

# Information on grid control cooperation and international development

## - Further TSOs joins IGCC (International Grid Control Cooperation) -

### 1 History of the grid control cooperation (GCC)

In December 2008, the implementation of the first development phase of the grid control cooperation finally made it possible to avoid the counter activation of secondary control reserves between three German transmission system operators (TSOs). After the implementation of additional modules and the expansion of the grid control cooperation to all German TSOs, further technical and economic optimisations were achieved with regard to the procurement and use of control reserves.

Grid control cooperation is based on an optimisation system for the activation of secondary control reserves. Intelligent communication of the power-frequency control of single TSOs enables online balancing of the different power imbalances. The aFRR demand of participating control areas is reported to the coordinating optimisation unit, which returns a correction value to power-frequency control after each optimisation. This allows the optimised activation of aFRR, reducing the future need for mFRR.

The following development phases have already been successfully carried out in Germany:

- Module 1 (avoiding counter activation between CA/CB)
- Module 2 (Mutual assistance in real-time)
- Module 3 (Common market area)
- Module 4 (Common merit order list)

The implementation of all modules in Germany increased the synergies for German system control.

### 2 Development of the IGCC – International Grid Control Cooperation

With the grid control cooperation developed in Germany, the international optimisation potential can also be increased. The focus lies on the expansion of grid control cooperation module 1 to foreign control areas. This creates an opportunity for further technical and economic optimisations that do not require the alteration of national framework conditions. The planned correction of imbalance netting across control areas enables all participating TSOs to decrease the use of control energy and increase system security.

The cooperation with foreign TSOs has no influence on the total control energy volume acquired by the four German TSOs.

In case of congestion-proof borders, imbalance netting can only take place in the scope of non-purchased residual capacity. The TSOs will not reserve capacity for the optimisation. Basically, the reserves exchanged through GCC can always be limited in case of physical real-time bottlenecks.

The German TSOs started uninterrupted trial operation with the Danish TSO Energinet.dk on 1 October 2011, shifting to regular operation on 1st January 2012.

In the following time other TSOs joined IGCC or are planning to do so:

TSO	Country	Status	Date
Energinet	Denmark	participating	01.10.2011
TenneT NL	Netherland	participating	01.02.2012
Swissgrid	Switzerland	participating	01.03.2012
CEPS	Czech Republic	participating	01.06.2012
Elia	Belgium	participating	01.10.2012
APG	Austria	participating	01.04.2014
RTE	France	participating	22.02.2016
ELES	Slovenia	participating	01.02.2019
HOPS	Croatia	participating	01.02.2019
PSE	Poland	planned to join	H1 2020
Terna	Italy	planned to join	H1 2020
REE	Spain	planned to join	H1 2020
REN	Portugal	planned to join	H1 2020
MAVIR	Hungary	planned to join	H1 2020
SEPS	Slovakia	planned to join	H1 2020
Transelectrica	Romania	planned to join	H1 2020
ESO	Bulgaria	planned to join	H1 2020
Admie	Greece	planned to join	H1 2020

The following rules apply to the IGCC. This particularly concerns the following aspects:

- IGCC methodology
- Saving control energy
- Energy volume settlement
- Impact on the balancing energy price

### 3 Correction of power imbalances - how does it work?

The TSOs of the member countries exchange the actual imbalance capacity in their control areas (for Germany, this corresponds with the total imbalance for all four national control areas) through a common optimisation system. Optimising with other countries is only done if the optimisation potential inside the German borders has been completely used. Using the energy consumption figures exchanged between the power-frequency controls, the balancing potential can be determined each second. The avoidable control energy is exchanged online according to this result: the TSO with too much energy in its own control area (i.e. a surplus of power), supplies electricity to the control area with too little energy (i.e. with a power deficit). This reduces the need for control energy in each of the TSOs' control areas. Moreover, no more control energy is activated than required for the remaining demand. This way, the use of control energy reserves can be avoided by all TSOs.

#### 4 Determining the financial economy and its settlement between partners

The energy volumes exchanged through the IGCC are settled between the member countries, based on the following considerations. The energy volume supplied to the deficit control area by the surplus control area shall be given a value based on the amount of costs saved by avoiding the use of control energy in the control areas concerned through balancing (opportunity costs).

TSOs that can reduce the activation of positive control energy through the IGCC, save a corresponding amount of costs. These saved activation costs are determined by the energy prices for positive secondary control energy and the energy volumes exchanged.

TSOs that reduce the activation of negative control energy because of the IGCC balancing miss out on proceeds in case of positive SCR energy prices. Because of the systematic price spreads between positive and negative control energy, this loss of profit is usually lower than the costs saved by TSOs that avoid positive control energy at the same time, i.e. in the end, financial savings are achieved through the IGCC. In case of negative energy prices for negative control energy, the mutual savings are increased. As this concerns an SCR optimisation, the direct activation costs for secondary control energy are relevant for a settlement.

Even though in total, all participants economise through the IGCC, separate participants may not experience any financial effects, depending on the avoided control energy product (positive or negative) and the corresponding prices for positive and negative control energy. In the least favourable case, participants who avoid negative control energy at positive energy prices may even experience a loss of profit as a result of these effects.

To make it possible to fairly spread the achieved overall savings per time unit as a result of the reduced activation of secondary control energy between the countries, it is necessary to settle the energy volumes exchanged within the IGCC framework.

The objective is to fairly split up the savings made through the prevented use of control energy between the member countries.

The following specific premises are agreed for the settlement price:

- A single price is determined per invoicing period (15 minutes).
- The value of the avoided activation of secondary control energy (opportunity costs) is taken into account.
- The calculation is as simple and transparent as possible.
- The system can be applied to new participants as well.

To reflect the value of the energy supply, an international settlement price is calculated based on the opportunity costs for the use of control energy (see above) avoided by the member countries.

Given the country-specific systems to calculate the control energy prices and the resulting differences in activation costs for control energy, the opportunity prices have to be determined for each member country on the basis of the opportunity costs in view of the settlement model described below.

A precondition is that no participant in the GCC shall suffer financial losses in the long term. Each participant shares in the savings through correction of power imbalances if he exchanges energy volumes within the GCC module 1 framework.

The determination of the opportunity prices is explained below. The opportunity prices are based on the costs that are saved each time the use of secondary control energy is avoided, meaning they are also directed by the national secondary reserve prices, which are therefore more accurately described per country.

#### 4.1 Opportunity price for Germany

In Germany, calls for secondary control energy are made based on a common merit order list for the four TSOs. The offers taken up are then settled on a "pay-as-bid" basis.

The opportunity prices are determined separately for positive and negative secondary control energy per each quarter of an hour. For the calculation of the settlement price, the average price of secondary control energy exchanged in each balancing direction during a 15-minute interval is used.

In case positive secondary balancing is needed by the German TSOs, the opportunity price corresponds with the quotient of the positive secondary control energy costs per 15 minutes and the positive secondary control energy volume per 15 minutes.

In case negative secondary control energy is needed by the German TSOs, the opportunity price corresponds with the quotient of the negative secondary control energy costs or proceeds per 15 minutes and the negative secondary control energy volume per 15 minutes.

If there was no demand in a certain direction, the lowest energy price of the merit order for that direction will be used as the opportunity price.

#### 4.2 Opportunity price for Denmark

The secondary control reserve price in Denmark is calculated depending on the prices of manually activated tertiary reserve (minute reserve in Germany) as well as depending on the Nordpool Spot prices, always on an hourly basis. The activated tertiary reserve creates a positive REG price (up-regulation) or a negative REG price (down-regulation) depending on the balancing direction, based on the marginal price of a common merit order of the tertiary control reserves in Scandinavia. The merit order is based on the control reserve offers available for western Denmark.

The secondary control energy price is determined separately for positive and negative control energy. There is only one hourly price for each energy direction.

The positive secondary balancing price corresponds with the price for positive tertiary control energy, unless this price is lower than the Nordpool Spot price for that hour + 100 DKK (13.41 €), in which case the price for SCR equals the Nordpool Spot price (of the day-ahead auction) + 100 DKK.

The negative secondary balancing price corresponds with the price for negative tertiary control energy, unless this price is higher than the Nordpool Spot price for that hour - 100 DKK (13.41 €), in which case the price for SCR equals the Nordpool Spot price (of the day-ahead auction) - 100 DKK.

The relevant price for the secondary control energy determines the opportunity price for Denmark. For positive secondary control energy, this amounts to at least the Nordpool Spot price + 100 DKK/MWh. For negative secondary control energy, this amounts to at most the Nordpool Spot price - 100 DKK/MWh.

A precise representation can be found in the annexe.

#### 4.3 Opportunity price for the Netherlands

In the Netherlands, contrary to the situation in Germany there is a yearly symmetrical call for tenders for control reserve capacity. The merit order of the providers is decided by the capacity acquired through the auction and the energy price quoted the day before. Providers can quote or change their offers (volumes and energy prices) until 1 hour before activation of or call for secondary control energy. Based on the yearly call for tenders for control reserve capacity, at least 300 MW of secondary control reserve are secured by contract.

