Proposal for a Cost Benefit Analysis methodology in accordance with Article 156 (11) of the Commission Regulation (EU) 2017/1485 of 2 August 2017

Luca Ortolano

Georgios Giannopoulos

Aurelien Peyrac

Thorsten Schneiders

David Whitley

Public Workshop
15 January 2018

Workshop Agenda

- Introduction to the workshop
- Purpose of the workshop
- Regulatory Framework
- CBA methodology explanation (with Q&A)
- Compliance with Article 156(11)(a)to(e)
- Q&A

Introduction

Purpose of the workshop

Regulatory framework

Introduction
Purpose of the workshop

- **To inform all the involved parties about the CBA methodology proposal**
- **To describe the rationale of the solutions proposed in the CBA methodology**
- **To define the core issues**
- **To describe the future work and next steps of the CBA methodology**

Introduction
Regulatory Framework

- **SO GL - title V – describes the requirements for Frequency Containment Reserve**
- **Under title V, art. 156 describes FCR provision requirements, also for Limited Energy Reservoirs (LER)**
- **In particular, about LER – art. 156(9) prescribes that:**
  - "For the CE and Nordic synchronous areas, each FCR provider shall ensure that the FCR from its FCR providing units or groups with limited energy reservoirs **are continuously available during normal state**. For the CE and Nordic synchronous areas, as of triggering the alert state and during the alert state, each FCR provider shall ensure that its FCR providing units or groups with limited energy reservoirs are able to **fully activate FCR continuously for a time period to be defined pursuant to paragraphs 10 and 11**. […]"
- Art. 156(10) and 156 (11) requires that **CE and Nordic SAs' TSOs "shall develop a proposal concerning the minimum activation period to be ensured by FCR providers"** which shall consider the results of a CBA

Introduction
Regulatory Framework

Article 156 (11) of SO GL

The aforementioned CBA shall take into account at least:

a) experiences gathered with different time frames and shares of emerging technologies in different LFC blocks;

b) the impact of a defined time period on the total cost of FCR reserves in the synchronous area;

c) the impact of a defined time period on system stability risks, in particular through prolonged or repeated frequency events;

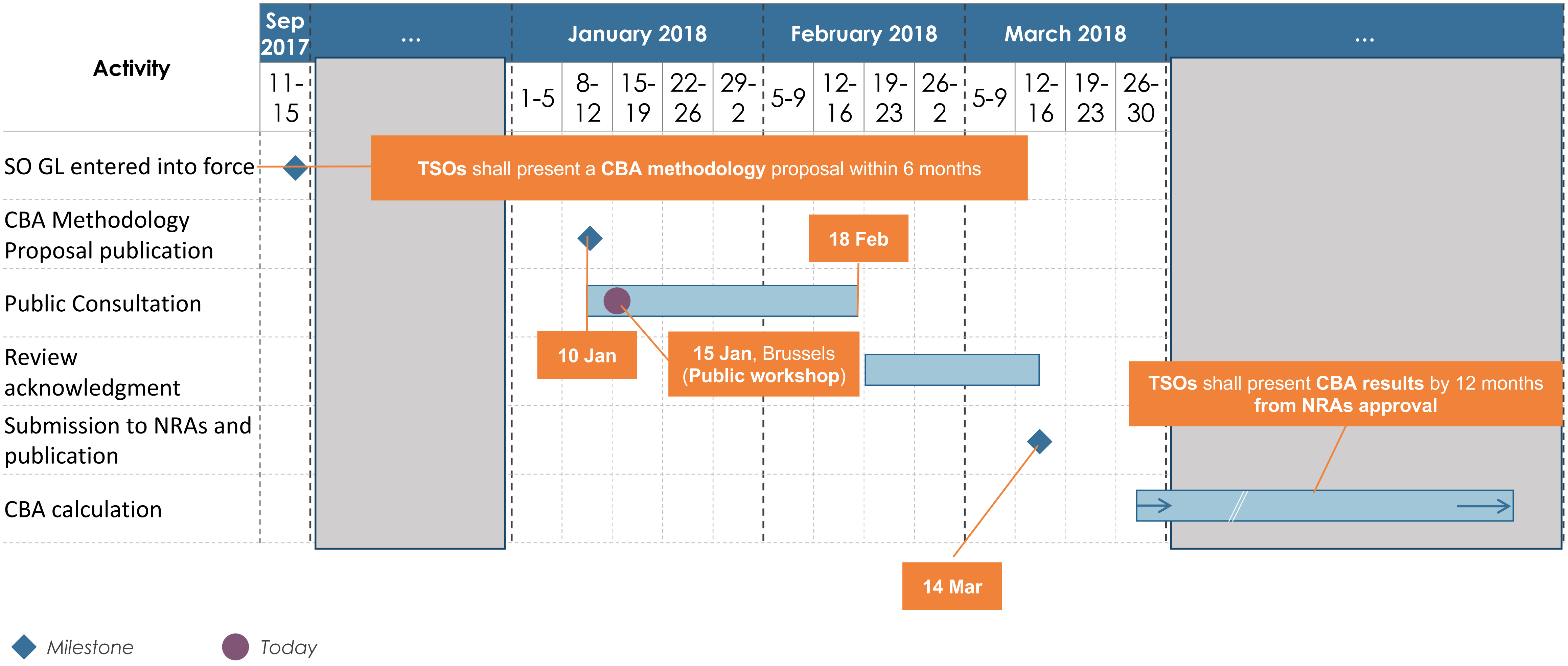
d) the impact on system stability risks and total cost of FCR reserves in case of increasing total volume of FCR reserves;

e) the impact of technological developments on costs of availability periods for FCR from its FCR providing units or groups with limited energy reservoirs.

Introduction
Regulatory Framework

- In order to accomplish the requirements under article 156 ENTSO-E constituted a project team with members of both SAs CE and Nordic with the goal of editing the CBA for FCR provision by LER.
- The public consultation of the CBA methodology proposal will last 1 month: from **January 10th** to **February 18th**
- The consulted CBA shall be sent to all NRAs by 6 months from the SO GL entry into force (**14th of March 2018**)

Introduction
Regulatory Framework



CBA Methodology Proposal

Description of objectives, assumptions and analyses

CBA Methodology Proposal
Overview

Objective of the CBA methodology:

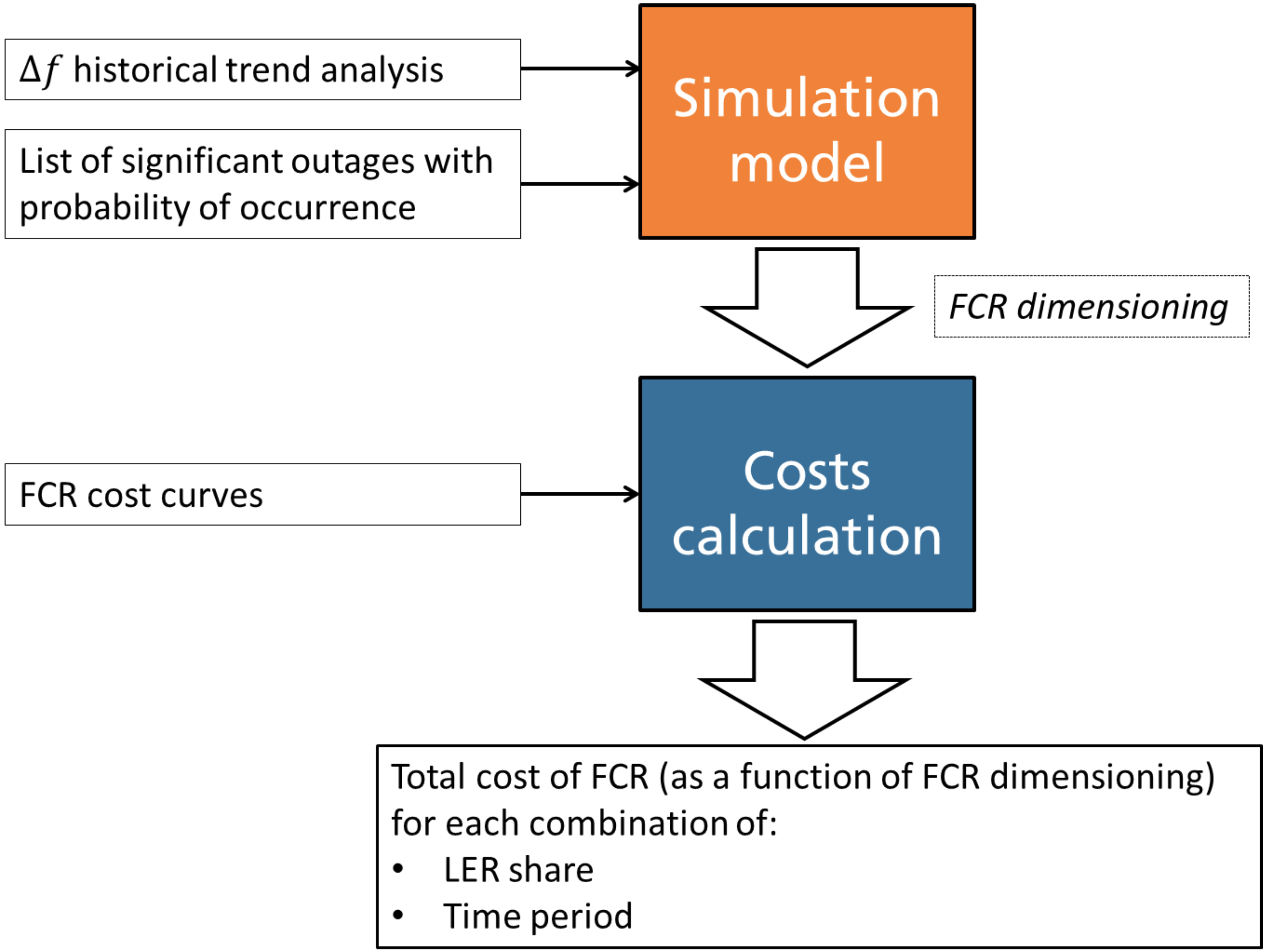
FCR costs estimation and dimensioning without jeopardising the system stability.

Considered variables are defined by varying:

- **Time period,**
- **LER share**
- **FCR needed amount**

The output of the methodology will then be the time period that minimizes the costs of FCR for each LER share.

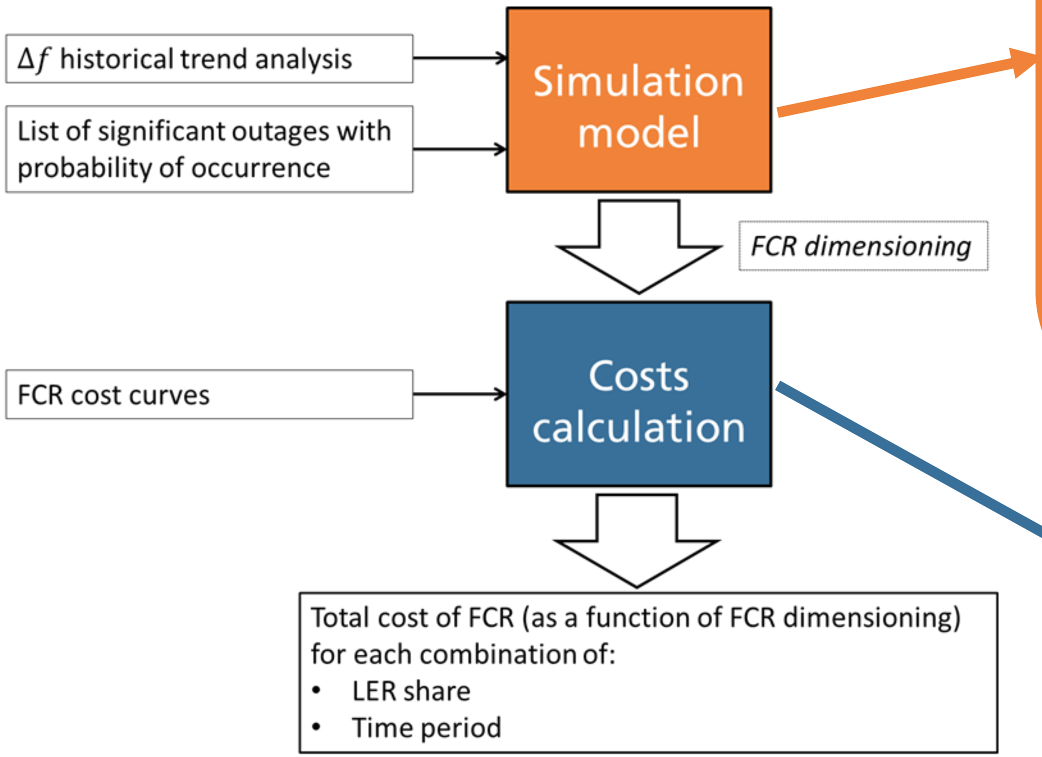
CBA Methodology Proposal
Overview

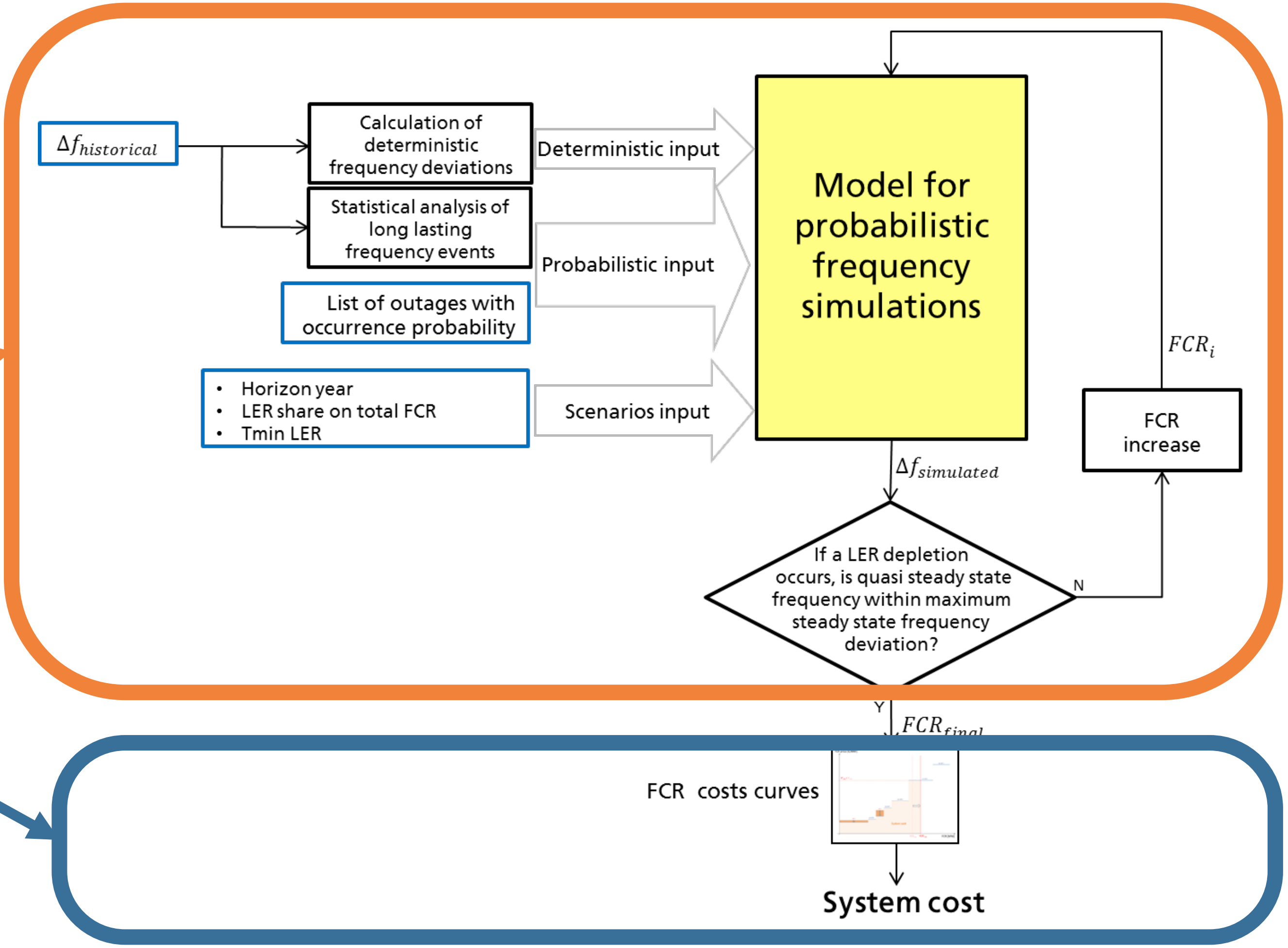


CBA Methodology Proposal
Overview

The CBA proposes an **iterative workflow** useful to assess the needs of increase in FCR dimensioning due to the presence of LER.

