Second Euro-mediterranean
Rendez-vous on Energy

January 6th 2015
European Parliament, Brussels



Feasibility studies for Euro-Mediterranean interconnections at year 2020

COULOIR CENTRE (Algérie - Tunisie - Libye - Italie)

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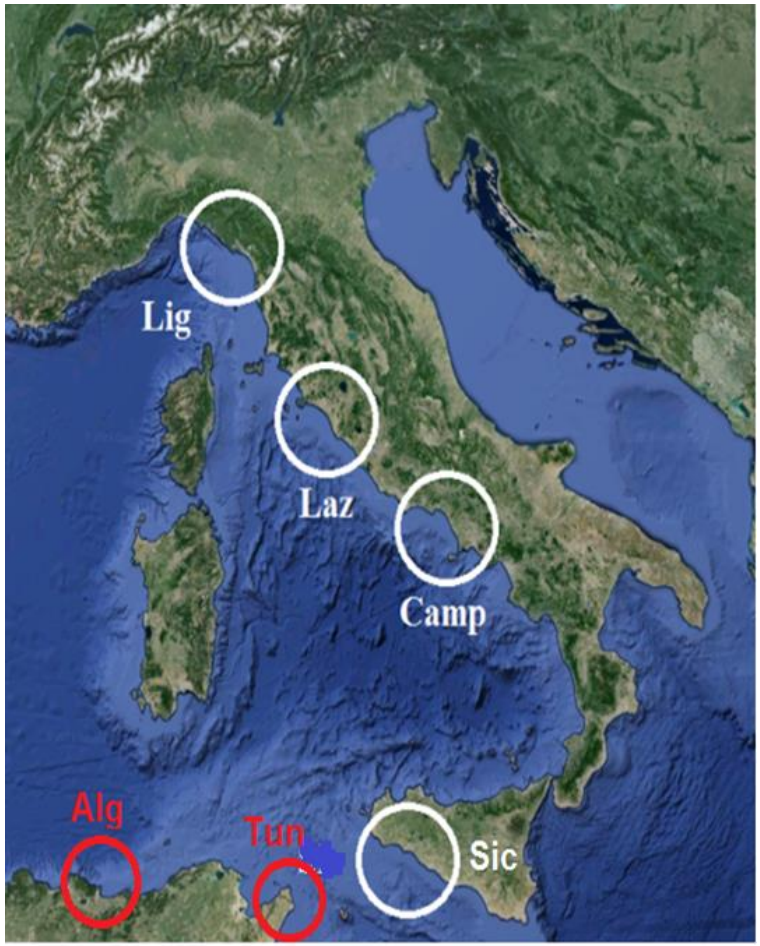
CENTRAL CORRIDOR
POWER TRANSFER FROM NORTH AFRICA TO EUROPE VIA ITALY

- → Export from Northern Africa
- → Wheeling through Italy
- → DC links across Mediterranean Sea
- → Ranking of projects based on technical-economic-environmental issues
- → Check on North to South transit



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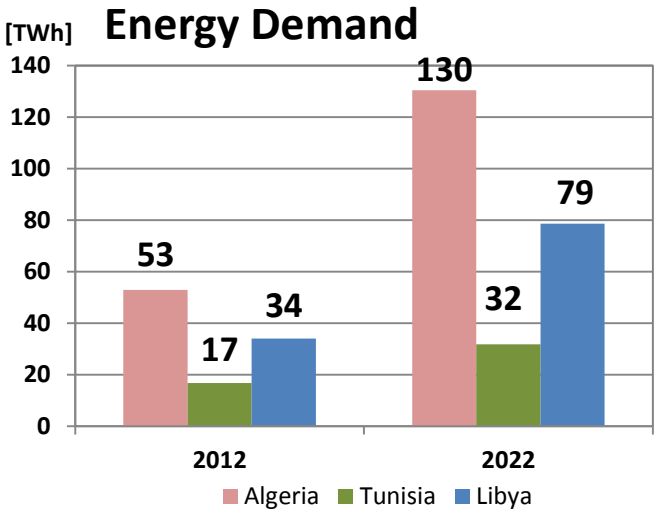
TREND OF ELECTRICITY DEMAND IN MAGHREB

