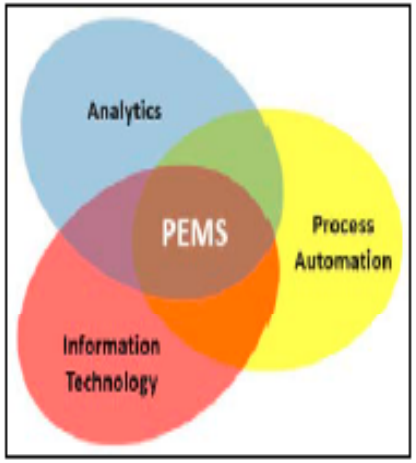
Günter Haberzettl, ABB Automation GmbH - Frankfurt, March 2016

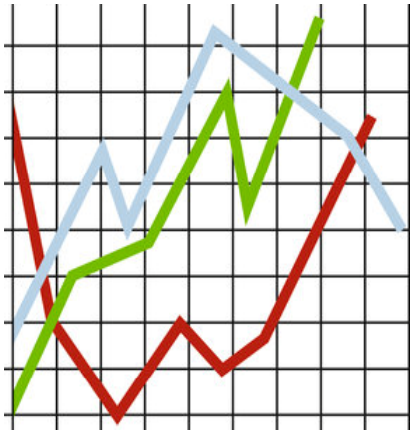
PEMS
Predictive Emission Monitoring
A software based application

Power and productivity
for a better world™

Emission Monitoring Systems
What is PEMS ?

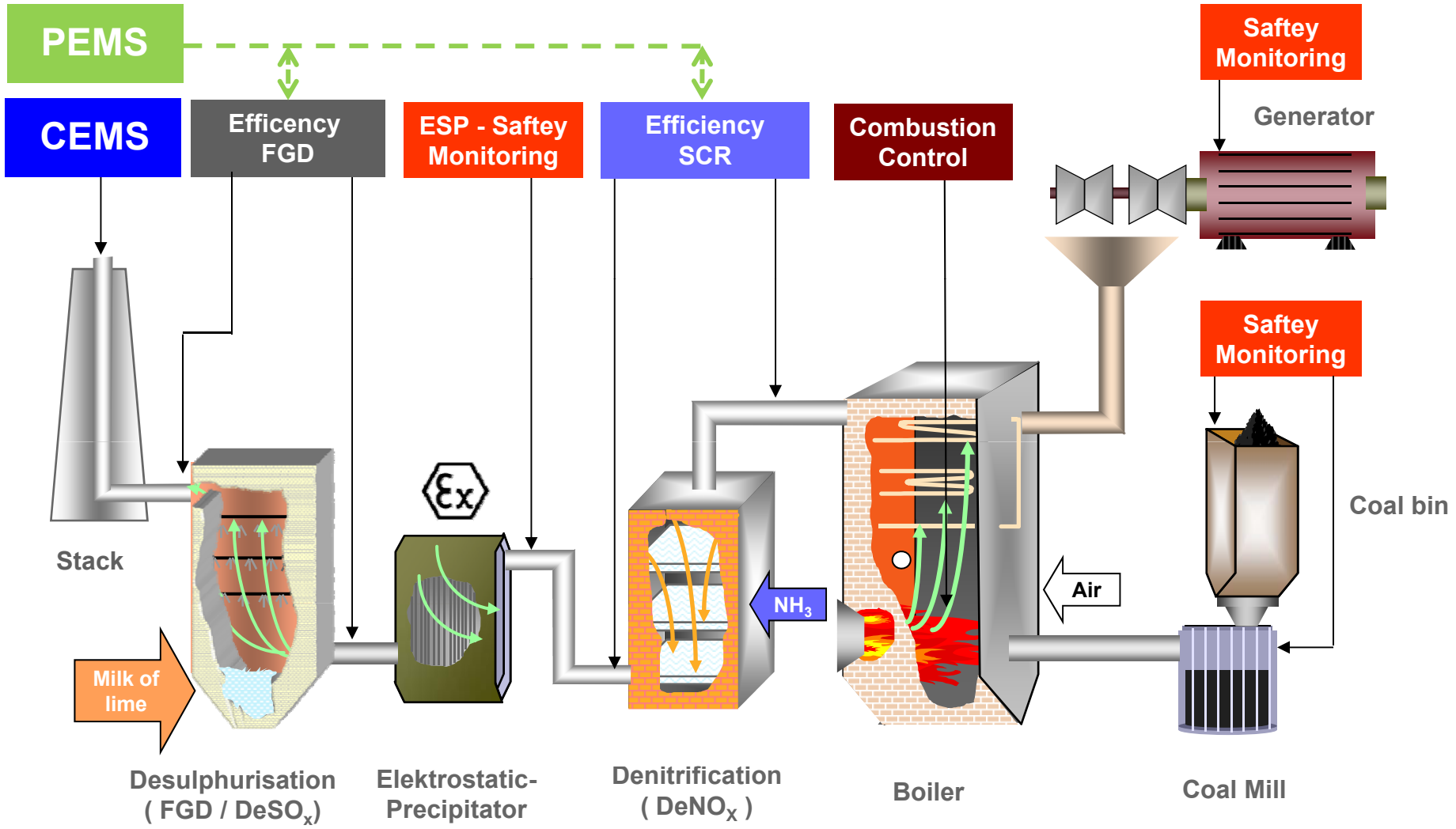


- **PEMS - Predictive Emission Monitoring Systems**
  - A software based technology compared to CEMS
- **PEMS** provide "emission estimation" based on sophisticated **Models**
  - Using mathematical and/or statistical techniques
- **Models** are able to exploit the inherent correlation
  - Between process variables (flow, temperature and pressure) and emission properties (NO_x, SO_2, CO, CO_2)

