MEDELEC Annual Meeting

New drivers for the deployment of interconnections in the MENA region: outcomes from recent CESI analyses

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Summary

- Mediterranean interconnections: where are we now?
- North-North interconnections: key drivers
- South-South and North-South interconnections: key drivers
- Long term perspectives: EU-MENA integration in a decarbonised power system
- Conclusions and recommendations
Overview of the power system pools around the Mediterranean basin

Two synchronous power pools:
- ENTSO-E, Turkey, Maghreb
- Mashrek

Isolated systems:
- Israel; Cyprus; Crete
- Malta (synchronised with ENTSO-E on April 9th, 2015)

Demand: 3255 TWh
Installed capacity: 998 GW

ENTSO-E

Demand: 242 TWh
Installed capacity: 57 GW

Turkey

Demand: 103 TWh
Installed capacity: 23 GW

South & East Med Countries

Demand: 47 TWh
Installed capacity: 13 GW

Israel

Demand: 294 TWh
Installed capacity: 50 GW

South & West Med Countries
Euro-Med region: axes of development

Different drivers prompting interconnections along the various axes

Summary

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- North-North interconnections: key drivers
- South-South and North-South interconnections: key drivers
- Long term perspectives: EU-MENA integration in a decarbonised power system
- Conclusions and recommendations
North-North axis: key facts

- Demand stagnation across Europe, negative in some countries

**ELECTRICITY CONSUMPTION [TWh]**

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENTSO-E</td>
<td>3 360</td>
<td>3 339</td>
<td>3 336</td>
<td>3 255</td>
</tr>
</tbody>
</table>

**Load demand trend**: four visions recently formulated by ENTSO-E

<table>
<thead>
<tr>
<th>Vision (year 2030)</th>
<th>Demand incl. Pumping (TWh)</th>
<th>RES penetration</th>
<th>CO2 reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1 Slow Progress</td>
<td>3610</td>
<td>41%</td>
<td>42%</td>
</tr>
<tr>
<td>V2 Money Rules</td>
<td>3712</td>
<td>40%</td>
<td>36%</td>
</tr>
<tr>
<td>V3 Green Transition</td>
<td>4167</td>
<td>49%</td>
<td>62%</td>
</tr>
<tr>
<td>V4 Green Revolution</td>
<td>4327</td>
<td>60%</td>
<td>78%</td>
</tr>
</tbody>
</table>

**Peak demand evolution**: slow growth in the next decade. CAGR of January peak load =1% per year.
Decarbonisation targets in Europe

**EU targets**

<table>
<thead>
<tr>
<th>Year</th>
<th>Target 1</th>
<th>Target 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>20% CO₂ reduct.</td>
<td>20% RES</td>
</tr>
<tr>
<td>2030</td>
<td>“at least” 40% CO₂ reduct.</td>
<td>27% RES</td>
</tr>
<tr>
<td>2050</td>
<td>80% / 95% CO₂ reduct.</td>
<td></td>
</tr>
</tbody>
</table>

*Proposed in January 2014 by the “Barroso EC; approved by the European Council on Oct. 24th*

**Change in Generation mix in Europe**

**Longer term trends**

- **Vision 1**: Slow progress
- **Vision 2**: Money rules
- **Vision 3**: Green transition
- **Vision 4**: Green revolution

**2050 Energy goals**

- **920 GW**
- **1150 GW**
- **647 GW**

*Installed RES capacity, compared to less than 200 GW today*

Source: ENTSO-E and CESI elaborations
Grid development in Europe: drivers

1\textsuperscript{st} driver: integration of RES generation

The dramatic change in the generation mix is prompting for substantial investments in the transmission grids.

The TYNDP 2014 of ENTSO-E estimates about \textbf{150 b€} of investments by 2030 in transmission grid expansion.

The vast majority of new transmission reinforcements is related to the integration of RES generation: “approximately 80\% of the projects of pan-European significance help integrate RES either by directly connecting RES or by transporting RES power to end-consumers” \footnote{ENTSO-E TYNDP 2014}

* Grid development mix in Europe: drivers

2\textsuperscript{nd} driver: market integration

According to the EC, a full day-ahead market integration shall be achieved by 2014.

Market coupling already adopted from the Iberian peninsula to Nordpool, Italy joined the EU market coupling in Febr. 2015,… nevertheless price differentials between market zones occur frequently.

