RES Impact Study In The Northern Region of KSA, The First Step Toward Energy Diversification

by:

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Contents

I. Introduction

Integration of RES (Renewable Energy Sources):

- Brief Background
    - 2030 Vision
    - NREP (The National Renewable Energy Program)
    - REPDO and SEC

- NERP plan
    - 9.5 GW by 2023
    - 54 GW by 2032

I. Introduction

RES Plants Types and Locations:

- Solar Energy (Photo-Voltaic plants)
  - Rafha 50 MW
  - Al-Jouf 50 MW
  - Skaka 300 MW

- Wind Farms
  - Midyan 400 MW in 2018 and 600 MW by 2024
  - Doumat Al-Jandal 100 MW

II. Energy Yield

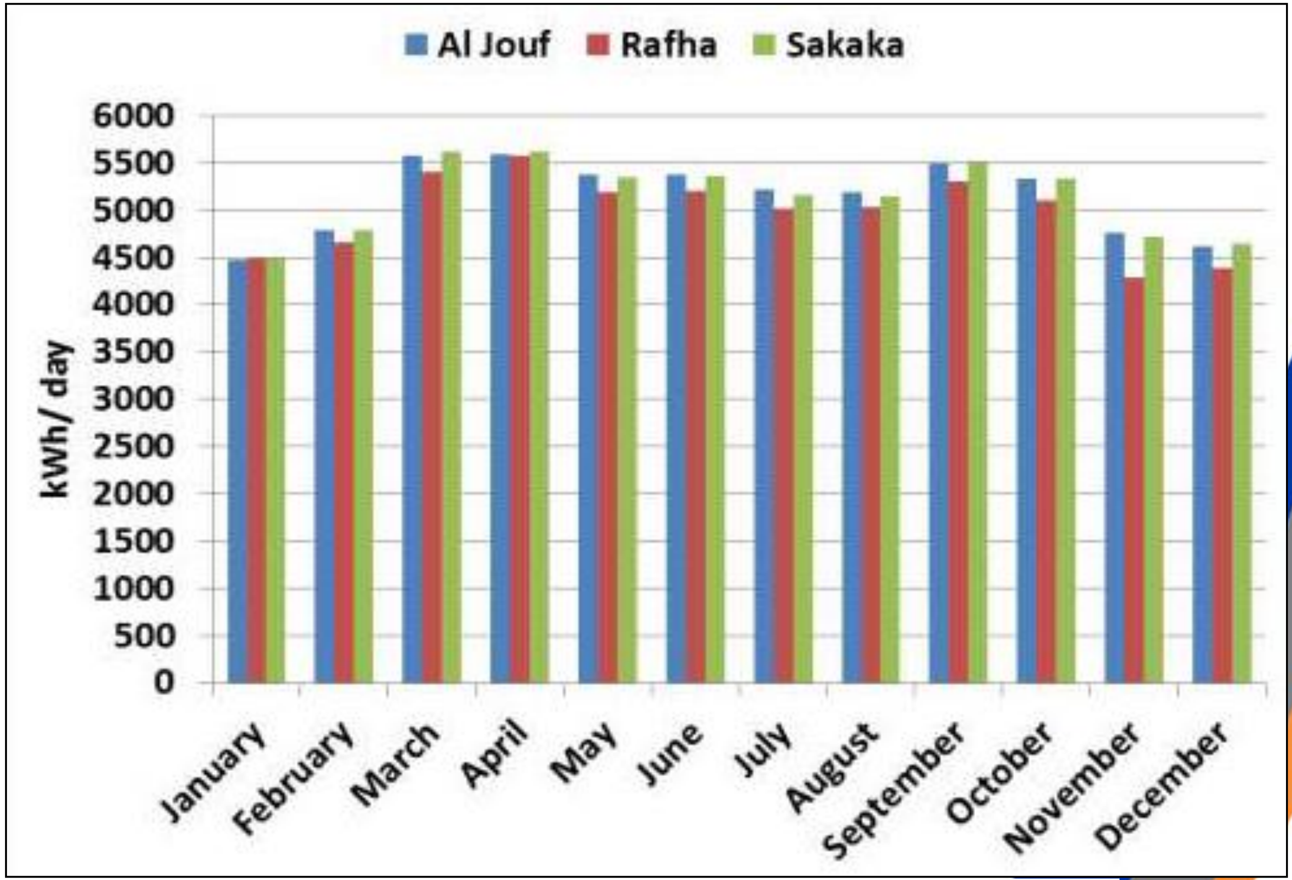
<u>Required data for the analysis of the expected production:</u>

- Geographical coordinates of the considered sites.
- Irradiation and climatic data of the different sites for PV plants.
- Historic measurements of Wind speed and direction for the wind farms.
- The characteristics of the plants (inverters, modules, losses).