The workflow exploits a **Monte Carlo probabilistic approach.**

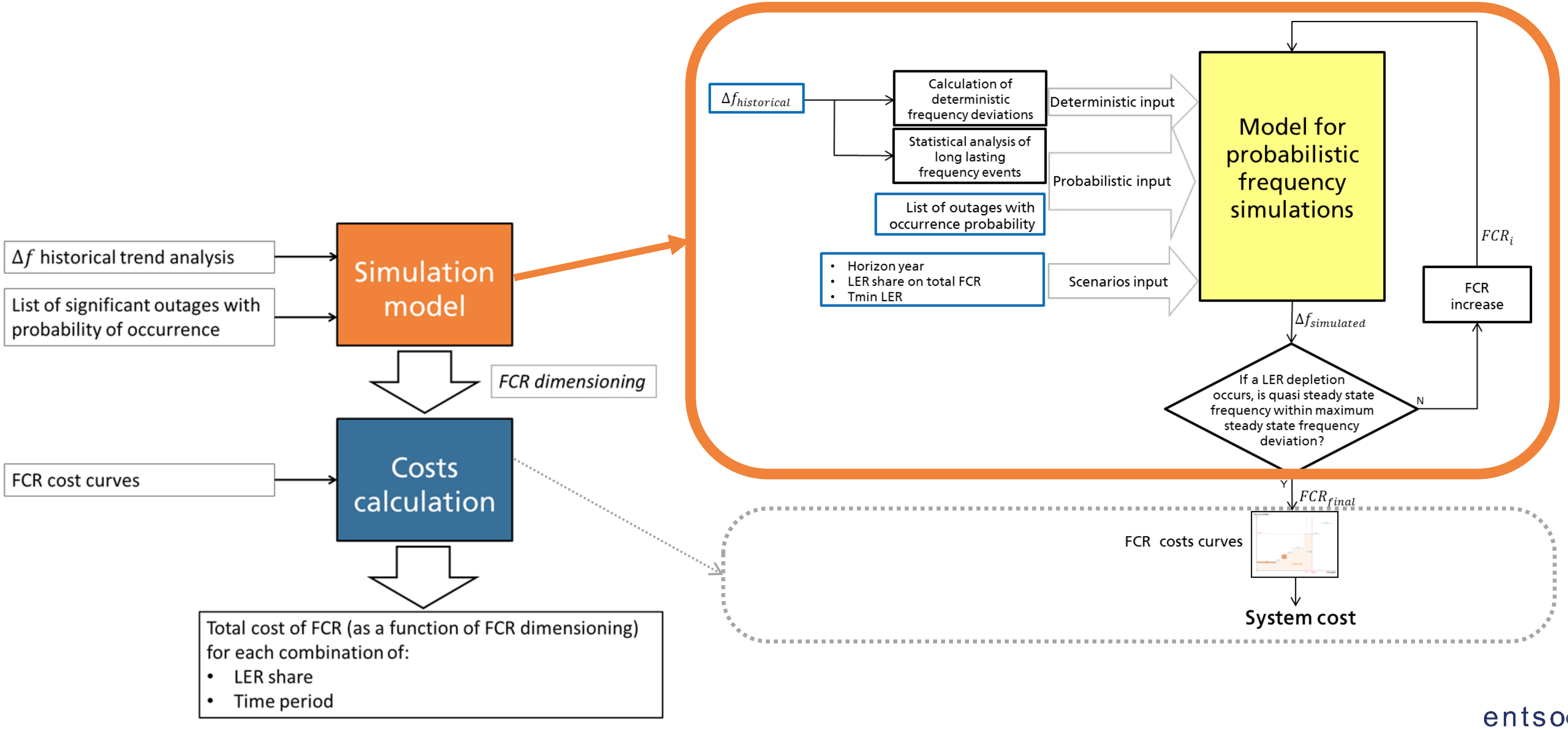




The <u>increased FCR</u> requirements are used in order to **assess the costs** related to the LER presence.

Simulation model

CBA Methodology Proposal
Simulation model



CBA Methodology Proposal
Input data

The CBA methodology takes into account the following prolonged or repeated frequency events:

1. Deterministic frequency deviation

→ deviations at the change of the hour

2. Long lasting frequency deviation events

→ Probabilistic model based on Monte Carlo approach

3. Outages

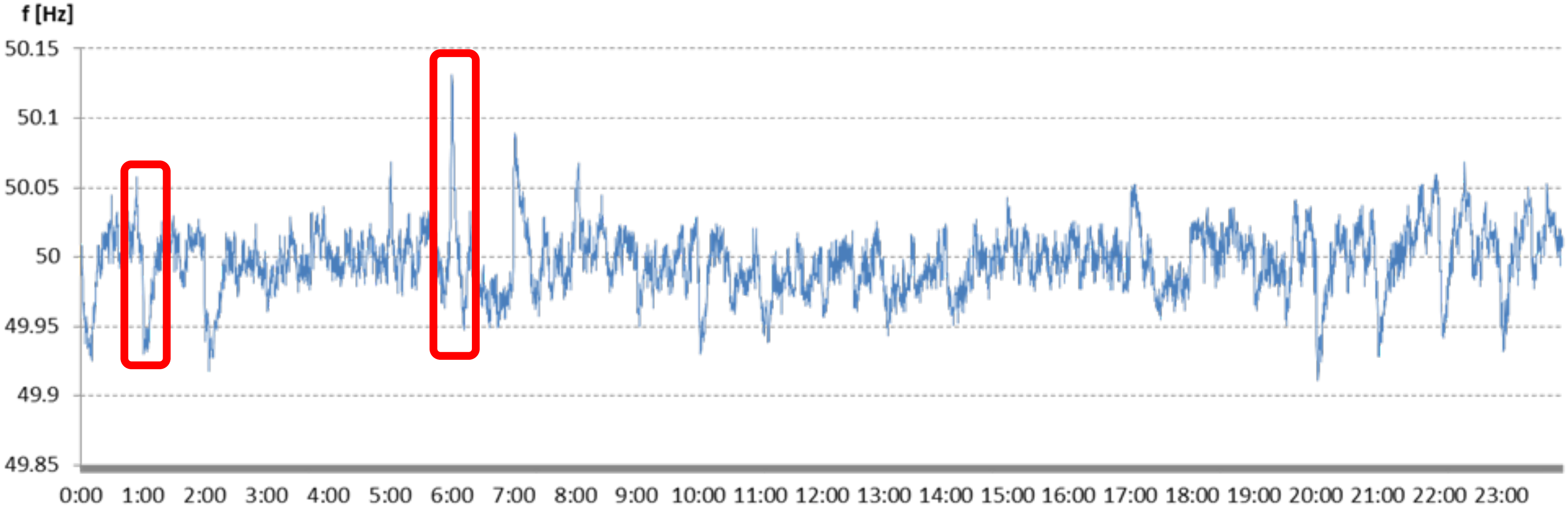
→ Probabilistic model based on Monte Carlo approach

CBA Methodology Proposal
Input data

1. Deterministic frequency deviations

Are phenomenon where **difference of power between load and generation** are stressed by schedule exchange at the change of the hour.

They usually occur **several times every day.**

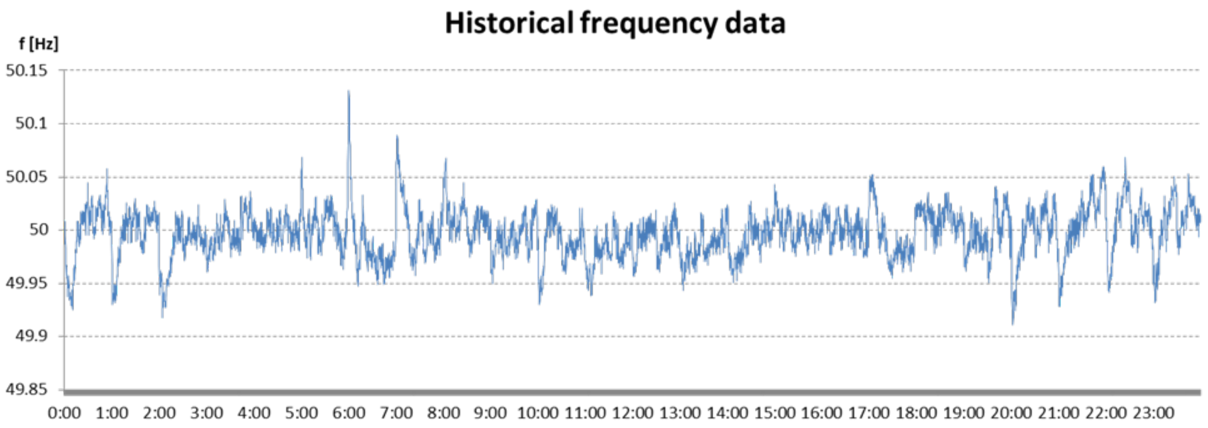


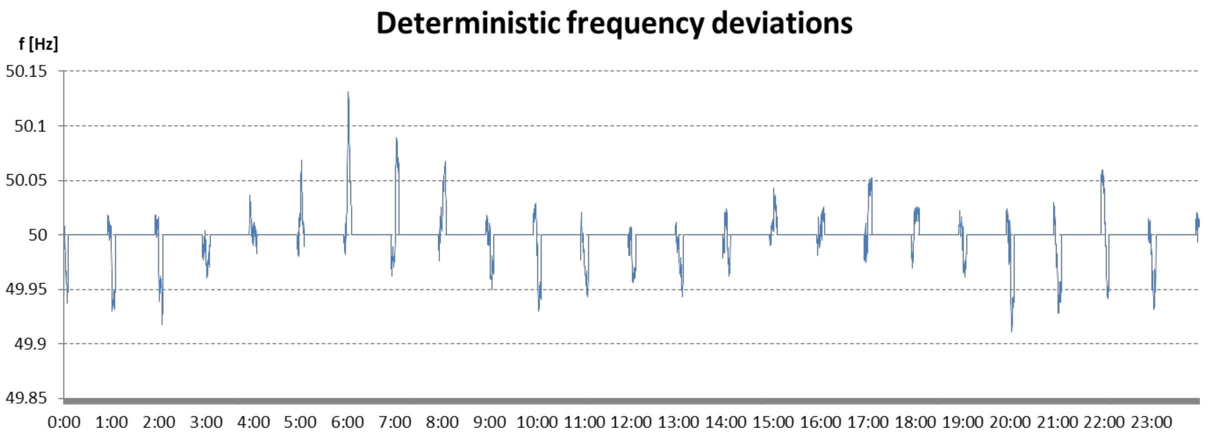
The main characteristic of these deviations is that they **occur in specific periods during the day**, with **specific trend patterns.**

CBA Methodology Proposal
Input data

1. Market induced effects

The **deterministic frequency deviations** considered in the FCP assessment will be obtained by analysing **historical frequency deviations** recorded by TSOs in the **last 15 years**, 2017 included.





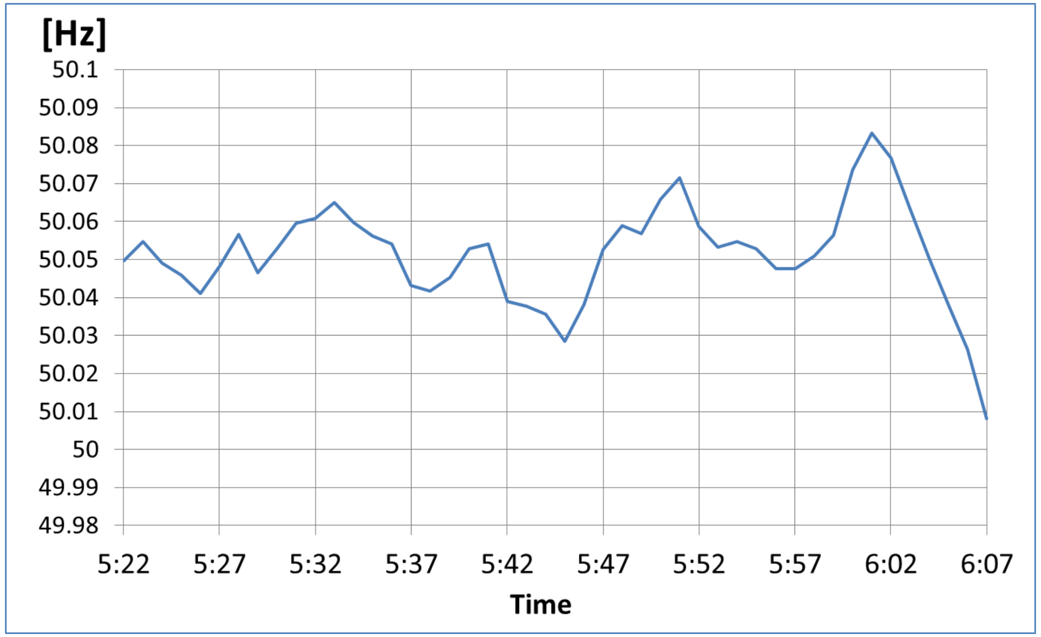
Potential overlap with recorded outages will be investigated in order to avoid double counting of phenomena.

CBA Methodology Proposal
Input data

2. Long lasting frequency deviation events

During the operation of each synchronous area, some events in which the **frequency deviation cannot be restored to 50 Hz by FRP** can occur (even without the triggering of an alert state).

Frequency trend on 26 January 2016



Long lasting frequency deviation is defined as an event with "an average steady state frequency deviation larger than the standard frequency deviation over a period longer than the time to restore frequency"

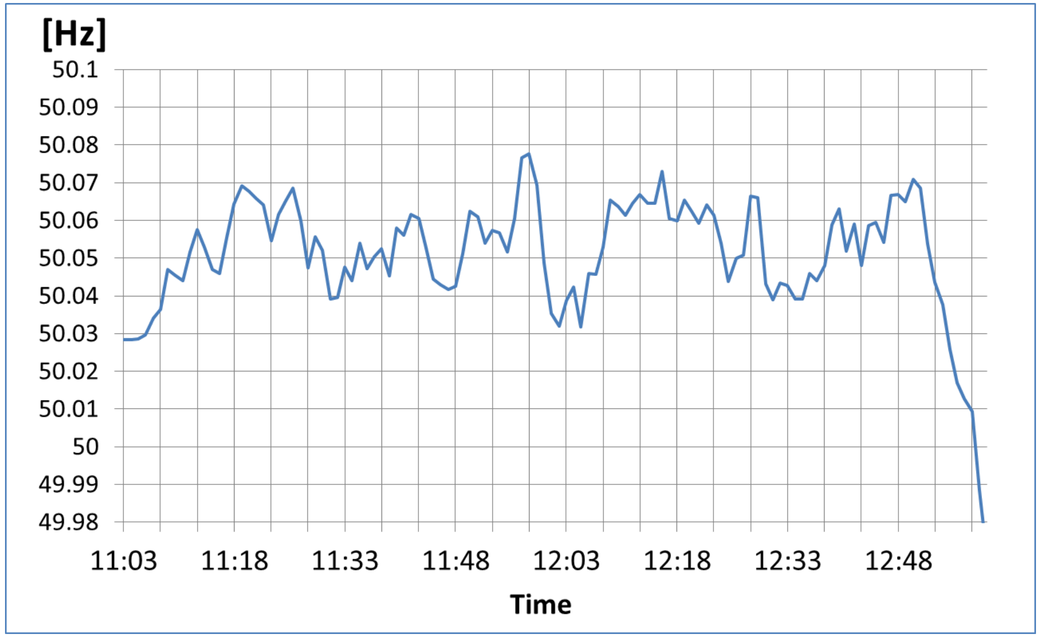
2. Long lasting frequency deviation events

Long lasting frequency deviations are typically **related to the exhaustion of FRR in a single LFC area**.

On a **single LFC area**, the **total amount of available FRR** of that area is **already activated**, and **part of the power imbalance is constantly balanced by FCR** with **consequent long lasting deviation**.

This kind of events shall be taken into account since they **may overlap** with other sources of frequency deviation such as **outages**.

Frequency trend on 21 September 2017



Potential overlap with recorded outages will be investigated in order to avoid double counting of phenomena.

CBA Methodology Proposal
Input data

3. Outages

The power imbalance due to outages is calculated starting from a **list of possible contingencies** with their own **probability of occurrence**.

Probability of occurrence of outages by **type of event** and by **generation technology** shall be obtained by means of **statistics about historical data** considering at least:

- **ENTSO-E transparency platform data**;
- Information collected in the **LFC report** related to the **most relevant power imbalances** (power imbalances greater than 1000 MW);
- **Research studies** based on statistics of unit failure.

