Quality of Supply
The generators' performance perspective

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Energy Market transformation: Challenges and implications

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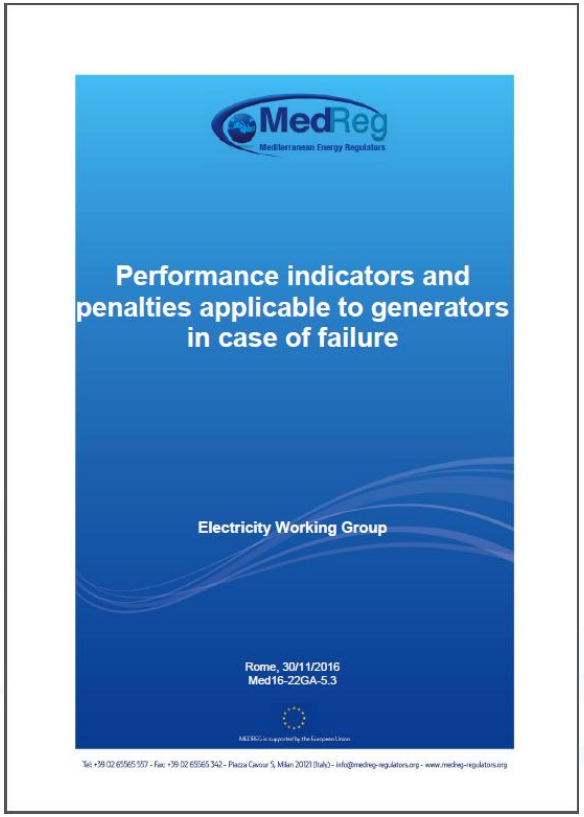
The overall context

- Quality of Supply (QoS) is a high priority for modern electrical systems applicable to all segments of the market - generation, transmission, distribution
- Various Key Performance Indicators (KPIs) have been developed for the three market segments
- From the power generation side QoS is linked to Security of Supply and Environmental Sustainability
- Liberalised wholesale electricity markets are supposed to self-deliver QoS since generators' performance is "optimized"; however, KPIs are still used by TSOs-NRAs to ensure compliance with technical/environmental standards and account for market inefficiencies.
- Monopolistic segments (transmission-distribution) are still regulated based on KPIs

Performance indicators in Med-countries

- In Med-countries sustainable and secure energy is mainly based on the existing generation availability and performance
- The ELE-WG of MedReg published a report on KPIs and penalties for non-compliance used in Med-countries
- Analysis based on responses to internal questionnaire amswered by NRAs
- Information from 11 NRAs collected (Albania, Algeria, Cyprus, Egypt, France, Israel, Italy, Palestine, Portugal, Spain and Turkey)



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Generation performance assessment (1)

- Assessment of generation performances aims to establish requirements and indicators for the technical performances of the generating power plants with the following objectives:
  - promote data exchange and best practices to achieve the most effective use of generation assets and energy resources,
  - provide realistic expectations for power plants in the near term to ensure that they can be achieved,
  - ensure that necessary information for monitoring compliance with the issued generation license is provided to NRAs,
  - enable the evaluation and comparison of technical performances of power plants

Generation performance assessment (2)

- NRAs have different responsibilities regarding generation regulation partly depicting the various stages of market opening
- Out of 11 answers :
  - Generation tariffs are regulated in 5 cases
  - Market based generation rates in 5 cases
  - Rates based on bilateral agreements between generators and distributors in 1 case
- Generation performance assessment responsibility
  - Liberalised markets – mainly TSO; NRAs overall supervision
  - Non liberalized markets - NRA and the TSO.
  - In all cases performance data need to be reported to NRA&TSO