The secondary control energy price in the Netherlands is calculated according to a uniform marginal price system that, depending on the offers, is guided by the highest activated energy price, i.e. the final offer determines the price for all providers. The prices for the delivery of the control energy are published the next day. As a rule, there is only a positive or a negative price for secondary control energy, as usually, only one energy direction is activated per quarter of an hour. However, should both energy directions be activated within the same 15 minutes, prices will be determined, published and invoiced for both directions. These prices determine the opportunity prices for the Netherlands.

A precise representation can be found in the annexe.

#### 4.4 Opportunity price for Switzerland

The Swissgrid opportunity price corresponds with the price for activated secondary control energy in the matching invoicing interval. This is linked to the SwissIX spot price.

- Positive secondary control energy is invoiced at the SwissIX spot price plus 20 %, but never at less than the weekly base price.
- Negative secondary control energy is invoiced at the SwissIX spot price less 20 %, but never at more than the weekly base price.

The weekly base is the average price (spot price - SwissIX, day-ahead) between Monday 00:00 and Sunday 24:00.

As the weekly base price is used as price cap for the calculation of the secondary control energy price and therefore of the opportunity price, it is only fixed after the week has ended.

In principle, separate opportunity prices are calculated for both IGCC imports and IGCC exports, i.e. there is always an opportunity price for IGCC imports and one for IGCC exports for each quarter of an hour.

In Switzerland, however, only one control energy price is applied per invoicing period for the net (settled) control energy requirements. Before the compensation is calculated, the delivery of secondary control reserves within a quarter of an hour is netted and Swissgrid always settles the net balancing (either positive or negative) with the providers at the corresponding control energy price per invoicing period. Accordingly, the same opportunity price applies for IGCC imports and IGCC exports in this case.

A precise representation and further explanations can be found in the annexe.

#### 4.5 Opportunity price for the Czech Republic

The Czech secondary control energy price is always fixed by the Czech energy regulator for the duration of a year. There is a price for positive and a price for negative secondary control energy. Like in Switzerland, the positive and negative SCR activations within a certain invoicing period (CZ: one hour) are netted when invoiced. Netting is done for all providers who were called on pro rata based on the price regulation. If more negative than positive SCR is activated within an hour, the balance is settled at the negative secondary control energy price. If the balance is positive, the balance is settled with the provider at the positive secondary control energy price.

The opportunity price is determined according to the opportunity principle, according to which the secondary control energy costs avoided through the IGCC in the Czech Republic are taken into consideration. To this end, the actual SCR costs for the corresponding invoicing period are deducted from the Czech SCR costs that would have become due if CEPS had not participated in the IGCC. To calculate the Czech opportunity price, the avoided secondary control energy costs are divided by the balance of the Czech energy imports and exports within the IGCC. The Czech opportunity price is constant over the invoicing period of one hour and applies in equal measure to IGCC exports and imports as a result of the netting procedure described above for control energy settlement with providers.

If the hourly control area balance in the Czech Republic does not change because of the IGCC, the Czech opportunity price corresponds with the positive or negative secondary control energy price, depending on the positive or negative value of the control area balance. If the hourly control area balance in the Czech Republic changes because of the IGCC, the opportunity price is situated between the positive and negative secondary control energy price.

A precise representation can be found in the annexe.

#### 4.6 Opportunity price for Belgium

Like in the Netherlands, long-term calls for tenders are carried out for control energy capacity, with contract terms of one year. These auctions provide the positive and negative SCR volumes to be maintained by the provider, which create a symmetric product here. For these SCRs to be maintained, the providers offer separate energy prices for positive and negative SCR on a daily basis. The secondary control energy bids are subject to a "price cap" based on fuel cost and a mark-up. The Maximum Price for positive SCE is the fuel cost of a standard CCGT with an efficiency of 50% plus 40€/ MWh. The Minimum Price for negative SCE is 0 €/MWh.

For the Belgian opportunity price, it is furthermore important to point out that the activation of SCRs is performed on a pro rata basis here, according to the part that each SCR provider contributes to the total SCR to be maintained. This means that the merit order is not followed, but that all providers are activated simultaneously. As a result, especially if the providers offer different energy prices, the average volume-weighted energy price of the positive SCR is used to determine the positive Belgian opportunity price, and the average volume-weighted energy price of the negative SCR is then used accordingly to determine the negative opportunity price.

For further details, please consult the annexe.

#### **4.7 Opportunity price for Austria**

In Austria the calls for secondary control energy are made based on a merit order list. The offers taken up are then settled on a "pay-as-bid" basis.

The opportunity prices are determined separately for positive and negative secondary control energy per each quarter of an hour. For the calculation of the settlement price, the average price of secondary control energy exchanged in each balancing direction during a 15-minute interval is used.

In case positive secondary balancing is needed by the Austrian TSO, the opportunity price corresponds with the quotient of the positive secondary control energy costs per 15 minutes and the positive secondary control energy volume per 15 minutes.

In case negative secondary control energy is needed by the Austrian TSO, the opportunity price corresponds with the quotient of the negative secondary control energy costs or proceeds per 15 minutes and the negative secondary control energy volume per 15 minutes.

If there was no demand in a certain direction, the lowest energy price of the merit order for that direction will be used as the opportunity price.

#### **4.8 Opportunity price for France**

The French secondary control energy price is fixed by the French energy regulator for the duration of a year. There is one single price for both positive and negative secondary control energy. The RTE opportunity price for IGCC corresponds exactly with the price for activated secondary control energy.

The French energy regulator approved in December 2015 to change the definition of the secondary control energy price in France from a fixed regulated price to the hourly Day-Ahead EPEX spot price of the corresponding matching invoicing interval. There will still be one single price for both positive and negative secondary control energy.

The exact application date of the change, expected around end of first quarter of 2016, will be defined by the French energy regulator. Starting from this application date the RTE opportunity price will correspond exactly with the price for activated secondary control energy in the matching invoicing interval; which will be equal to the hourly Day-Ahead EPEX spot price of the interval.

#### **4.9 Opportunity price for Slovenia**

In Slovenia the calls for secondary control energy are made based on "pro rata". The offers taken up are then settled on a "pay-as-bid" basis.

The IGCC Opportunity Prices are determined based on avoided costs of non-activated aFRR energy due to IGCC exchange.

Determination of the IGCC Opportunity Price depends on the prevailed direction of the IGCC exchange over an accounting period for aFRR energy, which in Slovenia is one hour,  $j = 60$  minutes. If, during one hour, the amount of IGCC import is higher than IGCC export (i.e. Slovenia is net IGCC importer), the IGCC Opportunity Price for import is calculated as the quantity-weighted average of upward activated aFRR energy. Similarly, if the amount of IGCC import is lower than IGCC export (i.e. Slovenia is net IGCC exporter), the IGCC Opportunity Price for export is calculated as the quantity-weighted average of downward activated aFRR energy. Due to applied netting of positive and negative aFRR energy over the aFRR accounting period  $j$ , this will lead to 4 equal IGCC Opportunity Prices in both directions for each IGCC settlement period  $i = 15$  minutes belonging to accounting period  $j$ .

In case there is no aFRR activation in one or even both directions, the IGCC Opportunity Price is calculated as the quantity-weighted average of offered aFRR energy in the prevailed direction of IGCC exchanged energy. For further details, please consult the annexe.

#### 4.10 Opportunity price for Croatia

In Croatia the calls for secondary control energy are made based on "pro rata". The offers taken up are then settled on a "pay-as-bid" basis.

The Croatian IGCC Opportunity Prices are calculated separately for IGCC import and export.

For import of balancing energy through IGCC, the IGCC Opportunity Price is equal to a price of positive aFRR energy determined as the average price of Day-Ahead Prices achieved on local markets that are relevant for Croatian Control Area and the respective settlement period increased by a factor of 0,4.

$$OP_{Imp,i} = C_{aFRR+,i} = C_{avgD-1,i} + 0,4 \cdot |C_{avgD-1,i}|$$

For export of balancing energy through IGCC, the IGCC Opportunity Price is equal to a price of negative aFRR energy determined as the average price of Day-Ahead Prices achieved on local markets that are relevant for Croatian Control Area and the respective settlement period decreased by a factor of 0,4.

$$OP_{Exp,i} = C_{aFRR-,i} = C_{avgD-1,i} - 0,4 \cdot |C_{avgD-1,i}|$$

For further details, please consult the annexe.

#### 4.11 Opportunity price for Poland

The IGCC Values of avoided aFRR are the same for IGCC import and IGCC export. The value of avoided aFRR is equal to the Polish aFRR balancing energy price corresponding to the marginal system price at the Polish balancing market calculated according to the grid code approved by the Polish NRA. The Polish marginal system price results from the integrated scheduling process and refers to each accounting period equal to one hour taking into account the net value of IGCC exchange within this period. This leads to the same IGCC Values of avoided aFRR for four consecutive quarters of an hour constituting 60 min interval.

For further details, please consult the annexe.

#### 4.12 Opportunity price for Italy

The aFRR energy bids are subject to the following price caps : the maximum price for positive aFRR energy is 3.000 € / MWh and the minimum price for negative aFRR energy is 0 €/MWh.

A netting is applied for payment of positive aFRR energy and negative aFRR energy, for each settlement period (15 minutes).

All resources which are part of the activated aFRR are activated at the same time. The quantity of aFRR to be activated per resource is calculated as a pro rata.