CBA Methodology Proposal
Input data

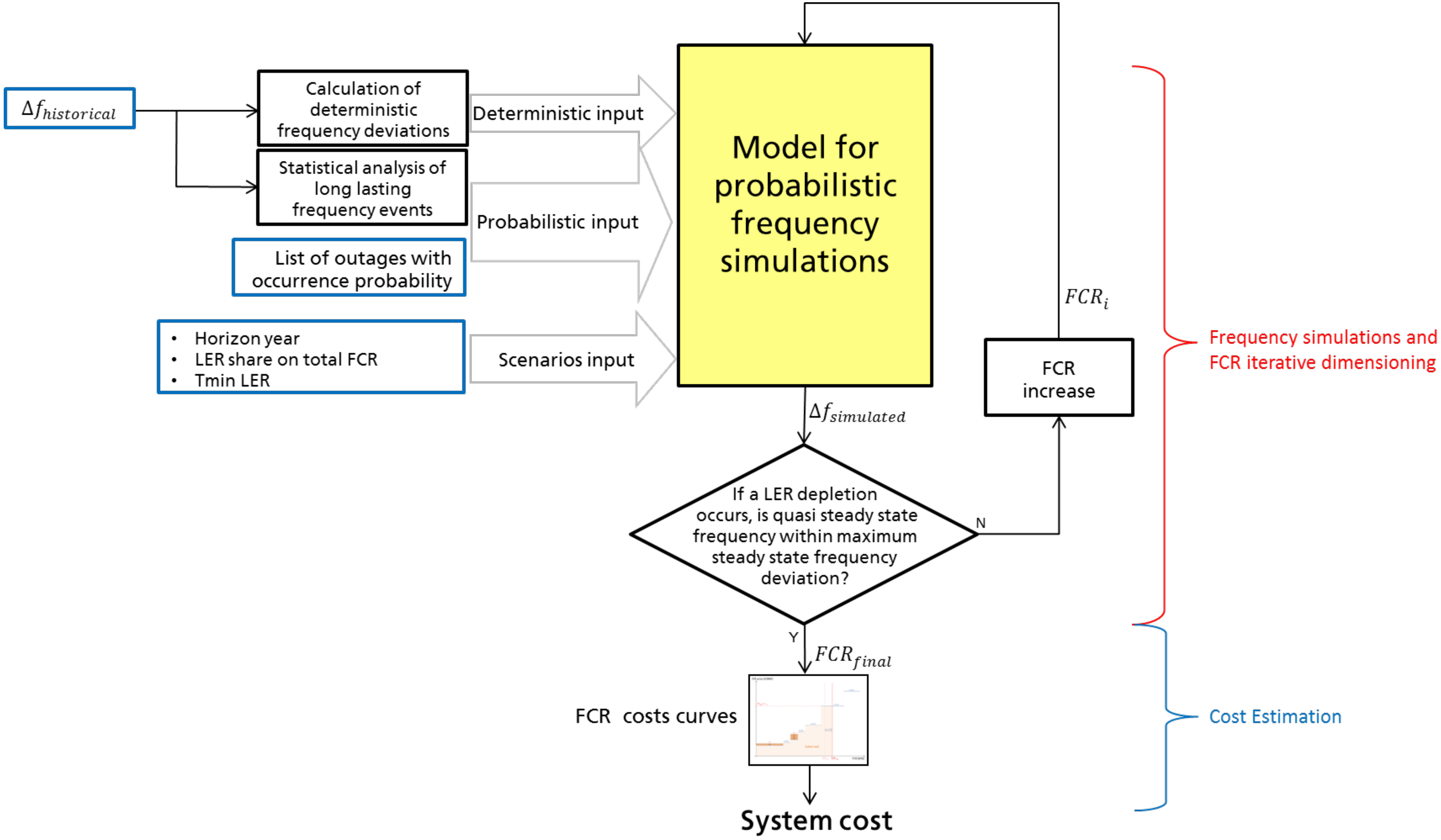
3. Outages

Contingency events (combination of outages and long lasting frequency deviation events) are considered as **stochastically independent from each other**.

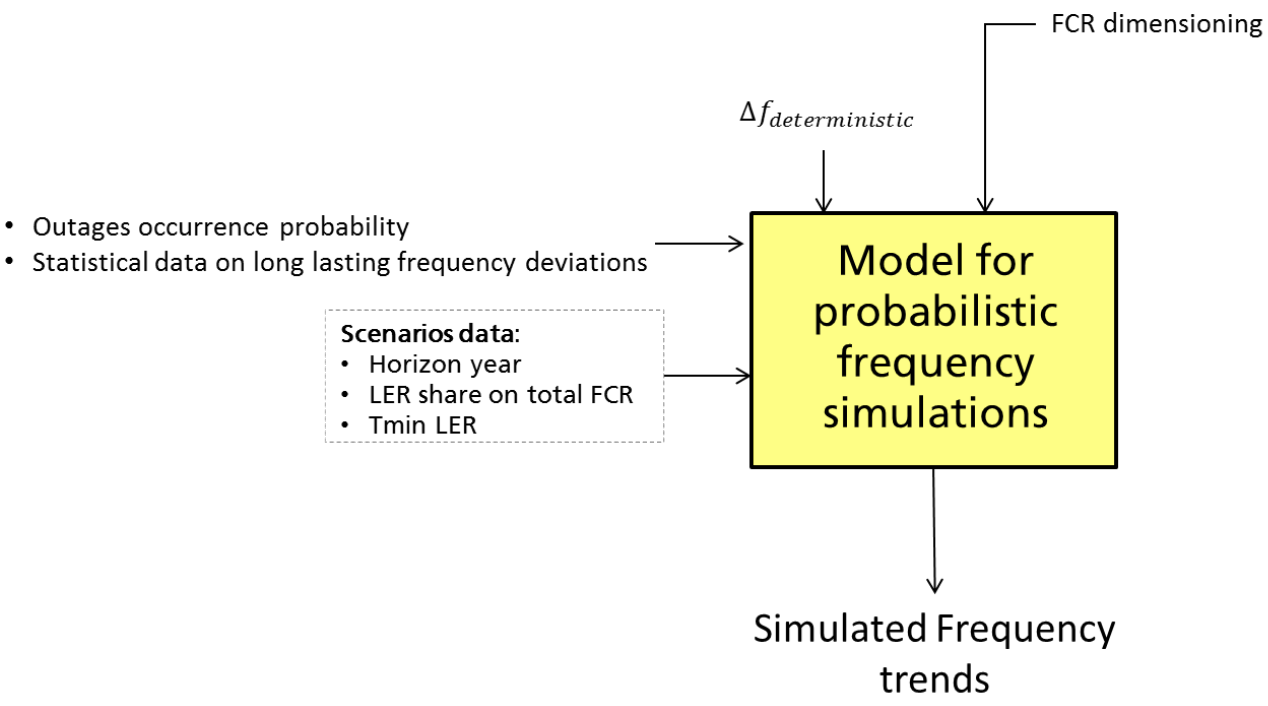
This is an **approximation** of the real system operation, in fact a **correlation between outages and significant frequency deviation caused by other factors could occur**.

E.g. An untimely trip of a generation unit can be caused by the activation of its under frequency protection, increasing the power imbalance even during critical conditions.

CBA Methodology Proposal
Workflow overview



CBA Methodology Proposal
Model for probabilistic frequency simulations

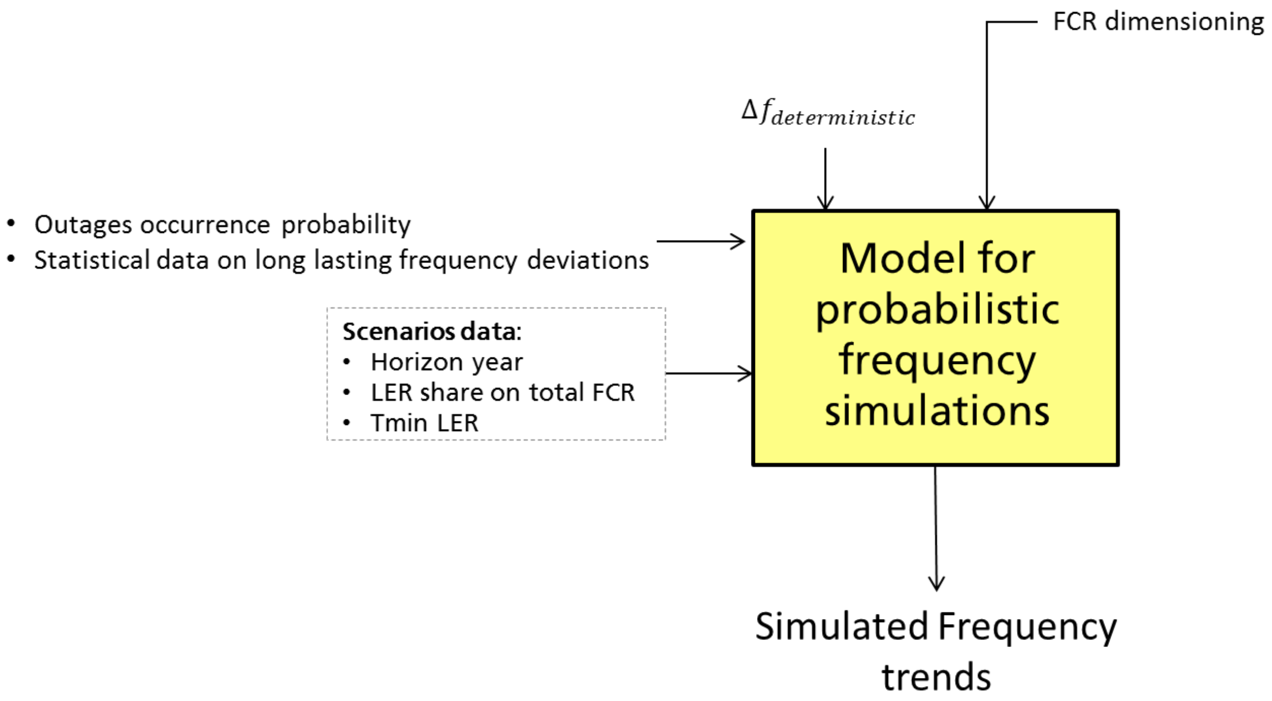


The core of the workflow is a **Monte Carlo model** able to simulate the Load-Frequency Control Process of a whole synchronous area.

The model is capable to simulate an high numbers of years in order to **explore the domain of possible operational conditions** of the system.

The aim is to test the effects of LER presence taking into account the **largest possible number of operational condition** that might occur in the real system.

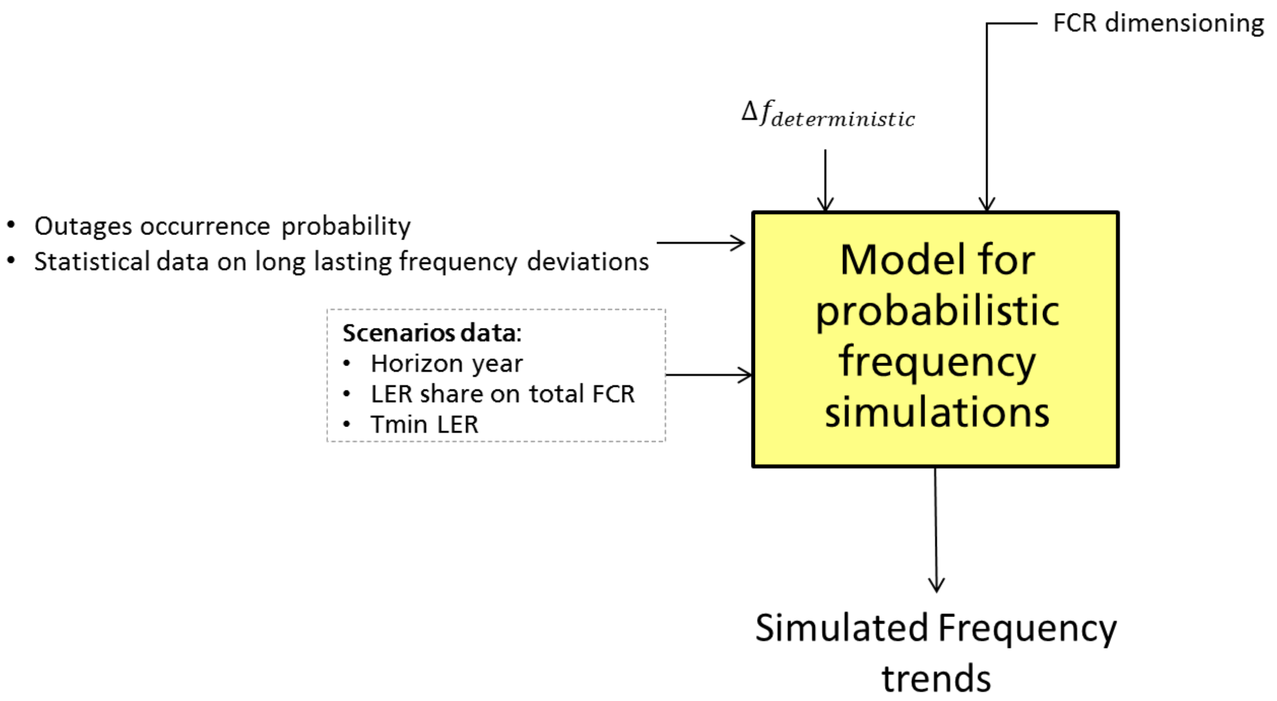
CBA Methodology Proposal
Model for probabilistic frequency simulations



The input data considered for calculating the probabilistic frequency shall be:

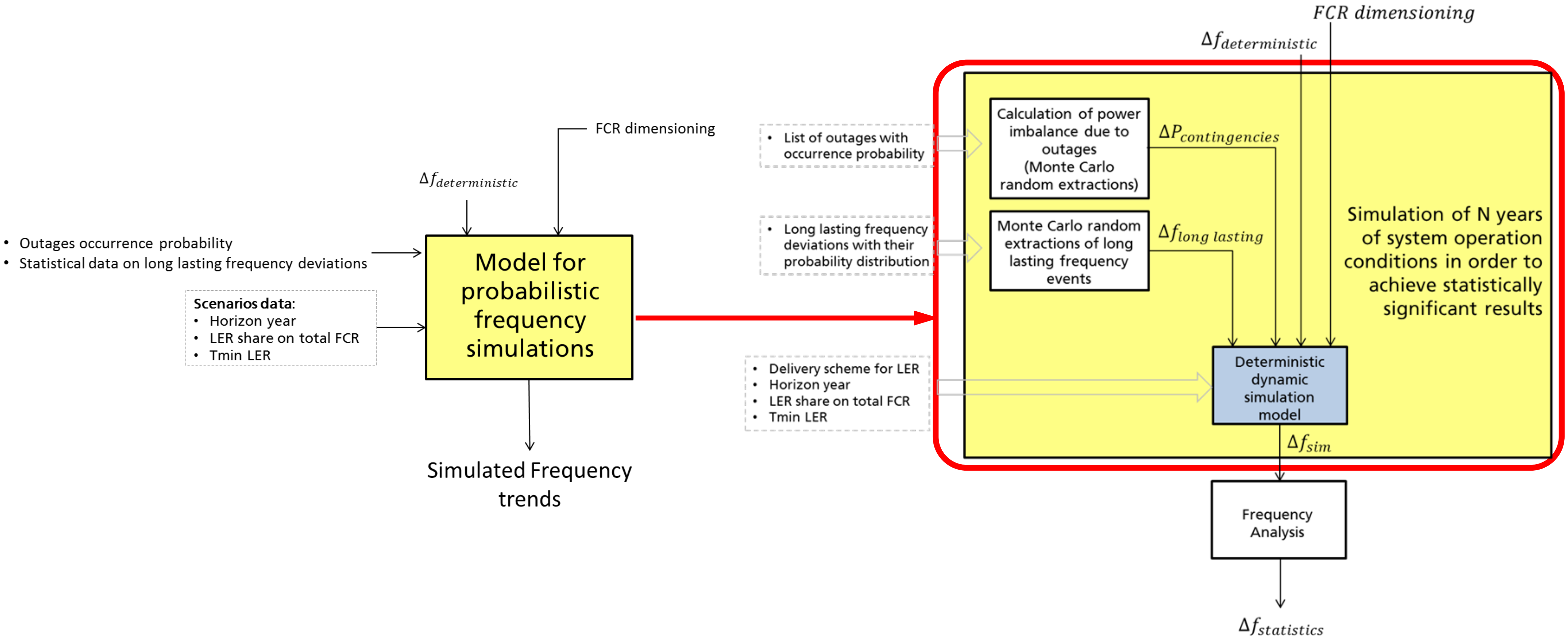
- **FCR:** total amount of FCR in the synchronous area.
- **FRR:** Full Activation Time;
- **A list of** considered **outages** for the synchronous area with the correspondent **probability of occurrence**;
- The statistical information related to **long lasting frequency deviation events**;
- The **deterministic frequency deviations**

