European Network of
Transmission System Operators
for Electricity

All CE and Nordic TSOs' results of CBA in accordance with Art.156(11) of the Commission Regulation (EU) 2017/1485 of 2 August 2017

- Draft Version to be submitted for consultation -

Steering Group Operations

19 February 2020

DISCLAIMER
This document is released on behalf of the all CE and Nordic transmission system operators ("TSOs") only for the purposes of the public consultation on the all CE and Nordic TSOs' results of CBA in accordance with Art.156(11) of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a Guideline on Transmission System Operation. This version of the all CE and Nordic TSOs' results of CBA in accordance with Art.156(11) does not in any case represent a firm, binding or definitive TSOs' position on the content.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

1. Contents

1. Contents 2
2. Scope of the Document 3
3. Reference and Acronyms 3
4. Background 3
5. General information on the methodology 4
6. Results for CE synchronous area 7
   - Results of the probabilistic analysis 7
     - FCR dimensioning 7
     - Costs associated to increased FCR 7
     - Yearly average LER depletions 8
   - Results of the tests against the most relevant events 10
7. Options of minimum activation time period for CE 12
8. Results for Nordic synchronous area 15
   - Results of the probabilistic analysis 15
     - FCR dimensioning 15
     - Costs associated to increased FCR 15
     - Yearly average LER depletions 16
   - Results of the test against the most relevant events 17
9. Options of minimum activation time period for Nordic 18

2. Scope of the Document

This report presents the CBA approved Methodology, the results of the CBA analysis and details the pros and cons of all possible options of minimum activation time period for both Continental Europe and Nordic synchronous areas.

3. Reference and Acronyms

CBA	Cost Benefit Analysis compliant with the requirements contained in Article 156(11) of Commission Regulation (EU) 2017/1485 of 2 August 2017
SA	Synchronous Area
DFD	Deterministic Frequency Deviations
LL	Long Lasting frequency deviation events
CE	Continental Europe Synchronous Area
Nordic	Nordic Synchronous Area
FCR	Frequency Containment Reserve
FRR	Frequency Restoration Reserve
FAT	Full Activation Time of FRR
LER	FCR providers with Limited Energy Reservoir
TminLER	As of triggering the alert state and during the alert state, time for which each FCR provider shall ensure that its FCR providing units with limited energy reservoirs are able to fully activate FCR continuously
SOC	State of Charge of LER
MaxSSdf	Maximum Steady State frequency deviation (0.2 Hz in CE and 0.5 Hz in the Nordic)

[1] All Continental Europe and Nordic TSOs' proposal for assumptions and a Cost Benefit Analysis methodology in accordance with Article 156(11) of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation.

[2] Explanatory document of the proposal for assumptions and methodology for a Cost Benefit Analysis (CBA) compliant with the requirements contained in Article 156(11) of Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (System Operation Guideline Regulation – SOGR) – found here

[2] COMMISSION REGULATION (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation.

4. Background

This document is aiming at reporting the results of the Cost Benefit Analysis carried out by all Continental Europe and Nordic TSO's in accordance with the requirements contained in Article 156(11) of Commission Regulation 2017/1485 of 2 august 2017.

In March 2019 all TSOs of the CE and Nordic synchronous areas have submitted for regulatory approval assumptions and methodology for the CBA to be conducted, in order to assess the time period required for FCR providing units or groups with limited energy reservoirs to remain available during alert state.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

All Nordic NRAs have approved the assumptions and methodology for the CBA on 16th April 2019, whereas all CE NRAs have given their approval on 23rd May 2019.

All the assumptions regarding the input data and the methodology to be used to undertake the CBA are described in [1] and [2].

Article 156(11) provides that by 12 months after all NRAs approval, all TSO's of the CE and Nordic synchronous areas are requested to submit the results of the CBA to the regulatory authorities.

The public consultation aims at collecting the opinion of the affected stakeholders with a view to concluding on a recommended time period for both Nordic and Continental Europe synchronous areas.

5. General information on the methodology

According to [1] and [2] the CBA analyses a set of scenarios. For each synchronous area, the scenarios are defined considering the following criteria:

- Different TminLER: 15 min, 20 min, 25 min and 30 min.
- Different share of LER[1] in the FCR provision: from 0% to 100% with 10% steps.
- Presence or absence of mitigation action against the DFD.

Given the previous criteria, a total number of 88 scenarios have been investigated.

According to [1] and [2] the CBA is based on a probabilistic approach. For each synchronous area and each scenario, the probabilistic dimensioning of FCR needed to avoid critical LER depletions[2] is calculated. To each dimensioned FCR a cost is associated; it is divided in cost due to LER and cost due to non-LER.

