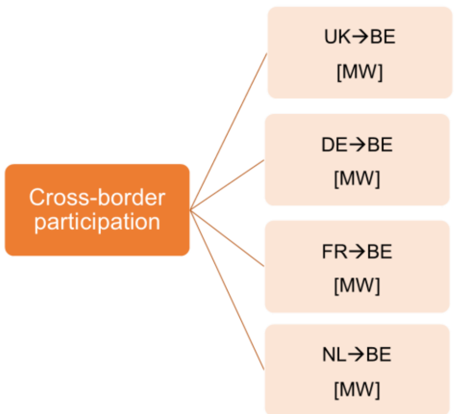



*Figure 12: Interconnections categories*

[9] Through the Allegro connection that will be available for the first delivery year.
[10] Luxemburg is not considered because it is part of the same market zone as Germany.

The approach to determine cross-border contributions for the input scenario is presented on Figure 13.

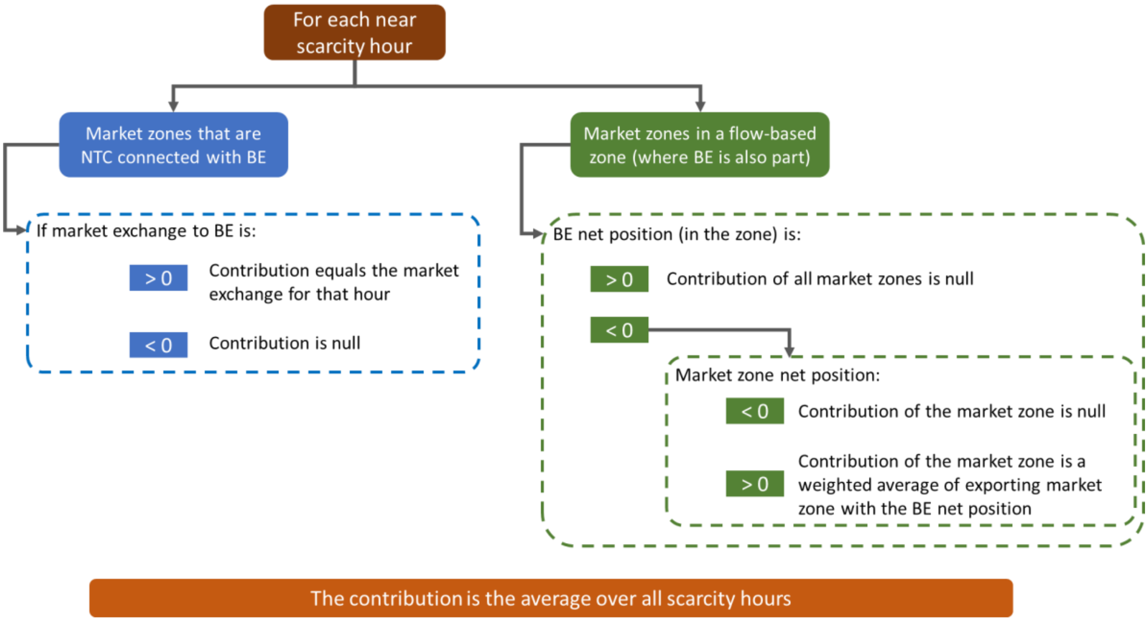



*Figure 13: Interconnection contribution calculation*

This methodology could further evolve when the methodology for the determination of the maximum entry capacity following the Regulation Internal Market for Electricity (RIME) Art. 26.11 (a) becomes available. Note that according to Art. 26.7 of RIME in the future also the RSC (Regional Security Coordinator center) (Coreso) will have to provide a recommendation.