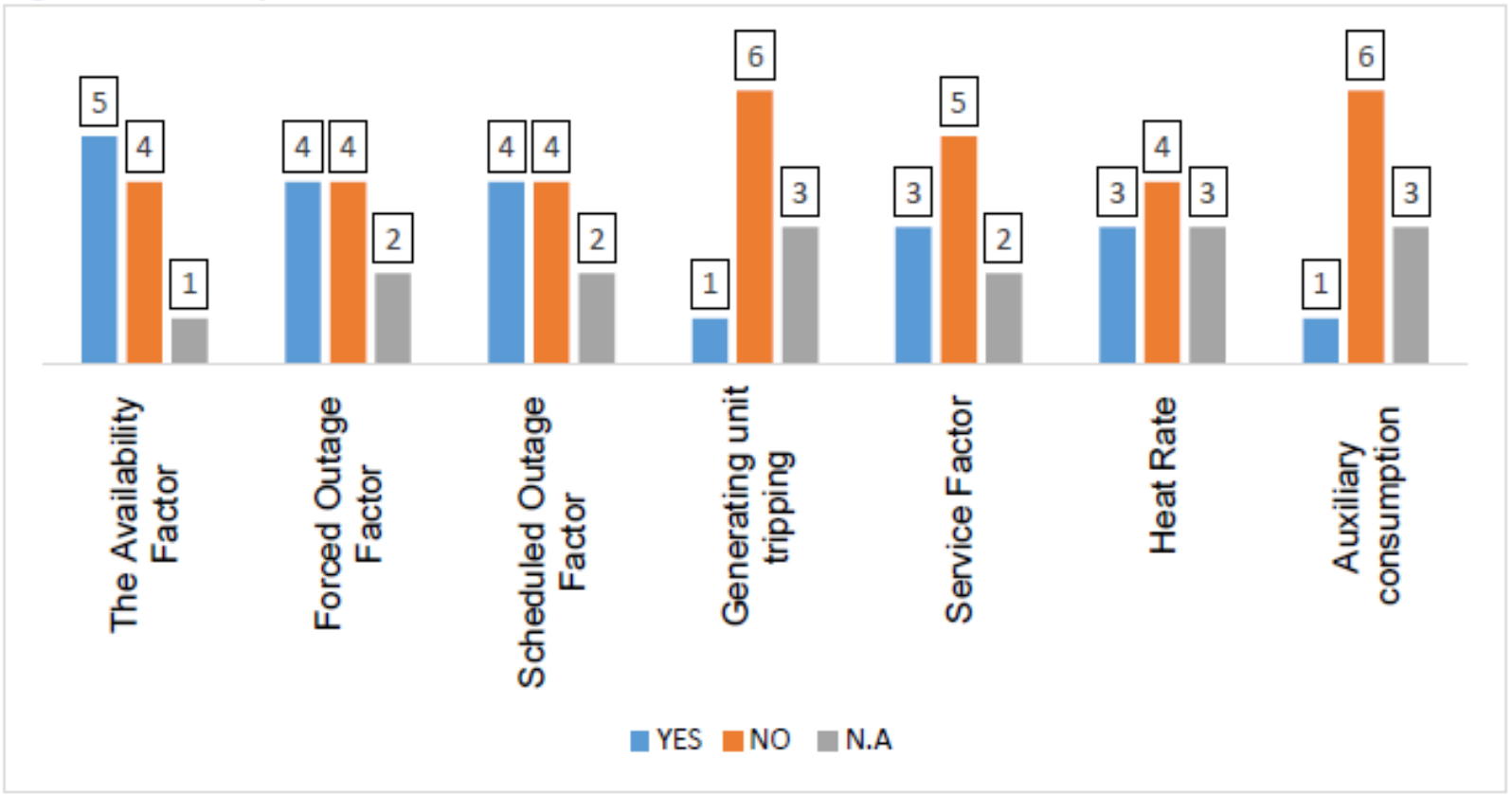
Key Performance Indicators (1)

- Generation performance standards can be categorized into three types:
  - Technical parameters and other national standards (e.g. voltage, frequency, harmonics or rather environmental compliance);
  - Plant availability and energy generation capability standards,
  - Efficiency standards (e.g. combustion efficiency and heat rate)
- Various KPIs are used by NRAs-TSOs:

Availability Factor	Service Factor
Forced Outage Factor	Heat Rate
Scheduled outage Factor	Auxiliary Consumption
Generating unit tripping	

Key Performance Indicators (2)

Figure 1. Used Key Performance Indicators



* N.A: Not Available.