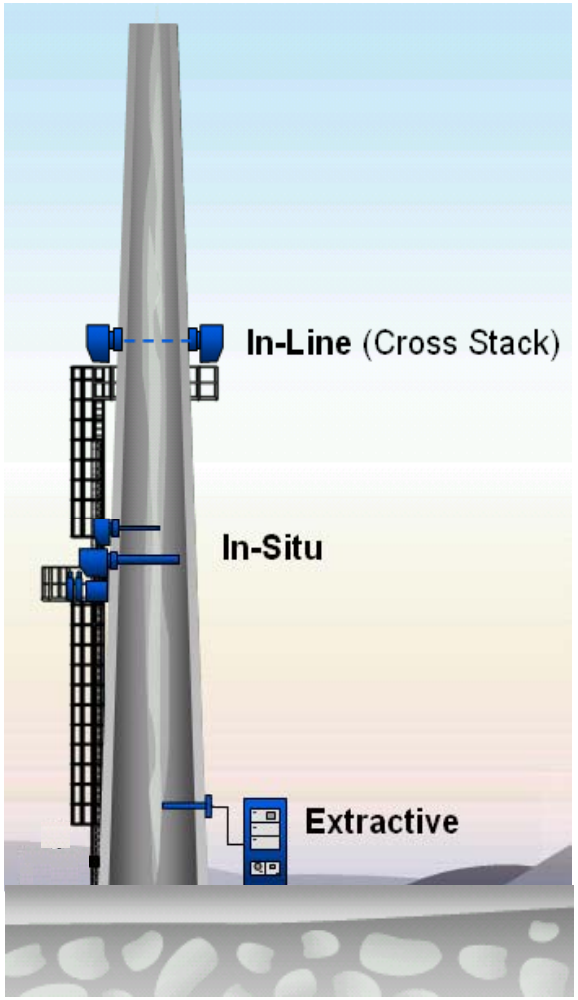


- **Correlation** of values are assessed and evaluated through CEMS
  - Emission Data collected first from existing analyzers
    - Acquisition compaign of Emission values
  - Process Data from plant Control System (DCS, PLC)

Coal fired Power Plants
Measurement Tasks



Continuous Gasanalysis in CEMS
Applied Methods



Cold / Dry – Measurements ► **Extractive / On-Line**

- Combustion Control
- Emission monitoring

Hot / Wet – Measurements ► **Extractive / On-Line**

- Process Control for DeNOx
- Emission monitoring

Cross Stack – Measurements ► **In-Line**

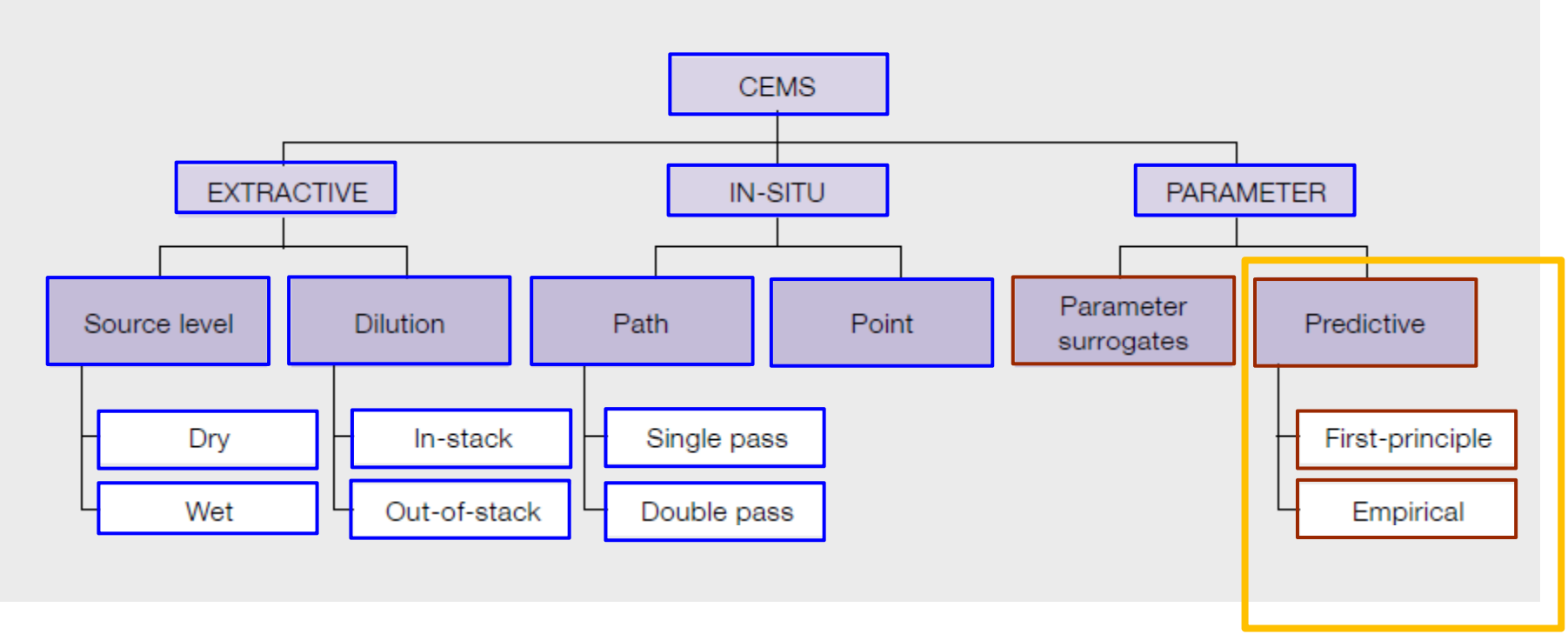
- Laser based measurement

In-Situ – Measurements ► **In-Line**

- Dust monitoring

Introduction
PEMS in the field of CEMS

- Comparing 3 types of methods …..