## *Example of interconnection contribution calculation*

*Let's assume a situation where Belgium is in scarcity and is importing 1 GW of available energy in electrically directly connected market zones.*


*On this particular hour, other market zones can also be in scarcity situations and have no capacity to export electricity abroad. The electrically directly connected market zones net position (for 'flow-based' domain, in red) and market exchange to Belgium (for 'NTC-connected' market zone, in blue) are presented on the figure to the side. In this case, only Germany and Netherlands are exporting whereas France and United Kingdom are importing. Therefore, the contribution of these countries can be calculated:*

- $FR \rightarrow BE = 0$
- $UK \rightarrow BE = 0$
- $NL \rightarrow BE = BE_{import} \cdot \frac{NL_{export}}{NL_{export}+DE_{export}} = 1 \cdot \frac{3}{3+2} = 0.6\ GW$
- $DE \rightarrow BE = BE_{import} \cdot \frac{DE_{export}}{NL_{export}+DE_{export}} = 1 \cdot \frac{2}{3+2} = 0.4\ GW$

*On average, the latest Adequacy and Flexibility report of Elia [I] gives some insights of the capability of other countries to export energy during Belgian scarcity moments (Figure 14)*

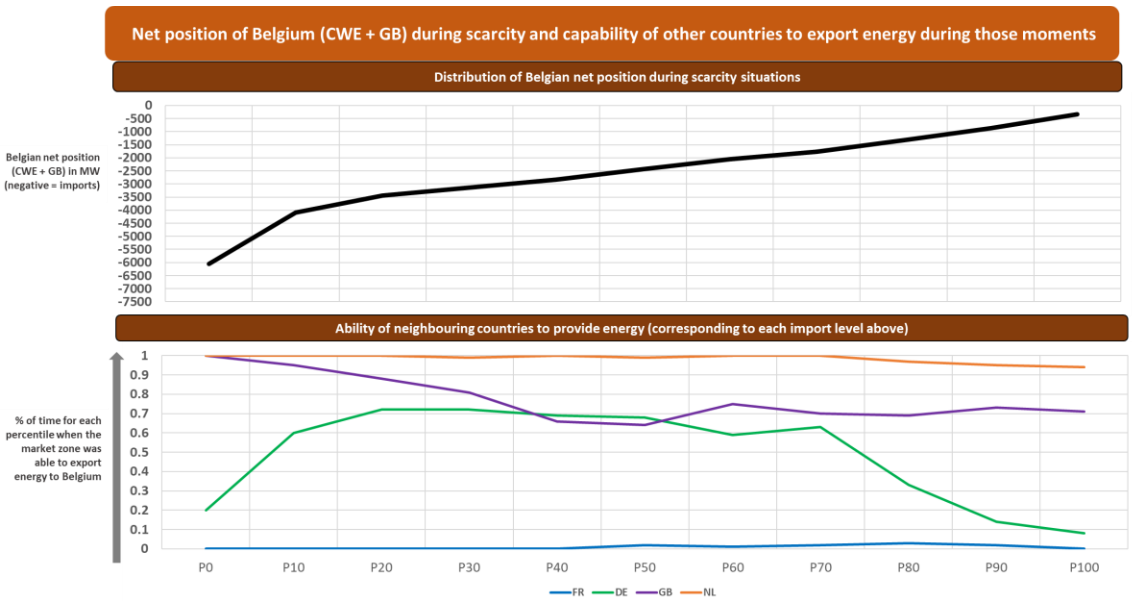



*Figure 14: Example of electrically directly connected market zones contribution to Belgian adequacy from the Adequacy and Flexibility report [I]*

Main principles which serve as input for the Royal Decree proposal

12. The contribution of interconnections to adequacy is expressed in power [MW].
13. The contribution of each electrically directly connected market zone is determined by averaging the contribution of each market zone over all near-scarcity hours.
14. The contribution of a market zone in the same “flow-based” zone as Belgium at a specific hour is determined as the weighted Belgian net position for exporting market zones, and zero for importing market zones.
15. The contribution of a market zone connected with a “net transfer capacity” with Belgium at a specific hour is determined by the market exchange for that hour if positive (from the market zone to Belgium) and zero if Belgium exports.