The IGCC values of avoided upward and downward aFRR activations for both export and import direction are determined as follow :

Variable	Description	Unit	Sign/ source
$aFRR_{pos;i;k}$	Positive activated aFRR energy from supplier <sub>k</sub> for the aFRR energy accounting period <sub>i</sub> .	[MWh]	Always positive.
$aFRR_{neg;i;k}$	Negative activated aFRR energy from supplier <sub>k</sub> for the aFRR energy accounting period <sub>i</sub> .	[MWh]	Always positive.
$P_{pos;i;k}$	aFRR energy price for the positive activated aFRR energy from supplier <sub>k</sub> for the aFRR energy accounting period <sub>i</sub> .	[€/MWh]	Always positive (Terna pays for activation of positive aFRR energy).
$P_{neg;i;k}$	aFRR energy price for the negative activated aFRR energy from supplier <sub>k</sub> for the aFRR energy accounting period <sub>i</sub> .	[€/MWh]	Always positive (Terna is paid for activation of negative aFRR energy).
$C_{i,Imp}$	Resulting IGCC Value of aFRR Avoided Activation of Terna for IGCC import for the IGCC settlement period <sub>i</sub> .	[€/MWh]	Positive (Terna pays for activation of positive aFRR energy).
$C_{i,Exp}$	Resulting IGCC Value of aFRR Avoided Activation of Terna for IGCC export for the IGCC settlement period <sub>i</sub> .	[€/MWh]	Positive (Terna is paid for activation of negative aFRR energy).

$$C_{i,Imp} = \frac{\sum_k^{all\ suppliers} [P_{pos;i;k} * aFRR_{pos;i;k}]}{\sum_k^{all\ suppliers} [aFRR_{pos;i;k}]}$$

$$C_{i,Exp} = \frac{\sum_k^{all\ suppliers} [P_{neg;i;k} * aFRR_{neg;i;k}]}{\sum_k^{all\ suppliers} [aFRR_{neg;i;k}]}$$

For further details, please consult the annexe.

#### 4.13 Opportunity price for Spain

The IGCC Value of avoided upward and downward aFRR activations in the case of REE are determined using the economic information coming from the upward/downward aggregated mFRR energy Spanish upward/downward bid curves, which is used nowadays to calculate the price of upward/downward aFRR. The reason for that is that currently, there is no aFRR energy market implemented in the Spanish System, so mFRR prices are used to value aFRR upward/downward usage.

For further details, please consult the annexe.

#### 4.14 Opportunity price for Hungary

The IGCC Values of avoided aFRR are determined by the activated aFRR energy. The IGCC Values of avoided aFRR for both IGCC import and IGCC export are determined as the quantity-weighted average of aFRR energy costs billed for the respected direction within the settlement period in Hungary.

The IGCC Values of avoided aFRR are determined separately for IGCC import and IGCC export deliveries.

If there was no aFRR energy activation neither for negative nor positive direction, the aFRR energy price that would have been paid for the first activated bid in the Hungarian merit order list in the respective direction (respectively in case of aFRR cooperation the first activated bid in the common merit order list of the cooperation) is taken as the IGCC Values of avoided aFRR.

$$C_{i,IMP} = \frac{M_{aFRR\_pos,i}}{aFRR_{pos,i}}$$

$$C_{i,EXP} = \frac{M_{aFRR\_neg,i}}{aFRR_{neg,i}}$$

Variable	Description	Unit	Sign
$aFRR_{pos,i}$	Amount of activated positive aFRR energy for the IGCC settlement period <sub>i</sub> .	[MWh]	Always positive.
$aFRR_{neg,i}$	Amount of activated negative aFRR energy for the IGCC settlement period <sub>i</sub> .	[MWh]	Always positive.
$C_{i,Imp}$	Resulting IGCC Value of avoided aFRR of MAVIR for IGCC import for the IGCC settlement period <sub>i</sub> .	[€/MWh]	Positive values means MAVIR pays for activation of positive aFRR energy. Negative value means MAVIR is paid for activation of positive aFRR energy.
$C_{i,Exp}$	Resulting IGCC Value of avoided aFRR of MAVIR for IGCC export for the IGCC settlement period <sub>i</sub> .	[€/MWh]	Positive value means MAVIR is paid for activation of negative aFRR energy. Negative value means MAVIR pays for activation of negative aFRR energy.
$M_{aFRR\_pos,i}$	Total costs for positive aFRR energy deliveries of MAVIR for the IGCC settlement period <sub>i</sub> .	[€]	Positive value means MAVIR has costs. Negative value means MAVIR receives payment.
$M_{aFRR\_neg,i}$	Total costs for negative aFRR energy deliveries of MAVIR for the IGCC settlement period <sub>i</sub> .	[€]	Positive value means MAVIR receives payment. Negative value means MAVIR has costs.

For further details, please consult the annexe.

#### 4.15 Opportunity price for Portugal

The IGCC Values of avoided aFRR are determined by the activated aFRR energy and separately for IGCC import and IGCC export deliveries.

The IGCC Values of avoided aFRR for both IGCC import and IGCC export are determined as the quantity weighted average of aFRR energy costs billed for the respected direction within the settlement period. As the aFRR prices are hourly, there will be 4 quarter of an hour periods with the same value for aFRR price in each direction.

If there is no aFRR price for negative or positive direction, the value to be considered as the IGCC Values of avoided aFRR will be the hourly Day-ahead Market Price in the Portuguese area. As these values are hourly, there will be also 4 quarter of an hour periods with the same value.

Variable	Description	Unit	Sign
$P_{aFRR_{pos}, i}$	Price for positive aFRR for the settlement period $i$	[€/MWh]	Always positive
$P_{aFRR_{neg}, i}$	Price for negative aFRR for the settlement period $i$	[€/MWh]	Always positive
$P_{Market, i}$	Day-ahead Market Price in the Portuguese area for the settlement period $i$	[€/MWh]	Always positive
$C_{i, Imp}$	Resulting IGCC Value of avoided aFRR activation for import from IGCC for the settlement period $i$ (price for IGCC Settlement Price calculation)	[€/MWh]	Positive if REN pays for activation of positive aFRR energy and negative if REN is paid for activation of positive aFRR energy
$C_{i, Exp}$	Resulting IGCC Value of avoided aFRR activation for export to IGCC for the settlement period $i$ (price for IGCC Settlement Price calculation)	[€/MWh]	Positive if REN is paid for activation of negative aFRR energy and negative if REN pays for activation of negative aFRR energy

$$C_{i, Imp} = \begin{cases} P_{aFRR_{pos}, i} & \text{if } P_{aFRR_{pos}, i} \text{ exists} \\ P_{Market, i} & \text{if } P_{aFRR_{pos}, i} \text{ doesn't exist} \end{cases}$$

$$C_{i, Exp} = \begin{cases} P_{aFRR_{neg}, i} & \text{if } P_{aFRR_{neg}, i} \text{ exists} \\ P_{Market, i} & \text{if } P_{aFRR_{neg}, i} \text{ doesn't exist} \end{cases}$$

#### 4.16 Opportunity price for Greece

The IGCC Values of avoided aFRR activations reflects the cost of avoided aFRR activation in the LFC Block of Greece and is currently linked to hourly Imbalance Marginal Prices and dispatchable units' variable costs. In the current Greek Wholesale Electricity Market, balancing energy (i.e. mFRR, aFRR) is compensated as following:

- Balancing energy up: The TSO determines ex-post hourly Zonal Imbalance Marginal Prices (ZIMPs) and a weighted average hourly System Imbalance Marginal Price (SIMP) by executing the Ex post imbalance-pricing procedure. This procedure is similar to the Day Ahead Scheduling (DAS) optimization procedure but uses actual system demand, actual RES injections and ex-post calculated dispatchable units' availability. Balancing energy up is compensated with the ZIMP of the corresponding hour,

$$C_{u,t}^{up} = aFRR_{u,t}^{up} \times ZIMP_{u,t}$$

Thus, the Value of avoided aFRR activation for importing aFRR energy during accounting period t, equals to:

$$C_t^{imp} = \frac{\sum_u ZIMP_{u,t}}{\text{number of units}}$$

- Balancing energy down: The TSO determines ex-post the hourly variable cost of each dispatchable unit, accordingly to an established methodology. The aFRR provider pays to the TSO for balancing energy down the minimum of:

- the unit's variable cost at the metered generation level
- the Day Ahead Market Price

$$C_{u,t}^{down} = aFRR_{u,t}^{down} * \min(SMP_t, VCU_{u,t})$$

Thus, the value of avoided downward aFRR activation during accounting period t, equals to:

$$C_t^{exp} = \frac{\sum_u \min(SMP_t, VCU_{u,t})}{\text{number of units}}$$

Variable	Description	Unit	Sign/ source
$aFRR_{u,t}^{up}$	Positive activated aFRR energy from unit u for the aFRR energy accounting period t.	[MWh]	Always positive.
$aFRR_{u,t}^{down}$	Negative activated aFRR energy from unit u for the aFRR energy accounting period t.	[MWh]	Always positive.
$ZIMP_{u,t}$	Zonal Imbalance Marginal Price for the unit u concerning the accounting period t, determined ex-post.	[MWh]	Always positive.
$SIMP_t$	System Imbalance Marginal Price for the aFRR energy accounting period t, determined ex-post.	[€/MWh]	Always positive (ADMIE pays for the provision of energy).
$SMP_t$	System Marginal Price, which equals to the Day Ahead Market marginal price for the accounting period t.	[€/MWh]	Always positive (ADMIE pays for activation of positive aFRR energy).
$VCU_{u,t}$	Variable Cost of each dispatchable Unit u (thermal or hydro) that provides aFRR energy during an accounting period t, which derives from the techno-economic characteristics of the unit's offer.	[€/MWh]	Always positive (ADMIE is paid for activation of negative aFRR energy).
$C_{u,t}^{up}$	Resulting compensation for positive aFRR for the unit concerning the accounting period t.	[€]	Positive (The unit is paid for activation of positive aFRR energy).
$C_{u,t}^{down}$	Resulting compensation for negative aFRR for the unit concerning the accounting period t.	[€]	Positive (The unit pays for activation of negative aFRR energy).
$C_t^{imp}$	Resulting IGCC Value of avoided afRR activation of ADMIE for IGCC import for the settlement period t.	[€/MWh]	Always positive.
$C_t^{exp}$	Resulting IGCC Value of avoided afRR activation of ADMIE for IGCC export for the settlement period t.	[€/MWh]	Always positive.