Performance Comparison

- Based on NRAs replies a performance comparison for major KPIs was conducted

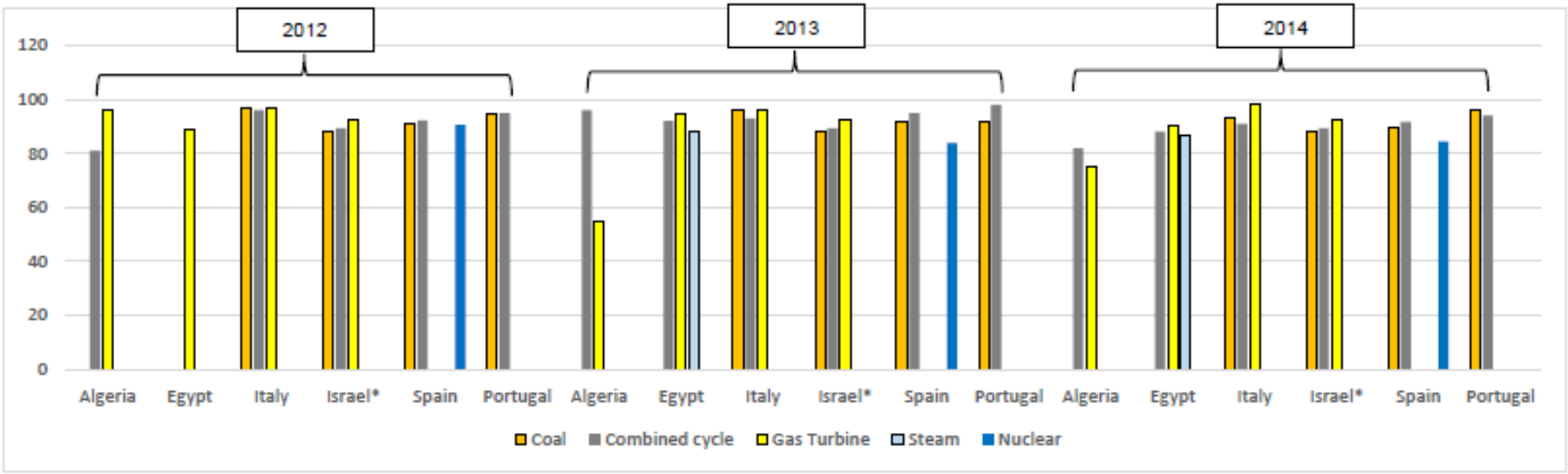


Figure 2. Yearly comparison of the Availability Factor (%), *Case of Israel: values are normative

Performance Comparison (2)