Source: "*EPA Handbook – Continuous Emission Monitoring Systems for Non-criteria Pollutants*", 1997

Legislation
Requirements for PEMS

European Committee for Standadization

Permit conditions

- Permit conditions issued by the local authorities

Europe - Type approval procedure

- CEN Working Group TC264 / WG 37

  Disccussing the method PEMS (prEN264153)

US EPA

- Method needs to meet RATA test procedures

EU - Quality assurance

- Needs to meet the QAL2 - test before going into operation

EN 15267 • Type Approval in Europe

Approval scheme for **A**utomated **M**easuring **S**ystems (**AMS**)

European Committee for Standadization

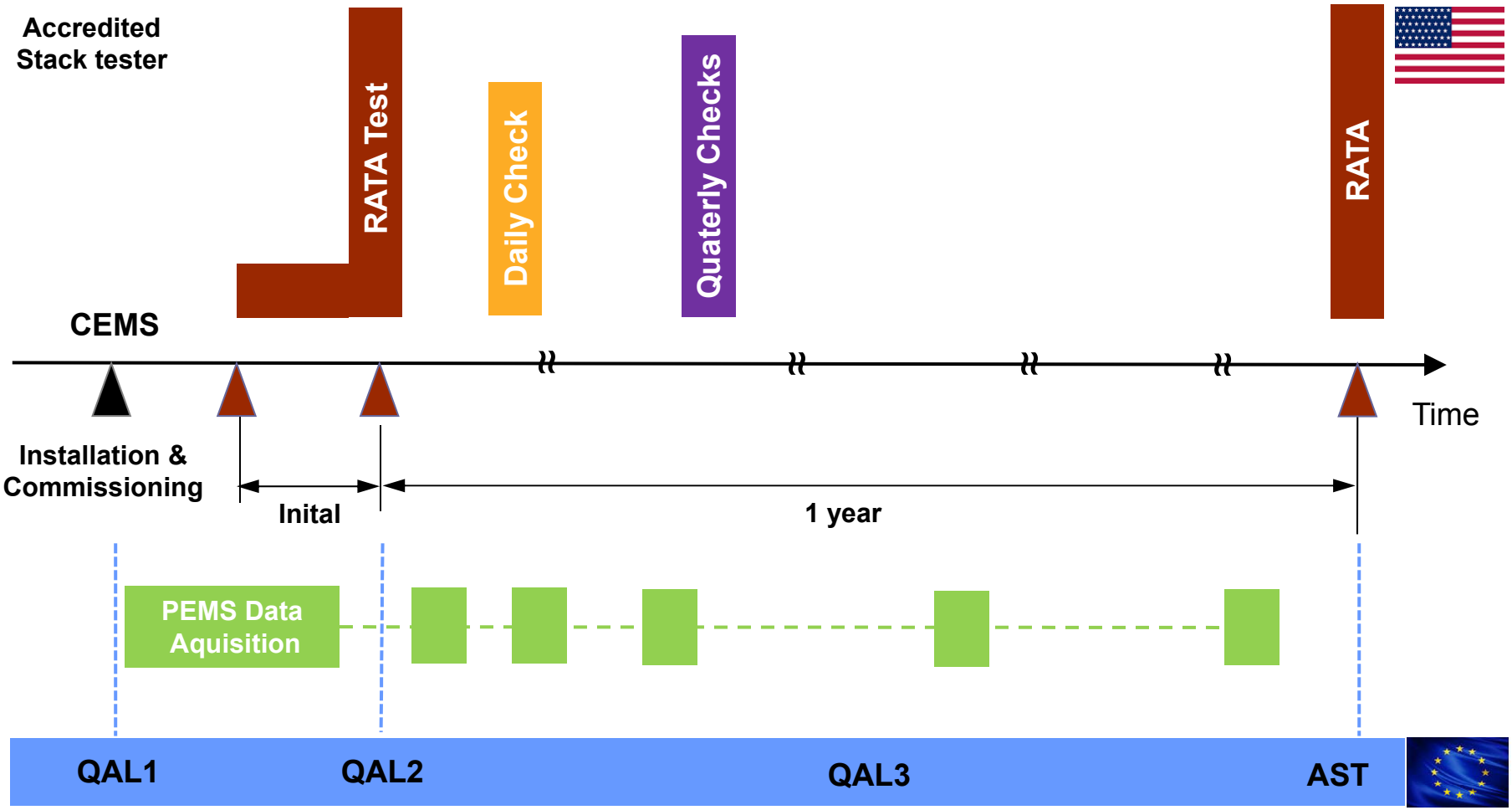
CEMS

- Performance tests
  - Laboratory tests
  - Field tests (duration minimum 3 months)

PEMS

- Not reasonable based on EN 15267
- Requires a data aquisition compaign before going into operation
  - Measurements to be conducted with a certified CEMS

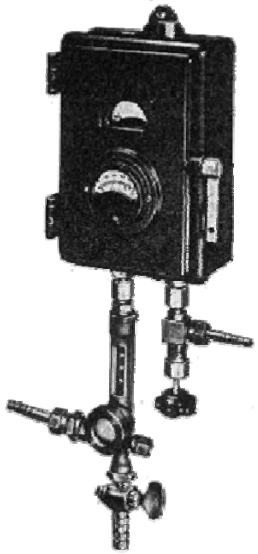
Europe & USA
Implementing PEMS



Emission Monitoring Systems
PEMS

What was the target thinking about PEMS at ABB ?