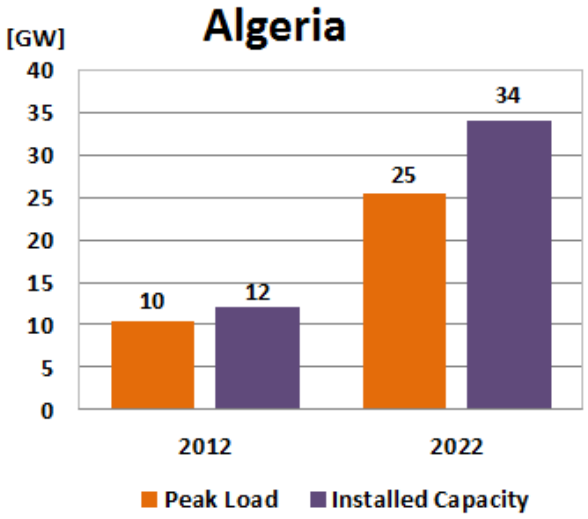
- Peak Load growth: 20.5 GW (CAGR 8.7%)
- New Installed Capac.: 35 GW (CAGR 9.2%)

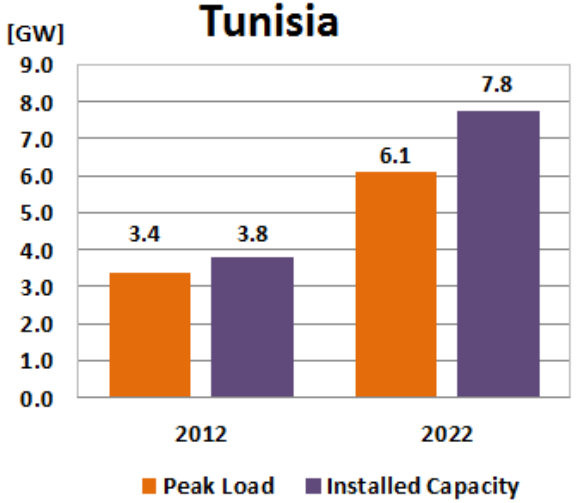


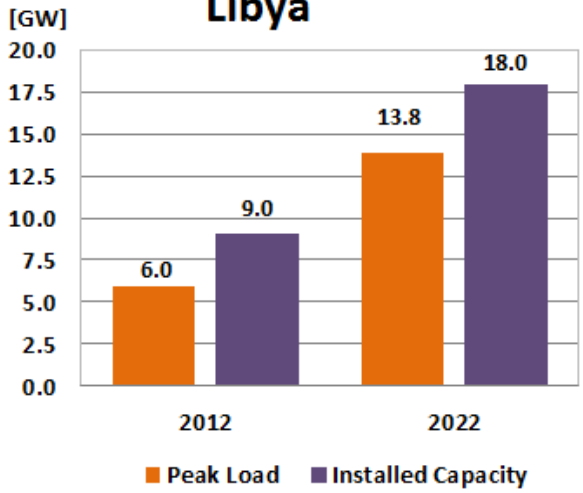
AL: +9,4%

TN: +6,5%

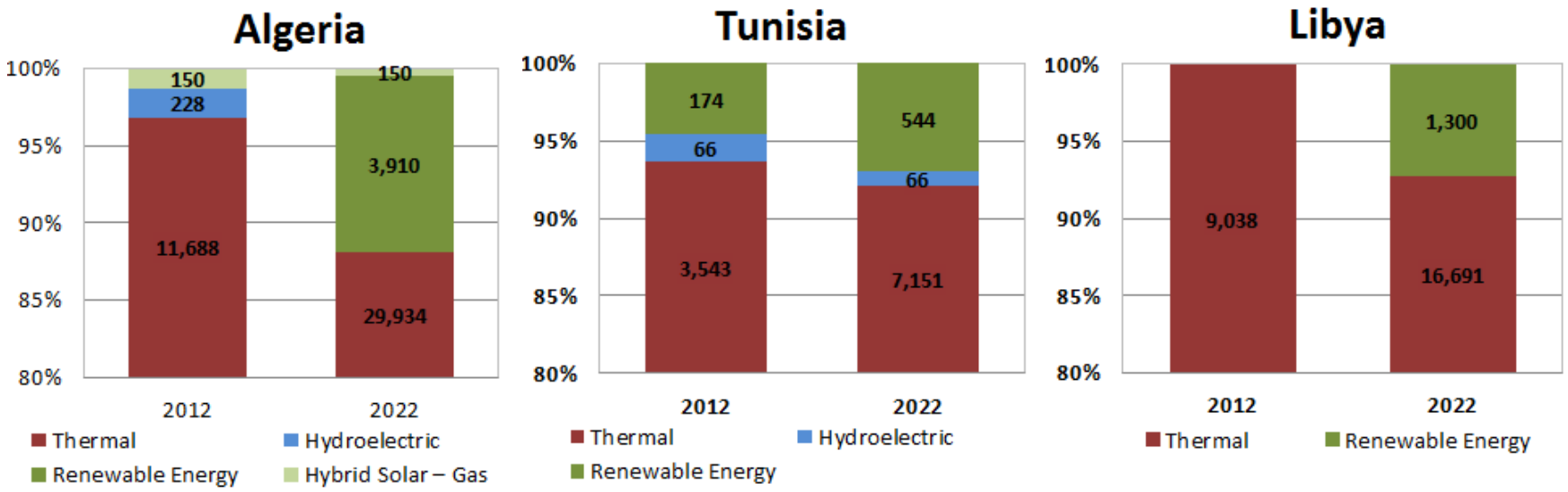