CBA Methodology Proposal
Model for probabilistic frequency simulations

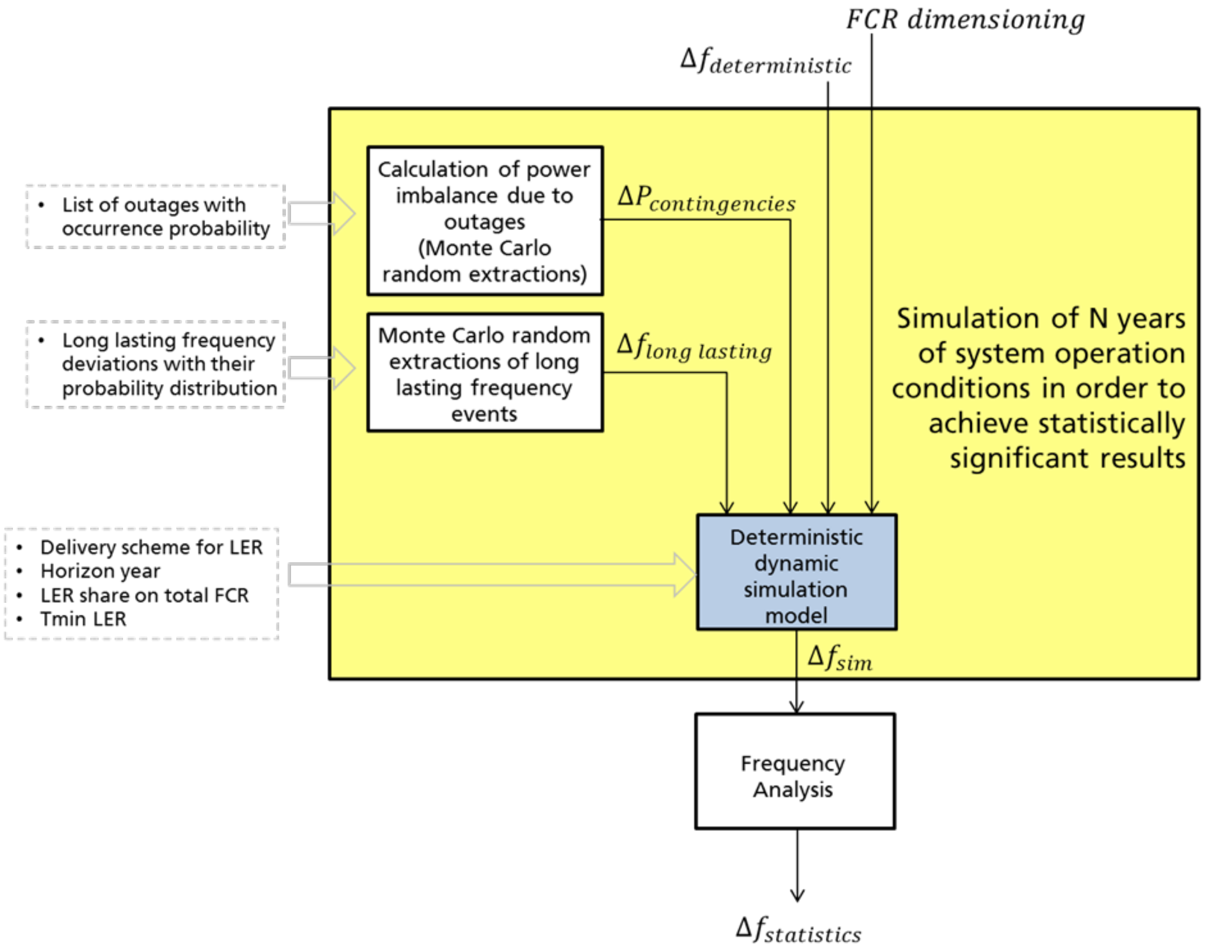


The results of the model are **frequency trends** in all the conditions simulated with the Monte Carlo method.

CBA Methodology Proposal
Monte Carlo approach



CBA Methodology Proposal
Monte Carlo approach

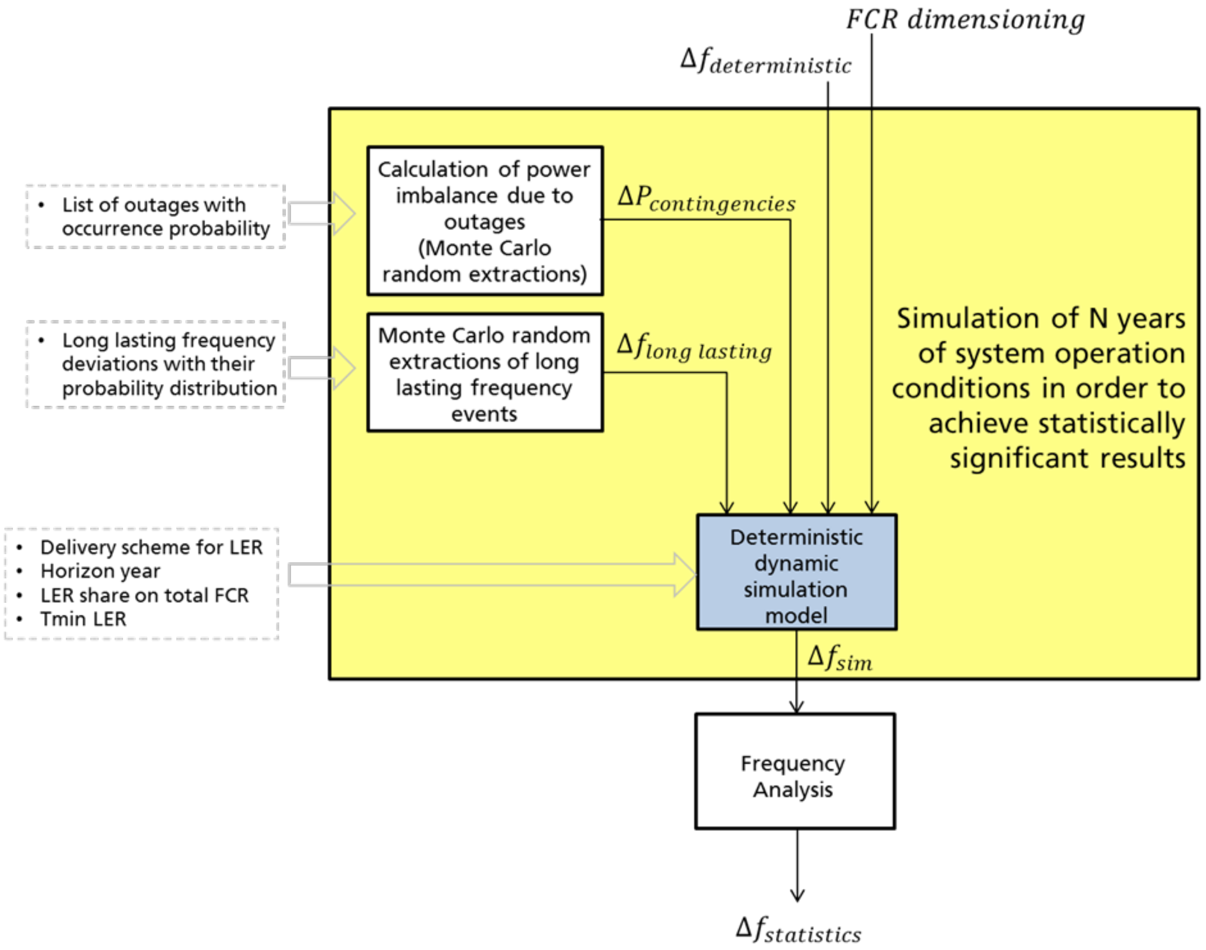


Monte Carlo approach

The power imbalance due to outages is calculated using **Monte Carlo random draws**, starting from the occurrence probability of each event.

While deterministic frequency deviations are direct input, the **long lasting frequency deviations** are considered as probabilistic events and they are **drawn starting from the statistical analysis of occurrence**.

CBA Methodology Proposal
Monte Carlo approach



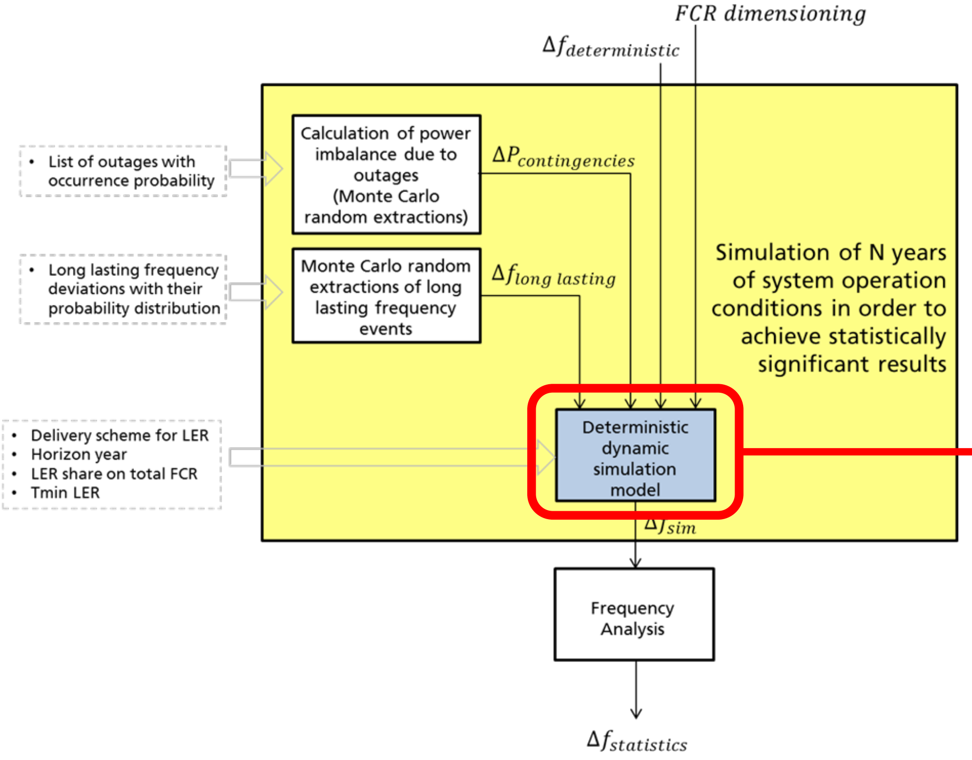
Monte Carlo approach

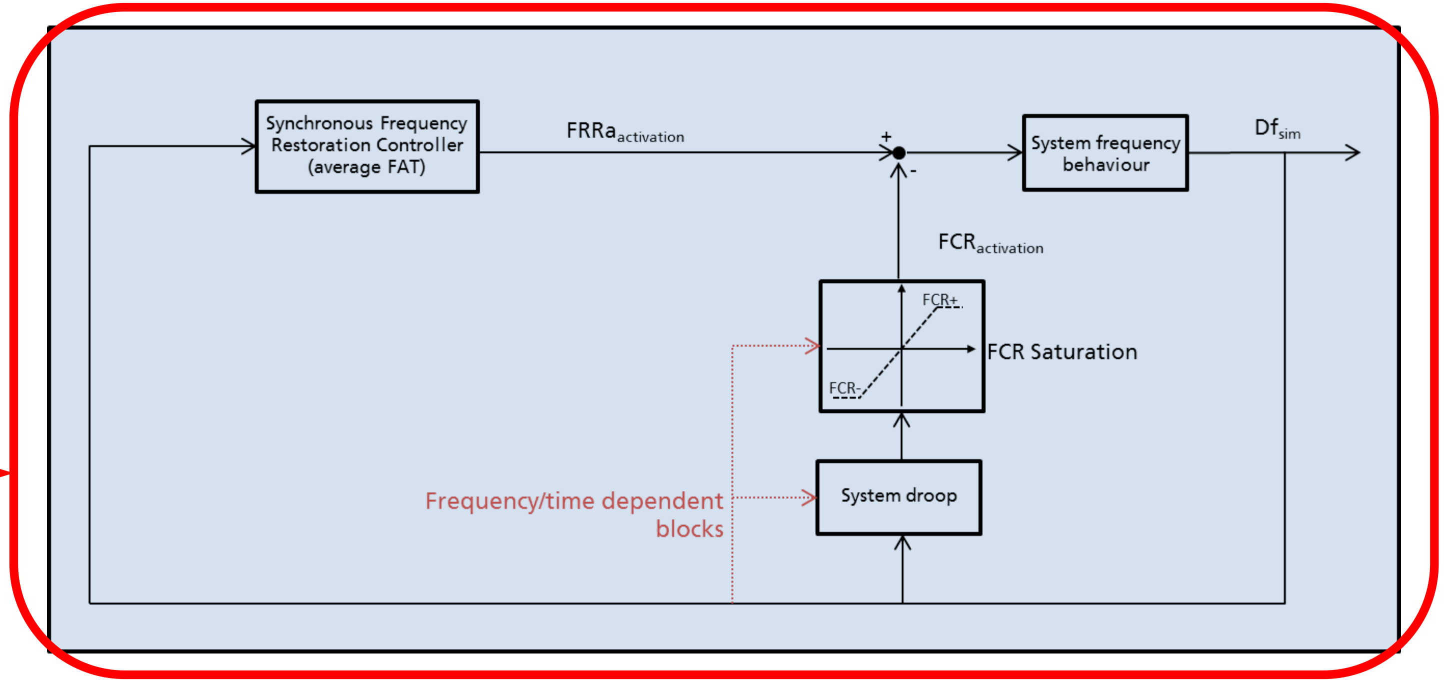
Deterministic frequency deviations, long lasting frequency deviations and power imbalance due to outages represent the input of a deterministic dynamic simulation model;

The dynamic model calculates the frequency trend, taking into account all the scenarios data (e.g. $T_{min\ LER}$, LER share, horizon year).

Frequency trends of all the simulated years are analysed in order to assess system stability in the simulated condition.

CBA Methodology Proposal
Dynamic simulation model





CBA Methodology Proposal
Dynamic simulation model assumptions

A main issue that should be evaluated in order to define a proper simulation model for the FCR provision analysis is related to the **timescale of phenomena involved**.

System inertia	FCR dynamic response	FRR dynamic response
✗ Neglected	✗ Neglected	✓ Considered

- The presence of LER has an effect on the system once the energy reservoir is depleted.
- SO GL Article156(10): **depletion must occur not before 15 minutes** after the triggering of an alert state or, in case of frequency deviations that are smaller than a frequency deviation requiring full FCR activation, for an equivalent length of time.

- Effects of LER providers **depletion take place on a timescale much larger than** the timescales in which **inertia and FCR dynamic** response show their effects.
- The **presence of LER FCR providers does not affect the system frequency in this context**, since LER FCR provider deliver their reserve regardless of their reservoir.

CBA Methodology Proposal
Dynamic simulation model assumptions

FRP simulation assumptions

Assumptions

The model **simulates** the system of the **whole synchronous area**

Simulated FRP operates only on the disturbances caused by the outages as both Standard Frequency Deviations and Long Lasting Frequency Deviations already implicitly involve an activation of FRR

Model features

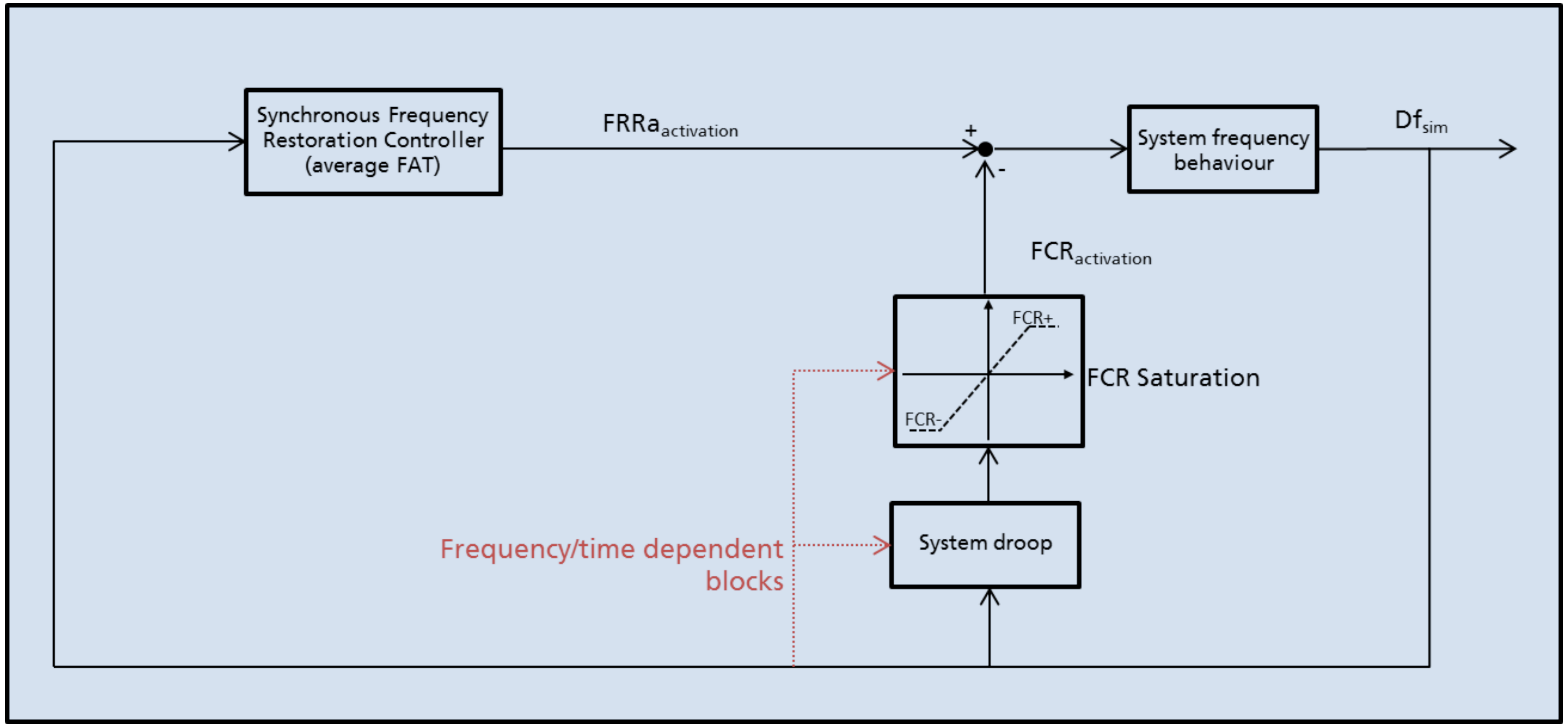
The entire **Cross-Border Load-Frequency Control Process** could be then **neglected**