II. Energy Yield

<u>PV Plants</u>

- PVSyst software was utilized.
- Rafha plant production is 4% lower due to the lower GHI levels.
- Highest production is reached during spring.
- In summer, although the average horizontal irradiation increases, the one on the sloped modules decreases.



Daily average production per 1 MW installed capacity

Saudi Electricity Company

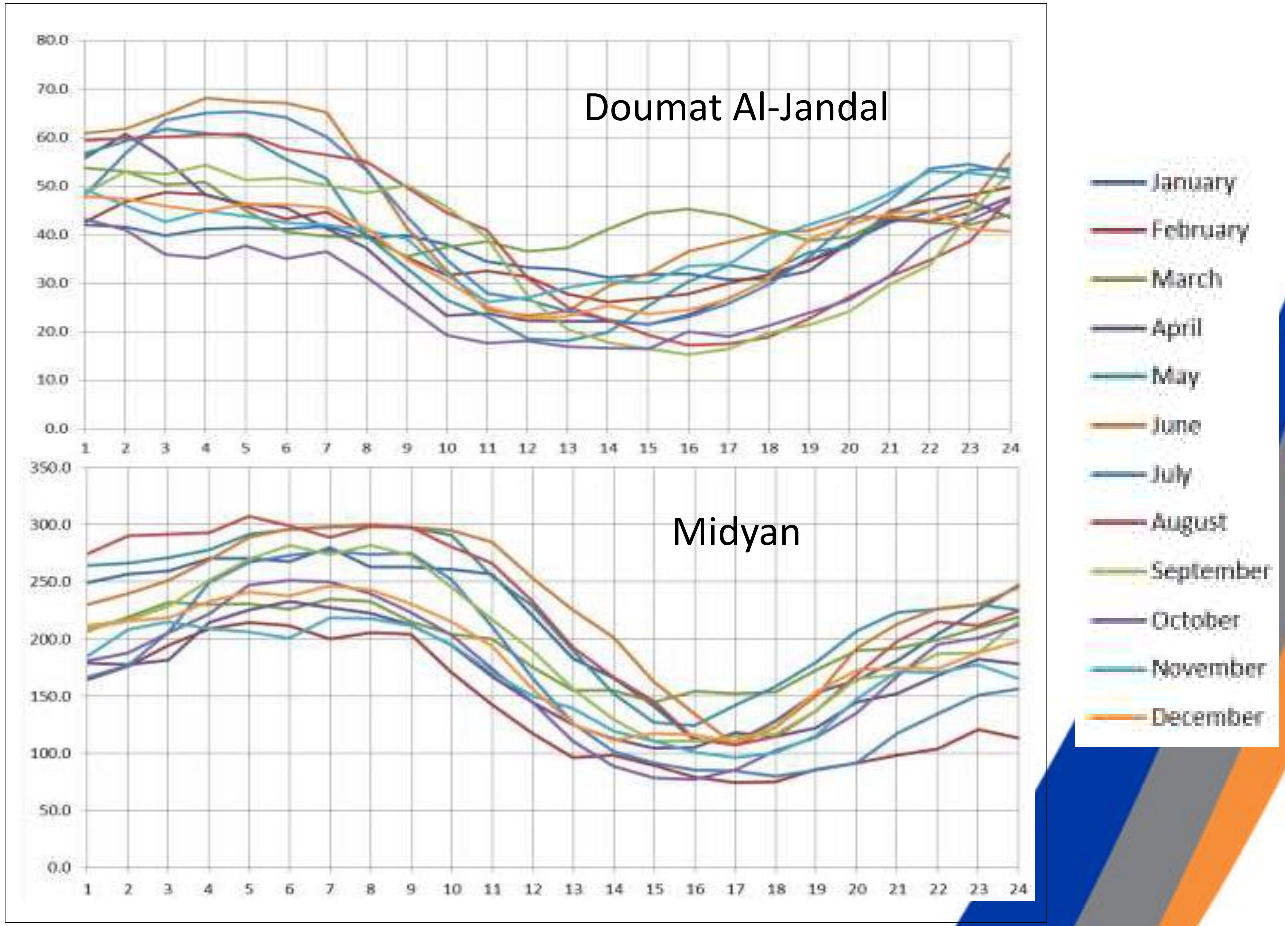
II. Energy Yield

<u>Wind Farms</u>

- High correlation between the expected average production and the time of the day

- A higher production is expected in early morning and a low production in the afternoon

- No significant trend in yearly production.