LY: +8,8%







EVOLUTION OF THE GENERATION MIX IN MAGHREB



RES capacity from 600 MW to 6000 MW in ten years

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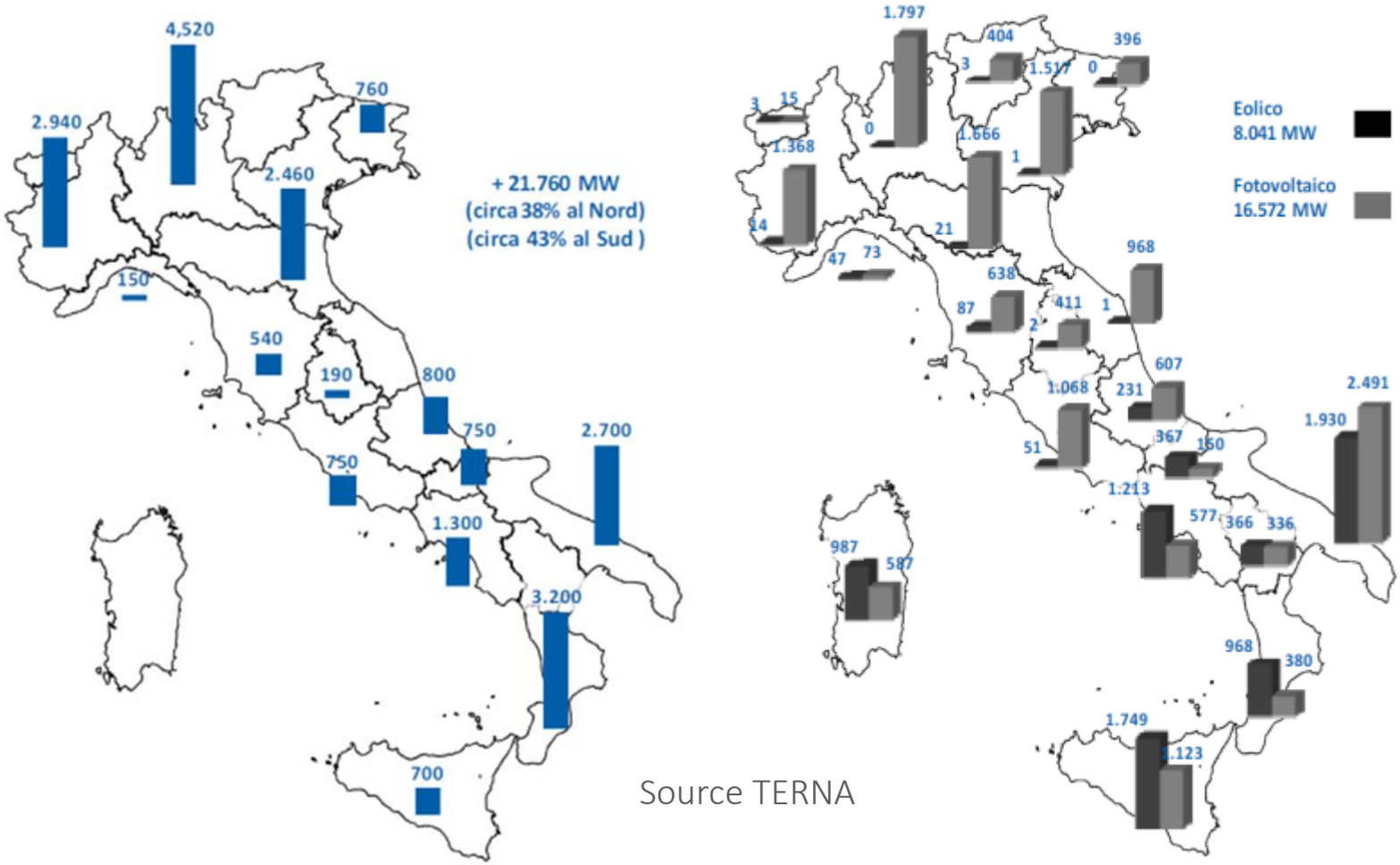
ITALIAN REFERENCE SYSTEM