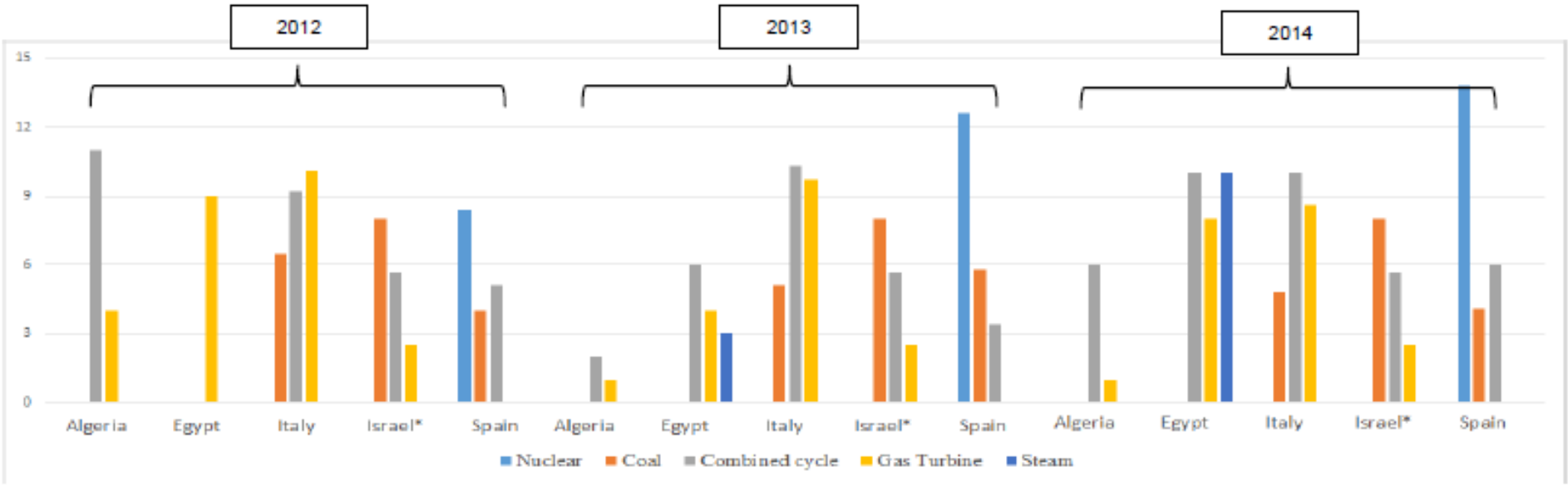


Figure 3. Yearly comparison of the scheduled outage Factor (%), ***Case of Israel: values are normative**

Performance Comparison (3)

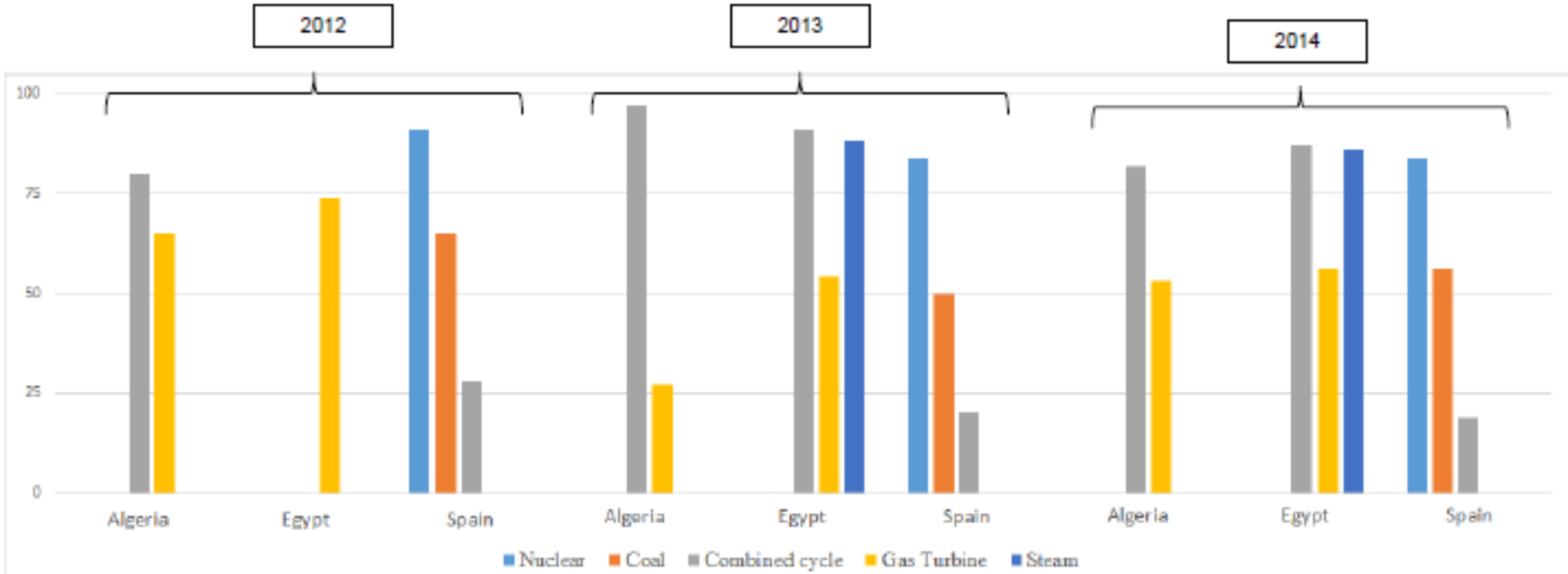


Figure 5. Yearly comparison of the Service Factor (%), ***Case of Israel: values are normative**