For further details, please consult the annexe.

## 5 Settlement model

The objective of the international settlement model is to determine a settlement price per MWh and per 15 minutes for the energy volumes exchanged within the IGCC framework. Each MWh acquired as well as delivered by a participant within the same 15 minutes is invoiced at the same settlement price. The settlement price is calculated as the volume-weighted average of the opportunity prices, based on the opportunity costs, of the participating countries. This means that the energy volumes delivered and acquired for each country are multiplied by the corresponding opportunity prices, after which the opportunity costs determined in that manner are added up. To determine the settlement price, the sum of the opportunity costs is then divided by the total volume of positive and negative deliveries of energy.

Settlement price =

$$\text{opportunity price (negSCR)} \cdot \text{volume delivered (per TSO)} + \text{opportunity price (posSCR)} \cdot \text{acquired volume (per TSO)}$$

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Sum of the volume delivered and the acquired volume

The settlement price can be positive as well as negative. Settlement prices reach negative values when the negative opportunity prices exceed the positive ones.

Mathematical formula for the settlement price:

The price model for the IGCC (reduced activation of control energy reserves) is defined using the formula for the settlement price  $C_{GCC}$  with  $i$  as index for the participating country and  $n_s$  as sum of the participating countries:

$$C_{GCC} = \frac{\sum_{i=1}^{n_s} E_{i,Imp} \cdot C_{i,Imp} + \sum_{i=1}^{n_s} E_{i,Exp} \cdot C_{i,Exp}}{\sum_{i=1}^{n_s} E_{i,Imp} + \sum_{i=1}^{n_s} E_{i,Exp}}$$

The result is a settlement price  $C_{GCC}$  for all energy deliveries and participants (which is why  $C_{GCC}$  does not have an index  $i$ ). For each quarter of an hour, there is a settlement price, determined ex post. To achieve a weighted average of the opportunity prices, all energy volumes are included with the amount of their absolute value.

Resulting payment or revenue

The resulting payment or revenue  $M_{i,GCC}$  is determined by applying the settlement price to IGCC imports and exports for the same invoicing period (15 min.):

$$M_{i,GCC} = (E_{i,Imp} - E_{i,Exp}) \cdot C_{GCC},$$

$$i = 1, K, n_s.$$

Definition of variables and algebraic signs:

Variable	Description	Definition of positive/negative value
$E_{i,Imp}$	Imports of control area $i$ within the IGCC module 1 framework (MWh)	always positive / absolute value
$E_{i,Exp}$	Exports of control area $i$ within the IGCC module 1 framework (MWh)	always positive / absolute value
$C_{i,Imp}$	Opportunity price of control area $i$ for positive secondary control energy (€/MWh)	Positive in case of payment to supplier by TSO. Negative vice versa.
$C_{i,Exp}$	Opportunity price of control area $i$ for negative secondary control energy (€/MWh)	Positive in case of payment to TSO by supplier. Negative vice versa.
$C_{GCC}$	Resulting settlement price for GCC module 1 (€/MWh)	Positive or negative
$M_{i,GCC}$	Resulting payment or revenue of control area $i$ (€)	Positive in case of payment. Negative in case of revenue.

In case of time steps where some IGCC-members pay more for IGCC-netting than they would have had to pay for local activation of secondary reserves, but the overall IGCC-benefit is positive, the positive and also the negative benefits of all IGCC-members are reduced until the negative benefits become zero.

## 6 Example calculations (two)

### 6.1 Example 1 - integration of a country in the IGCC with Germany

Two TSOs A and B exchange energy through the IGCC. The exchange is 20 MWh from TSO B to TSO A, as TSO B had 20 MWh in surplus and TSO A had a deficit of at least 20 MWh. For TSO A, the opportunity costs amount to 100 €/MWh x 20 MWh as a result of the avoided activation of positive control energy. For TSO B, the opportunity costs amount to -50 €/MWh x -20 MWh for the avoided activation of negative control energy. The calculation of this example is as follows:

Opportunity price TSO A = 100 €/MWh

Opportunity price TSO B = -50 €/MWh<sup>(1)</sup>

Opportunity costs TSO A without IGCC = 20 MWh x 100 €/MWh = 2000 €

Opportunity costs TSO B without IGCC = -20 MWh x -50 €/MWh = 1000 €

IGCC settlement price =

$$\frac{(20 \text{ MWh} \times 100 \text{ €/MWh} + 20 \text{ MWh}^{(2)} \times -50 \text{ €/MWh})}{(20 \text{ MWh} + 20 \text{ MWh}^{(2)})}$$

= 25 €/MWh

Resulting payment:

Payment TSO A = 20\*(25) € = +500 € (TSO A has to pay 500 €)

Payment TSO B = -20\*(25) € = -500 € (TSO B receives 500 €)

A positive value means a payment, a negative value means that the TSO receives money. Energy exports have a negative value.

Resulting savings after settlement:

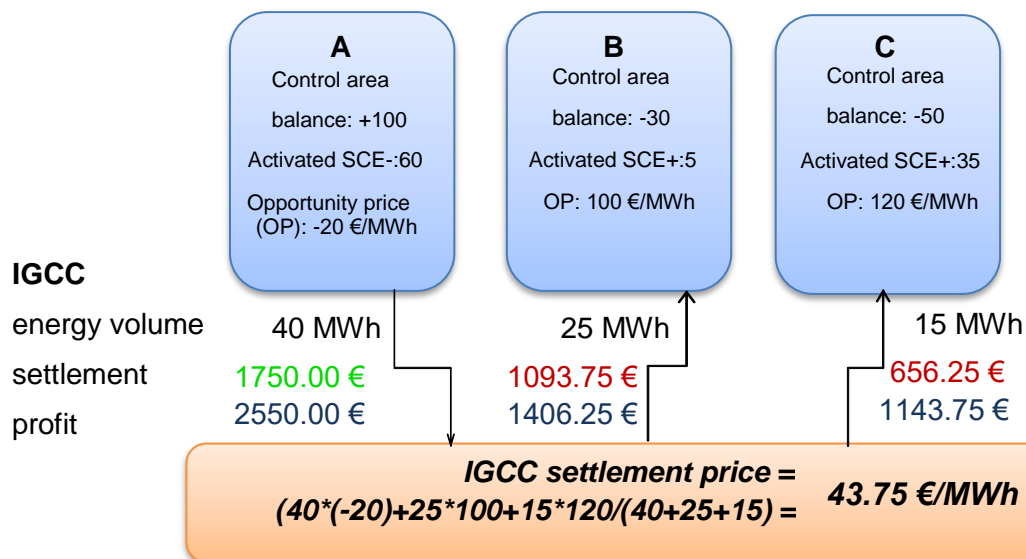
Savings by TSO A after settlement = 2000 € - (+500 €) = 1500 €

Savings by TSO B after settlement = 1000 € - (-500 €) = 1500 €

<sup>1</sup> Negative opportunity price, i.e. the provider receives 50 €/MWh for the activation of negative control energy.

<sup>2</sup> To obtain a weighted average of the opportunity prices, all energy volumes are included with the amount of their absolute value.

## 6.2 Example 2 - integration of two countries in the IGCC with Germany



A red figure represents a payment by the TSO, while a green figure signifies revenue for the TSO.

The examples show that all participants benefit from the non-activation of control energy.

## 7 Transfer of savings to the balancing groups

The savings achieved through the expansion of the GCC beyond the German borders (IGCC) are reflected in the balancing groups through their inclusion in the balancing energy price. The savings are a result of the fact that less control energy needs to be activated and that the high control energy quotes need to be called on less often as a result. As the IGCC settlement price is obtained by sharing the savings achieved, it is more advantageous than when each country individually uses control energy. As a result, the balancing groups profit from the IGCC thanks to the single price for balancing energy for all control areas (reBAP).