Expected daily production of the wind farms

III. Reserve Capacity And Unit Dispatching

- Wind and solar energy are non-dispatchable generation sources.

- The power generated by wind farms and PV power plants strongly depends on weather conditions such as:
  - Wind speed and direction.
  - Solar irradiation.
  - Cloudiness.

- Output fluctuations requires compensation from thermal units (reserve capacity) in order to control the frequency deviations

III. Reserve Capacity And Unit Dispatching

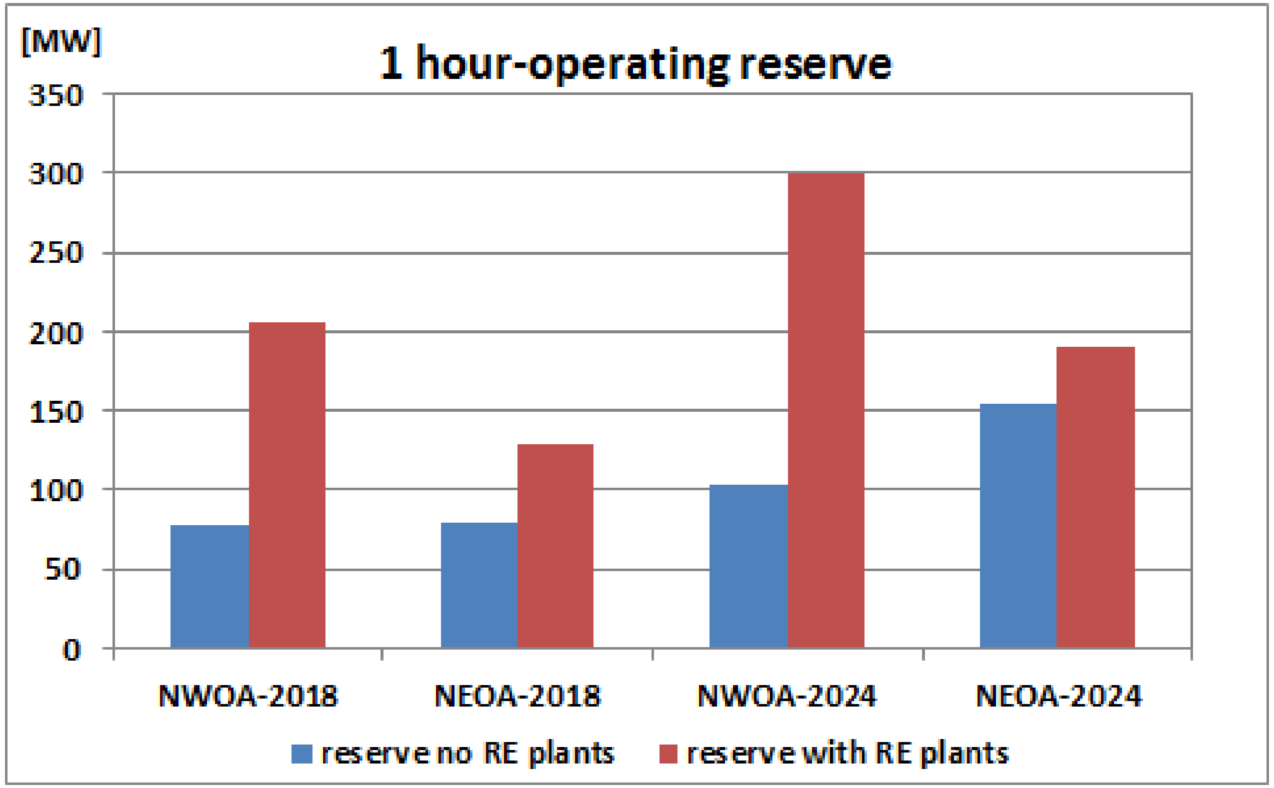
Two timeframes levels of reserve capacity have been assessed:

- 10 Minutes: required in short time by the thermal units in service.