→ +22 GW of conventional capacity in last ten years, +3 GW by 2022

→ +38 GW of RES capacity up to 2022



Source TERNA

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ITALIAN REFERENCE SYSTEM

→ Internal reinforcements to support RES production

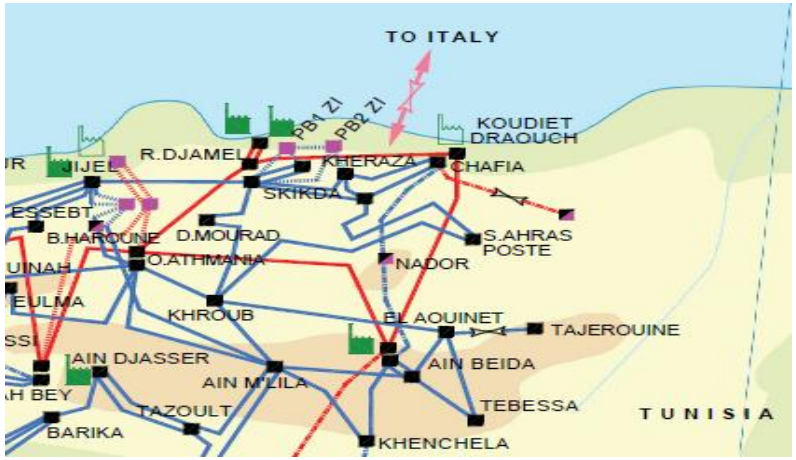
→ Reinforcing interconnections with neighbouring countries

Source TERNA

IMPACT OF POWER EXPORT IN NORTHERN AFRICA CONNECTION OF THE HVDC CONVERTER STATIONS

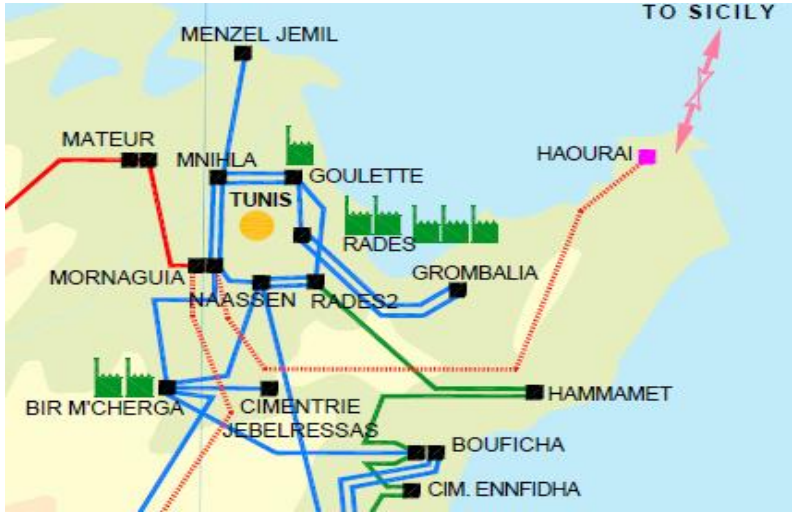
ALGERIA

- HVDC converter station connected to the 400/220 kV substation of **Cheffia** with **two 400 kV overhead lines of 44 km each**
- **third 400 kV line** necessary for power transfer of 2 GW from Algeria to Italy



TUNISIA

- HVDC Converter Station connected to the 400/220 kV substation of **Mornaguia** with **two 400 kV lines of 150 km each**
- **third 400 kV line** for power transfer of 2 GW from Tunisia to Italy