FRP is modeled with a single controller with a Full Activation Time (FAT) calculated as an average of the FAT of all the LFC areas belonging to the synchronous area weighted on FRR K-factor

FRR is considered without limitations

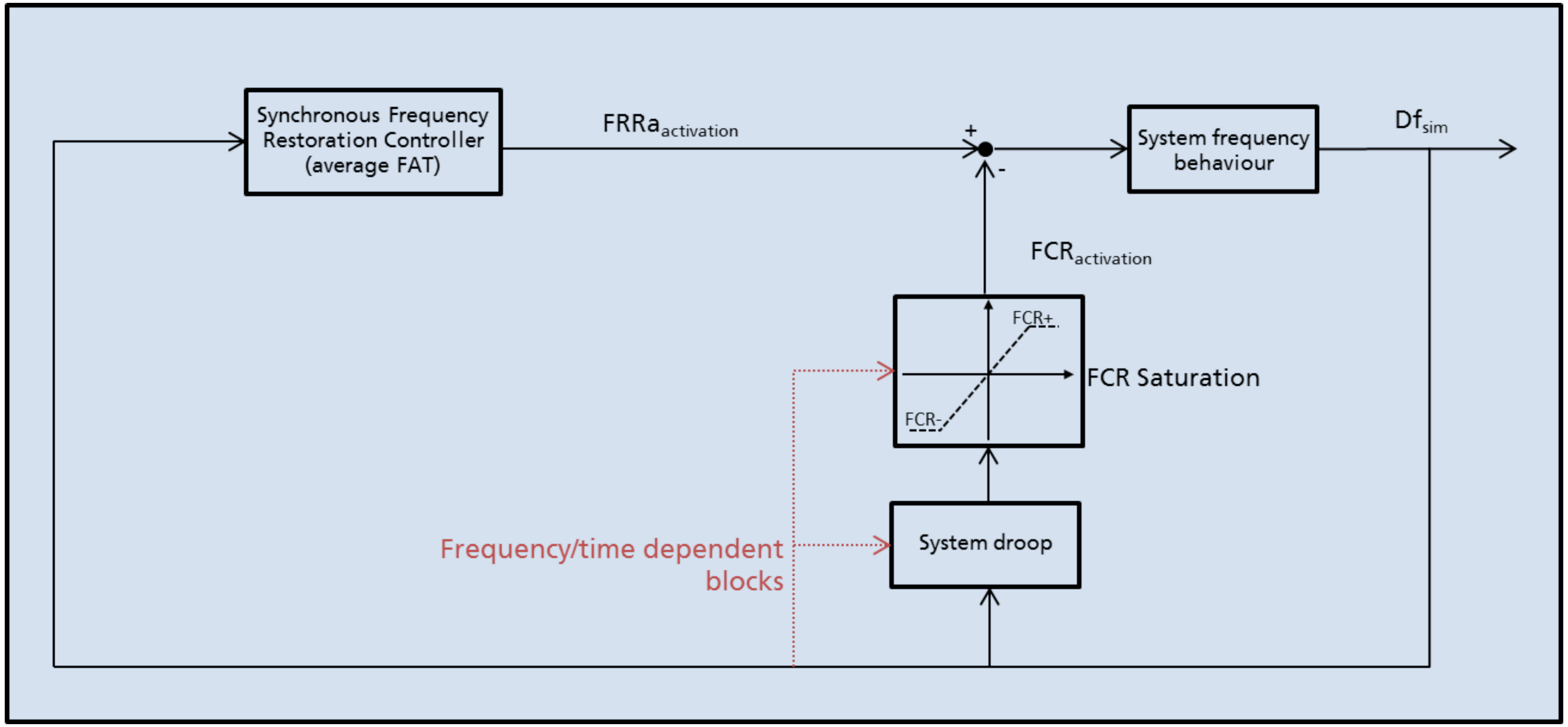
FRR-exhaustion-related phenomena are taken into account in the Long Lasting Frequency Deviation.

CBA Methodology Proposal
Dynamic simulation model



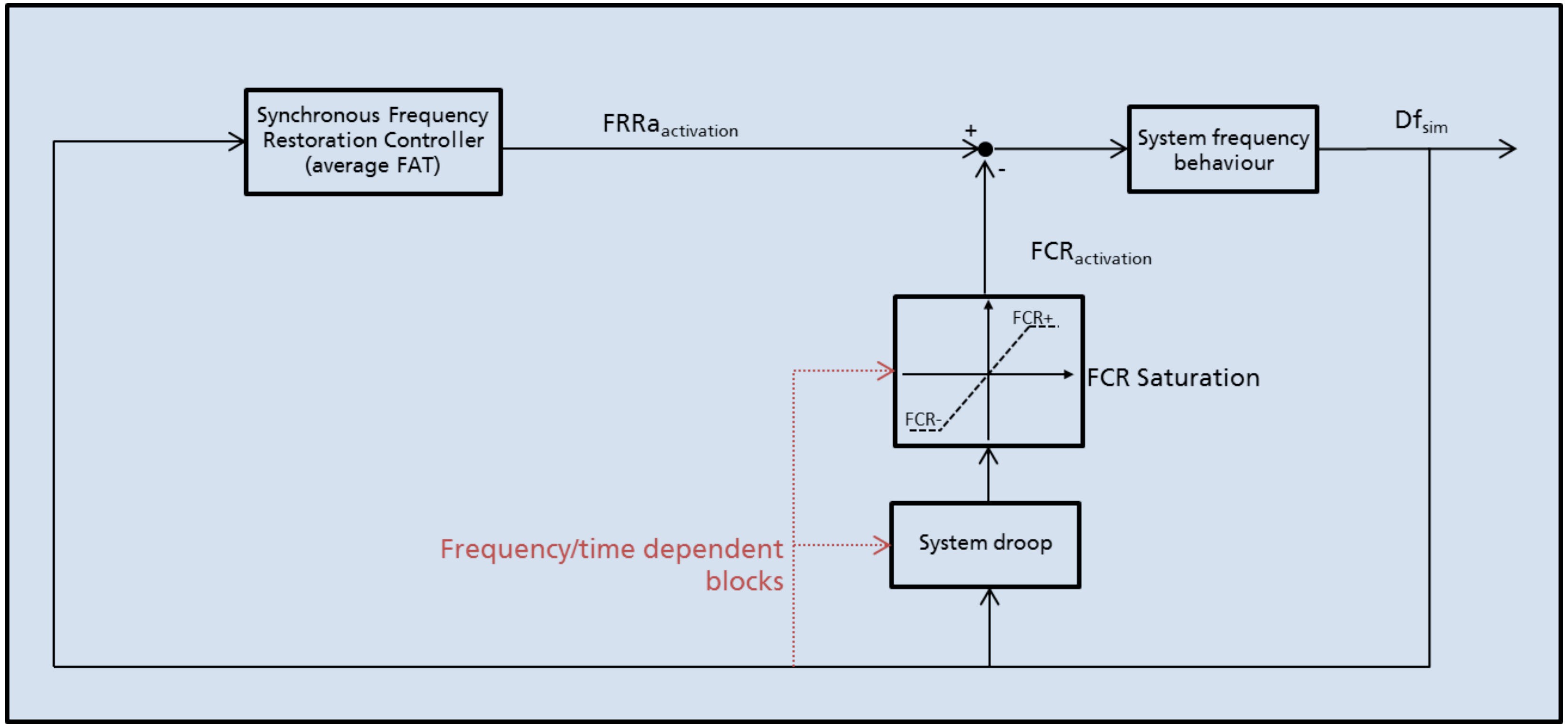
- Simplified **FCR and FRR dynamic simulation** in the time domain
- All the scenarios data are taken into account (e.g. horizon year, LER, etc.)
- **Depletion effects of LER are simulated**

CBA Methodology Proposal
Dynamic simulation model



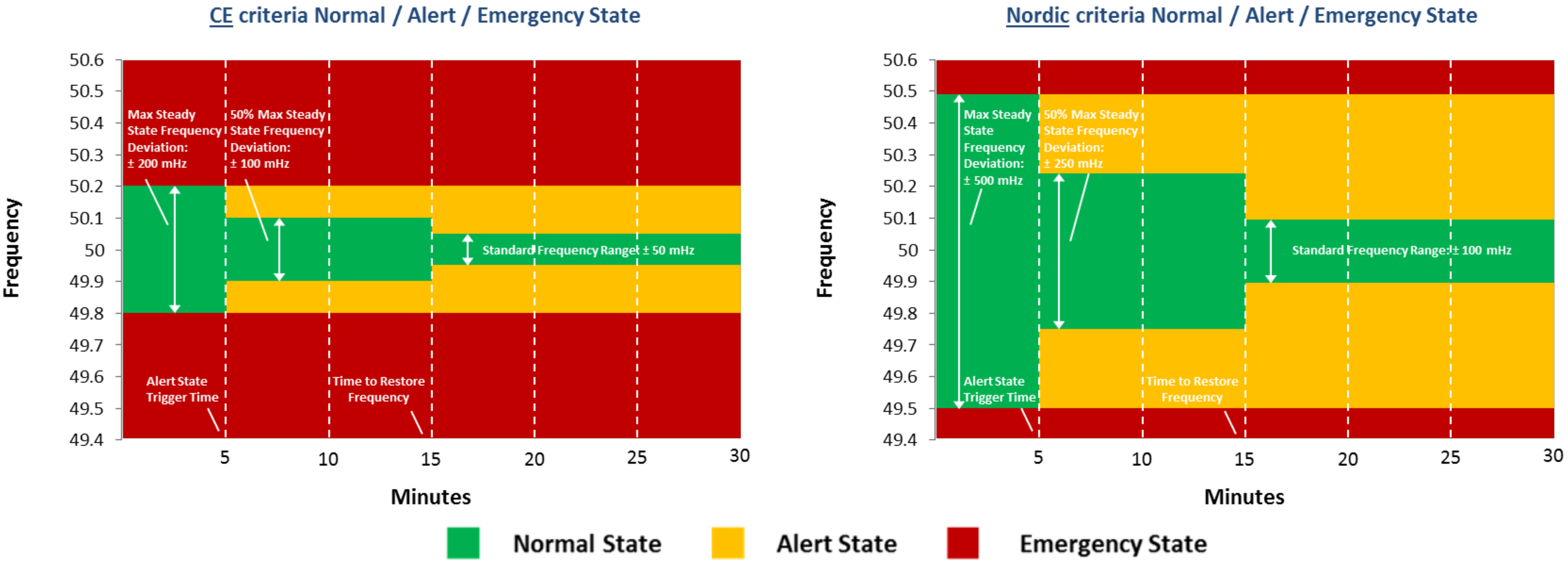
- The model simulates the system of a whole synchronous area, the entire **Cross-Border Load-Frequency Control Process is** then **neglected**.
- The whole Frequency Restoration Process of the synchronous area is modeled with a **single controller with an average Full Activation Time (FAT).**
- **FRR saturation is neglected.**

CBA Methodology Proposal
Dynamic simulation model



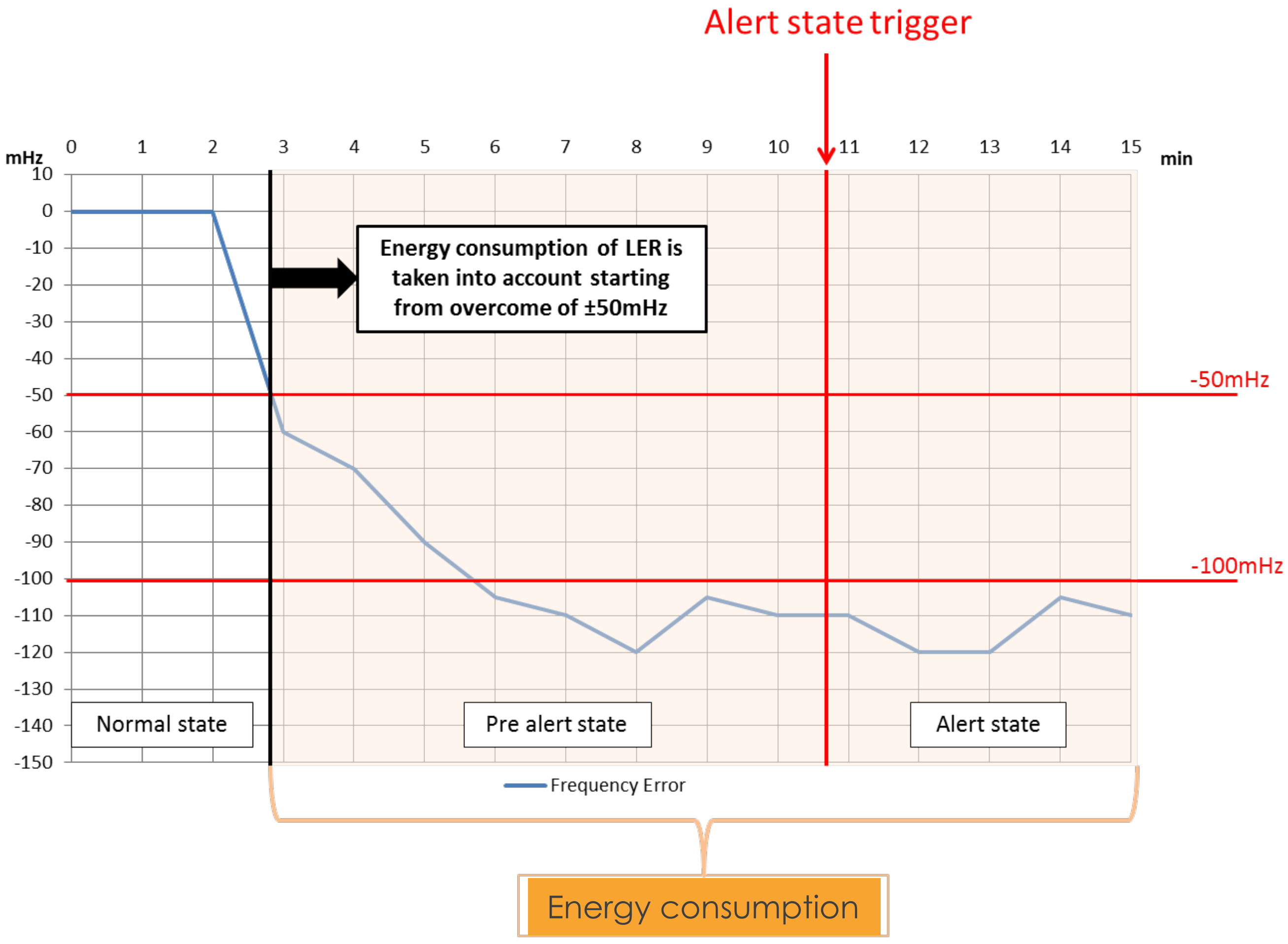
- The ‘FCR saturation’ block models the **limited availability of FCR of the synchronous area**.
- The ‘System Frequency Behaviour’ block models the relationship between power imbalance and frequency deviation

CBA Methodology Proposal
Simulation of energy depletion of LER



Pursuant to Art.156(9) the **time period shall be ensured "as of triggering the alert state and during the alert state"**.
However the **storage capacity** associated to a time period **is exploited also in pre alert state.**