The energy volumes exchanged with other countries, along with their costs and proceeds, are considered as an additional control energy provider when determining the balancing energy price. This means that the method for determining the reBAP remains unaltered. Every fifteen minutes, the financial balance of the activated secondary control reserve and minute reserve is furthermore divided by the energy balance. Costs and proceeds from the IGCC form the numerator and the energy volumes exchanged with other countries form the denominator of the reBAP formula.

$$\text{reBAP} = \frac{\text{costs/proceeds control energy activation Germany} + \text{settlement price} \times \text{IGCC volume}}{\text{control energy volume Germany} + \text{IGCC volume}}$$

The savings achieved by avoiding the use of control energy are already included in the factor "costs/proceeds control energy activation Germany".

The advantages of this approach are the simple integration into the payment and invoicing process as well as the causal allocation of exchanged energy volumes and costs to the corresponding quarters of an hour.

## **8 Transparency**

To achieve as much transparency as possible with regard to the effects of the GCC expansion, the settlement price and the energy exchanged every 15 minutes for each participating IGCC partner are published on the common internet platform [www.regelleistung.net](http://www.regelleistung.net). The settlement price shall be published at the same time as the balancing energy price. Insofar as possible, the energy volumes shall be published each workday.

## Annex

### Precise description of the opportunity prices for **western Denmark**

The Danish opportunity price is calculated based on the secondary control energy prices in Denmark, which are linked to the prices for manually activated tertiary reserves (in Germany: minute reserves) as well as the Nordpool Spot prices and always apply on an hourly basis. Below is described the composition of the Danish SCR price for different situations.

Abbreviations:

LFC price = price for load-frequency control or SCR in DKK/MWh

REG price = price of manual tertiary control energy in DKK/MWh

Spot price = price per MWh on the Nordpool Spot market (exchange)

#### Situation A:

If pos. REG price > spot price + 100 DKK/MWh

→ pos. LFC price = pos. REG price

#### Situation B:

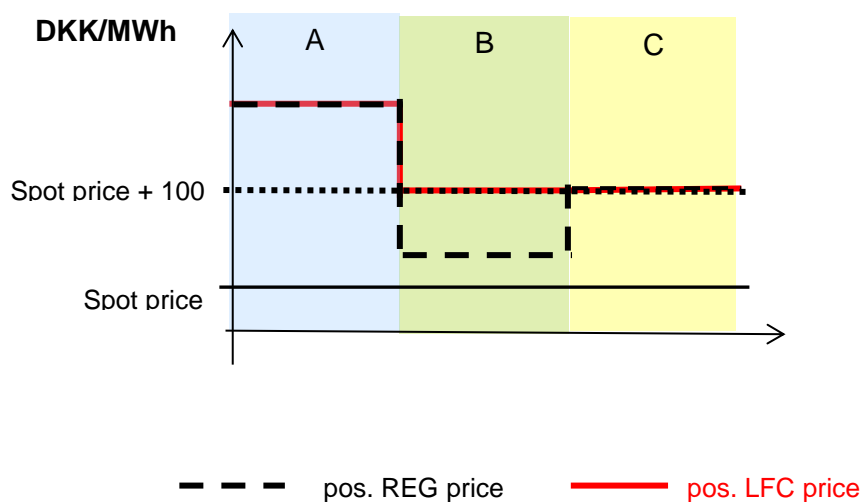
If pos. REG price < spot price + 100 DKK/MWh

→ pos. LFC price = spot price + 100 DKK/MWh

#### Situation C:

If pos. REG price = spot price + 100 DKK/MWh

→ pos. LFC price = pos. REG price = spot price + 100 DKK/MWh



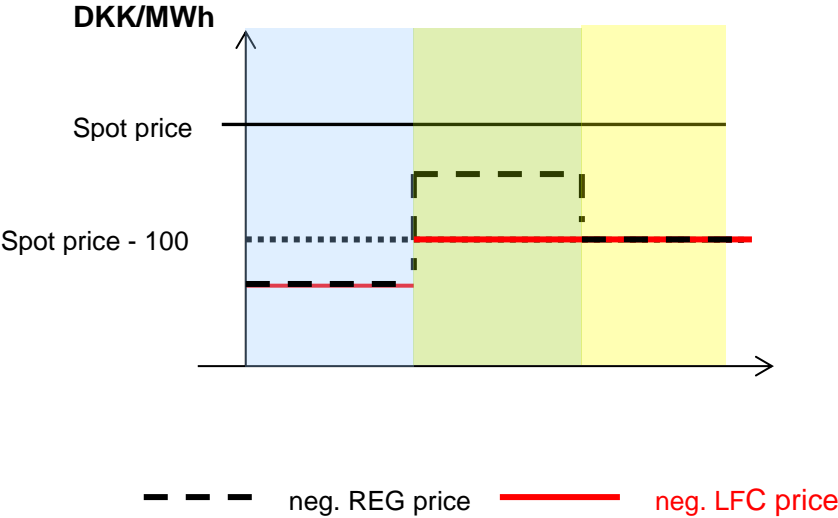
#### Situation A:

If neg. REG price < spot price - 100 DKK/MWh

→ neg. LFC price = neg. REG price

**Situation B:**  
If neg. REG price > spot price - 100 DKK/MWh  
→ neg. LFC price = spot price - 100 DKK/MWh

**Situation C:**  
If neg. REG price = spot price - 100 DKK/MWh  
→ neg. LFC price = neg. REG price = spot price - 100 DKK/MWh



Precise description of the opportunity prices for the **Netherlands**

The opportunity price (OPP) for the Netherlands is the relevant marginal price (highest activated price) of the merit order for the negative or the positive secondary control reserve per ¼-h (settlement period). If there is no activation in an energy direction within a settlement period, the lowest offer from the relevant merit order becomes the OPP for that direction.

For clarity's sake, the following overview has been added, showing the differences per situation:

**Control Reserve Activation NL**

Case		1	2	3	4
	positiv	✗	⊙	⊙	✗
	negativ	⊙	✗	⊙	✗

✗ (SCR activation)  
 ⊙ (no SCR activation)

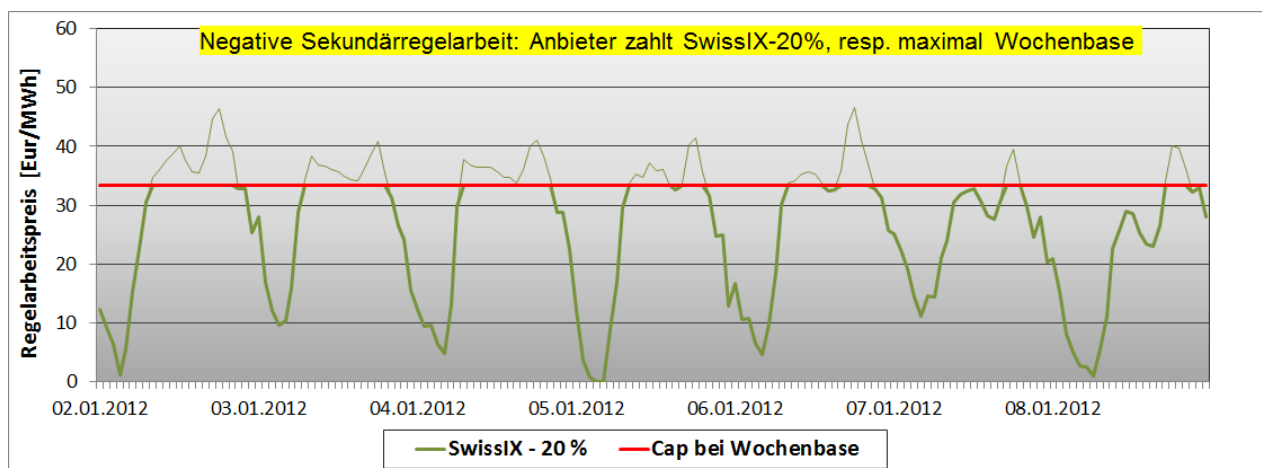
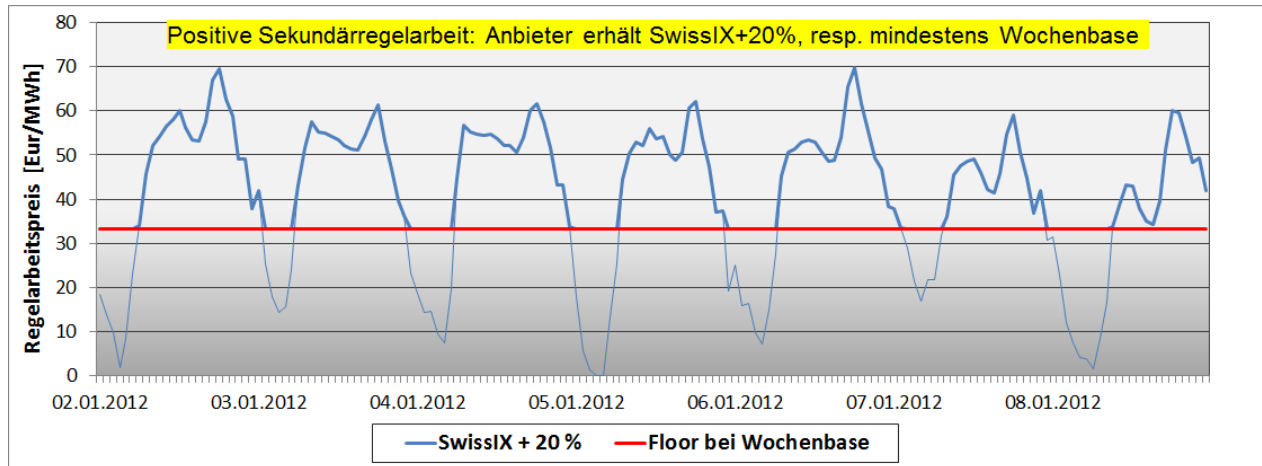
}  
 ¼-h  
 (period time unit)

**Opportunity prices for energy exchange with GCC**

		GCC			
OPP	Import	limit price neg. SCR	lowest price in MOL	lowest price in MOL	limit price neg. SCR
	Export	lowest price in MOL	limit price pos. SCR	lowest price in MOL	limit price pos. SCR

## Precise description of the opportunity prices for **Switzerland**

The secondary control energy price and thus the Swissgrid opportunity price is linked to the SwissIX spot price (day-ahead). Below you can find an example of the calculation for a single week.