IMPACT OF POWER EXPORT IN NORTHERN AFRICA INTERCONNECTIONS

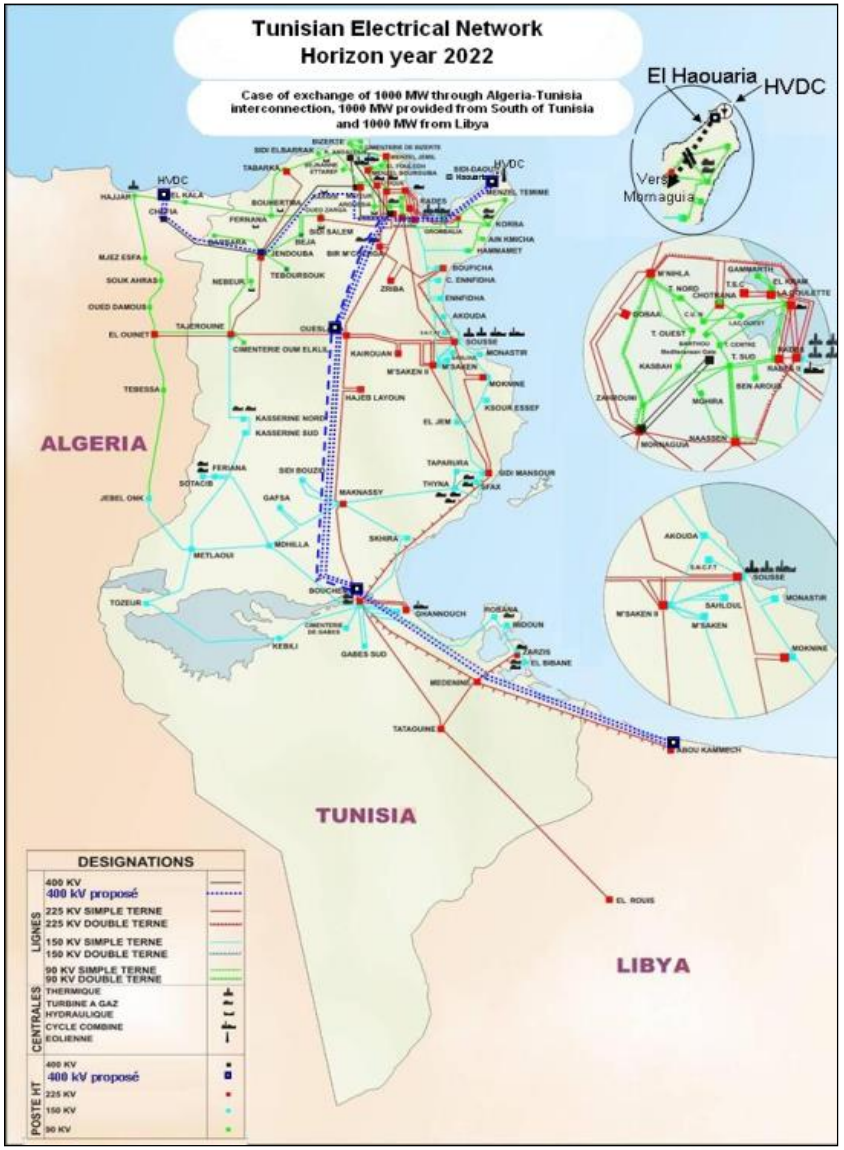
→ Increase transfer capacity between the countries

→ current limit 300 MW between Algeria and Tunisia

→ No interconnections between Tunisia and Libya in operation

IMPACT OF POWER EXPORT IN NORTHERN AFRICA INTERCONNECTIONS

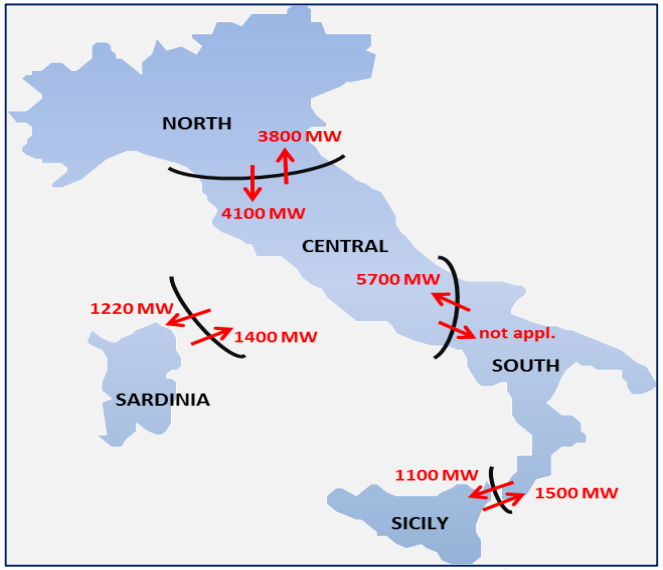
- second 400 kV line (Cheffia – Jendouba 90 km) is needed for 1000 MW transfer between Algeria and Tunisia
- new 400 kV line Jendouba – Mornaguia, 170 km is required for 1000 MW transfer from Algeria through Tunisia
- two 400 kV lines (420 km each) from South Tunisia (Bouchema) to North (Mornaguia) in case of export from Southern area or Libya
- third 400 kV line in case of 2000 MW transfer from South to North of Tunisia and new Libya-Tunisia interconnection with two 400 kV lines (210 km each)



IMPACT OF POWER WHEELING IN ITALY COMPETITION WITH RES

- Large amounts of RES production from South to Central & Northern Areas along two main corridors
- Power Injections from Maghreb are in « competition » with the usual transits South to North through the « critical sections » of the Network

- **Reinforcement of North-South backbones**
  - **350 / 390 km of new OHLs**



IMPACT OF POWER WHEELING IN ITALY
INCREASE OF JOULE LOSSES DUE TO THE SUPERIMPOSED WHEELING

Increase of transmission losses due to a power wheeling of 1000 MW

→ AC Italian Network
- Variant “1000 Sicily” (+697 GWh/yr)
- Variant “1000 Lazio” (+460 GWh/yr)
- Variant “1000 Liguria” (+60 GWh/yr)