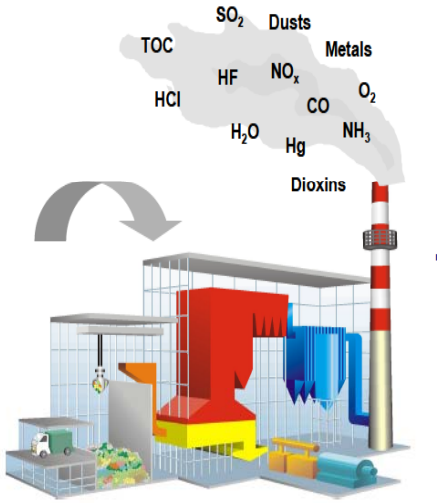
- **Availability during downtimes of a CEMS**
- **Redundancy**
- **Real-time product quality prediction of processes was the driver**



Caldos
~ 1930

EL3000 Series
~ 2010

PEMS - Model-based Emission Monitoring Applications

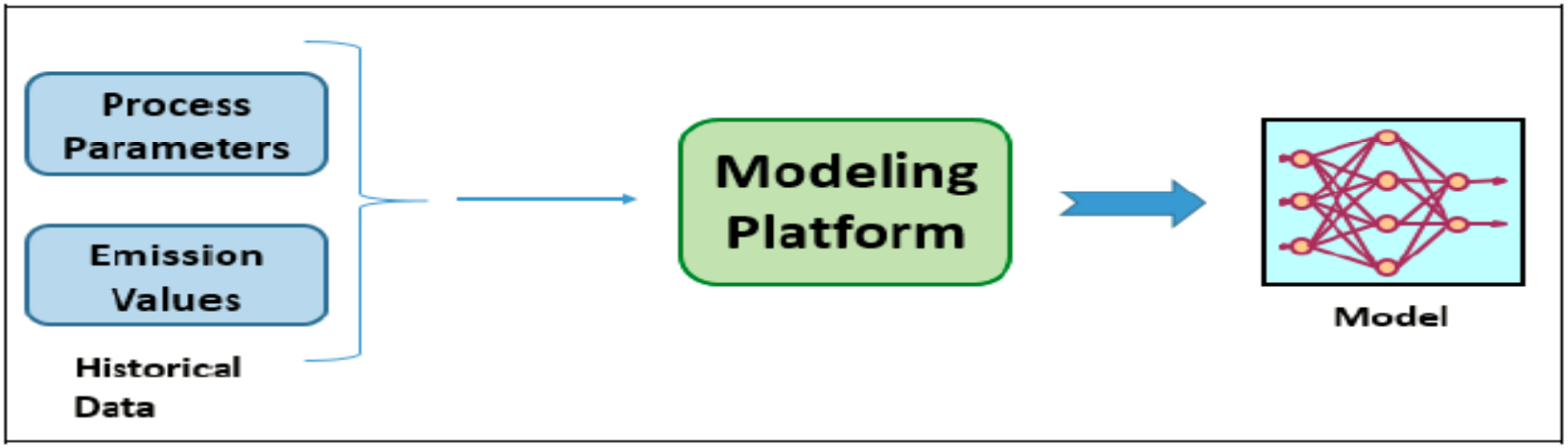


- **PEMS can be applied to processes**

which are enforced to monitor continuously pollutants

- Stable combustion processes (Power)
- Gas Turbine applications
- Refinery applications (e.g. Fluid Catalytic Cracking units)
- Batch processes

Model-based Emission Monitoring
Parameters for mathematical models



- **Emission values**

  and reference values

  - **O_2 / CO / CO_2 / SO_2 / NO / NO_2 / PM**
  - **Gathering sufficient values to build a validate mathematical model**
- **Turbine data**
- **Roughly up to 25 Parameters required**

- **Process Parameters**
  - **Fuel flow & Composition (quality)**
  - **Temperatur**
  - **Pressure**
  - **Load**
  - **Burner air**
  - **Flap position of air preheater**

Model-based Emission Monitoring
Key items for effective implementation

Technology

- Software environment able to handle data from different sources
- Integration in existing IT-structures, e.g. OPC protocol, Serial Interfaces
- No additional IT components
- Seamless integration

OLE for Process Control

PROFI PROCESS FIELD BUS

MODBUS RTU

Ethernet TCP/IP

Know-how

- Engineering and software services able to blend instrumentation and analytics conditions with process automation and modelling building

Local presence / Maintenance

- A service engineer should be close to support modifications
- Periodic recalibration useful for extending new operating conditions

Model-based Emission Monitoring
Where does it come from?

Let's move from Definitions …

- A **SYSTEM** is defined as ***a collection of objects*** among which it exists a set of cause-effect relationships
- A **MODEL** is defined as ***a set of rules*** by which, knowing the inputs, it is possible to derive the outputs behaviors

It is possible to quantitatively represent a system by a model:

$$Y_i = L_i [x_1, x_2, \ldots, x_s] \qquad i=1, \ldots, r$$

Model-based Emission Monitoring
ABB Inferential Modeling Platform - IMP

- Interferential sensors have been developed
  to provide a practical and affordable alternative,
  instead the use of process values