The netting of the activated secondary control energy settled per 15 minutes in Switzerland (see chapter 4.4 Opportunity price for Switzerland) influences the opportunity costs and is therefore processed as follows:

- The balance of the secondary control energy demand within the invoicing period without application of the IGCC is decisive for the opportunity costs and is therefore determined in a first step.
- In case of a positive balanced demand for secondary control energy (power deficit), the deliveries to the IGCC and by the IGCC the price rating has to be done for positive secondary control energy according to the opportunity cost estimate.
- In case of a negative balanced demand for secondary control energy (power surplus), the deliveries to the IGCC and by the IGCC the price rating has to be done for negative secondary control energy according to the opportunity cost estimate. In the unlikely case that the balance of the secondary control energy demand within an invoicing period is zero, the price rating for the opportunity price has to be done with the average of the positive and negative SCE price.

## Precise description of the opportunity prices for the **Czech Republic**

Principles of the secondary control energy price model:

- The energy regulator fixes the prices for negative and positive secondary control energy once a year (2,350 CZK/MWh for positive SCE, -1 CZK/MWh for negative SCE in 2012, <http://www.eru.cz/>).
- The invoicing period is one hour.
- SCR providers are called pro rata.
- The secondary control energy volume is netted (balanced) per provider over the invoicing period so that only the balance is actually settled.  
Example: In one hour, 60 MWh of positive SCE and 40 MWh of negative SCE are activated. In this case, the provider is compensated for 20 MWh at the positive SCE price.

Determination of the opportunity prices as a formula

$$\text{CEPS opportunity price in } \frac{\text{€}}{\text{MWh}} = \frac{(\text{SCE costs without IGCC in €} - \text{SCE costs with IGCC in €})}{(\text{IGCC energy import in MWh} - \text{IGCC energy export in MWh})}$$

Opportunity price principles:

- Determination of opportunity price according to the opportunity principle
- Comparison of the secondary control energy costs with and without participation in the IGCC
- Only one opportunity price applies to imports and exports per invoicing period
- The opportunity price will usually be the positive or negative secondary control energy price, or, in certain cases, be situated between both prices

Tabular overview:

Situation	1	2	3	4
<b>Control area balance before IGCC</b>	positive	negative	positive	negative
<b>Control area balance after IGCC</b>	positive	negative	negative	positive
<b>Opportunity price</b>	Price SCE+	Price SCE-	Price between SCE+ and SCE-	Price between and SCE-

Precise description of the opportunity prices for **Belgium**

## Determination of opportunity price

The Opportunity Prices for both Export and Import direction are determined as the quantity-weighted average of the offered SCE prices. The weighting factor corresponds with the share of the (ex ante fix) quantity [MW] of SCP per supplier:

$$C_{i;imp} = \frac{\sum_k^{all\ suppliers} [P_{pos;i;k} * SCP_{pos;i;k}]}{\sum_{k=1}^{all\ suppliers} [SCP_{pos;i;k}]}$$

$$C_{i;Exp} = \frac{\sum_{k=1}^{all\ suppliers} [P_{neg;i;k} * SCP_{neg;i;k}]}{\sum_k^{all\ suppliers} [SCP_{neg;i;k}]}$$

Variable	Description of the data record	Format of the value
$SCP_{pos,k,i}$	Positive Selected SCP from supplier k for the Accounting Period i [MWh]	Always positive
$SCP_{neg,k,i}$	Negative Selected SCP from supplier k for the Accounting Period i [MWh]	Always positive
$P_{pos,k,i}$	SCE-Price for the positive Selected SCP from supplier k for the Accounting Period i	Always positive (Elia pays for activation of positive SCE)
$P_{neg,k,i}$	SCE-Price for the negative Selected SCP from supplier k for the Accounting Period i	Always positive (Elia is paid for activation of negative SCE)
$C_{i;Imp}$	Opportunity Price for Import from IGCC for the Accounting Period: (price for Settlement Price calculation) [€/MWh]	Positive (Elia pays for activation of positive SCE)
$C_{i;Exp}$	Opportunity Price for Export to IGCC for the Accounting Period: (price for Settlement Price calculation) [€/MWh]	Positive (Elia is paid for activation of negative SCE)

## Description of the SCE price cap

As described in chapter 4.6, the SCE prices communicated daily by the SCR providers are subject to a price cap based on fuel cost and a mark-up. There is a Maximum Price for positive SCE and Minimum Price for negative SCE which both form the valid area for the provider submitted SCE Prices. The Maximum Price for positive SCE is the fuel cost of a standard CCGT with an efficiency of 50% plus 40€/MWh. The Minimum Price for negative SCE is 0 €/MWh.

## Precise description of the opportunity price for **Austria**

### Determination of opportunity price

The Opportunity Prices are determined by the SCE that has to be activated inside of the Austrian Control Area.

The Opportunity Prices for both Export and Import direction are determined as the quantity-weighted average of SCE costs billed for the respected direction within the accounting period in the Control Area of APG. The Opportunity Prices are determined separately for Export and Import IGCC energy deliveries.

If there was no activation for the respective direction in an accounting period, the SCE price that would have been paid for the first bid in Merit Order List in the respected direction must be taken as the Opportunity Prices for the respected activation direction.

On this basis the following Opportunity Price determination has been agreed:

$$C_{i,IMP} = \frac{M_{SCEpos,i}}{SCE_{pos,i}}$$

$$C_{i,EXP} = \frac{M_{SCEneg,i}}{SCE_{neg,i}}$$

Variable	Description of the data record	Format of the value
$SCE_{pos,i}$	Positive SCE for the Accounting Period <sub>i</sub> [MWh]	Always positive
$SCE_{neg,i}$	Negative SCE for the Accounting Period <sub>i</sub> [MWh]	Always positive
$C_{i,Imp}$	Opportunity Price for Import from IGCC for the Accounting Period <sub>i</sub> (price for Settlement Price calculation) [€/MWh]	Positive (APG pays for activation of positive SCE) – Negative (APG is paid for activation of the positive SCE)
$C_{i,Exp}$	Opportunity Price for Export to IGCC for the Accounting Period <sub>i</sub> (price for Settlement Price calculation) [€/MWh]	Positive (APG is paid for activation of negative SCE) – Negative (APG pays for activation of negative SCE)
$M_{SCEpos,i}$	Total costs for positive SCE for the Accounting Period <sub>i</sub> (€)	Positive (APG has costs) – Negative (APG receives payment)
$M_{SCEneg,i}$	Total costs for negative SCE for the Accounting Period <sub>i</sub> (€)	Positive (APG receives payment) – Negative (APG has costs)

Examples for the Opportunity Price Determination of APG for one Accounting Period:

Example for Opportunity price for Import			
	SCE amount in MWh	Price in €/MWh	Costs in €
Bid 1	30	80	2400
Bid 2	200	100	20000
Bid 3	5	110	550
Sum (SCE <sub>pos</sub> and M <sub>SCEpos</sub> )	235		22950

Opportunity Price €/MWh	97,660
-------------------------	--------

Example for Opportunity price for Export			
	SCE amount in MWh	Price in €/MWh	Revenues <sup>3</sup> in €
Bid 1	30	15	450
Bid 2	200	-8	-1600
Bid 3	5	-50	-250
Sum (SCE <sub>neg</sub> and M <sub>SCEneg</sub> )	235		-1400

Opportunity Price €/MWh	-5,957
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<sup>3</sup> Negative is a cost

Precise description of the opportunity price for **France**

The table below illustrates how the IGCC Opportunity prices of RTE is defined:

15-min intervals	aFRR positive or negative energy price (= French EPEX spot Price) €/MWh	RTE IGCC Opportunity Price €/MWh
00:00-00:15	31.78	31.78
00:15-00:30	31.78	31.78
00:30-00:45	31.78	31.78
00:45-01:00	31.78	31.78
01:00-01:15	31.24	31.24
01:15-01:30	31.24	31.24
...	...	...