Need for cross-border network reinforcements to increase the “Net Transfer Capacity”
Effect on wholesale price differentials vs cross-border NTC (1/2)

Scenario 2014

- Net Importer
- Net Exporter
- Average Spot Price [€/MWh]
- Net Flow [TWh]

<table>
<thead>
<tr>
<th>Country</th>
<th>Net Importer</th>
<th>Net Exporter</th>
<th>Average Spot Price [€/MWh]</th>
<th>Net Flow [TWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BE</td>
<td>80</td>
<td>82</td>
<td>52</td>
<td>82</td>
</tr>
<tr>
<td>CH</td>
<td>52</td>
<td>35</td>
<td>29</td>
<td>35</td>
</tr>
<tr>
<td>SL</td>
<td>38</td>
<td>28</td>
<td>31</td>
<td>28</td>
</tr>
<tr>
<td>AT</td>
<td>43</td>
<td>57</td>
<td>53</td>
<td>57</td>
</tr>
<tr>
<td>NL</td>
<td>998</td>
<td>2014</td>
<td>2020</td>
<td>2030</td>
</tr>
<tr>
<td>P</td>
<td>15</td>
<td>10</td>
<td>7</td>
<td>13</td>
</tr>
</tbody>
</table>

Source: ENTSO-E; Terna and CESI elaborations

- Bernet peninsula still relatively isolated
- Italy: 13% of energy is imported

Effect on wholesale price differentials vs cross-border NTC (2/2)

Pan-European forward simulation (2030 Vision 1 Slow Progress ENTSO-E)

- Net Importer
- Net Exporter
- Average Spot Price [€/MWh]
- Net Flow [TWh]

<table>
<thead>
<tr>
<th>Country</th>
<th>Net Importer</th>
<th>Net Exporter</th>
<th>Average Spot Price [€/MWh]</th>
<th>Net Flow [TWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BE</td>
<td>82</td>
<td>80</td>
<td>82</td>
<td>80</td>
</tr>
<tr>
<td>CH</td>
<td>82</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>SL</td>
<td>35</td>
<td>38</td>
<td>35</td>
<td>38</td>
</tr>
<tr>
<td>AT</td>
<td>57</td>
<td>43</td>
<td>57</td>
<td>43</td>
</tr>
<tr>
<td>NL</td>
<td>1,117</td>
<td>1,182</td>
<td>1,117</td>
<td>1,182</td>
</tr>
<tr>
<td>P</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: CESI simulation on ENTSO-E Vision 1; assumptions: Gas 10.28 Eur/Net GJ, CO2 31 Eur/ton; Lignite 0.44 Eur/Net GJ, Nuke 0.377 Eur/Net GJ

- Balanced mix of fossil and RES generation in Germany
- France keeps its role of export leadership
- Italy: slight increase of CCGT operating hours due to growth of CO2 prices

Illustrative not exhaustive
North-North interconnections: achievements and developments

Piedmont-Savoy
- 2x600 MW HVDC-VSC
- Length: 180 km – whole link in cable (XLPE)
- Cable laying in tunnels: Fréjus (10 km), Baselines (5 km) and dozen of motorways viaducts
- Estimated CAPEX: 1,3 b€

Italy-Montenegro
- 2x500 MW HVDC-LCC
- Length: 415 km
- Cable laying: 390 km submarine
- Estimated CAPEX: 0,8 b€

France-Spain
- 2x1000 MW HVDC-VSC
- Length: 64,5 km – whole link in cable (XLPE)
- Cable laying in tunnels: Pertus (8,5 km) to cross Pyrenees
- CAPEX: 0,7 b€ (225 M€ from EEPR)
- In operation since April 2015

Euroasia Interconnector
- 2x1000 MW HVDC-VSC (4 terminals) linking: Athens-Crete-Cyprus-Israel
- Length: ±1500 km – max sea depth ± 2700 m
- Estimated CAPEX: 5,3 b€

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- South-South and North-South interconnections: key drivers (part 1)
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### Evolving drivers justifying North-South interconnection developments

- **1990-2005**: power export from Africa to Italy generated from NG
- **2005-2010**: power export/import from Africa to Italy generated from a mix of RES and NG
- **2010 onward**: capacity surplus in Italy and most of Europe - power export from Europe to Africa to cope with a sharp demand growth in Africa

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### Surge in power demand in the Southern Med countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Yearly Load (TWh)</th>
<th>Yearly Load %</th>
<th>CAGR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>45.6</td>
<td>117.6</td>
<td>4.7%</td>
</tr>
<tr>
<td>Egypt</td>
<td>142.6</td>
<td>439.8</td>
<td>5.5%</td>
</tr>
<tr>
<td>Libya</td>
<td>28.7</td>
<td>100.6</td>
<td>6.2%</td>
</tr>
<tr>
<td>Morocco</td>
<td>27.4</td>
<td>74.4</td>
<td>4.9%</td>
</tr>
<tr>
<td>Tunisia</td>
<td>14.7</td>
<td>39.9</td>
<td>4.9%</td>
</tr>
<tr>
<td><strong>TOTAL Demand</strong></td>
<td><strong>259.0</strong></td>
<td><strong>772.3</strong></td>
<td><strong>5.4%</strong></td>
</tr>
</tbody>
</table>