- 1 hour: provided by the thermal units in service as well as the diesel units which can be switched on and off in short time.

III. Reserve Capacity And Unit Dispatching

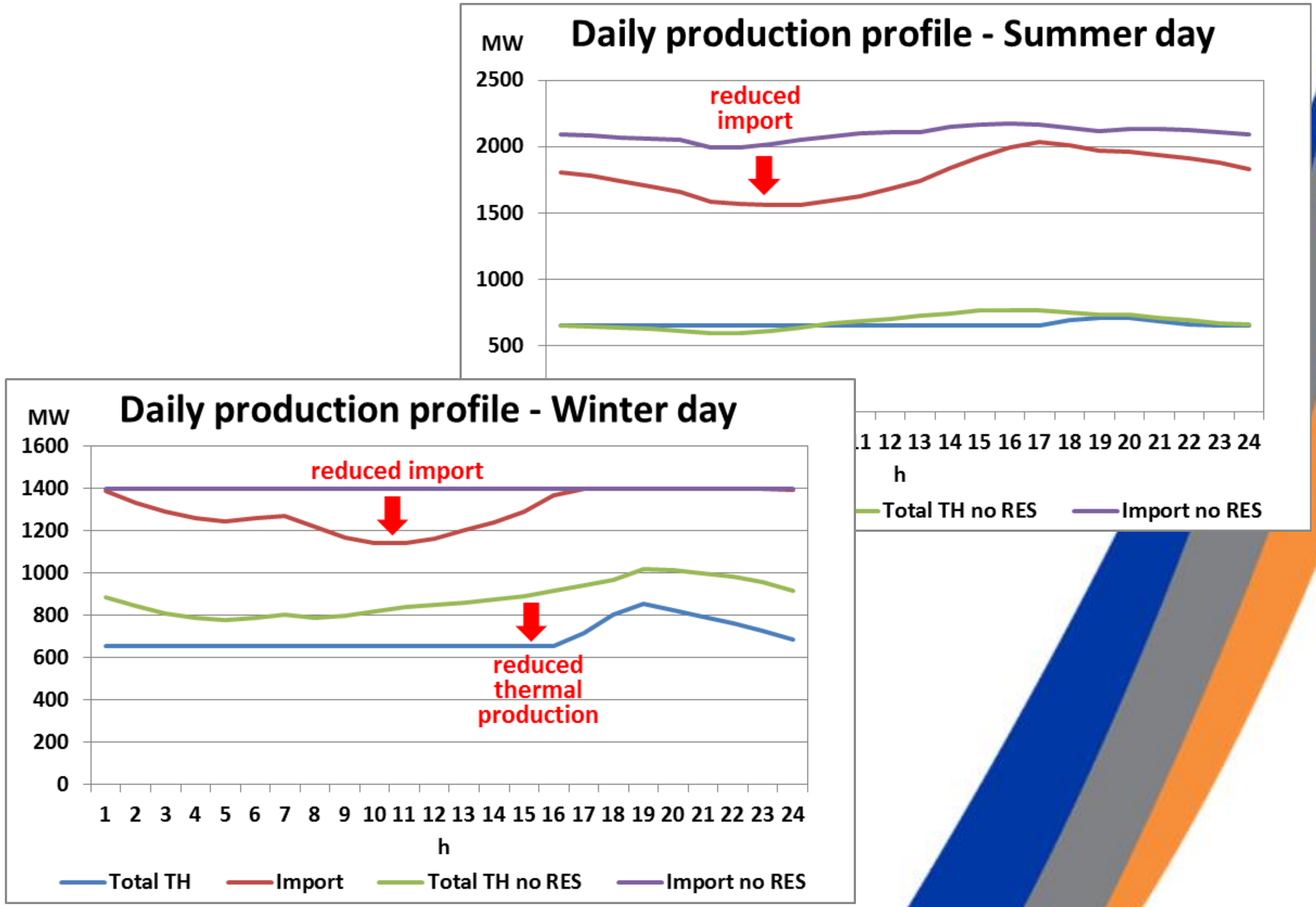
- The wind production has a higher influence one the reserve due to the rapid variability.
- In NEOA, the 1 hour reserve increases by 62% in 2018 and 22% in 2024
- In NWOA, the 1 hour reserve increases by 173% in 2018 and 185% in 2024
- The high impact in the western part due to the high wind capacity installed.