CBA Methodology Proposal
Simulation of energy depletion of LER – SA CE

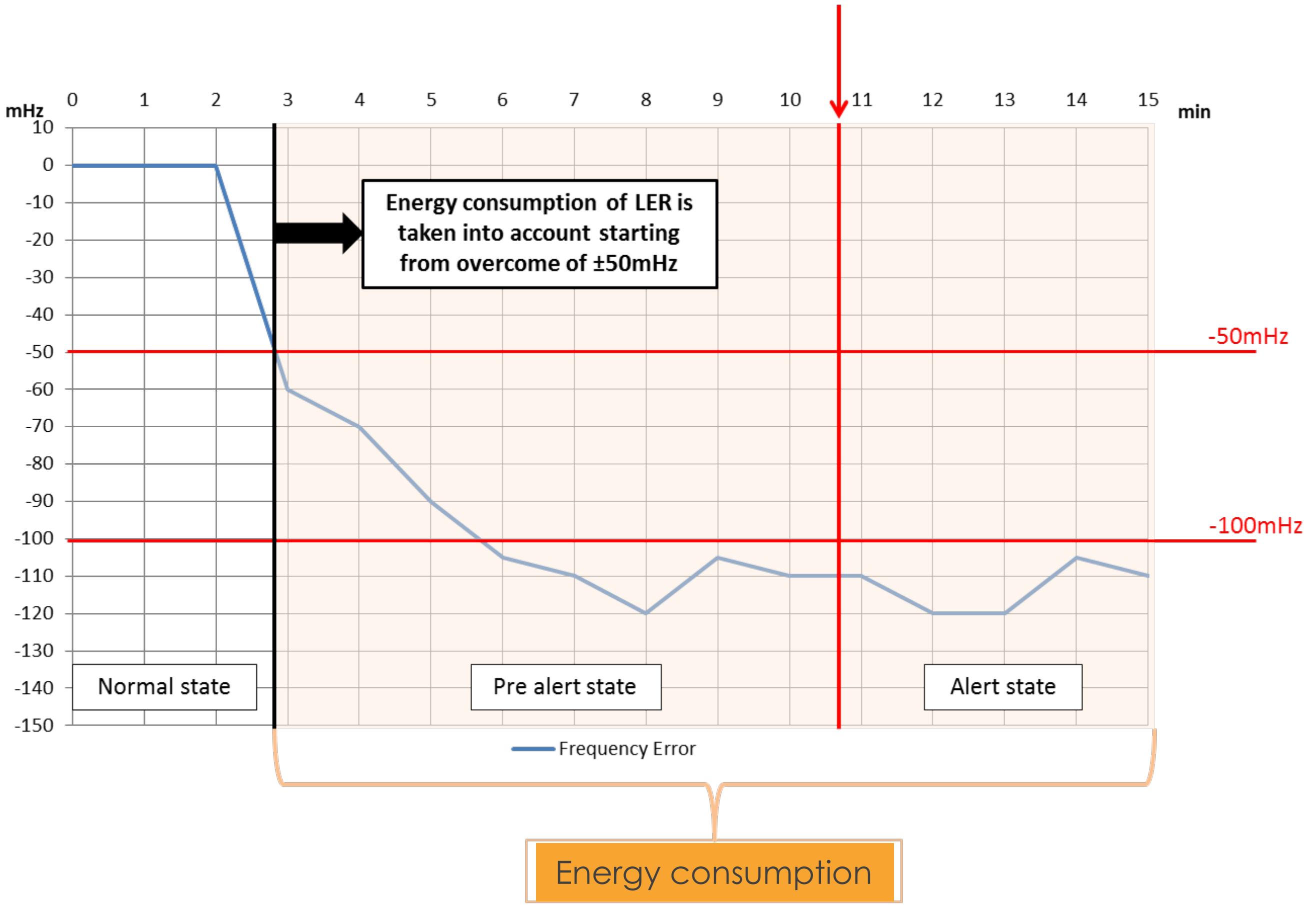


- The LER are considered **without energy limitations** while frequency remains **inside the standard frequency range**
- **Once the simulated frequency exceeds this range**, the model starts to **calculate** the activated energy and the **residual energy** in the reservoir

Example considering CE synchronous area

CBA Methodology Proposal
Simulation of energy depletion of LER – SA CE

Alert state trigger



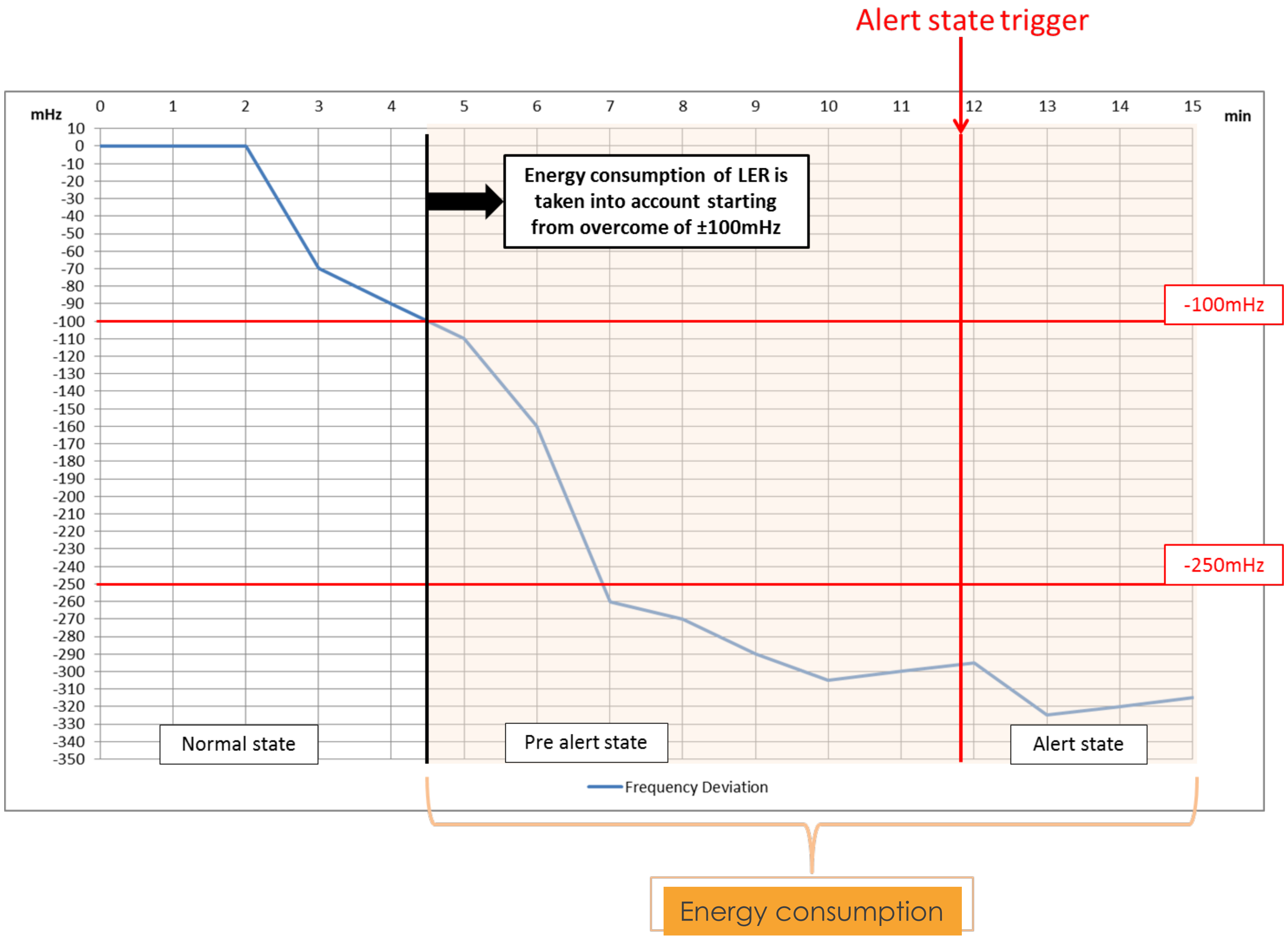
The **starting value** of the reservoir energy level will be **equal to half of the equivalent reservoir energy capacity** (E_{max}):

$$E_{max} = 2 * \frac{T_{min\ LER}}{60} * FCR_{LER}\ [MWh]$$

where FCR_{LER} is the FCR provided by LER [MW]

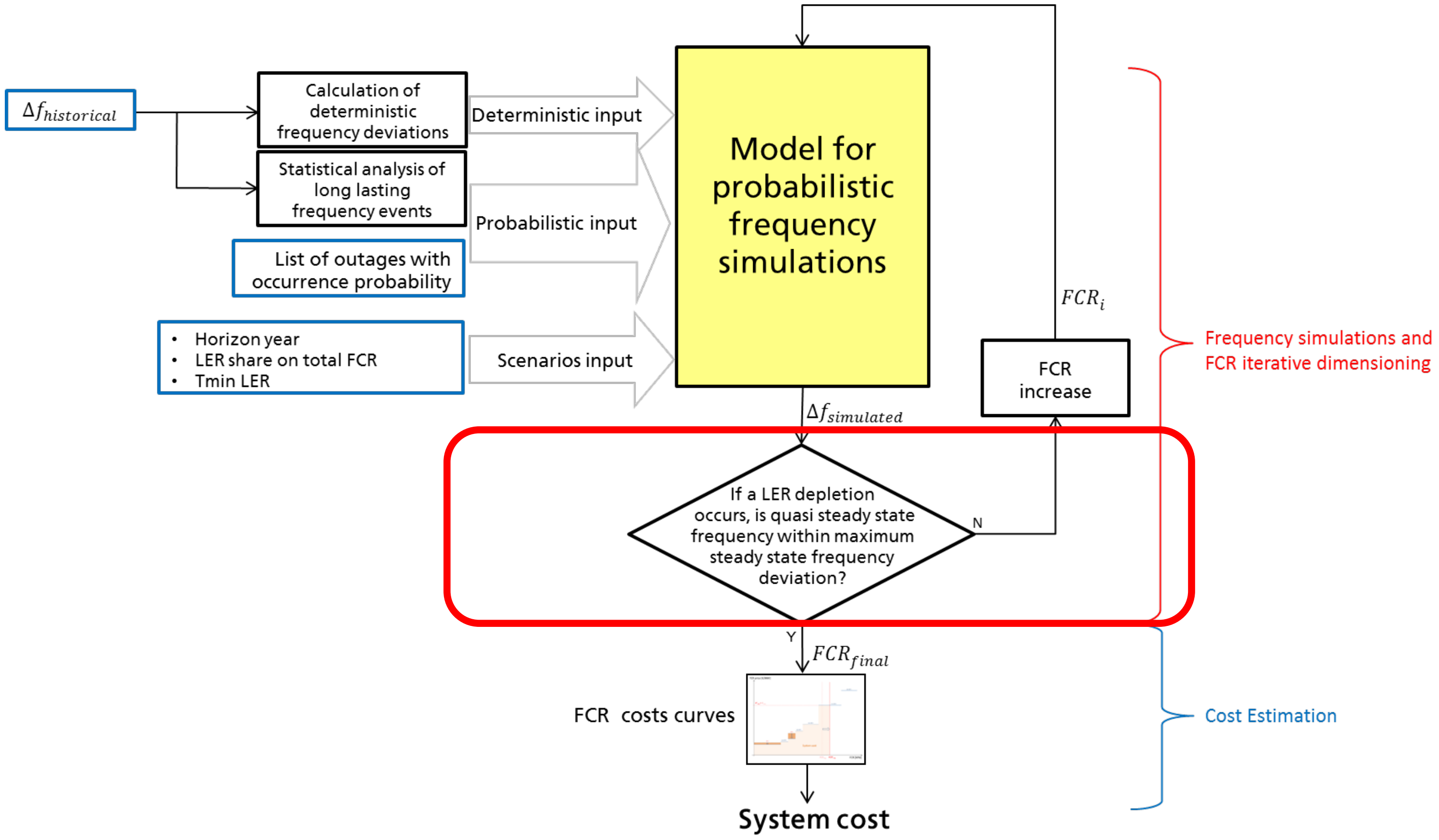
Example considering CE synchronous area

CBA Methodology Proposal
Simulation of energy depletion of LER – SA Nordic



Example considering Nordic synchronous area

CBA Methodology Proposal
LER depletion acceptance criterion



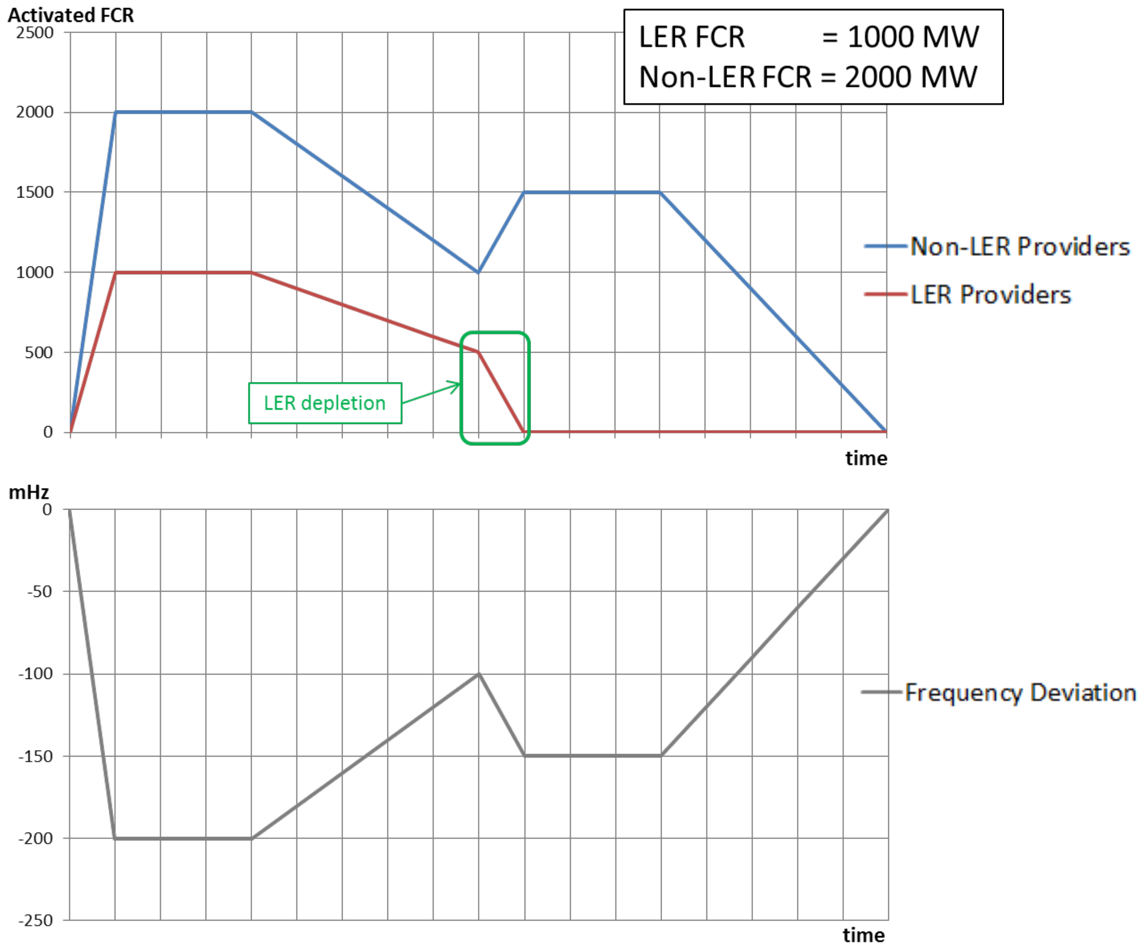
LER depletion is acceptable only if it never brings to a saturation of FCR. **LER depletion shall never entail the steady state frequency to overcome the maximum steady state frequency deviation**.

If a LER depletion occurs, the FCR provided by LER disappears. **The FCR previously provided by LER must be replaced by residual non-LER**.

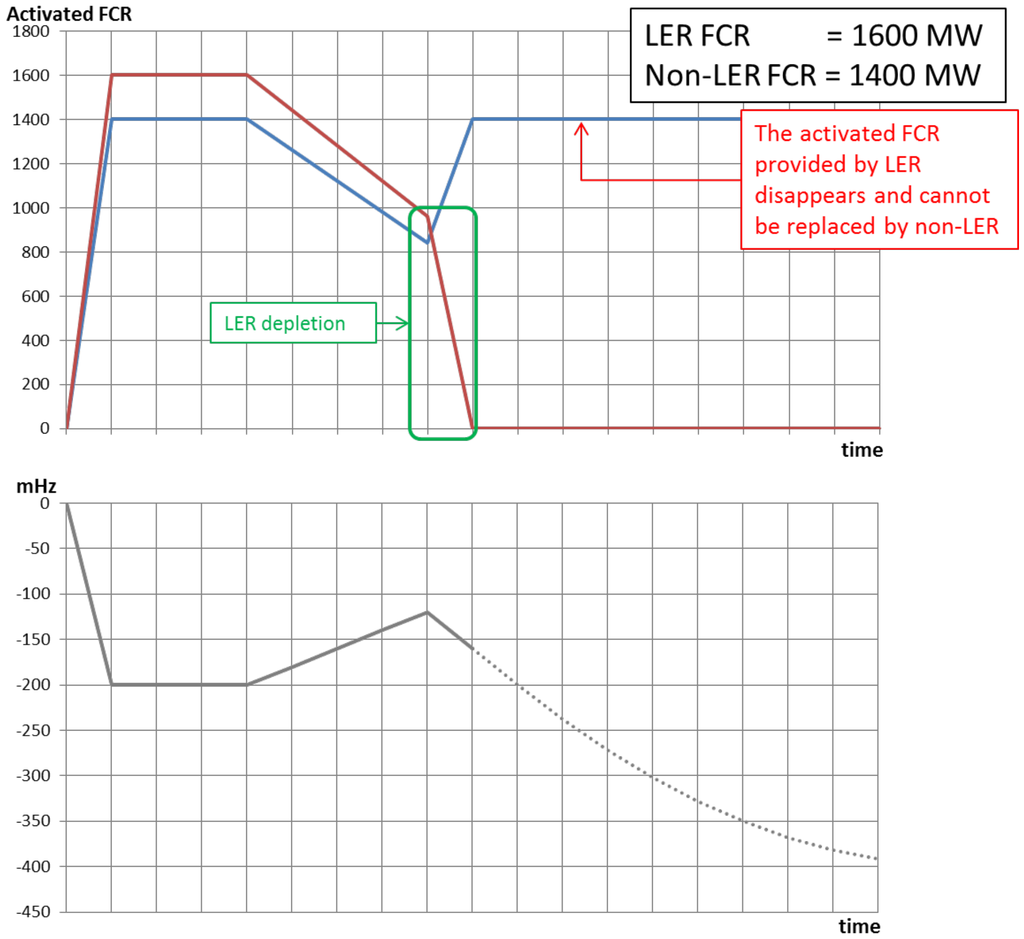
In high LER penetration scenarios, the requirement entails that it must never occur an energy depletion.