Performance Comparison (4)

Table 11. Heat Rate

Year	2012				2013				2014			
Country	Algeria	Egypt[1]	Italy	Israel*	Algeria	Egypt	Italy	Israel*	Algeria	Egypt	Italy	Israel*
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-
Coal	-	-	-	2,170	-	-	-	2,170	-	-	-	2,170
Combined cycle	1,587	N/A	-	1,533	1,586	167		1,533	1,532	166	-	1,533
Gas Turbine	2,545	272	-	2,592	2,579	272	-	2,592	2,538	274	-	2,592
Steam	-	N/A	-	-	-	214	-	-	-	214	-	-

*Case of Israel: values are normative

Table 13. Auxiliary consumption for Egypt and Italy

Year	2012		2013		2014	
Country	Egypt	Italy	Egypt	Italy	Egypt	Italy
Nuclear	-	-	-	-	-	-
Coal	-	9,0	-	9,5	-	9,3
Combined cycle	N/A	2,6	2	2,5	2	2,6
Gas Turbine	1	2,5	1	2,7	1	2,6

Penalties for non-compliance (1)

- Market wise non-compliance should be “penalized” by the market itself (income loss)
- Market imperfections and externalities may induce explicit penalties for non-compliance
- In case of non-market mechanisms (e.g. capacity payments) non-compliance penalties shall be incurred
- Non-compliance-Failures examined :
  - Non-compliance with production commitments
  - Technical failure causing a major incident
- Long unavailability effecting security of supply
- Notably the impact of penalties is small and mainly felt by small producers!

Conclusions

- QoS of power generation important in relation to Security of Supply and Environmental Considerations
- Fully liberalized markets should theoretically self-deliver QoS in terms of generators' performance –
- Still market imperfections and externalities induce explicit performance monitoring and assessment and imposition of penalties in case of non-compliance with performance standards
- Monitoring is shared between NRAs and TSOs the later being more involved in liberalized markets
- In most cases NRAs develop/approve the relevant rules- Availability of data is in this case a major challenge

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ADDITIONAL SLIDES

KPIs – Definitions (1)

- **Availability Factor**: The Availability Factor is a measure of the extent to which the generation unit is actually available for electricity production. It is defined for any considered period of time as the ratio between the period of time that a unit is able to provide service and the considered period.
- **Forced Outage Factor** : A forced outage is an unplanned component failure
- **Scheduled Outage Factor**: The Scheduled Outage Factor is an indication of the frequency of outages that were planned or related to maintenance activities. Scheduled outages is defined as the sum of planned and maintenance outages and their extensions.

KPIs – Definitions (2)

- **Generating unit tripping**: Number of times the unit triggered.
- **Service Factor**: The Service Factor is defined as the ratio between the total number of hours a unit was electrically connected to the transmission system divided by the number of hours in the period. The factor is important for the dispatch of a unit (base load versus peak load). A high service factor of a unit indicates that unit is used as base load unit and a low service factor indicates that the unit is used as peaking unit

KPIs – Definitions (3)

- **Heat Rate**: Heat Rate is supporting information that is defined as the ratio of thermal energy of the fuel consumed and the gross electricity generated by the same period.
- **Auxiliary Consumption**: Means the quantum of energy consumed by auxiliary equipment of the generating plant and transformer losses within the generating station, and shall be expressed as a percentage of the sum of gross energy generated at the generator terminals of all the units of the generating station.