The procedure adopted to calculate the needed FCR in each scenario and the resultant costs is shown in the Figure 1.

[1] The LER share is referred to the proportion of LER amongst the FCR provider selected to fulfil the requirements. E.g.: a LER share equal to 50% in CE with a FCR requirement of 3000 MW means that 1500 MW of FCR are given by LER.

[2] According to [1], a critical LER depletion is a condition in which occur both a LER depletion (reservoir completely empty or completely full) and an exceeding of steady state frequency deviation over the maximum steady state frequency deviation as defined in [3] Annex III Table 1.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

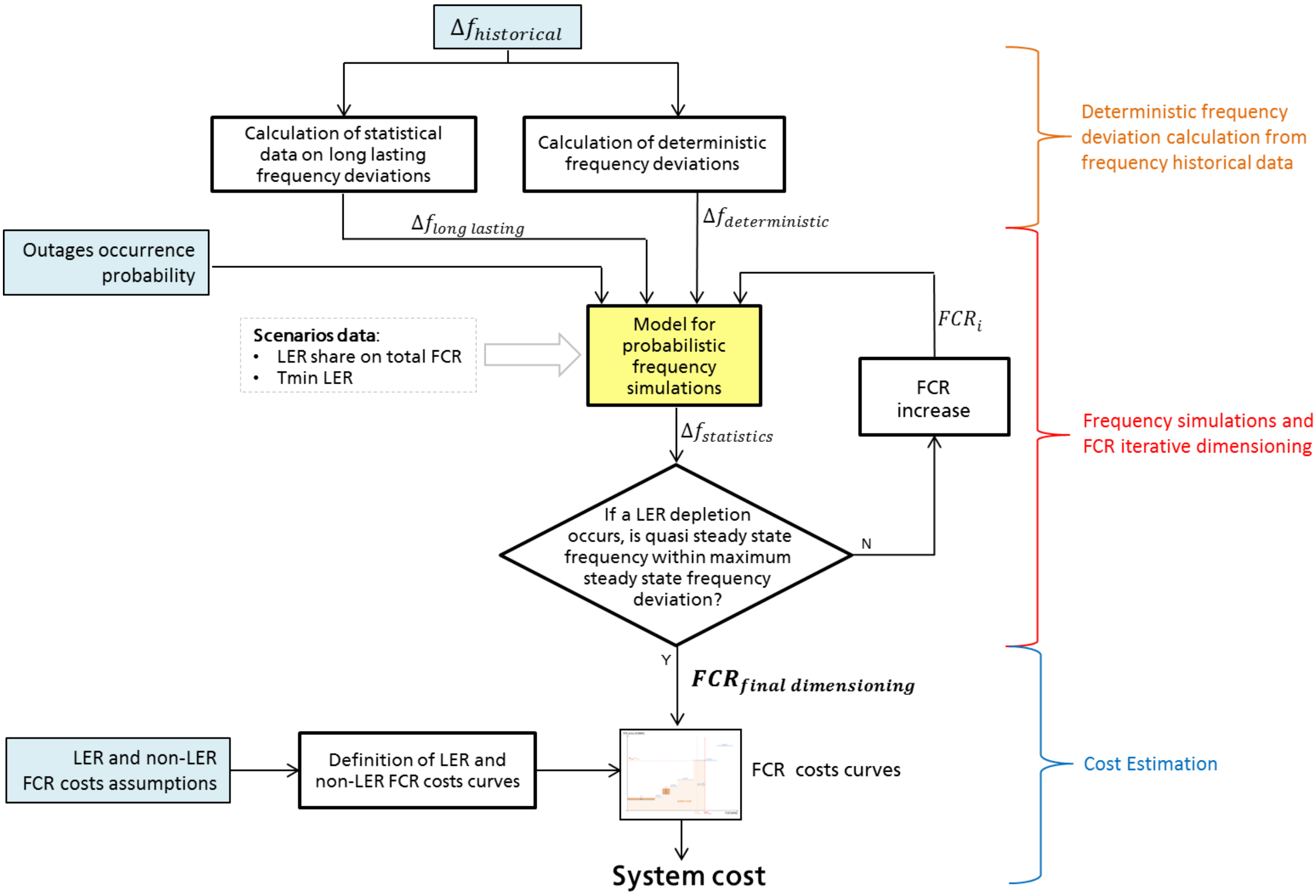

Figure 1: Process for calculating the needed FCR in each scenario and the resultant costs

The previous diagram shows in light blue the input[3]:

- historical frequency deviations;
- occurrence probability of outages leading to loss of production in the system;
- assumptions on FCR costs for both LER and non-LER providers.