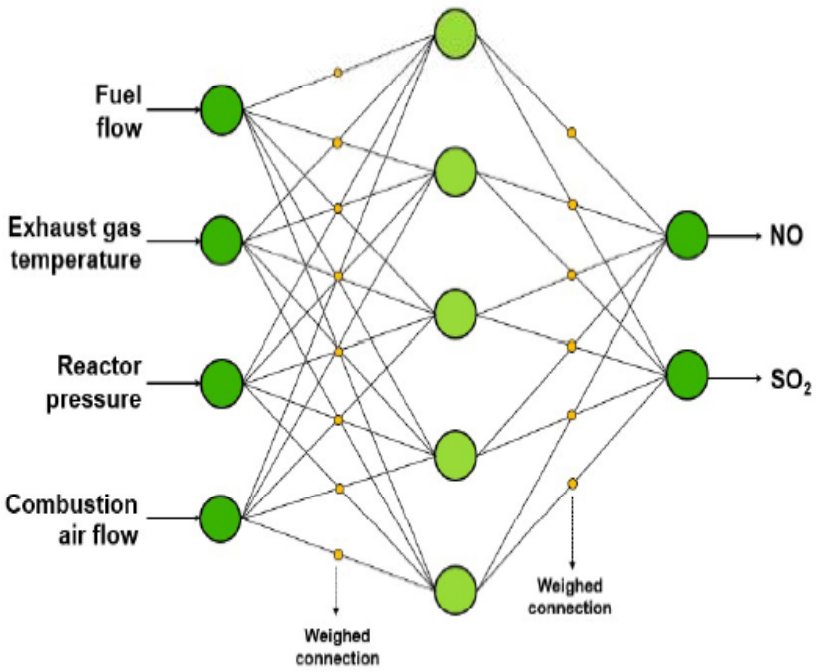
- Interferential sensors can deliver continuously
  estimated values in real-time without using devices

- The fundamental principle behind interferential sensors
  is the functional relationship between variables
  to predict process conditions → Emission values

Model-based Emission Monitoring
ABB Inferential Modeling Platform - IMP

- A unique software platform → ABB proprietary
- Development and deployment of empirical process models by using different technologies :
  - Neural networks
  - Statistical regressions
  - Multivariate statistical analysis
  - Equation – based models
- Composed by two different environments
  - The Model Builder for data analysis, model building and validation
  - The On-line evironment for effective and quick model implementation, execution and monitoring

Model-based Emission Monitoring
Modelling techniques divided in 2 main categories



ANN - Artifical neural network schematic

Firstly : Fundamental modelling

- Fuel / Energy (BAT conditions)
- Thermodynamic laws

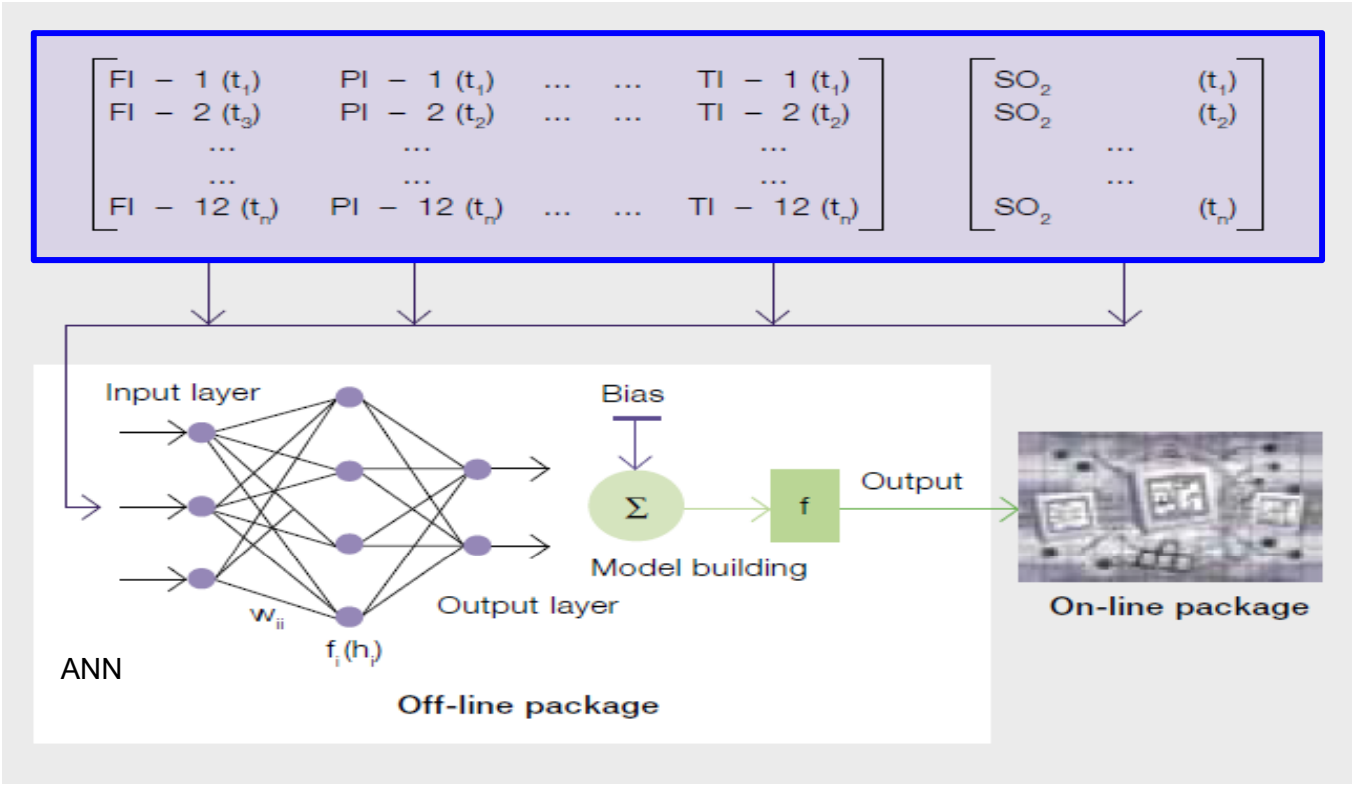
Secondly : Empirical modelling

- Historical process data
- Topical process data
- Emission values

The tools behind for data driven predictions

- Artifcal neural networks (ANN)
- Multi-linear regressions (MLR)
- Generic algorithms

Model-based Emission Monitoring
ABB Inferential Modeling Platform - IMP



- **Bias (Interference-statistic)**

  Difference between the expected value of an estimating function, and the estimated parameter. Best case : Bias = 0 . If so, the unbiasedness is given.