Precise description of the opportunity price for **Slovenia**

Variable	Description	Unit	Sign/ source
$aFRR_{pos;j;k}$	Positive activated aFRR energy* from supplier $k$ for the aFRR energy accounting period $j$ .	[MWh]	Always positive.
$aFRR_{neg;j;k}$	Negative activated aFRR energy* from supplier $k$ for the aFRR energy accounting period $j$ .	[MWh]	Always positive.
$P_{pos;j;k}$	aFRR energy price for the positive activated aFRR energy* from supplier $k$ for the aFRR energy accounting period $j$ .	[€/MWh]	Always positive (Eles pays for activation of positive aFRR energy).
$P_{neg;j;k}$	aFRR energy price for the negative activated aFRR energy* from supplier $k$ for the aFRR energy accounting period $j$ .	[€/MWh]	Positive (Eles is paid for activation of negative aFRR energy) or negative (Eles pays for activation of negative aFRR energy).
$IGCC_{i,Imp}$	IGCC import for the settlement period $i$ .	[MWh]	Always positive.
$IGCC_{i,Exp}$	IGCC export for the settlement period $i$ .	[MWh]	Always positive.
$OP_{i,Imp}$	Resulting IGCC Opportunity Price of Eles for IGCC import for the IGCC settlement period $i$ .	[€/MWh]	Positive (Eles pays for IGCC imported energy).
$OP_{i,Exp}$	Resulting IGCC Opportunity Price of Eles for IGCC export for the IGCC settlement period $i$ .	[€/MWh]	Positive (Eles is paid for IGCC exported energy) or negative (Eles pays for IGCC exported energy).

\* after netting of aFRR energy by each supplier

If  $IGCC_{j,Imp} > IGCC_{j,Exp}$

$$\text{then } OP_{i,Imp} = \frac{\sum_{k=1}^{all\ suppliers} [P_{pos;j;k} * aFRR_{pos;j;k}]}{\sum_{k=1}^{all\ suppliers} [aFRR_{pos;j;k}]} \quad i \in j \rightarrow OP_{i,Exp} = OP_{i,Imp}$$

elseif  $IGCC_{j,Imp} < IGCC_{j,Exp}$

$$\text{then } OP_{i,Exp} = \frac{\sum_{k=1}^{all\ suppliers} [P_{neg;j;k} * aFRR_{neg;j;k}]}{\sum_{k=1}^{all\ suppliers} [aFRR_{neg;j;k}]} \quad i \in j \rightarrow OP_{i,Imp} = OP_{i,Exp}$$

where  $i = 15$  minutes and  $j = 60$  minutes.

Due to applied hourly netting of positive and negative aFRR energy, the IGCC Opportunity Price in both directions is the same over the whole aFRR accounting period of one hour.

Examples for the Opportunity Price Determination of ELES for one Accounting Period:

Determination of IGCC Opportunity Price depends on the IGCC exchanged energy within an accounting period of one hour:

a) IGCC import > IGCC export

Example for IGCC Opportunity Price for import			
	Netted aFRR energy (only upward amounts) in MWh	Price for upward regulation in €/MWh	Costs in €
Supplier 1	1	80	80
Supplier 2	2	110	220
Supplier 3	17	140	2.380
Sum	20		2.680
IGCC Opportunity Price €/MWh	134,00		

	IGCC energy in MWh		IGCC Opportunity Price in €/MWh		Costs in €	
	Import	Export	Import	Export	Import	Export
00-15	40	0	134,00	134,00	5.360	0
15-30	20	5	134,00	134,00	2.680	-670
30-45	5	10	134,00	134,00	670	-1.340
45-00	5	15	134,00	134,00	670	-2.010
In hour	70	30			5.360	

b) IGCC export > IGCC import

Example for IGCC Opportunity Price for export			
	Netted aFRR energy (only downward amounts) in MWh	Price for downward regulation in €/MWh	Revenues in €
Supplier 1	1	10	10
Supplier 2	3	0	0
Supplier 3	26	-35	-910
Sum	30		-900
IGCC Opportunity Price €/MWh	-30,00		

	IGCC energy in MWh		IGCC Opportunity Price in €/MWh		Revenues in €	
	Import	Export	Import	Export	Import	Export
00-15	0	40	-30,00	-30,00	0	-1.200
15-30	5	20	-30,00	-30,00	150	-600
30-45	10	5	-30,00	-30,00	300	-150
45-00	15	5	-30,00	-30,00	450	-150
In hour	30	70			-1.200	

Precise description of the opportunity price for **Croatia**

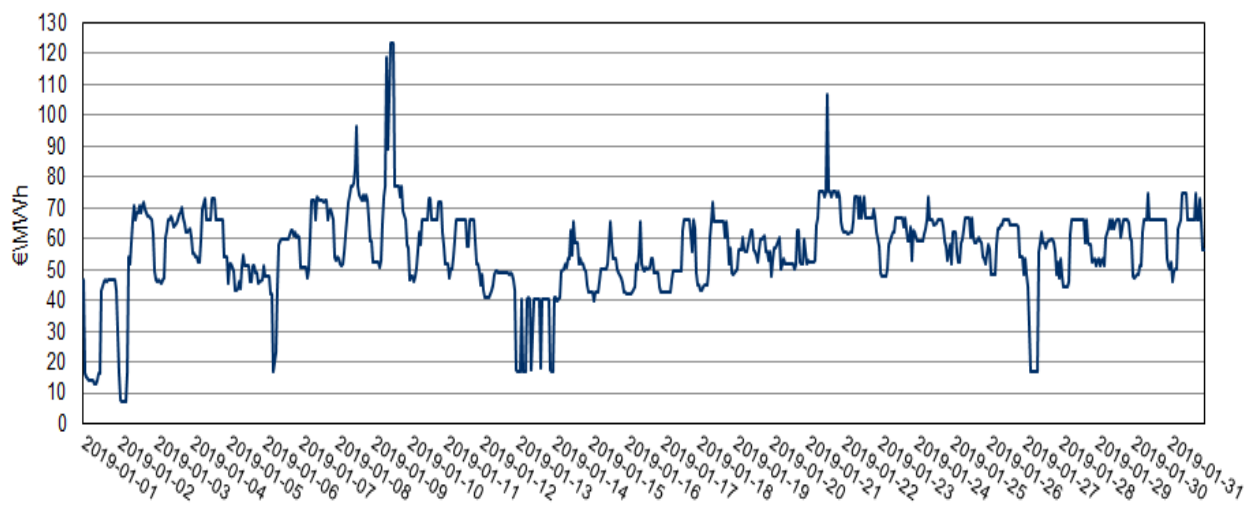
The table below illustrates how the IGCC Opportunity prices of HOPS are defined:

Hourly intervals	Average D-1 prices [€/MWh]	HOPS aFRR+ price [€/MWh]	HOPS aFRR- price [€/MWh]	15-min intervals	HOPS IGCC Opportunity Price Import [€/MWh]	HOPS IGCC Opportunity Price Export [€/MWh]
00:00 - 01:00	100	140	60	00:00-00:15 00:15-00:30 00:30-00:45 00:45-01:00	140 140 140 140	60 60 60 60
01:00 - 02:00	80	112	48	01:00-01:15 01:15-01:30 01:30-01:45 01:45-02:00	112 112 112 112	48 48 48 48
...	...	...	...	...	...	...

Precise description of the opportunity price for **Poland**

Time unit	aFRR energy price	IGCC Values of avoided aFRR:	IGCC Values of avoided aFRR:
h	PLN/MWh	PLN/MWh	€/MWh
00:00 - 01:00	200,000	200,000	46,512
01:00 - 02:00	70,020	70,020	16,284
02:00 - 03:00	65,000	65,000	15,116
03:00 - 04:00	60,000	60,000	13,953
.....	.....	.....	.....
23:00 - 00:00	70,000	70,000	16,279

## IGCC Values of avoided aFRR for the period



Prices to be published on PSE's website not later than in D+4:

<https://www.pse.pl/dane-systemowe/funkcjonowanie-kse/raporty-dobowe-z-pracy-kse/imbalance-netting>

IGCC Values of avoided aFRR are calculated in Polish currency and are converted into Euro with "current average exchange rates of foreign currencies" of National Bank of Poland - included in "Middle exchange rates archive – table A":