→ AC Maghreb Network
- Variant “1000 North Tunisia” (+6 GWh/yr)
- Variant “1000 South Tunisia” (+222 GWh/yr)
- Variant “1000 Algeria” (+51.8 GWh/yr)

For higher power Wheeling (e.g. 2000 MW) the increase is higher

→ AC Italian Network
- Variant “2000 Lazio” (+830 GWh/yr)

→ AC Maghreb Network
- Variant “2000 Algeria” (+374 GWh/yr)

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PREFERRED PATHS IN THE MEDITERRANEAN SEA

Sending ends

→ Cheffia - Algeria

→ Mornaguia - Tunisia

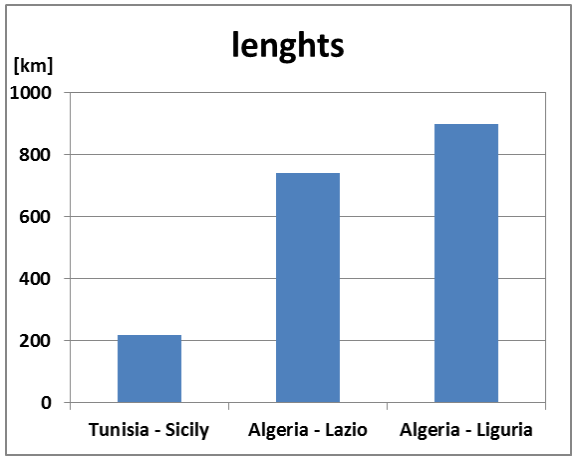
Receiving ends

→ along Italian coasts

Undersea cables

→ 220 to 900 km

→ 700 to 2000 m under sea level



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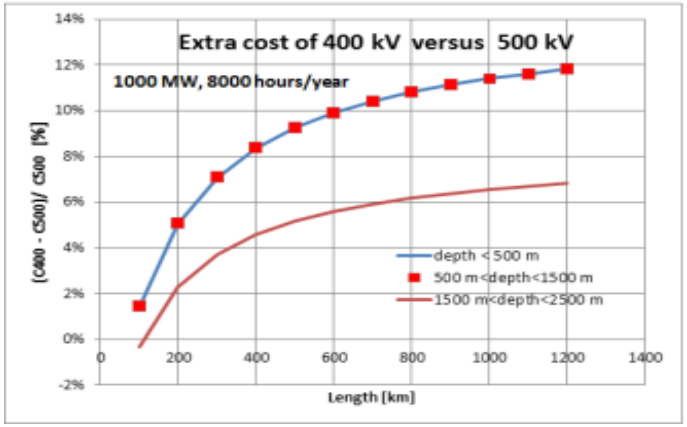
CHARACTERISTICS OF THE HVDC LINKS
CONVERTER TECHNOLOGY AND CABLES

- 1000 MW with a bipolar link, mono-polar operation via sea return in case of one pole failure
- fast or frequent power reversal and multi-terminal solutions not needed
- Voltage support not needed

Adopted solution

- LCC converters and MI cables independently on the maximum depth of the link
- 500 kV solution 10% cheaper than 400 kV



Availability at 2022 of a vessel for laying the cable at 2000 m depth is questionable