Further information on the input data used in the methodology are provided in here

As shown in Figure 1, the procedure is based on a probabilistic frequency simulation model to verify if it is possible a critical depletion in the system. This probabilistic model exploits a Monte Carlo methodology: it simulates a large number of working conditions for the power system, randomly extracting the occurrence of outages and frequency deviations patterns due to long lasting events and DFD.

The results presented in this report are associated with Monte Carlo simulations over a working period of the system of 200 years.

The simulated frequency deviation trends - resulting from the randomly extracted outages, DFD and LL - are calculated by mean of a simplified simulation model whose assumptions are described in [1] and [2].

The main parameters adopted for the analysis presented in this report are sum up in the following list.

- **Starting FCR value**: 3000 MW for CE – 2050 MW for Nordic

[3] A detailed description of the meaning of each input can be found in [1] and [2].

It is the current dimensioning value for FCR. If the model detects a critical depletion, the iterative increase of FCR starts from this value.

- **FCR increase step**: 100 MW for CE – 50 MW for Nordic.
  It is the iterative increase step for FCR.
- **FAT**: 10.5 min for CE – 12.1 min for Nordic.
  The FRR is simulated considering a simplified single centralized controller for each synchronous area which operates only to restore the frequency deviation to 0 mHz. The FAT value affects how fast the controller operates.
- **Recharge time**: 120 minutes for both synchronous areas.
  It represents the time needed for LER to completely recover from depletion conditions (either full or empty). After a depletion, it is the time needed to reach the condition such that state of charge is equal to 50% of the reservoir.
- **Minutes around change of hour (DFD)**: 5 minutes for both synchronous areas.
  For both synchronous areas the DFD are considered within an interval of ±5 minutes around the change of the hour.
- **DFD Mitigation coefficient**: 0.8 for both synchronous areas.
  For both synchronous areas, the scenarios with mitigation actions on DFD are calculated reducing the current DFD of a factor equal to 0.8.

According to [1], the simplified simulation model has been used also for testing all the scenarios against a set of most relevant frequency events actually occurred in the past.

The complete set of events for CE is the following:

- 28/09/2003 Italian blackout;
- 04/11/2006 Continental Europe event.
- 10/01/2019 Significant frequency deviations in Continental Europe

For Nordic the two worst significant frequency deviations have been tested; they occurred on:

- 03/10/2011 h 21-23;
- 09/05/2018 h 00-02.

6. Results for CE synchronous area

Results of the probabilistic analysis

FCR dimensioning

The results in terms of FCR needed to avoid critical depletion are presented in the Table 1.
The scenarios are organized in a matrix having different TminLER on the rows and different LER share on the columns.

Table 1: FCR required to avoid critical depletions in CE

	LER share										
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
15’	**3000**	**3000**	**3000**	**3000**	**3400**	**4100**	**4700**	**4800**	**4800**	**4800**	**4800**
20’	**3000**	**3000**	**3000**	**3000**	**3400**	**3700**	**4200**	**4400**	**4400**	**4400**	**4400**
25’	**3000**	**3000**	**3000**	**3000**	**3100**	**3500**	**3900**	**4100**	**4100**	**4100**	**4100**
30’	**3000**	**3000**	**3000**	**3000**	**3000**	**3200**	**3500**	**3500**	**3500**	**3500**	**3500**

As expected, the needs of further FCR to avoid critical depletion grows as the LER share increases and as TminLER decreases.

The results with and without DFD mitigation actions are completely the same.

Costs associated to increased FCR

The costs for providing FCR for a year-long period in each scenario are shown in the following Table 2 (the values are in M€/year).

The Table 3 and Table 4 show respectively the costs due to non-LER and the costs due to LER.

Table 2: Total yearly costs to provide FCR in CE [M€/year]

	LER share											
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	Mean
15’	**110**	**89**	**70**	**53**	**77**	**125**	**168**	**188**	**206**	**231**	**264**	144
20’	**110**	**89**	**70**	**55**	**85**	**110**	**151**	**181**	**200**	**227**	**259**	140
25’	**110**	**89**	**71**	**62**	**75**	**108**	**148**	**179**	**200**	**227**	**259**	139
30’	**110**	**89**	**71**	**71**	**78**	**103**	**138**	**156**	**177**	**203**	**232**	130
Mean	110	89	70	60	79	112	151	176	196	222	253	

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

Table 3: Yearly costs to provide FCR in CE due to non-LER [M€/year]