KPIs – Formulas (1)

1. Availability Factor

Table 3. Availability factor

Country	Proposed Formula	Applied Formula
Italy	$AF = \frac{\text{Available Hours}}{\text{Period Hours}} * 100\ \%$	$AF(i) = 1 - \frac{\sum_{h=1}^{H} P_{available}(i,h)}{\sum_{h=1}^{H} P_{installed}(i,h)}$ Where H is the set of hours of the year, defined as a subset of the 100 hours of higher load in the year in which: $P_{available}(i,h) \geq 0{,}75 * P_{installed}(i,h)$ The Power Plant is not affected by a planned outage The factor AF (i) is considered reliable if the set H is composed by more than 49 hours, otherwise AF for the Power Plant "i" is assumed equal to the average value of AF over the Power Plants of the same technology belonging to the same bidding zone.
Portugal		This factor may also be calculated using the ratio between the delivered energy and the scheduled energy. For the hydro plants these energy takes into account the actual head (efficiency)

KPIs – Formulas (2)

2. Forced Outage Factor

Table 4. Forced outage factor

Country	Proposed Formula	Applied Formula
Italy	$FOF = \frac{\text{Forced Outage Hours}}{\text{Period Hours}} * 100\ \%$	The set of hours of the year (H1) in which the Power Plant was not in planned outage (H1). Then, the final FOF value for the Power Plant i is calculated as: $FOF(i) = \frac{FOF'(i) \cdot H1 + FOF^{avg}(i) \cdot (Hyear - H1)}{Hyear}$ Where: - FOF'(i) is the FOF computed for the Power Plant i in the hours which belong to the set H1. - FOFavg(i) is the average value of FOF'(i) on the Power Plants of the same technology.

3. Service Factor

Table 5. Service factor

Country	Proposed Formula	Applied Formula
Spain	$SF = \frac{\text{Service Hours}}{\text{Period Hours}} * 100\ \%$	Number of functioning hours in a year: Total number of hours a unit was feeding electricity to the grid throughout a natural year.

KPIs – Formulas (3)

4. Heat Rate

Table 6. Heat rate

Country	Proposed Formula	Applied Formula
Spain	Ratio of thermal energy of the fuel consumed and the gross electricity generated by the same period	Equivalent electrical performance (EEP) for cogeneration: $$EEP = \frac{E}{F - \frac{H}{RefH}}$$ - E: Electrical energy fed into the grid - F: Fuel consumption - H: Useful heat produced - Ref H: Performance reference value for production of (only) heat

Penalties for non-compliance

Country	Instrument used for penalty	Responsibility and control	To whom are they owed (payable)?	What are the key challenges to applying them?	What impact are those penalties likely to exert on the costs of energy?	Role of the NRA
France	Regulation	TSO and CRE	To the TSO and deducted afterwards from the transmission tariffs	/	/	NRA monitors the functioning of the balancing regime
Israel	Tariff formula	PUA and TSO	To the TSO	/	/	Setting tariff and market rules
Portugal	-Contracts -Government legislation -ERSE Regulation -Market rules	ERSE and TSO	-Reduce the electrical tariffs as the corresponding costs are lower -Paid to the generators that replace the faulty units	Availability of data	/	ERSE verifies the capacity mechanism payments' adequacy and includes them in the electrical tariffs
Spain	Regulations, including market rules	Established by regulation	-Imbalance charges: to the TSO -Capacity payments and reductions in payments to RES and cogeneration: to the electrical system (to the access tariff)	-Imbalance charges -Need to certify auditors that assess the performance. -Need to follow up the number of functioning hours of each unit. -Monitor the availability of power plants (for capacity payment)	Low	To establish the rules, to enforce them, to impose sanctions if necessary and to settle the payments of the penalties in the overall settlement process of regulated costs and incomes
Turkey	Regulation, use of system agreements, market rules	TSO DSO (for distributed generators), MO	To the TSO ((DSO for distributed generators)	TSO's lack of monitoring infrastructure	Directly: none Indirectly: It is theoretically possible that the monetary penalties become a serious financial burden to small generators	Preparing regulations, mains of use of system agreements, and market rules,