Long term operating reserve

III. Reserve Capacity And Unit Dispatching

- The RE power plants change the operation conditions of the system in the Northern region.
- RE power plants reduce the production of the expensive thermal units.
- Import from the rest of the system is also decreased due to introducing the RE energy in the northern region.



Daily Production Profiles in The Northern Region

IV. Power System Analysis

RE impact on the static and dynamic security have been evaluated using PSSE software

Scenarios of RE production:

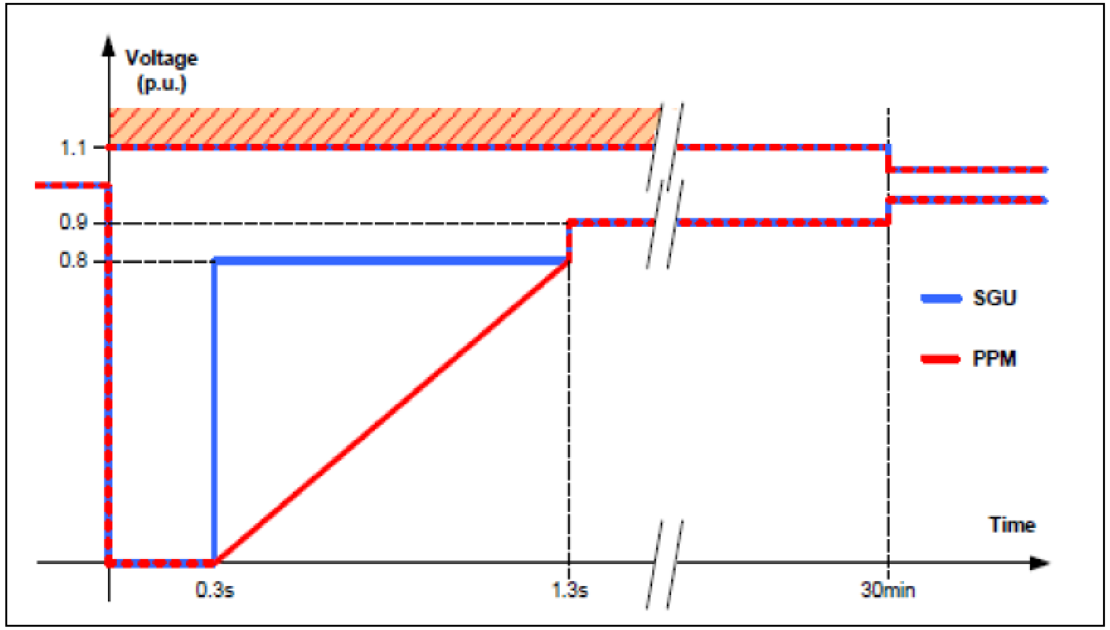
- Base Scenarios:
  - Peak Load: 30% from wind farms and 45% from PV
  - Minimum load: 40% from Doumat Al Jandal, 60% from Midyan and zero production from PV
- Extreme Scenarios:
  - Peak Load: 30% from wind and 80% from PV
  - Minimum load: 88% from wind and zero production from PV
- 100 % production from the largest wind farm and PV power plants (Midyan and Skaka)