	LER share											
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	Mean
15'	**110**	**89**	**70**	**53**	**49**	**50**	**40**	**23**	**8**	**0**	**0**	45
20'	**110**	**89**	**70**	**53**	**49**	**38**	**30**	**19**	**6**	**0**	**0**	42
25'	**110**	**89**	**70**	**53**	**39**	**32**	**26**	**16**	**5**	**0**	**0**	40
30'	**110**	**89**	**70**	**53**	**35**	**27**	**21**	**11**	**3**	**0**	**0**	38
Mean	110	89	70	53	43	37	29	17	5	0	0	

Table 4: Yearly costs to provide FCR in CE due to LER [M€/year]

	LER share											
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	Mean
15'	**0**	**0**	**0**	**1**	**28**	**75**	**128**	**165**	**198**	**231**	**264**	99
20'	**0**	**0**	**0**	**2**	**36**	**72**	**121**	**162**	**194**	**227**	**259**	98
25'	**0**	**0**	**0**	**10**	**36**	**76**	**122**	**163**	**195**	**227**	**259**	99
30'	**0**	**0**	**1**	**18**	**43**	**76**	**117**	**145**	**174**	**203**	**232**	92
Mean	0	0	0	8	36	75	122	159	190	222	253	

Yearly average LER depletions

A further indication given by the probabilistic model is the yearly average number of depletion that occur (as simulated by the Monte Carlo algorithm). These values are derived from the number of depletion detected by the system (either critical or not) along the 200 years simulation of the system work.

The results for each scenario are presented in the following Table 5. The results are referred to simulations in which the FCR requirement is not increased (FCR equal to 3000 MW).

Table 5: Yearly average depletion number in CE (with FCR = 3000 MW)

	LER share											
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	Mean
15'	**1.11**	**1.11**	**1.11**	**1.11**	**1.11**	**1.11**	**1.11**	**1.11**	**1.11**	**1.11**	**1.11**	1.11
20'	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	0.46
25'	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**	0.28
30'	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	0.14
Mean	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	

Another interesting statistic derived from the probabilistic model is the yearly average number of critical depletion without FCR increase (FCR equal to 3000 MW). These data are shown in Table 6.

Table 6: Yearly critical average depletion number in CE (with FCR = 3000 MW)

	LER share											
TminLER	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	Mean
15’	**0**	**0**	**0**	**0**	**0.22**	**0.28**	**0.29**	**0.72**	**0.91**	**0.98**	**1.11**	0.41
20’	**0**	**0**	**0**	**0**	**0.22**	**0.28**	**0.28**	**0.35**	**0.45**	**0.46**	**0.46**	0.22
25’	**0**	**0**	**0**	**0**	**0.09**	**0.14**	**0.23**	**0.23**	**0.23**	**0.28**	**0.28**	0.13
30’	**0**	**0**	**0**	**0**	**0**	**0.09**	**0.12**	**0.14**	**0.14**	**0.14**	**0.14**	0.07
Mean	0.00	0.00	0.00	0.00	0.13	0.20	0.23	0.36	0.43	0.46	0.49	

It is interesting to highlight that the average number of critical depletions depends on the LER share while the total average number of depletions (critical and not) is the same regardless the LER share.

This result is due to the fact that an event of LER depletion does not depend on how much FCR is provided by LER but only on the size of the reservoir and on the frequency deviation. The criticality of a LER depletion event depends instead on the effect of the depletion on the frequency deviation: a larger share of FCR provided by LER entails that the loss of LER regulation capacity has a deeper impact on the system.

Results of the tests against the most relevant events

The frequency deviation deriving from each most relevant event has been tested in each scenario. The test is aimed at understanding which might have been the effect of the presence of LER if they had been in place when the event actually occurred.

The purpose of the tests is to assess whether - in the presence of LER - a critical depletion would have occurred with the consequent loss of FCR and potential further degradation of the system condition.

The tests are carried out as follows:

- the frequency deviation of the real event is converted into an equivalent power imbalance considering the MW/Hz curve;
- the power imbalance is simulated in the model, considering the LER depletion;
- if LER depletion occurs, the frequency deviation is recalculated given a modified MW/Hz curve;
- is verified whether the frequency deviation exceeds the MaxSSdf.

The tests are carried out within an iterative process in which the FCR requirement is gradually increased, starting from the current dimensioning value (3000 MW for CE and 2050 MW for Nordic). The purpose of the iterative process is to calculate the theoretical FCR requirements that allows to avoid critical depletions during the events.

It is important to highlight that the tested actual frequency trends are associated to events with extremely degraded system conditions. It means that an exceeding of MaxSSdf actually occurred during the event, even without the presence of LER. However, the LER could potentially worsen the situation if they deplete.

The presented results (Table 7) are then to be considered as an indication of how much the presence of LER could potentially have worsened the system conditions in different scenarios. The higher the FCR requirements are, the more the presence of LER could impact the system during the tested event.