PEMS Application
Typical SW Architecture (Back-up to CEMS)

Analyzer Values

Predicted values

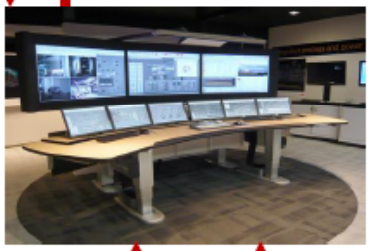
IMP

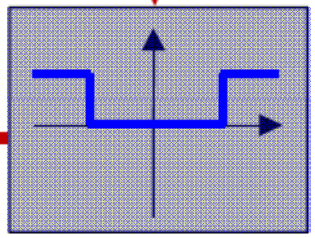
+

-

Σ

Discrepancy between measured - and predicted values





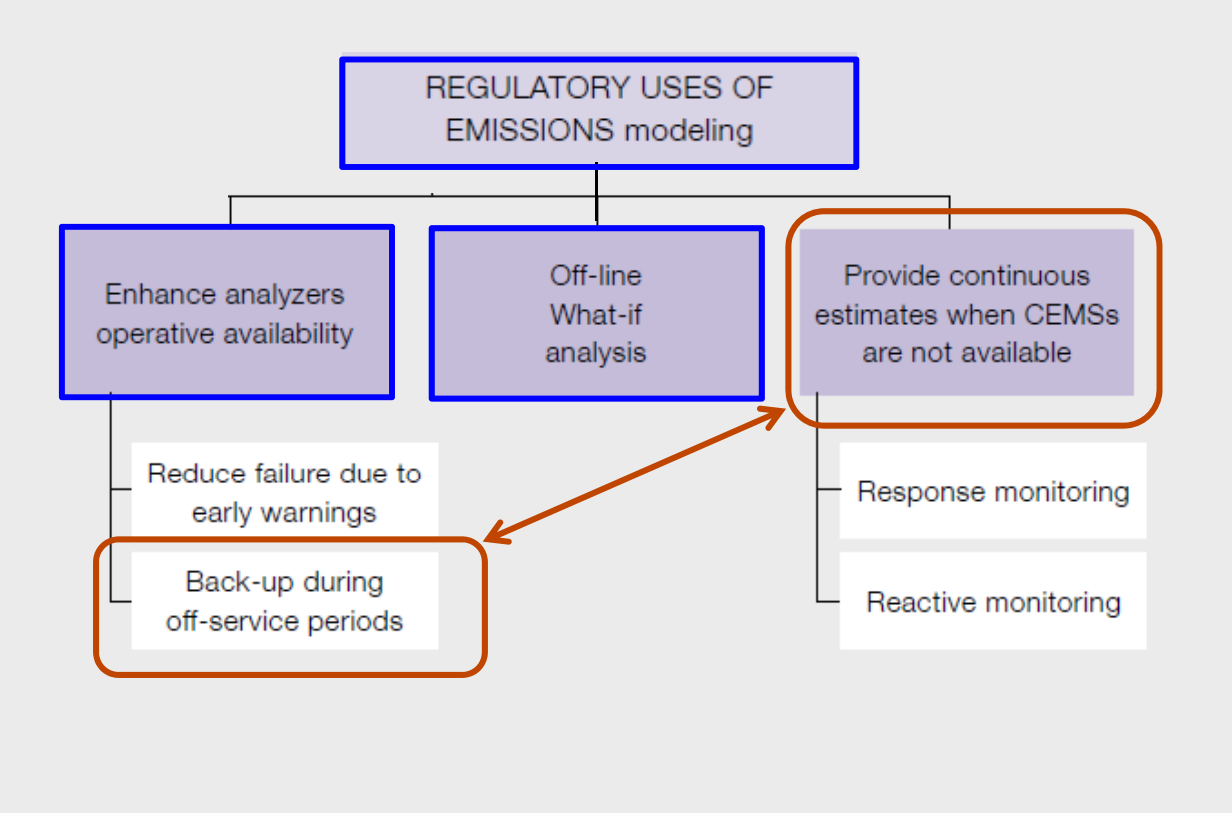
Maintenance trigger

FIELD

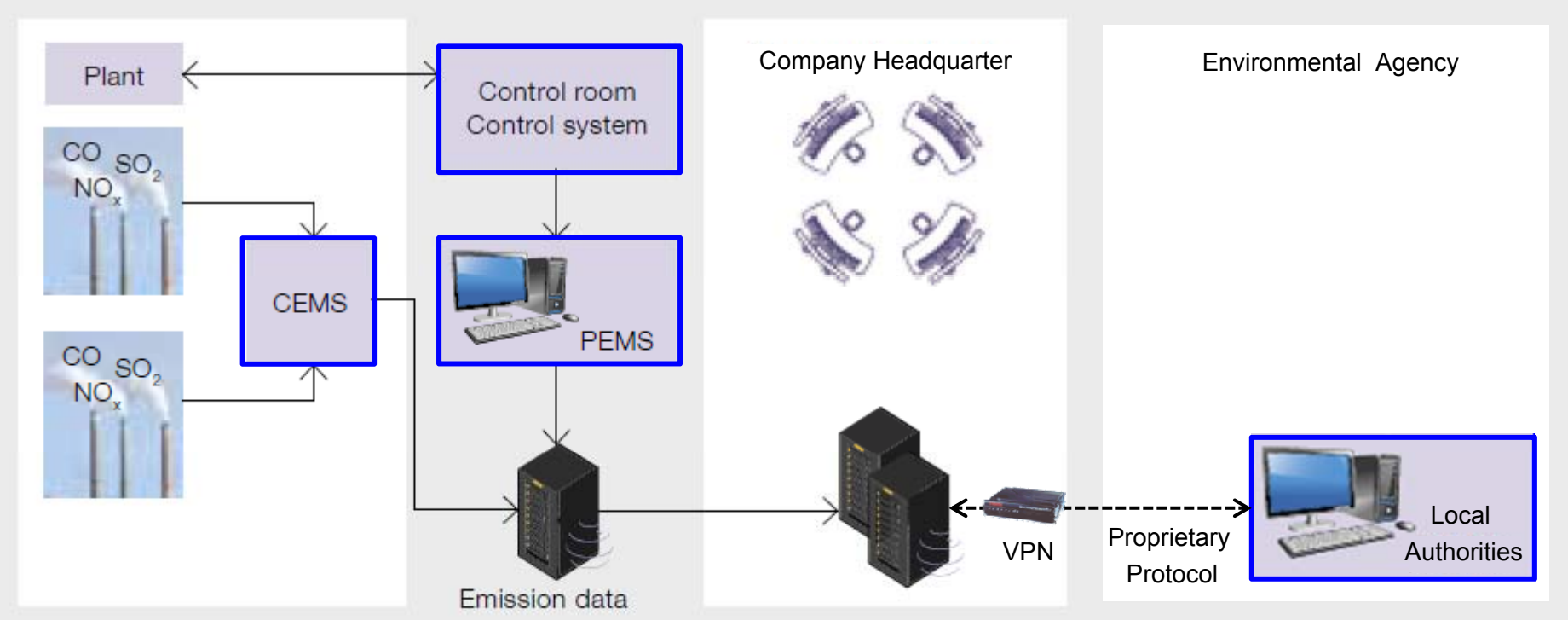
Process Variables

FT TT FT PC TC FC

Model-based Emission Monitoring
Application of PEMS

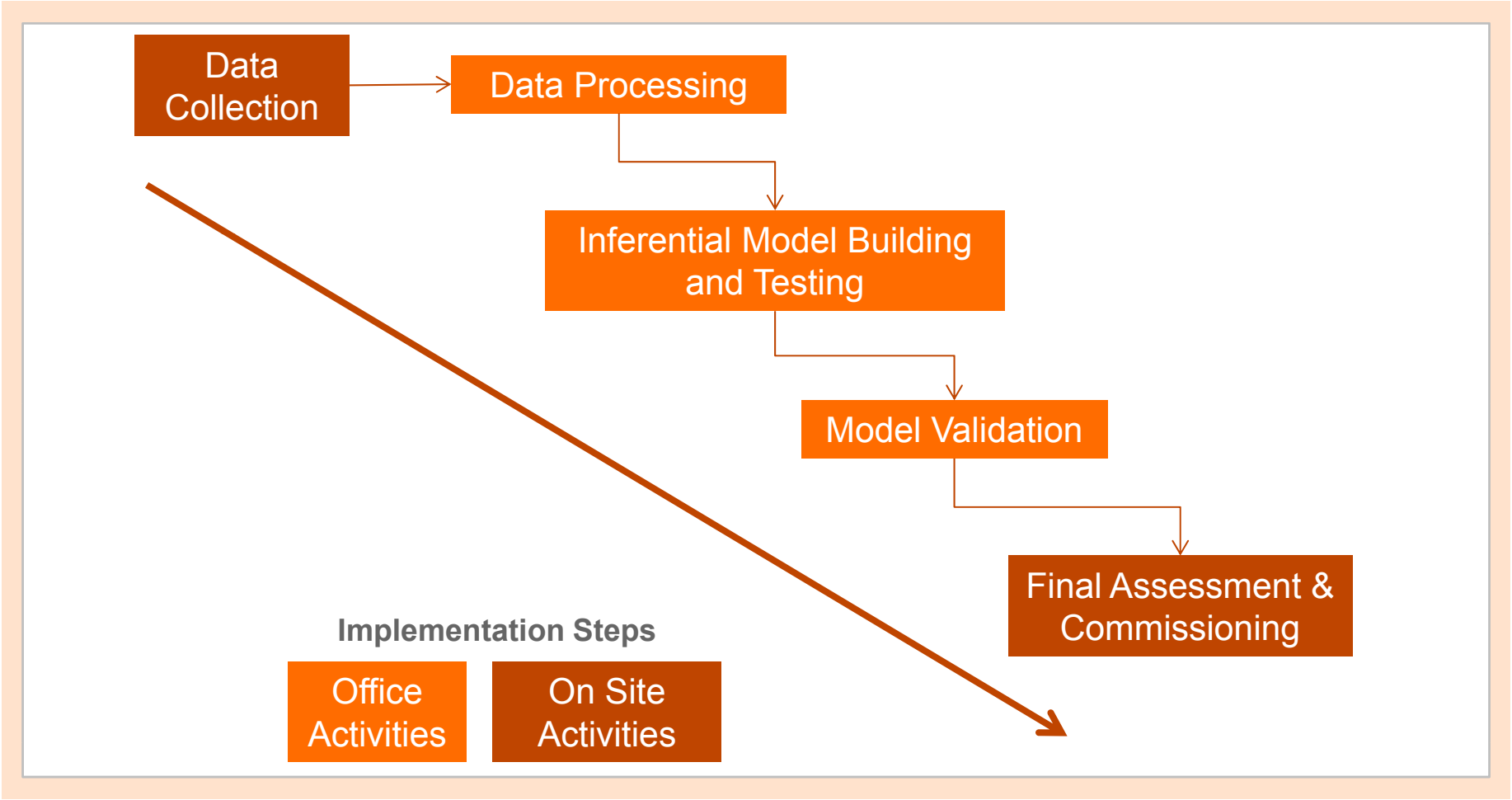


Environmental Management System (EMS)
Correlation of CEMS and PEMS in a plant