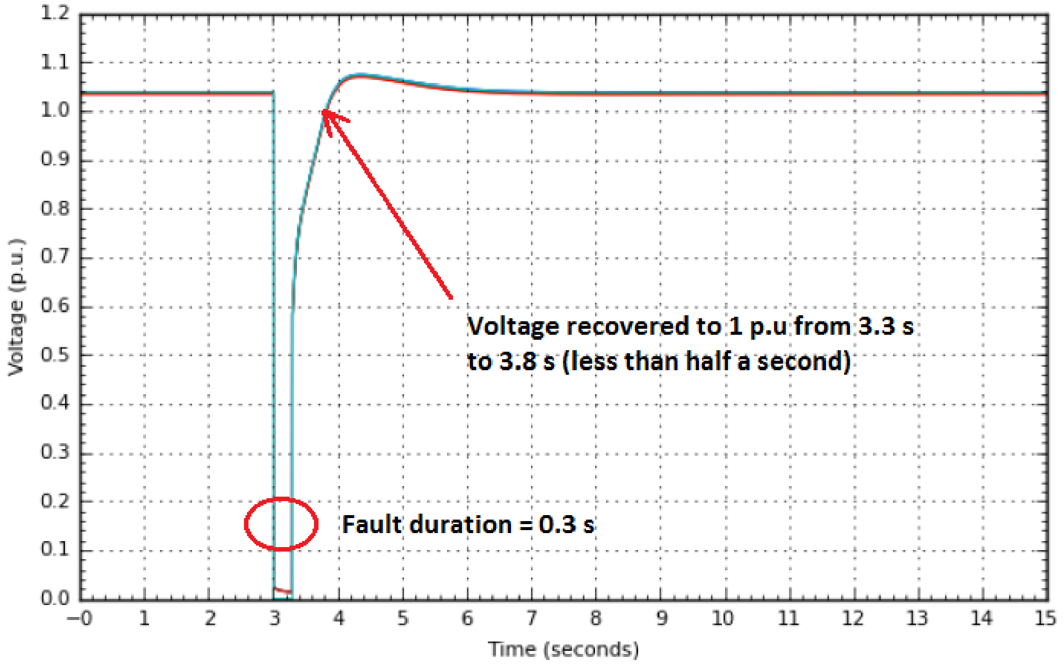
IV. Power System Analysis

Steady State and Dynamic Analysis:

Analysis	Conclusion
Contingency check	N-1, N-2 and the voltage and transient stability criteria have been met.
Static and Dynamic analysis	RE integration do not negatively impact on the static security and dynamic behavior of the Northern region.
Voltage Control	RE plants are able to control the voltage profile in static conditions and support the voltage recovery after faults
Spinning Reserve Impact	No significant impact on the spinning reserve as the RE capacity is less than 2% of the generation capacity of KSA.

IV. Power System Analysis





Low Voltage Ride Through - Comparison between Grid code requirement and the dynamic simulation for Rafha PV

IV. Power System Analysis

Power Evacuation Analysis:

- The evacuation of all RE plants is acceptable, except Midyan production which is critical in the case of Duba-Midyan 380 kV D/C outage.
- Therefore, automatic curtailment of the production in Midyan is needed in this case. This scheme shall limit the output of the wind farm to 240 MW after the fault.
- This solution is preferable instead of limiting the installed capacity of the wind farm or to add additional 380 kV lines.
- The expected curtailed energy production is below 0.3% in 2018 and 0.4% in 2024.

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V. Economic Impact of RES Integration

Two economic assessments have been carried out:

- The Levelized Cost of Electricity (LCOE).
- The operational costs saving of the system