Table 7: Results of most relevant event tests on CE system

2003 Italian Black out

	LER share									
TminLER	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
15	3700	4000	4500	5200	5900	6300	6800	8000	8200	8200
20	3500	3900	4400	4700	5000	5200	6000	6800	6800	6800
25	3300	3500	3800	4000	4200	4600	5500	5900	5900	5900
30	3000	3000	3100	3400	3700	4300	4900	5100	5100	5100

2006 CE East

	LER share									
TminLER	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
15	7300	7800	8200	9100	10600	11200	12600	12800	12800	12900
20	6100	6900	7600	8300	8800	9600	9600	9800	9800	9900
25	5900	6600	6600	7100	7700	7700	7800	7800	7800	7900
30	5000	5300	5700	6300	6300	6500	6500	6500	6500	6600

2006 CE South

	LER share									
TminLER	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
15	3000	3000	3000	3000	3300	3700	3800	4300	4300	4300
20	3000	3000	3000	3000	3000	3000	3300	3300	3300	3300
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
30	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

2006 CE West

	LER share									
TminLER	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
15	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
20	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
30	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

2019 event

	LER share									
TminLER	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
15	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
20	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
30	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

The results show that the worst events are the 2003 Italian black-out (for the rest of CE system) and the 04/11/2006 event (in the eastern part in which CE system was splitted).

As expected the highest LER share and the lowest TminLER scenarios are associated with a larger impact of LER. A greater LER share implies that when LER depletion occurs the loss of regulating FCR is more. A smaller TminLER leads to an earlier depletion.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

7. Options of minimum activation time period for CE

The current installed LER in CE is about 970 MW with TminLER of 15 minutes and 690 MW with TminLER of 30 minutes[4].

The values are mainly due to electrochemical batteries in Germany (380 MW) and run of river plants in France (526 MW at 15 min).

Considering all the currently installed LER with costs such as to be selected to provide FCR in the market, the current LER share[5] depends on the TminLER:

- 32% with TminLER 15 minutes;
- 23% with TminLER 30 minutes.

The situation in terms of current LER share is shown in Figure 2.

	LER share											
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	Mean
15	110	89	70	53	77	125	168	188	206	231	264	144
20	110	89	70	55	85	110	151	181	200	227	259	140
25	110	89	71	62	75	108	148	179	200	227	259	139
30	110	89	71	71	78	103	138	156	177	203	232	130
Mean	110	89	70	60	79	112	151	176	196	222	253	

Current LER share*

Need to increase FCR

Figure 2: Current LER share in CE

Given the current situation the 15 minutes choice would be the most economical solution. However, the current situation is slightly above the threshold that leads to FCR increase need. As soon as the LER share will increase, the most economical situation will become 30 minutes (due to the FCR increase).
It should be highlighted that independently from the chosen time period an increased LER share could potentially lead to an increase of overall cost for procuring FCR.

All TSO's analysed the CBA results (Table 1, Table 2), considering the following elements:

- LER share;
- FCR amount needed to avoid critical depletion;
- most relevant event grid behaviour;
- costs;
- impact of different time period choice to the already existing LER.

From such analysis the most suitable solutions have been assessed to be the following:

- TminLER = 15 minutes for all LER, limiting the LER share to 30%. This technical solution assumes to maintain the current 3000 MW FCR dimensioning;

[4] The current LER have different minimum activation time requirements; if the requirement changes also the FCR provided by LER changes. The qualified LER values with different minimum activation times have been provided by the involved TSO's.

[5] The current LER share is the ratio between the current maximum available qualified FCR provided by LER and FCR requirement.

- TminLER = 30 minutes for all LER (including already existing LER). This technical solution allows LER share to increase by mean of an FCR increase;
- TminLER = 30 minutes for all LER (excluding already existing LER prequalified for a time period less than 30 minutes). This technical solution allows LER share to increase by mean of an FCR increase

The pros and cons of all the possible solutions are presented in the Figure 3 and are analysed in detail below.