# References

[I] Elia (2019). Adequacy and flexibility study for Belgium 2020-2030. http://www.elia.be/~/media/files/Elia/publications-2/studies/20190628_ELIA_Adequacy_and_flexibility_study_EN.pdf

# Annex 1: Correlation of climatic conditions

The various meteorological conditions having an impact on renewable generation and electricity consumption are not independent of each other. Wind, solar radiation, temperature and precipitation are correlated for a given region. In general, high-pressure areas are characterized by clear skies and little wind, while low-pressure areas have cloud cover and more wind or rain. Given the very wide range of meteorological conditions that countries in Europe can experience, it is very hard to find clear trends between meteorological variables for a given country. Figure 15 attempts to show the non-explicit correlation between wind production, solar generation and temperature for Belgium. The graph presents the seven-day average for these three variables for Belgium based on 34 climatic years. The hourly or daily trends cannot be seen as the variables were averaged by week but various seasonal and high-level trends can be observed:

- The higher the temperature, the lower the level of wind energy production. During the winter there is more wind than in the summer;
- The higher the temperature, the higher the level of PV generation. This is a logical result from the fact that more solar generation goes on during the summer and inter-season months;
- When the level of wind energy production is very high, the level of PV generation tends to fall;
- In extremely cold periods, wind energy production falls while there is a slight increase in PV generation. This is a key finding that will affect adequacy during very cold weather.

The various meteorological data are also geographically correlated as countries are close enough to each other to be affected by the same meteorological effects. A typical example of this is the occurrence of a tight situation due to a cold spell which first spreads over western France, then over Belgium and after that over Germany. It is essential to maintain this geographical correlation between countries in terms of climate variables.

Given the high amount of renewable energy from variable sources that is installed each year in Europe and the high sensitivity to temperature of some countries' electricity demand, it is essential to maintain the various geographically and time-correlated weather conditions in the assessment.

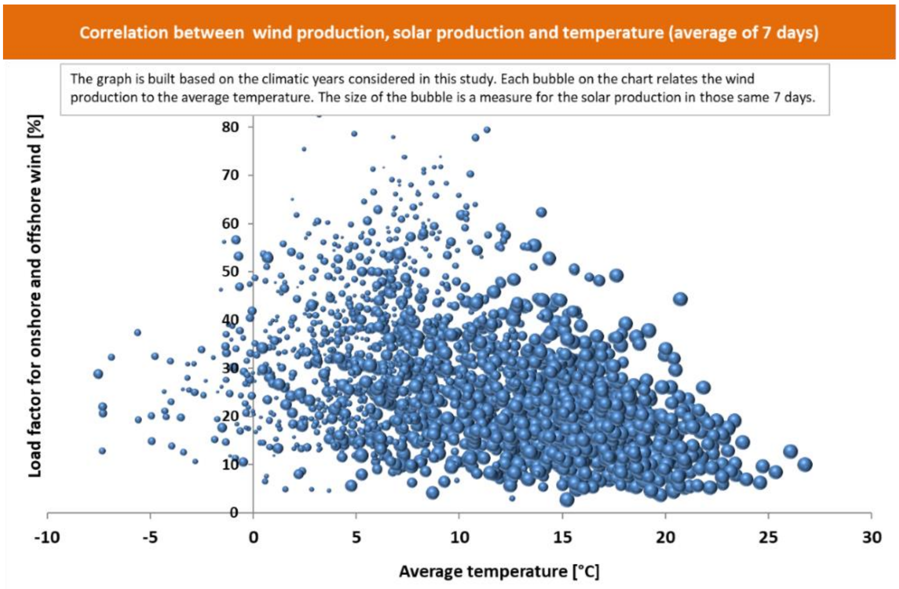



*Figure 15: Correlation between wind production, solar production and temperature*