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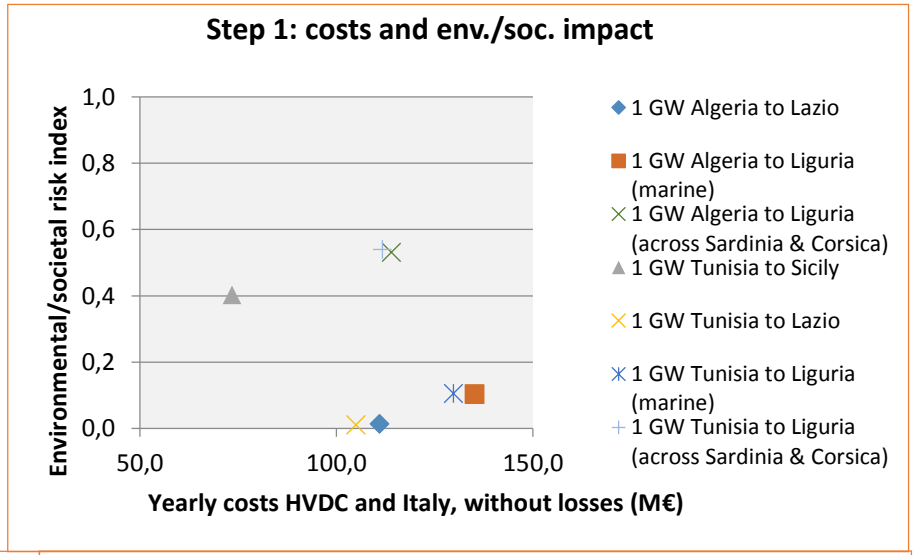
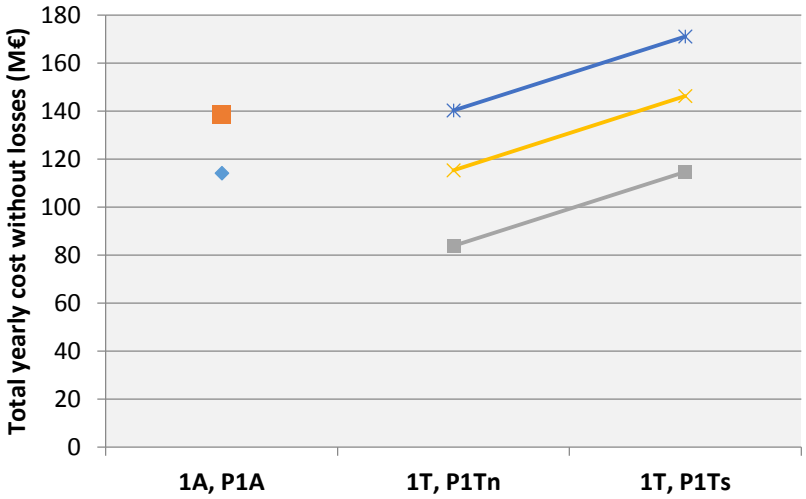
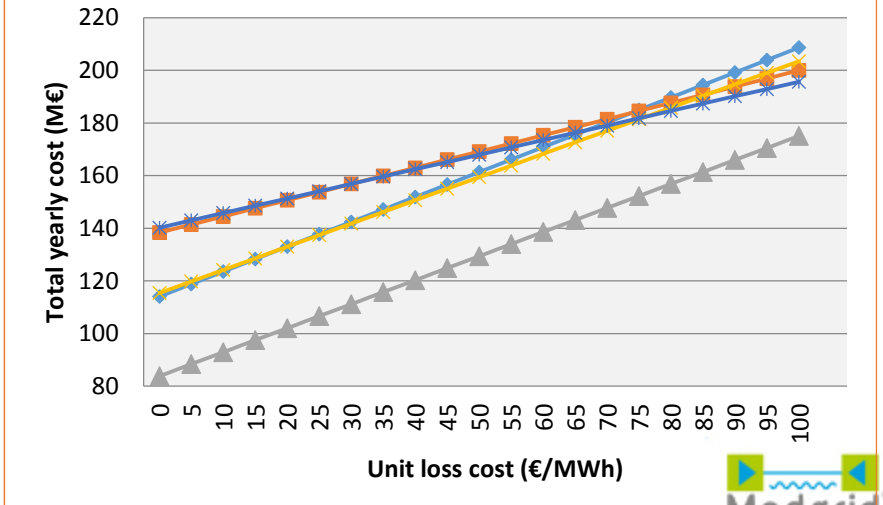
RANKING: THREE STEP ANALYSIS (EXAMPLES)

1. Compile yearly costs and benefits, as well as indices for environmental/societal impact
2. Investigate sensitivity to location of production in the Maghreb region
3. Investigate sensitivity to unit cost of losses







SUGGESTED INTERCONNECTIONS

Link name	Tracks		Under sea	Depth	Terrestrial
	From	To			
Tun - Sic	Tunisia	South West Sicily	192 km	≤ 700 m	32 km
Alg - Laz	Algeria	South Sardinia	262 km	≤ 2000 m	2 km
	South Sardinia	Lazio	480 km	≤ 1500 m	2 km
Alg - Lig	Algeria	South Sardinia	262 km	≤ 2000 m	2 km
	South Sardinia	Sardinia-Corsica	325 km	≤ 700 m	-
	Sardinia-Corsica	Liguria	315 km	≤1000 m	3 km