15 min (with LER share limitation)	30 min (without LER share limitation) + exemption for existing LER	30 min (without LER share limitation)
Limiting the LER share to 30% (reduction from current 32%) allows to keep the current FCR dimensioning (3000 MW).	Needs to increase FCR above 3000 MW (only as a consequence of the LER presence) if LER share is above 40%. Excluding the already installed LER having prequalified time period less than 30 minute	Needs to increase FCR above 3000 MW (only as a consequence of the LER presence) if LER share is above 40%.
With the current LER share is the most economical solution	With the current LER share is not the most economical solution	With the current LER share is not the most economical solution
Implies a reduction from current 32% to 30% LER share	Allows the increase of LER share	Allows the increase of LER share
Not permitted to have LER share larger than 30%: potential market distortion at LFC blocks with already different LER shares	As LER share increase, becomes the most economical solution	As LER share increase, becomes the most economical solution
Existing LER having 15' won't need to be retrofitted / to reduce their FCR qualification.	No impact on existing LER having 15'	Existing LER having 15' could be not able to fulfill the requirement
Considering the most relevant events, even with 30% limit, the imbalances are 45% bigger than with 30'. The corresponding corrective actions shall be put in place within 15'	Considering the most relevant events the imbalances are less than with 15' (45% with 30% LER share) but probably greater than 30' due to the presence of existing LER keeping 15'	Considering the most relevant events the imbalances are less than with 15' (45% with 30% LER share). The corresponding corrective actions shall be put in place within 30'
Homogeneous time period requirement: No problems regarding legal aspects	Coexistence of different time periods: Problems regarding legal aspects of having different TminLER	Homogeneous time period requirement: No problems regarding legal aspects

Figure 3: Pros and cons of 15/30 minutes TminLER in CE

15 minutes (with LER share limitation)

The most economical point of the entire matrix falls within the current situation, with TminLER=15 minutes and 30% of LER share. To keep this situation the system needs to be forced to limit the LER share at 30%, slightly cutting the already achieved share. This limitation could lead to potential market distortions at LFC blocks level which already have different LER shares. It also could imply a development of two FCR markets for procurement (LER and non-LER market).

The methodology requires also to consider the most relevant events, which for 15' TminLER provides imbalances 45% greater than with 30', with corrective actions that need to be implemented in 15'.

On the other side, choosing 15' as TminLER would have no impact on the existing LER already having 15' requirement: these will not need any retrofits or reduction of their FCR qualification; furthermore, the presence of a uniform time period requirement would not entail any issue on legal feasibility.

30 minutes (without LER share limitation) and exemption for existing LER

This solution is not the most economical with the current LER share. However, it allows the possibility to increase the LER share. Considering how fast the LER share has been growing in the recent years, a further LER share increase can be likely expected. The LER capex costs for electrochemical storage considered in the CBA are for 2020; a further drop can be seen after 2020, for instance as a consequence of new technologies.

Moreover, the survey establishing current LER share of 32% could be outdated when the proposed new TminLER will be in force. Probably the current share is moving rapidly towards 40% (which for 15 minutes

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

already requires FCR increase or a further limitation in the procurement). The 15 minutes solution with FCR increase (needed for a 40% LER share) has costs in line with TminLER = 30 minutes solution without need of FCR increase.

Another crucial difference that needs to be highlighted between 15 and 30 minutes solutions is the related need of FCR increase.
The more LER share will be in the system the more FCR will be needed and the FCR increase depends on the TminLER (longer time period = less FCR increase): e.g.

- with LER 50% the TminLER=15 min solution requires 4100MW of FCR while the 30 min needs 3200MW.
- With 40% LER share 15 min needs 3400 MW and 30 min needs 3000 MW.

An important drawback in choosing 30 minutes is the presence of already existing LER with a time period prequalification less than 30 minutes.

For this reason, a possible solution could be to have a 30 minutes time period requirement for all LER with exception of the already existing ones having a prequalified value less than 30 minutes.

This solution could potentially raise legal issues related to the competition between FCR providers with different requirements. Furthermore, the presence of different time periods was not simulated in the model, therefore quantitative results for this solution are not available: it is reasonable to assume that for most relevant events the imbalances would be smaller than with 15' TminLER and greater than 30' because of the coexistence of the two time periods.

30 minutes (without LER share limitation)

This solution implies the application of 30' for all LER, including the already existing. It provides the same advantages and drawbacks as the previous solution "30 minutes (without LER share limitation) and exemption for existing LER" except for these elements:

- Existing LER which have a 15' time requirement already active could need a retrofit or a reduction of FCR qualification to satisfy the new rule
- The presence of a homogeneous time requirement would not cause any legal problem compared to the coexistence of different time periods
- The most relevant events are better sustained due to the fact that all LERs have 30' time requirement, with imbalances 45% smaller with respect to 15' solution and with corrective actions to be implemented in 30'.

The whole CBA has been realized without taking into account the FCR Additional Properties (Art.154(2) of [2] – so called A-2), which are currently under approval and not enforced yet, and which will impact a series of regulatory and technical aspects (increase of aFRR dimensioning, corresponding costs, transitional period for to take place, how to deal with existing LER FCR providers, impact on FCR availability of existing LER with 15 min, etc.).