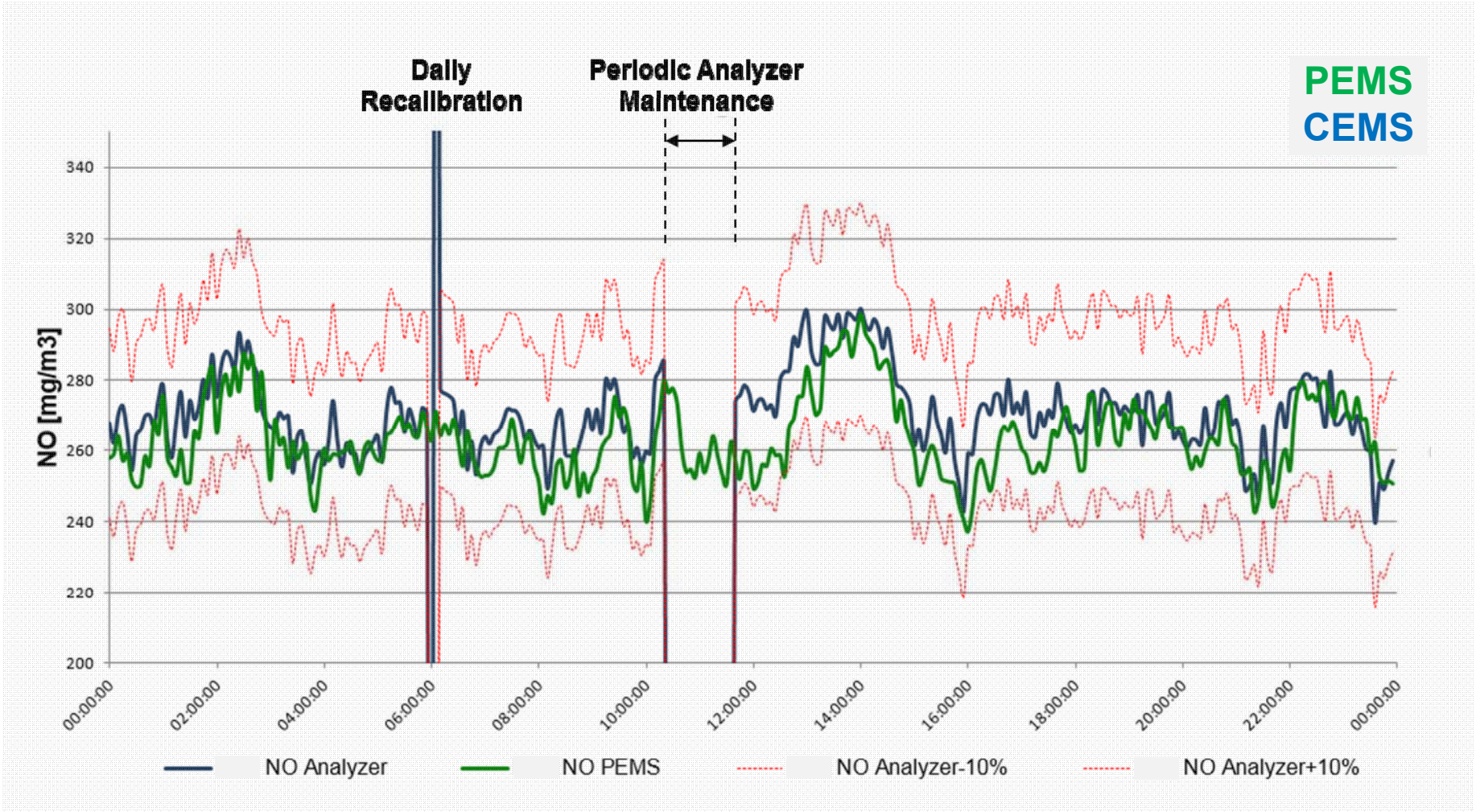


- Improved availability up to 99,5 %
- Permit conditions issued by the local authorities

PEMS Implementation
ABB project execution



PEMS Application
Example - Comparison PEMS & CEMS



1 day recording of NO

Comparison
PEMS & CEMS

Feature	PEMS	CEMS
Measuring Pollutions	Compaign / Frequently	Continuously
Applications suitable	Stable combustion processes	All types of combustion processes
Type approved EN 15267 Part 1-3	Not reasonable	Yes
Method released US EPA	Needs to meet RATA test	Yes
Quality assurance EN 14181	Needs to meet (Single) - QAL2 - test	Yes
Hardware	PC / PLS	CGA

Predictive Emission Monitoring Systems Summary

- PEMS can be a Back-up solution for existing CEMS
  - Avoiding downtime during maintenance or failure
  - Uptime improvement of the plant ≥ 99,5%
- Permit conditions
  - Acceptance by the local authorities
- Processes
  - Running stable
  - Petrochemical processes / Batch processes

    (e.g. Fluid Catalytic Crackering FCC)
- **ABB is the only supplier offering PEMS and CEMS**

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