Top ranked solutions

→ Scenario 1: Yellow path

→ Scenario 2: Yellow and Green paths

→ Scenario 3: Yellow, Green and Red paths, or Yellow and double Red paths

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SELECTED SOLUTIONS: COSTS AND YEARLY LOSSES

	1 GW	2GW	3GW Solution A	3GW solution B
Capital investments (CAPEX)	**M€**	M€	M€	M€
AC connection of HVDC in Maghreb	104.0	135.8	151.8	151.8
HVDC link	388.9	1377.5	2539.5	2712.8
AC reinforcements in Italy	282.4	294.6	396.3	396.3
Total CAPEX	**775.3**	**1808.0**	**3087.5**	**3260.9**
Yearly costs	**M€/yr**	M€/yr	M€/yr	M€/yr
Annuity	72.6	169.4	289.2	305.5
O&M costs	10.5	29.0	52.2	55.7
Costs of losses	46.8	105.2	152.8	138.0
Cost of benefits variation	0.5	-0.0	-3.9	-4.1
Total yearly costs	**130.4**	**303.6**	**490.3**	**495.0**
Yearly Energy Delivered (GWh)	**8000**	**16000**	**24000**	**24000**
Cost of transmission per delivered energy (€/MWh)	**16.3**	**19.0**	**20.4**	**20.6**
Yearly Losses (GWh)	**912**	**1977**	**2772**	**2449**
• AC Connection of HVDC in Maghreb	6	45	113	113
• HVDC Link	209	644	1148	1217
• AC network in Italy	697	1288	1511	1119

→ 25 years, interest rate 8.0 %

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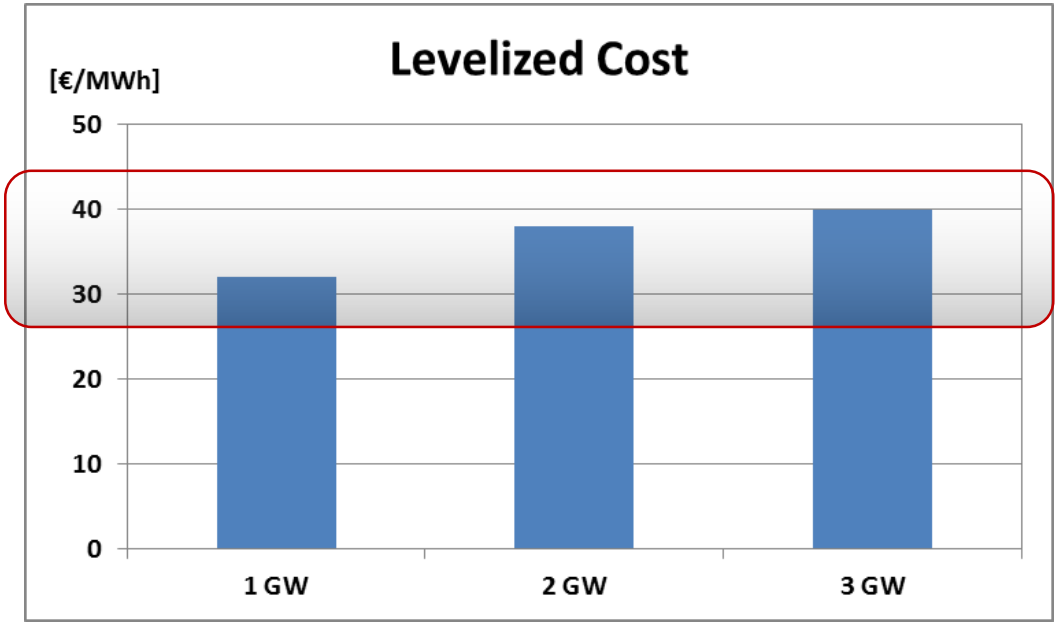
LEVELIZED COST OF TRANSMISSION

- CAPEX, OPEX, including cost of losses for the HVDC equipment and the AC upstream/downstream transmission reinforcements
- Equivalent hours at full power and 4000 h/y



POSSIBILITY OF TRANSFER FROM NORTH TO SOUTH AC NETWORK LOSSES

Two effects

→ **reduction effect**: power flow reduction from South-to-North of the Italian 380 kV lines leads to an overall reduction of Joule losses on the South-to-North Italian backbones

→ **increase effect**: import growth from Central Europe implies an increase in the flows on the Northern Border interconnection lines and in the North transmission system

→ 1000 MW and 2000 MW Power Wheeling

- reduction is higher than the increase
- **overall Joule losses reduction** 90-130 GWh/yr

→ 3000 MW Power Wheeling

- reduction is counterbalanced by the increase
- **overall Joule losses are almost equal**

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POSSIBILITY OF TRANSFER FROM NORTH TO SOUTH NETWORK CONSTRAINTS

→ No constraints in continental network for **1000 MW power wheeling** considering network reinforcements already planned

→ Limits on the section South→Sicily: **1100 MW**

- about 3500 GWh – 400 MW x 8760 h export covered by production in Sicily

→ **Additional 1000 and 2000 MW** can be transferred by HVDC links from Lazio or Liguria with only some local constraints between the corridor connecting the Adriatic backbone to the Tyrrhenian and Central ones

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