As stated in [1], when relevant changes in the assumptions occurs, the CBA shall be accordingly run again. Also FCR market liquidity risk linked to the FCR increase has not been part of the study.

8. Results for Nordic synchronous area

Results of the probabilistic analysis

FCR dimensioning

The results in terms of FCR needed to avoid critical depletion are presented in the Table 8.

The scenarios are organized in a matrix having different TminLER on the rows and different LER share on the columns.

Table 8: FCR required to avoid critical depletions in Nordic

	LER share										
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
15'	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2200**	**2400**	**2400**	**2400**	**2400**
20'	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2200**	**2200**	**2200**	**2200**	**2200**
25'	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**
30'	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**

The results with and without DFD mitigation actions are completely the same.

Costs associated to increased FCR

The costs for providing FCR along a year in each scenario are shown in the following Table 9 (the values are in M€/year).

The Table 10 and Table 11 show respectively the costs due to non-LER and the costs due to LER.

Table 9: Total yearly costs to provide FCR in Nordic [M€/year]

	LER share											
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	Mean
15'	**314**	**248**	**194**	**140**	**87**	**61**	**78**	**102**	**119**	**135**	**151**	148
20'	**314**	**252**	**199**	**146**	**93**	**68**	**86**	**101**	**117**	**133**	**149**	151
25'	**314**	**257**	**204**	**152**	**99**	**75**	**87**	**102**	**118**	**133**	**148**	154
30'	**314**	**262**	**210**	**158**	**106**	**83**	**95**	**111**	**127**	**143**	**159**	161
Mean	314	255	202	149	96	72	86	104	120	136	152	

Table 10: Yearly costs to provide FCR in Nordic due to non-LER [M€/year]

	LER share											
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	Mean
15'	**314**	**246**	**178**	**111**	**43**	**3**	**0**	**0**	**0**	**0**	**0**	81.3
20'	**314**	**246**	**178**	**111**	**43**	**3**	**0**	**0**	**0**	**0**	**0**	81.3
25'	**314**	**246**	**178**	**111**	**43**	**3**	**0**	**0**	**0**	**0**	**0**	81.3
30	**314**	**246**	**178**	**111**	**43**	**3**	**0**	**0**	**0**	**0**	**0**	81.3
Mean	314	246	178	111	43	3	0	0	0	0	0	

Table 11: Yearly costs to provide FCR in Nordic due to LER [M€/year]

	LER share											
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	Mean
15'	**0**	**2**	**16**	**30**	**44**	**58**	**78**	**102**	**119**	**135**	**151**	67
20'	**0**	**6**	**21**	**35**	**50**	**65**	**86**	**101**	**117**	**133**	**149**	69
25'	**0**	**11**	**26**	**41**	**56**	**72**	**87**	**102**	**118**	**133**	**148**	72
30'	**0**	**16**	**31**	**47**	**63**	**79**	**95**	**111**	**127**	**143**	**159**	79
Mean	0	9	24	38	53	68	86	104	120	136	152	

Yearly average LER depletions

The yearly average number of depletion that occur for each scenario are presented in the following Table 12. The results are referred to simulations in which the FCR requirement is not increased (FCR equal to 2050 MW).

Table 12: Yearly average depletion number in Nordic (with FCR = 2050 MW)

	LER share											
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	Mean
15'	**0.83**	**0.83**	**0.83**	**0.83**	**0.83**	**0.83**	**0.83**	**0.83**	**0.83**	**0.83**	**0.82**	0.83
20'	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.10**	0.10
25'	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	0.00
30'	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	0.00
Mean	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	

The yearly average number of critical depletion without FCR increase (FCR equal to 2050 MW). Is shown in Table 13.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

Table 13: Yearly critical average depletion number in Nordic (with FCR = 2050 MW)

	LER share											
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	Mean
15	**0**	**0**	**0**	**0**	**0**	**0**	**0.14**	**0.68**	**0.76**	**0.83**	**0.83**	0.29
20	**0**	**0**	**0**	**0**	**0**	**0**	**0.04**	**0.10**	**0.10**	**0.10**	**0.10**	0.04
25	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	0
30	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	0
Mean	0	0	0	0	0	0	0.04	0.20	0.22	0.23	0.23	

Results of the test against the most relevant events

In the Nordic synchronous area, the only tested events are the two worst recorded events.

The analysis has been made as described for the CE synchronous area.

The results are shown in the following Table 14.