- Impressive demand growth, both in energy and peak load
- Similar situation to what Italy and other Western European Countries experienced in the ‘60s

**Priority**: to achieve generation adequacy and a reliable transmission system
Targets of power generation from RES

RES penetration Targets in North Africa

<table>
<thead>
<tr>
<th>Country</th>
<th>Penetration rate(*)</th>
<th>Target year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morocco</td>
<td>42%</td>
<td>2020</td>
</tr>
<tr>
<td>Algeria</td>
<td>40%</td>
<td>2030</td>
</tr>
<tr>
<td>Tunisia</td>
<td>13.5%-22%(**)</td>
<td>2030</td>
</tr>
<tr>
<td></td>
<td>30% (***)</td>
<td>2030</td>
</tr>
<tr>
<td>Libya</td>
<td>10%</td>
<td>2025</td>
</tr>
<tr>
<td>Egypt</td>
<td>20%</td>
<td>2020</td>
</tr>
</tbody>
</table>

(*) RES generation over internal demand, yearly ratio
(**) previous scenario
(***) new scenario

Priority: how to fit RES generation in the North African power systems?

Euro-Med area: facts in summary

- Stagnating/declining demand
- Targets for RES generation integration
- Power market integration
- Robust demand growth
- RES generation integration
- Robust demand growth
- Targets for RES generation
- Uneven distribution of NG & oil resources
- Moderate demand growth
- Huge NG resources
Common South-South and South-North Integration: drivers and existing barriers

Drivers:
- Rapid demand growth
- Uneven distribution of primary energy resources
- Policy for RES generation deployment

Existing Barriers
- Lack of shared rules for the Cross-Border electricity Trading prevents the full exploitation of the cross-border lines
- Subsidised electricity prices are a further barrier for the free trade of electricity among the SEMC
- Lack of transparency
- The “political factor”

South-North Integration: drivers and existing barriers

Drivers:
- Possibility of enhancing SoS for the SEMC
- Strong political commitment from the EU for energy integration with neighbouring region
  - Clear legislative and regulatory framework:
Key messages from recent feasibility studies

**Algeria-Italy feasibility study (2012-2013)**

- Year: 2020
- Transfer capacity: 600/1000 MW
- Submarine section length: \( \approx 350 \) km
- Max sea depth: \( \approx 2000 \) m
- Yearly load:
  - Algeria: \( \approx 85 \) TWh
  - Italy: \( \approx 370 \) TWh
- NG prices:
  - Algeria: 8,8 $/GJ
  - Italy: 10,9 $/GJ

**Algeria-Italy feasibility study: results**

**Socio-economic Welfare** sensitivity variation with respect to the cable size

Welfare variations respect to “no cable” scenario [M€]
Algeria-Italy feasibility study: results

Flows Algeria -> Italy

Energy exchanges duration curve with losses [MWh]

In a short term horizon the south-north HVDC cable is exploited bidirectionally.

Key messages from recent feasibility studies

Tunisia-Italy feasibility study (2nd semester 2014)

- Years: 2020-2025
- Transfer capacity: 600 MW
- Submarine section length: ≈ 195 km
- Max sea depth: ≈ 600 m
- Yearly load (2020-2025):
  - Tunisia: ≈ 25-32.5 TWh
  - Italy: ≈ 330-350TWh
- NG prices (2020-2025):
  - same in the two countries: 10.9-11.3 $/GJ
Key messages from recent feasibility studies

**Tunisia-Italy feasibility study (2nd semester 2014)**

Results still under discussion (main outcomes):
- Italy is a net exporter towards Tunisia
- Cable is mostly used in a mono-directional way Europe→ Africa
- Benefits shared not only between the two parties, but also with other EU countries (study carried out simulating the pan-European power market)

Key messages from recent feasibility studies

- The assessment of **benefits arising from South-North interconnections** should be quantitatively evaluated with a methodology already shared among European countries
- **Market mechanisms** compliant with European policies should be simulated
- Though many SEMC are endowed with large fossil fuel resources and RES potential, **SEMC are expected to become net importers** during some periods of the year (or even over the whole year) accepting to trade energy at wholesale markets at international prices
- Possible **internal subsidies** based on transparent tariff schemes are allowed as long as they do not distort the wholesale market prices
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- South-South and North-South interconnections: key drivers (part 2)
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- Conclusions and recommendations

Role of Interconnection: perspectives in SEMC

<table>
<thead>
<tr>
<th>Years</th>
<th>Role of interconnections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-now</td>
<td>- Reserve and mutual support facing large perturbations</td>
</tr>
<tr>
<td>2000-now</td>
<td>- Energy exchanges based on pre-established contracts (usually long term contracts)</td>
</tr>
</tbody>
</table>