CBA Methodology Proposal
LER depletion acceptance criterion

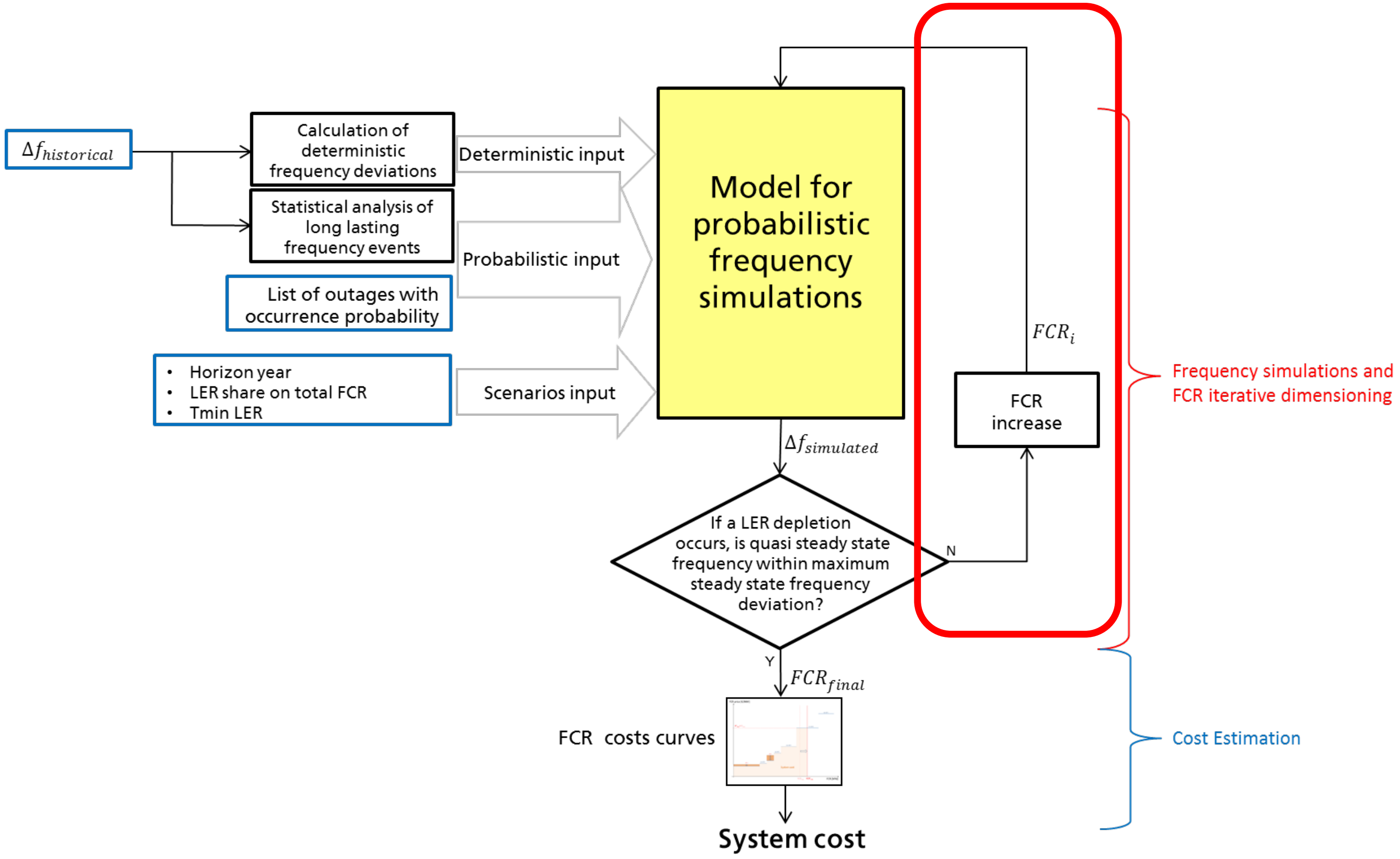
Acceptable situation



Not acceptable situation → FCR increase



CBA Methodology Proposal
Iterative dimensioning process

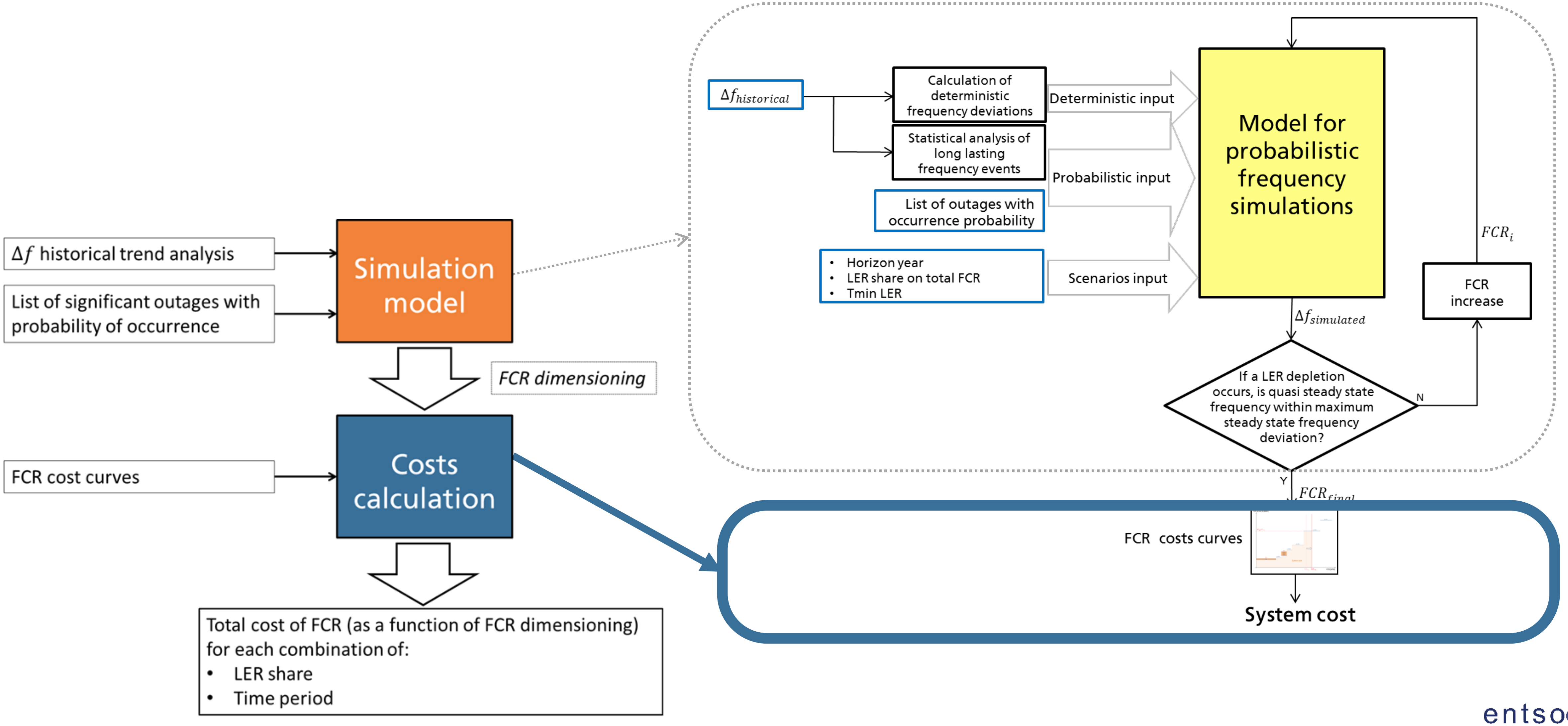


The workflow contains an iterative process in which, **if the requirement on LER depletion is not fulfilled, the FCR amount is gradually increased**.

The iterative process stops once the requirement on LER depletion is fulfilled.

Costs Calculation

CBA Methodology Proposal
Costs calculation



CBA Methodology Proposal
Costs calculation – FCR increase considerations

- It is possible that **when $T_{min\ LER}$ decreases, a greater volume of FCR is needed** to fulfil the stability requirements.

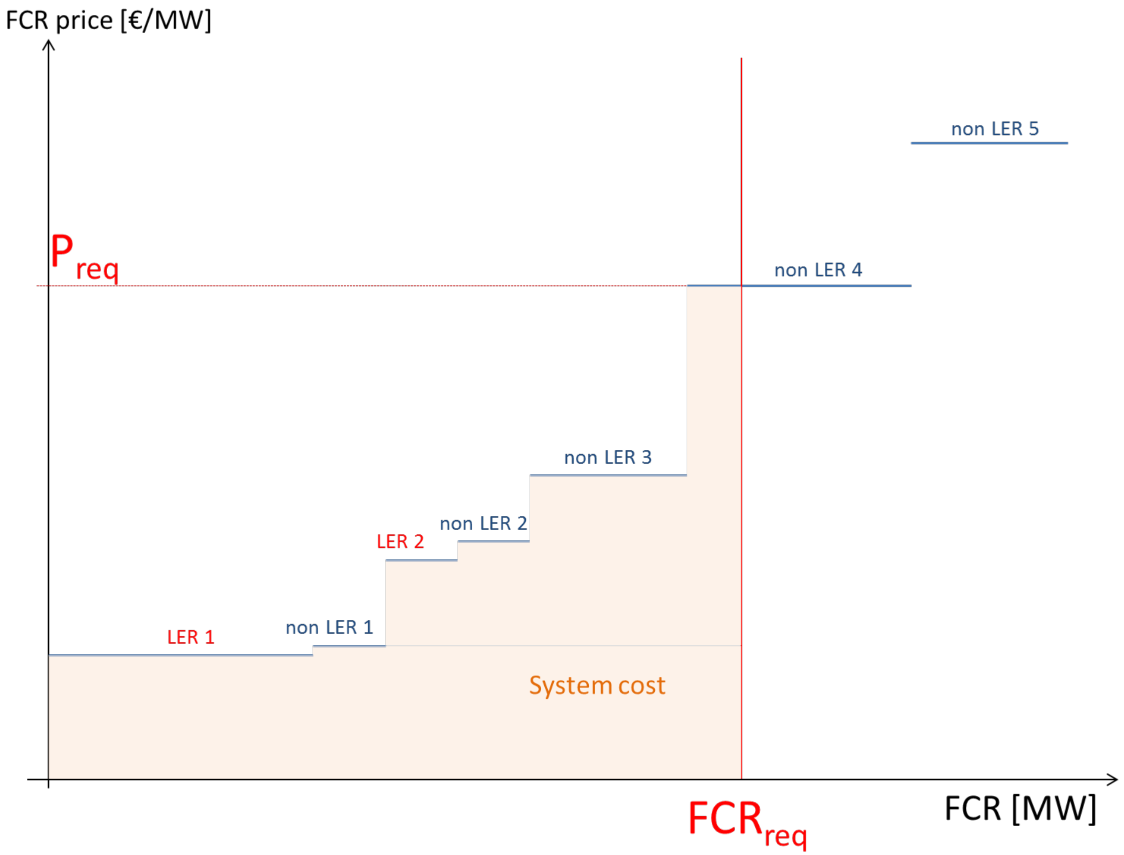
- The **FCR increase has only the aim to assess system stability risks and total cost of FCR** in case of increasing total volume of FCR as requested by Article 156 (11 d) of the SO GL.

- The **FCR dimensioning is defined in Article 153 of SO GL**, therefore **it cannot be the subject of this CBA** methodology.

FCR costs will be estimated during implementation phase.

CBA Methodology Proposal
FCR cost curves assumptions

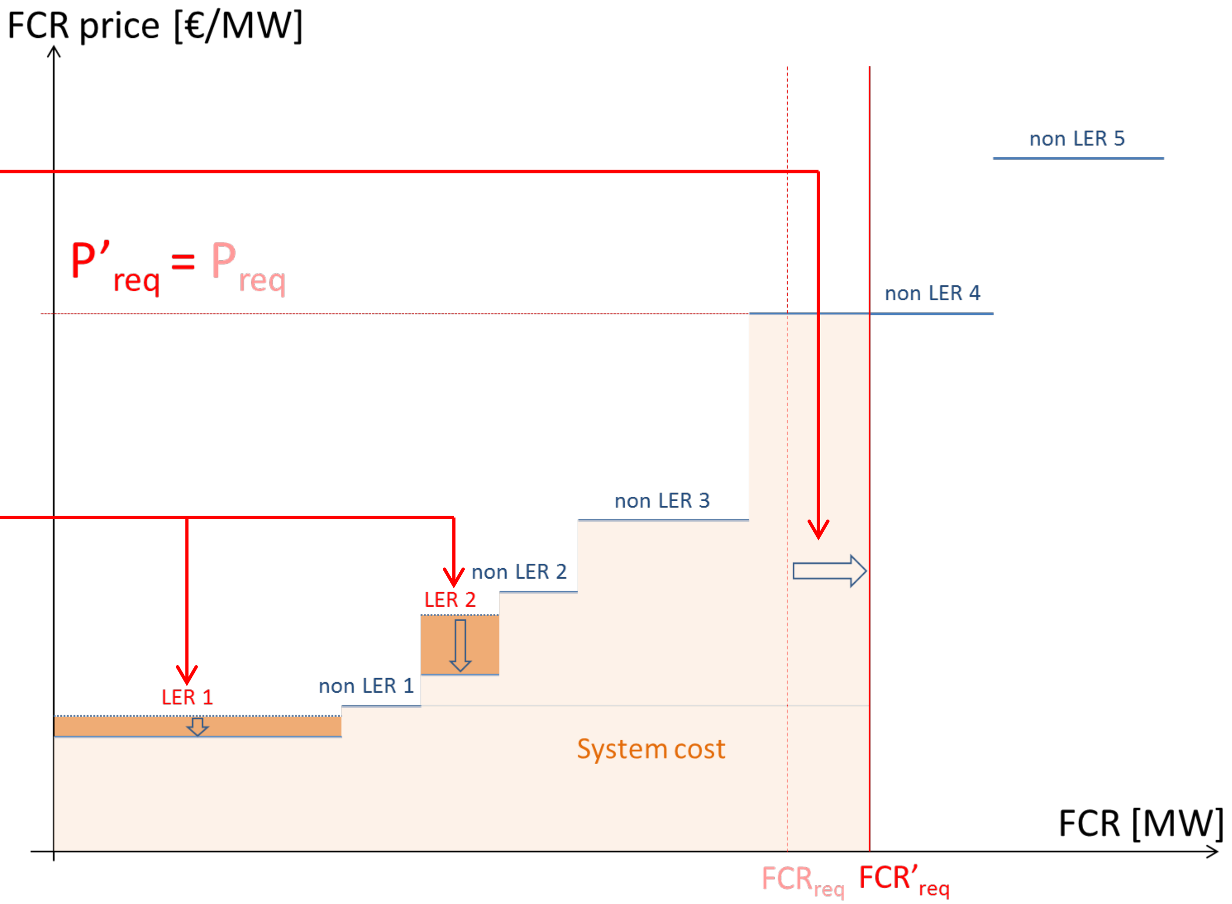
- A **competitive FCR market** reflects the costs of FCR provision.
- A **single cost curve** is taken into account **for each synchronous area**.