Table 14: Results of most relevant event tests on Nordic system

	LER share										
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
15	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2100**	**2250**	**2250**	**2250**	**2250**
20	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**
25	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**
30	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**

Event
03/10/2011 h21:09

	LER share										
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
15	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2200**	**2400**	**2400**	**2400**	**2400**
20	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2200**	**2200**	**2200**	**2200**	**2200**
25	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**
30	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**

Event
09/05/2019 h00:26

The most relevant results do not provide any further information in addition to the output of the probabilistic approach.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

9. Options of minimum activation time period for Nordic

The current installed LER in Nordic is about:

- 177 MW with TminLER of 15 minutes;
- 120 MW with TminLER of 20 minutes;
- 62 MW with TminLER of 25 minutes;
- 5 MW with TminLER of 30minutes.

The dependence of installed LER from TminLER is mainly due to run-of-river in Norway.

The situation in terms of current LER share is shown in Figure 4.

	LER share											
TminLER	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	Mean
15	314	248	194	140	87	61	78	102	119	135	151	148
20	314	252	199	146	93	68	86	101	117	133	149	151
25	314	257	204	152	99	75	87	102	118	133	148	154
30	314	262	210	158	106	83	95	111	127	143	159	161
Mean	314	255	202	149	96	72	86	104	120	136	152	

Current LER share*

Most economical path for increasing LER

Area with need to increase FCR

Figure 4: Current LER share in Nordic

Given the current situation the most economical solution is 15 minutes.

The current LER share is well below the thresholds above which an FCR increase is needed.

If the LER share exceeded 60% an FCR increase would be needed. In this situation the most economical solution depends on the LER share itself:

with 60%	15'
with 70%÷80%	20'
with 90%	20'÷30'
with 100%	25'

The differences between different scenarios costs are however very small.

All TSO's have considered the output of the CBA either regarding the needed FCR and the associated costs. The most suitable solutions have been assessed to be 15, 20 and 25 minutes. A synthetical presentation of pros and cons is provided in the Figure 5 and an extensive explanation is provided below.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

15 min (with LER share limitation)	20 min (without LER share limitation)	25 min (without LER share limitation)
Avoids the need to increase FCR above 2050 MW, limiting LER share	Needs to increase FCR above 2050 MW (only as a consequence of the LER presence) if LER share will be above 60%.	Avoids the need to increase FCR above 2050 MW
With the current LER share is the most economical solution	With the current LER share is not the most economical solution	With the current LER share is not the most economical solution
Non the most economical with LER share above 70%	Most economical in the LER share range 70%÷90%	It becomes the most economical only with 100% LER share
Needs to limit LER share below 60%. Currently the LER share is well below this threshold.	Need to increase FCR if LER share will exceed 60%	No need to increase the FCR for all LER shares
It has less impact on existing LER having 15' limitation	It has medium impact on existing LER having 15' limitation	It has more impact on existing LER having 15' limitation
The time period choice will only apply to FCR-D		

Figure 5: Pros and cons of 15/20/25 minutes TminLER in Nordic

15 minutes (with LER share limitation)

Considering the current LER share, 15' time period represents the most economical situation. Other time periods present total lower costs from 70% LER share, however it is significant to underline that the differences in terms of costs are quite small.

The choice of 15 minutes would need to limit the LER share to a maximum of 60% in order to avoid an increase of FCR needed for the system. However, this threshold is quite distant from the current situation.

Furthermore, this solution will not impact on existing LER which already have a 15' time requirement.

20 minutes (without LER share limitation)

This solution is not the most economical considering the current LER share, but it is not distant from the 15' cost. It will become the preferable one with LER share between 70% and 90%, and also in this case the differences with other solutions are not remarkable in terms of costs, even though the FCR amount are different for the time periods (2400 MW for 15', 2200 MW for 20', 2050 MW for 25' and 30').

This solution implies the need to increase the FCR for LER share above 60% in order to capture the benefits of lower costs for LER share between 70% and 90%.

Finally, this TminLER will likely have an impact on existing LER having 15' time period, but lower compared to higher time requirements, with the possible need of retrofit or adjustment of the FCR qualification.

25 minutes (without LER share limitation)

This solution will not need to increase FCR amount for all LER shares.

However, with the current LER share it does not represent the most economical solution. The only LER share which ensures the lowest cost is 100%. This TminLER could have a heavier impact on existing LER with an already enforced time period of 15'.

The time period choice will only apply to FCR-D.

The whole CBA has been realized without taking into account the FCR Additional Properties (Art.154(2) of [3]), which are currently in discussion and not enforced yet, and which will impact a series of regulatory and technical aspects (increase of aFRR dimensioning, costs to be associated, transitional period will be provided, how to deal with existing plants, impact on FCR availability of existing LER with 15'). As stated in the methodology, when relevant changes in the assumptions will occur, the CBA shall be accordingly run again.