- Borders: Spain-Morocco; Egypt-Jordan-Syria-Lebanon (up to 2011)
- Cross-border exchanges based on short-mid term contracts
- Mean to foster a higher penetration of RES
### South-South interconnections (1/2)

Main sections to be strengthened in North Africa

- Commissioning of 400 kV between AL-TN
- Construction of 400 kV north-south corridor in TN
- Back-to-back systems either at TN-LY or LY-EG border (or HVDC line EG-LY)
- Construction of a 500 kV AC line between EG-LY (or, alternatively) a HVDC line

### South-South interconnections (2/2)

Main sections to be strengthened in Eastern Mediterranean region

- Construction of a second EG-Gaza Strip 220 kV line; JO-West Bank 400 kV line
- Construction of a back-to-back in Birecik (TR)
- Construction of a second JO-SY 400 kV link
- Construction of a HVDC biterminal link JO-KSA
- Construction of a second EG-JO 400 kV link
- Construction of a HVDC triterminal link EG-KSA
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Medgrid - Central Corridor

Preferred links between Maghreb and Italy

HVDC:
- 1 GW bipoles modules
- LCC technology

Undersea cables:
- 220 to 900 km
- 700 to 2000 m under sea level
### Selected Solutions: main characteristics

<table>
<thead>
<tr>
<th>Link name</th>
<th>Trucks</th>
<th>Under sea</th>
<th>Terrestrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tun - Sic</td>
<td>Tunisia to South West Sicily</td>
<td>192 km ≤700 m</td>
<td>32 km</td>
</tr>
<tr>
<td>Alg - Laz</td>
<td>Algeria to South Sardinia</td>
<td>202 km ≤2000 m</td>
<td>2 km</td>
</tr>
<tr>
<td>Alg - Lig</td>
<td>Algeria to South Sardinia</td>
<td>480 km ≤1500 m</td>
<td>2 km</td>
</tr>
<tr>
<td>Alg - Lig</td>
<td>Algeria to South Sardinia</td>
<td>262 km ≤2000 m</td>
<td>2 km</td>
</tr>
<tr>
<td>Alg - Lig</td>
<td>South Sardinia to Corseca</td>
<td>325 km ≤700 m</td>
<td>-</td>
</tr>
</tbody>
</table>

### Top ranked solutions

**Scenario 1: Yellow path**

**Scenario 2: Yellow and green path**

**Scenario 3: Yellow, green and red path, or yellow and double red path**

Source: MedGrid

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### Long term perspectives: the Dii initiative

**Energy exchanges** (in TWh)

**EU-MENA exchanges** (in TWh)

Source: Dii
Long term perspectives: the Dii initiative

Power transfer capacities (in GW)

Assumptions for new e-highways:
- HVDC technology
- Cables:
  - Submarine links: 100% cables
  - EU: 50% OHL / 50% underground cables
  - MENA: 90% OHL / 10% underground cables

Estimated investments

<table>
<thead>
<tr>
<th>Transmission line / cable investments</th>
<th>Converter investments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (b€)</td>
<td>Annual (b€/yr)</td>
</tr>
<tr>
<td>436</td>
<td>32.2</td>
</tr>
<tr>
<td>Total (b€)</td>
<td>Annual (b€/yr)</td>
</tr>
<tr>
<td>118</td>
<td>8.7</td>
</tr>
</tbody>
</table>

Source: Dii
Summary

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Conclusions and recommendations

South-South:

- **South-South integration is a key priority** to face the demand rapid growth and foster the implementation of the RES generation policies\(^1\)
- **Existing “south-south” barriers should be swiftly overcome**: many of the barriers are costless, such as the enhancement of transparency.
- A **progressive reduction/elimination of internal subsidies** applied indiscriminately to all categories of consumers is also important to foster power exchanges.
- **Agreement on rules for the cross-border trading of electricity** is a further priority.
- When deciding new interconnections, **coordinated system analyses** should be undertaken since a reinforcement across a border can have an impact on the whole system.

\(^1\) South-North interconnections can also improve SoS in Southern Med countries
Conclusions and recommendations

South-North:

- **A legislative framework on the European side exists** to favour power exchanges and implement new interconnectors with the neighbouring regions
- **Rules for the cross-border trading of electricity** compliant with the EU standards should be adopted by the neighbouring countries
- In general, **reciprocity** for the international energy exchanges should be applied: e.g. considering CO₂ emission costs when trading electricity, whilst each SEMC is free to disregard this cost when formulating the electricity price in its internal market
- South-North transmediterranean interconnections will be exploited in the mid-term mostly for **power export from Europe**: SEMC should be ready to **purchase energy at international prices**
- Further **technological developments concerning high power and deep sea cables** are welcomed to overcome the existing limits on the maximum feasible sea depth for cable laying