<http://www.nbp.pl/homen.aspx?c=/ascx/ArchAen.ascx>

Precise description of the opportunity price for **Italy**

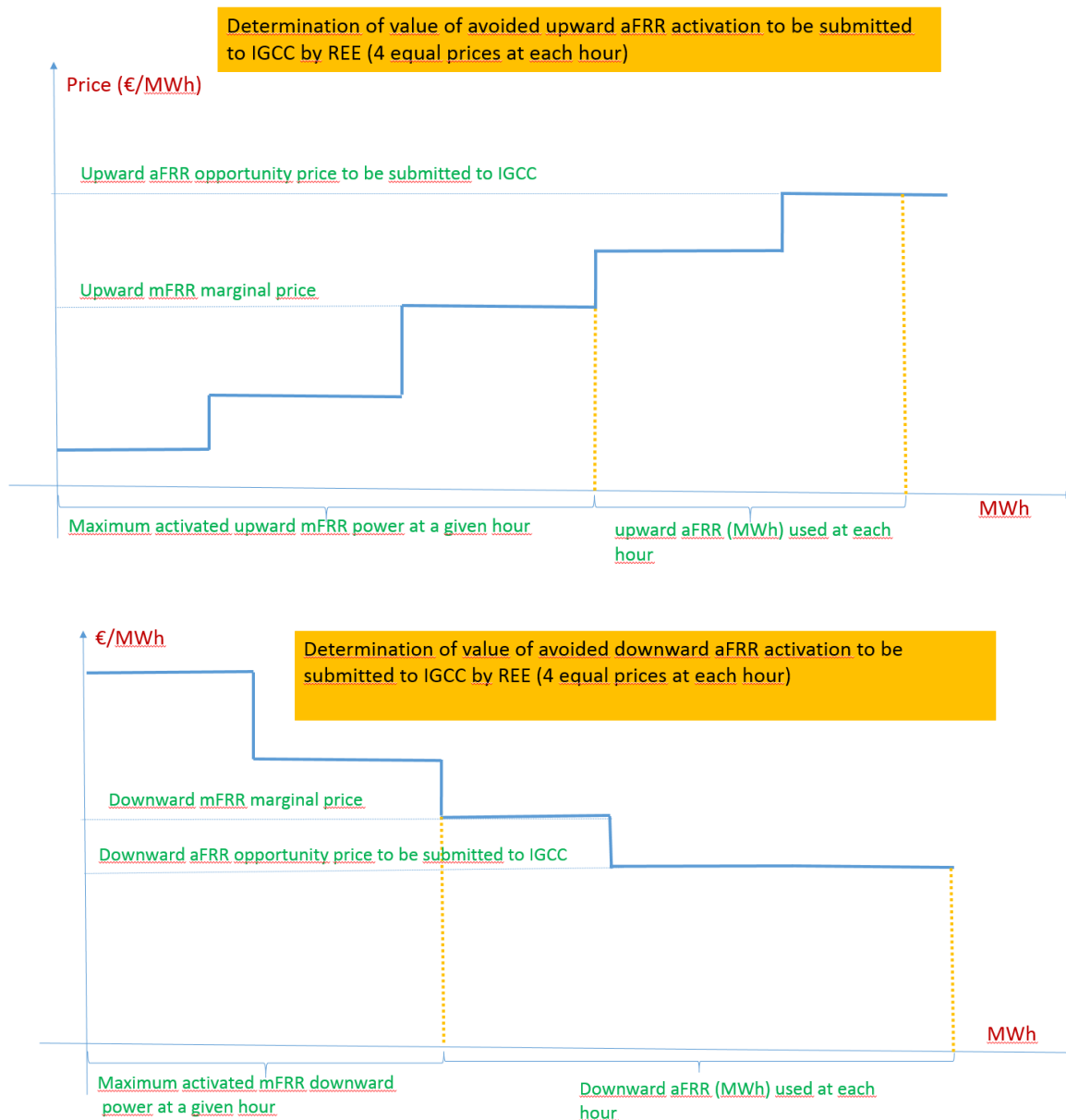
Examples for Terna IGCC Values of aFRR Avoided Activation determination for one IGCC settlement period:

Example for IGCC Value of aFRR Avoided Activation for import			
	aFRR energy amount in MWh	Price in €/MWh	Costs in €
Bid 1	100	100	10000
Bid 2	40	110	4400
Bid 3	20	120	2400
Sum	160		16800
IGCC Value of aFRR Avoided Activation €/MWh	105		

Example for IGCC Value of aFRR Avoided Activation for export			
	aFRR energy amount in MWh	Price in €/MWh	Costs in €
Bid 1	20	25	500
Bid 2	40	28	1120
Bid 3	10	30	300
Sum	70		1920
IGCC Value of aFRR Avoided Activation €/MWh	27,42		

## Precise description of the opportunity price for Spain

The following 2 figures illustrate how the aggregated upward and downward mFRR bid curves is used to value the avoided upward and downward aFRR :



Some remarks regarding the 2 figures above:

- In the Spanish system, mFRR upward/downward hourly marginal price is fixed by the highest/lowest mFRR bid activated even if this bid is activated for a short period of time (that is the reason why in the x axis it appears mFRR “power” instead of “energy”).
- For each hourly period, 4 equal prices of avoided upward aFRR activation and 4 equal prices of avoided downward aFRR activation will be determined with the above procedure.

Precise description of the opportunity price for **Hungary**

Example for one IGCC settlement period of a day:

Example for IGCC Value of avoided aFRR for import			
	aFRR energy amount in MWh	Price in €/MWh	Costs in €
Bid 1	30	80	2400
Bid 2	200	100	20000
Bid 3	5	110	550
Sum (aFRR <sub>pos</sub> and M <sub>aFRR_pos</sub> )	235		22950

IGCC Value of avoided aFRR €/MWh	97,660
----------------------------------	--------

Example for IGCC Value of avoided aFRR for export			
	aFRR energy amount in MWh	Price in €/MWh	Revenues <sup>4</sup> in €
Bid 1	30	15	450
Bid 2	200	-8	-1600
Bid 3	5	-50	-250
Sum (aFRR <sub>neg</sub> and M <sub>aFRR_neg</sub> )	235		-1400

IGCC Value of avoided aFRR €/MWh	-5,957
----------------------------------	--------

Precise description of the opportunity price for **Greece**

- There is **lack of energy** so the TSO either instructs the units to increase their production or imports aFRR energy from IGCC. The required quantity of energy  $aFRR_{u,t}^{up}$  shall be compensated at the System Imbalance Price (SIMP) of the corresponding accounting period:

IGCC time intervals = (1/4) * (accounting period)	Variables		
	Participant	$ZIMP_{u,t}$ (€/MWh)	$C_t^{imp}$ (€/MWh)
05:00-05:15	Unit 1	70,5	70,5
	Unit 2	70,5	
	Unit 3	70,5	
05:15-05:30	Unit 1	70,5	70,5
	Unit 2	70,5	
	Unit 3	70,5	
05:30-05:45	Unit 1	70,5	70,5
	Unit 2	70,5	
	Unit 3	70,5	
05:45-06:00	Unit 1	70,5	70,5
	Unit 2	70,5	
	Unit 3	70,5	
06:00-06:15	Unit 1	83,2	83,2
	Unit 2	83,2	
	Unit 3	83,2	
06:15-06:30	Unit 1	83,2	83,2
	Unit 2	83,2	
	Unit 3	83,2	
06:30-06:45	Unit 1	83,2	83,2
	Unit 2	83,2	
	Unit 3	83,2	
06:45-07:00	Unit 1	83,2	83,2
	Unit 2	83,2	
	Unit 3	83,2	

- There is **excess of energy**, so the TSO either instructs the units to decrease their production or exports aFRR energy to IGCC. The undelivered quantity of energy  $aFRR_{u,t}^{down}$  shall be charged as following:

IGCC time intervals = (1/4) * (accounting pe- riod)	Variables				
	Participant	$SMP_t$ (€/MWh)	$VCU_{u,t}$	$\min(SMP_t, VCU_{u,t})$	$C_t^{exp}$ (€/MWh)
04:00-04:15	Thermal unit 1	67,7	75,81	67,70	65,14
	Thermal unit 2		86,69	67,70	
	Thermal unit 3		89,00	67,70	
	Thermal unit 4		75,25	67,70	
	Hydro unit 1		130,79	67,70	
	Hydro unit 2		52,35	52,35	
04:15-04:30	Thermal unit 1	67,7	75,81	67,70	65,14
	Thermal unit 2		86,69	67,70	
	Thermal unit 3		89,00	67,70	
	Thermal unit 4		75,25	67,70	
	Hydro unit 1		130,79	67,70	
	Hydro unit 2		52,35	52,35	
04:30-04:45	Thermal unit 1	67,7	75,81	67,70	65,14
	Thermal unit 2		86,69	67,70	
	Thermal unit 3		89,00	67,70	
	Thermal unit 4		75,25	67,70	
	Hydro unit 1		130,79	67,70	
	Hydro unit 2		52,35	52,35	
04:45-05:00	Thermal unit 1	67,7	75,81	67,70	65,14
	Thermal unit 2		86,69	67,70	
	Thermal unit 3		89,00	67,70	
	Thermal unit 4		75,25	67,70	
	Hydro unit 1		130,79	67,70	
	Hydro unit 2		52,35	52,35	
05:00-05:15	Thermal unit 1	67,9	75,20	67,90	65,31
	Thermal unit 2		84,43	67,90	

	Thermal unit 3		89,00	67,90	
	Thermal unit 4		75,12	67,90	
	Hydro unit 1		130,79	67,90	
	Hydro unit 2		52,35	52,35	
05:15-05:30	Thermal unit 1	67,9	75,20	67,90	65,31
	Thermal unit 2		84,43	67,90	
	Thermal unit 3		89,00	67,90	
	Thermal unit 4		75,12	67,90	
	Hydro unit 1		130,79	67,90	
	Hydro unit 2		52,35	52,35	
05:30-05:45	Thermal unit 1	67,9	75,20	67,90	65,31
	Thermal unit 2		84,43	67,90	
	Thermal unit 3		89,00	67,90	
	Thermal unit 4		75,12	67,90	
	Hydro unit 1		130,79	67,90	
	Hydro unit 2		52,35	52,35	
05:45-06:00	Thermal unit 1	67,9	75,20	67,90	65,31
	Thermal unit 2		84,43	67,90	
	Thermal unit 3		89,00	67,90	
	Thermal unit 4		75,12	67,90	
	Hydro unit 1		130,79	67,90	
	Hydro unit 2		52,35	52,35	