CBA Methodology Proposal
Effects of time period on cost curves

A **decrease of $T_{min\ LER}$ can have a dual effect** on the system costs:

- The **required FCR** could **increase to fulfil the condition** of replacing a LER depletion.
- Since a **smaller $T_{min\ LER}$** could **entail lower investment costs** for the LER, the costs curve varies: the costs of FCR provided by LER decrease



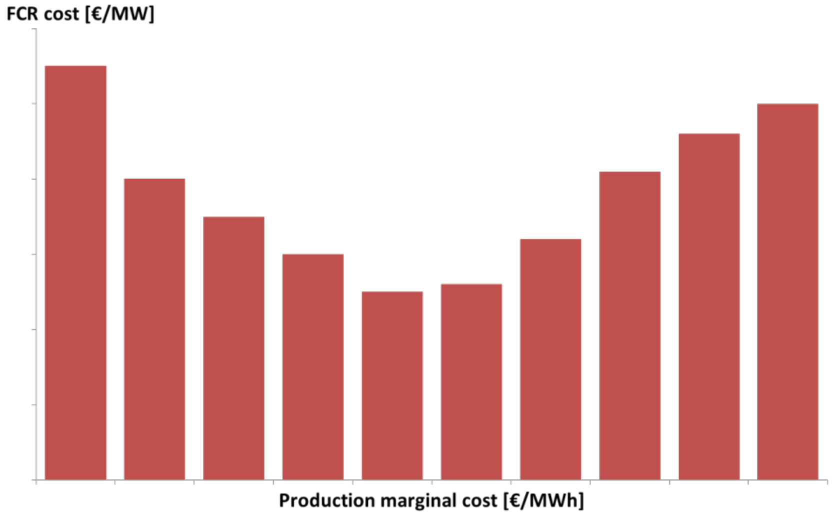
The combination of the two effects changes the overall FCR system cost.

CBA Methodology Proposal
FCR cost curves

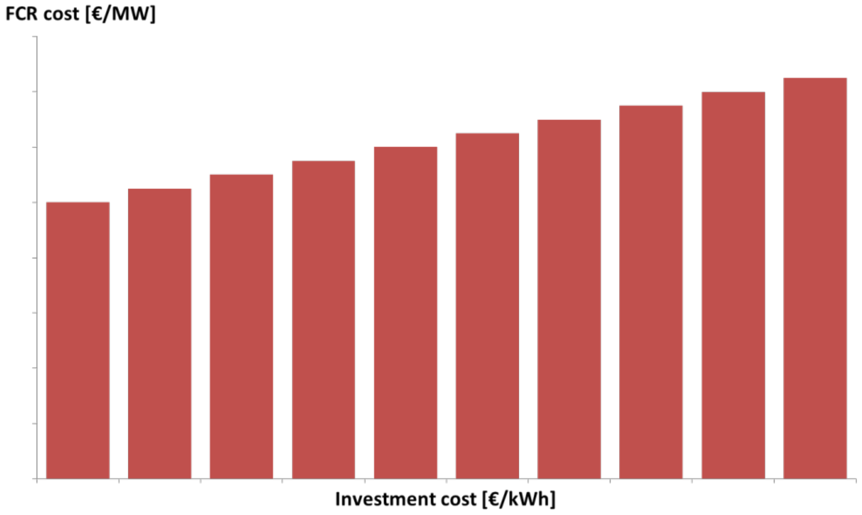
The **data needed** to build the curve are:

- **Energy market results** (energy market prices);
- An estimation of **production marginal costs** of the different generation technology present in the synchronous area;
- An estimation of the **investment costs for LER plants**.

Conventional non-LER costs



LER costs

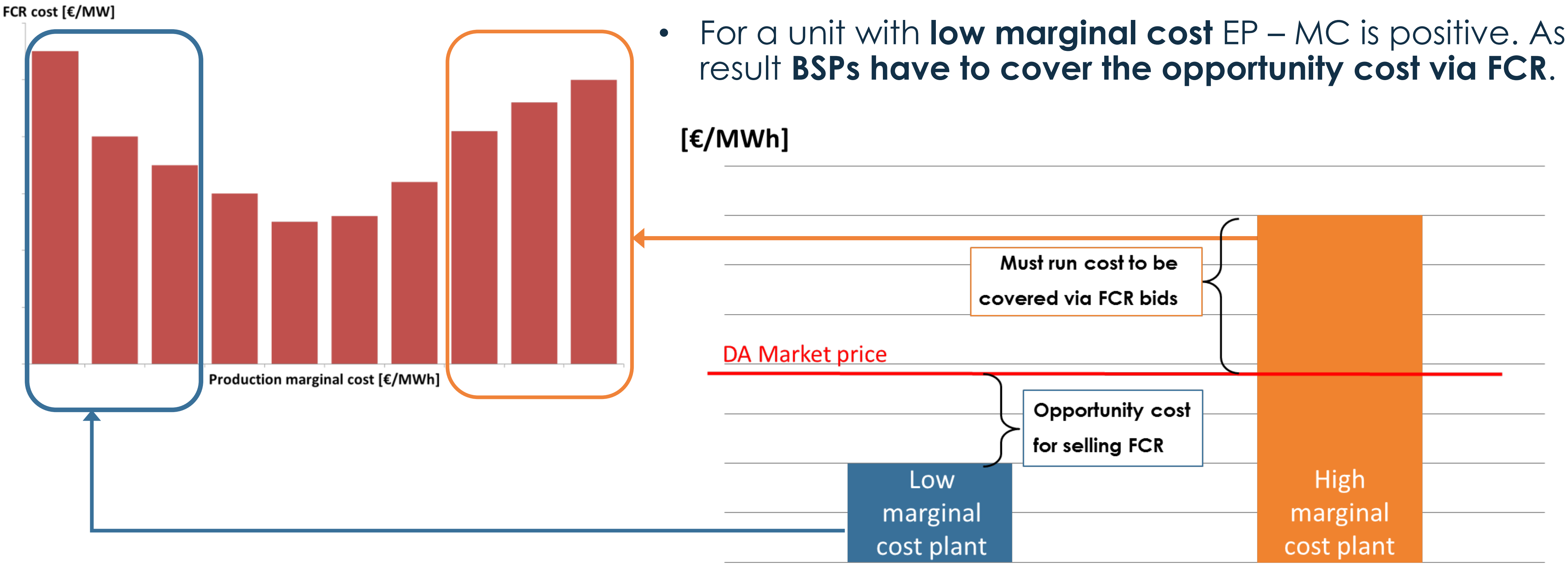


CBA Methodology Proposal
Conventional non-LER costs

The **FCR cost per unit** is the absolute value of:

Energy Price – Marginal Cost

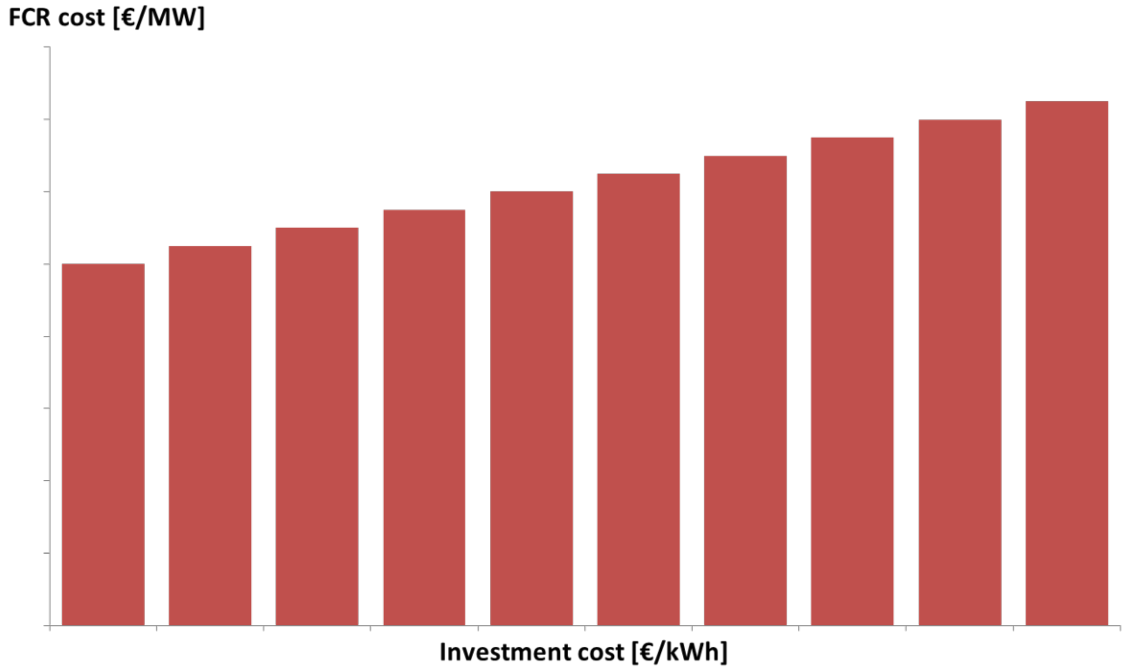
- For a unit with **high marginal cost** EP – MC is negative. As result **BSPs have to cover the difference EP – MC via FCR**.
- For a unit with **low marginal cost** EP – MC is positive. As result **BSPs have to cover the opportunity cost via FCR**.



CBA Methodology Proposal
LER costs

The **FCR cost for LER is proportional to investment costs**.

If the $\mathbf{T_{min\ LER}}$ **increases**, the **LER must have a higher energy/power ratio**.



Scenarios

CBA Methodology Proposal
Scenarios

The described **process workflow will be applied for several different scenarios**, defined by:

- **Horizon year**: at least over two time horizons among ENTSO-E TYNDP
  - 2020 (short term)
  - 2025 gas before coal (GBC) (medium term)
  - 2030 distributed generation (DG) (long term)
- **$T_{min\ LER}$**: discretization of 5 minutes between 15 and 30 minutes;
- **Share of LER** in the FCR provider mix (10% to 100%)

CBA Methodology Proposal
Scenarios

The set of combinations to be analyzed for each **Horizon year** are summarized in the following scheme.

Each combination (cell) shall contain FCR dimension [MW] and its costs [€]:

ENTSO-E TYNDP 2020	LER share on total FCR providers

ENTSO-E TYNDP 2025	LER share on total FCR providers

ENTSO-E TYNDP 2030		LER share on total FCR providers									
		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
T_{min} LER	15 min										
	20 min										
	25 min										
	30 min										

The use of these **horizon years allow to consider the evolution in the mid-long term of the generation portfolio, demand forecast, transmission system development, fuel costs and LER investment costs**.

The workflow process will be applied considering the scenarios developed in **ENTSO-E TYNDP** which can be adopted as **robust reference scenarios** because of their well-established definition process.

CBA Methodology Proposal
Scenarios

ENTSO-E TYNDP 2020	LER share on total FCR providers
T_{min}	

ENTSO-E TYNDP 2025	LER share on total FCR providers
T_{min}	

ENTSO-E TYNDP 2030		LER share on total FCR providers									
		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
T_{min} LER	15 min										
	20 min										
	25 min										
	30 min										

In order to **convert monetary costs** which characterize **different years** into a single present value, **a discount rate can be used to calculate the Net Present Value (NPV) of FCR costs** for comparison and evaluation of the impact of different minimum time periods.

NET PRESENT VALUE OF FCR COSTS		LER share on total FCR providers									
		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
T_{min} LER	15 min										
	20 min										
	25 min										
	30 min										

Most relevant real frequency events

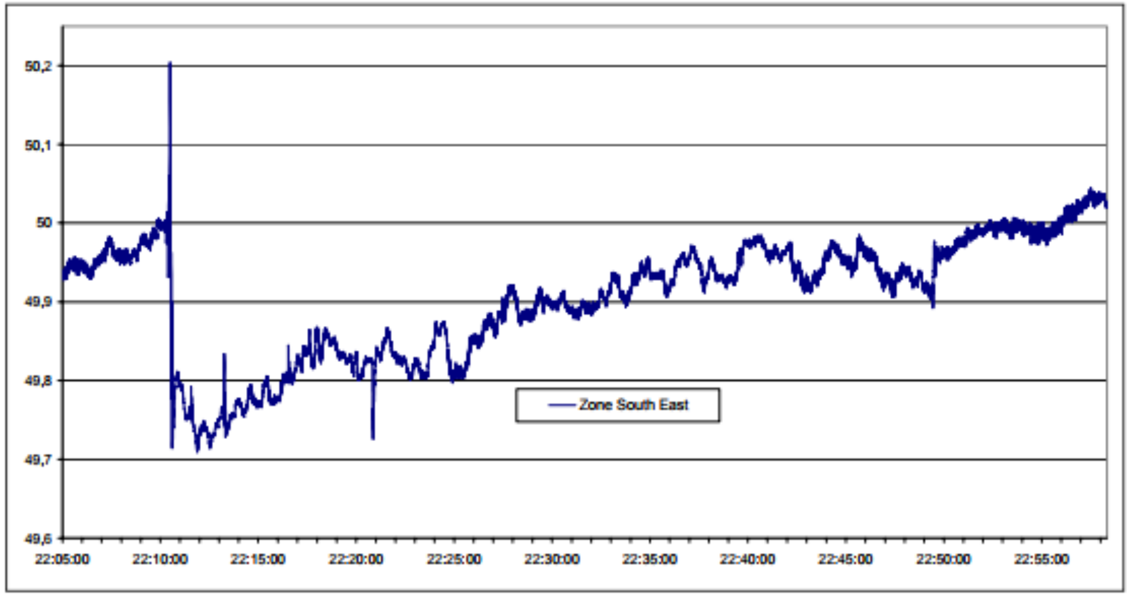
CBA Methodology Proposal
Most relevant real frequency events

The model used for the probabilistic approach is a **simplification of the real power system – there are important possible sequences of events that cannot be assessed with the Monte Carlo simulations.**

In order to test the LER effects at least in some of these possible sequence of events, it is needed **to simulate the most important actual grid disturbances that the synchronous area experienced in the past.**

Since these extreme working conditions are possible, it is fundamental to assess how the system with LER would react: the **real frequency data recorded during the events shall be used as an input in a dedicated model that simulates the presence of LER.**

E.g. CE system disturbance on 4 November 2006



CBA Methodology Proposal
Most relevant real frequency events

It shall be **verified if the LER would have been depleted during the disturbance and if this depletion would have been the cause of further critical worsening in the power system conditions**.

The **result of the test shall be a pass/fail (Y/N) condition for different scenarios** in terms of LER participation on FCR, FCR dimensioning and $T_{min\ LER}$

		LER share on total FCR providers									
		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Tmin LER	15 min	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
	20 min	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
	25 min	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
	30 min	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N

If a combination of Time Period and LER Share worsens operational security, potentially leading to a blackout state, the combination shall not be considered for the definition of the Time Period

CBA Methodology Proposal
Results

The result of CBA is the social cost of all the combinations of time period and LER share which does not jeopardise the system stability during the most relevant real frequency events.

NET PRESENT VALUE OF FCR COSTS		LER share on total FCR providers									
		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Tmin LER	15 min										
	20 min										
	25 min										
	30 min										

➕

		LER share on total FCR providers									
		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Tmin LER	15 min	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
	20 min	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
	25 min	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
	30 min	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N

These results allow to select the time period ensuring the conditions for maintaining operational security in the most effective way.

Compliance of the CBA methodology proposal with Article 156(11)(a)to(e)

Compliance with Article 156(11)(a)to(e)

Article 156 (11a)

experiences gathered with different time frames and shares of emerging technologies in different LFC blocks;

- Assessment of the **impact of LER** in countries where they are **already in service** (E.g. Germany, Italy, France, Belgium, SA Nordic).
- Evaluation of the **current procurement scheme** implemented in countries with LER (E.g. Germany, Italy, France, Belgium, SA Nordic).
- Analysis of the **existing research studies** aimed to assess the impact of different storage emerging technologies on FCP framework.

Compliance with Article 156(11)(a)to(e)

Article 156 (11b)

the impact of a defined time period on the total cost of FCR reserves in the synchronous area;

- Assessment of **the cost of the FCR** in the synchronous area considering the impact of a defined time period on **investment costs for LER**.
- Total cost of FCR estimation taking into account the relationship between cost of FCR provision and the energy market prices.
- Assessment of **cost variation** related to an **increase of FCR volumes**.

Compliance with Article 156(11)(a)to(e)

Article 156 (11c)

the impact of a defined time period on system stability risks, in particular through prolonged or repeated frequency events;

- **Statistical analysis** of prolonged and repeated frequency events that actually occurred in different synchronous areas.
- Model of the possible occurrence of **repeated frequency events with a probabilistic approach** (Monte Carlo method).
- Assessment of the **impact of LER in the most relevant real prolonged frequency events**.

Compliance with Article 156(11)(a)to(e)

Article 156 (11d)

the impact on system stability risks and total cost of FCR reserves in case of increasing total volume of FCR reserves;

- **Increase FCR volumes** in order to maintain operational security in the face of a LER depletion.
- Analysis of the **impact of FCR increase on the results** of CBA.
- Analysis of **cost increase related to the variation of the FCR volume**.

Compliance with Article 156(11)(a)to(e)

Article 156 (11e)

the impact of technological developments on costs of availability periods for FCR from its FCR providing units or groups with limited energy reservoirs;

- Analysis of **different time horizons** are considered in order **to assess future developments** of the energy system and regulations, **including costs** of availability periods **for LER**.
- Future developments will be **defined according to TYNDP scenarios** defined by ENTSO-E.

Q&A