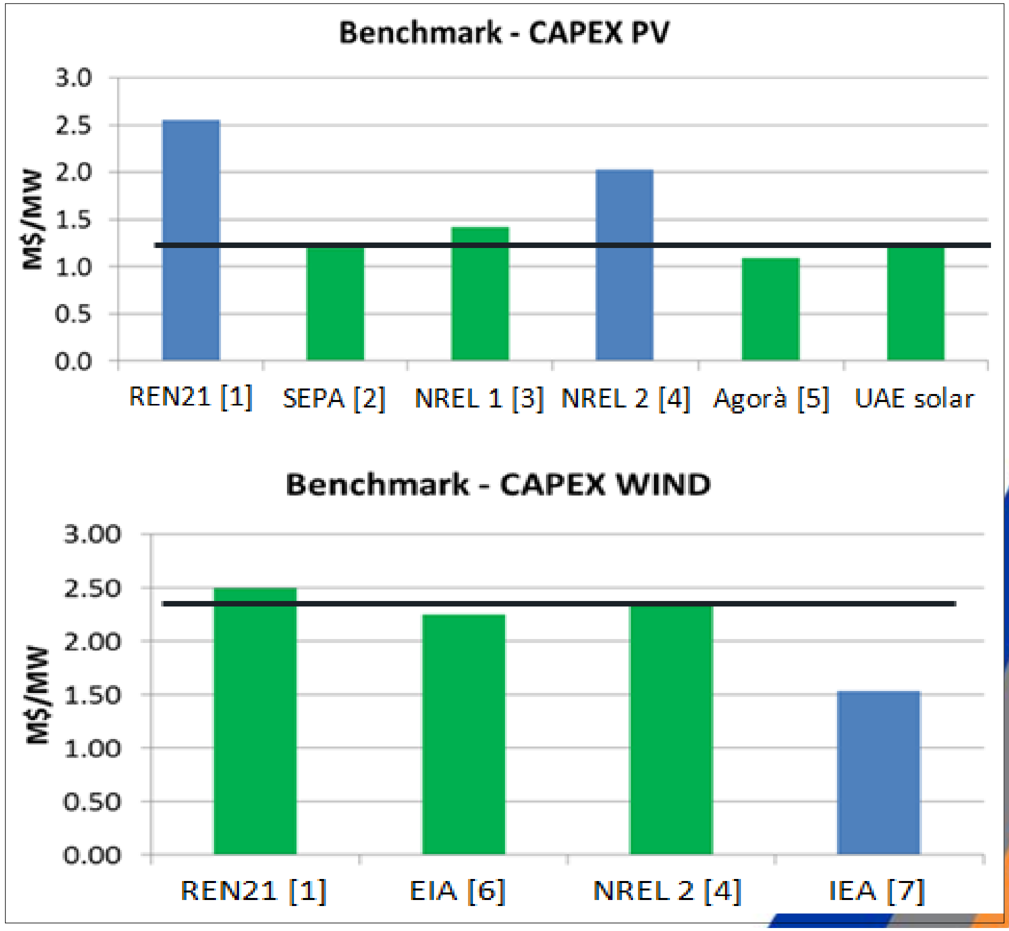
V. Economic Impact of RES Integration

<u>Benchmarking of PV and wind farms CAPEX/OPEX:</u>

- ➢ REN 21: The Renewable Energy Policy Network for the 21st Century.
- ➢ SEPA: Solar Electric Power Association.
- ➢ NREL: The National Renewable Energy Laboratory
- ➢ IEA: The International Energy Agency

Item	PV	Wind
CAPEX [M$/MW]	1.24	2.36
OPEX [M$/MW/year]	0.019	0.033

CAPEX/OPEX of Wind Farms and PV Plants



Benchmarks CAPEX of Wind Farms and PV plants

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V. Economic Impact of RES Integration

<u>Levelized Cost of Electricity (LCOE):</u>

Investment
Operations and Maintenance costs
Fuel cost
Discount Rate
De-rate Factor
Electricity production
Lifetime of the project

Technology	LCOE [$/MWh]
PV (All plants)	56.9
WIND (Midyan)	48.6
WIND (Doumat)	59.3

Results of The LCOE Calculation

V. Economic Impact of RES Integration

The operational costs saving of the system

Year	Savings due to	Amount (MSR)	Total (MSR)
2018	Reduction of the operating costs of local thermal units	130	254.3
	Reduction of Import from the rest of the system	124.3	
2024	Increasing the export from NOA to WOA and COA	144.3	183
	Reduction of the operating costs of local thermal units	38.7 (*)	

(*) The more efficient NOA generation in 2024 leads to a reduced saving in the local production compared to 2018

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Thank You!

Additional Slides

V. Economic Impact of RES Integration

Levelized Cost of Electricity (LCOE):

$$\text{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t + OM_t + F_t}{(1+DR)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+DF)^t}}$$

I_t = Investment
OM_t = Operations and Maintenance costs
F_t = Fuel cost
DR = Discount Rate
DF = De-rate Factor
E_t = Electricity production
n = Economic lifetime of the plant

Technology	LCOE [$/MWh]
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Results of The LCOE Calculation