Second Euro-mediterranean
Rendez-vous on Energy

January 6th 2015
European Parliament, Brussels



Which interconnections can be envisaged by 2020? Western corridor: Maghreb -Iberia

M. Rivier, A. Ramos, L. Olmos, F. M. Echavarren, L. Rouco
Universidad Pontificia Comillas

J. Dubois, V. Lambillon, L. Rese
Tractebel Engineering

Medgrid

OBJECTIVES & METHODOLOGY

→ Objectives

- To assess the grid investment costs for Western Corridor:
  - transit from Maghreb (MA) (Morocco and Algeria) towards France through the Iberian Peninsula (IB)
  - associated to an increase of +1GW, +2GW, +3GW
- Additional sensitivity analysis for North to South analysis

→ Similar to the Central Corridor one:

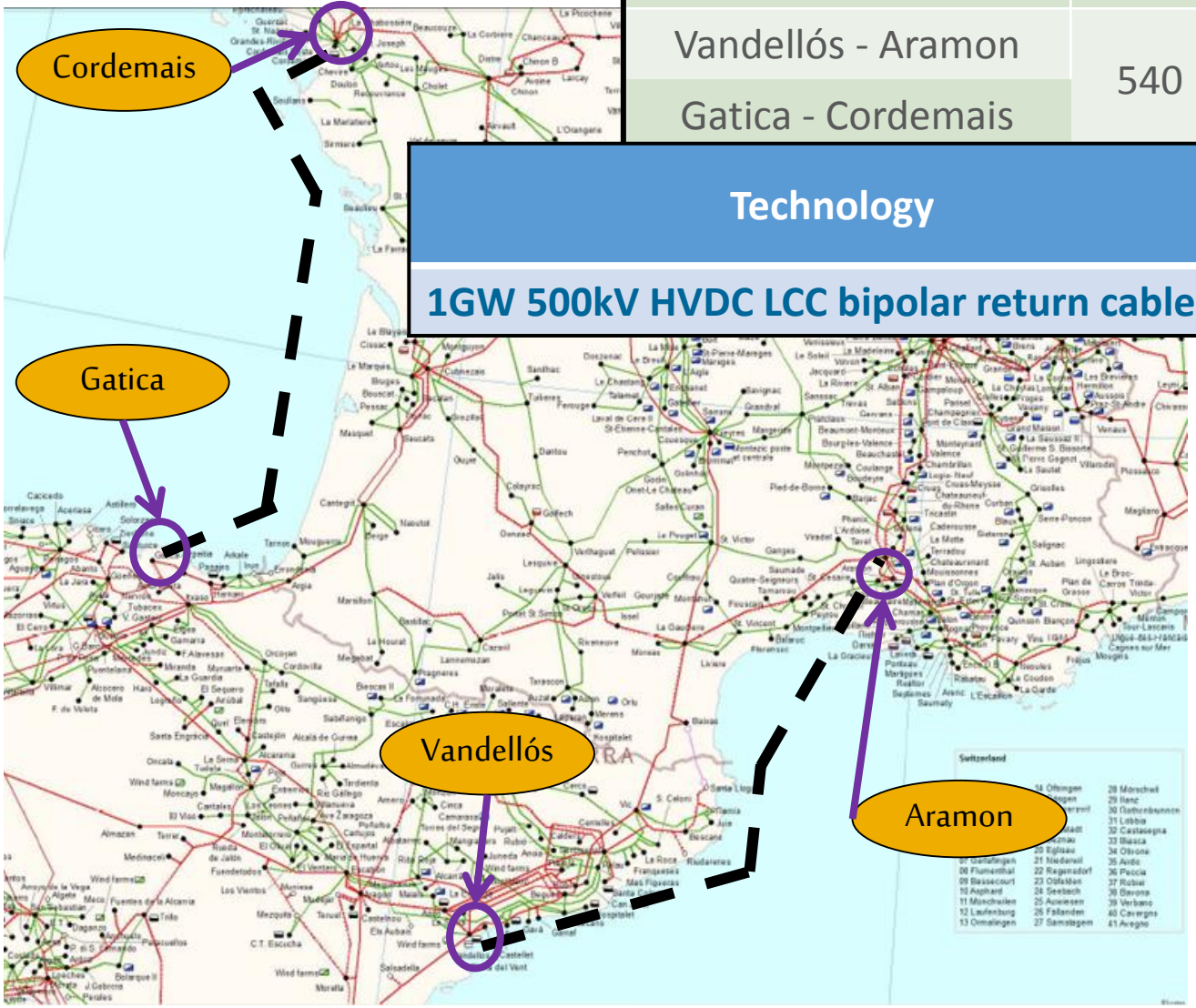
- Existing AC link between Morocco and Spain => N-1 rules are different

Exchange Scenarios
South to North

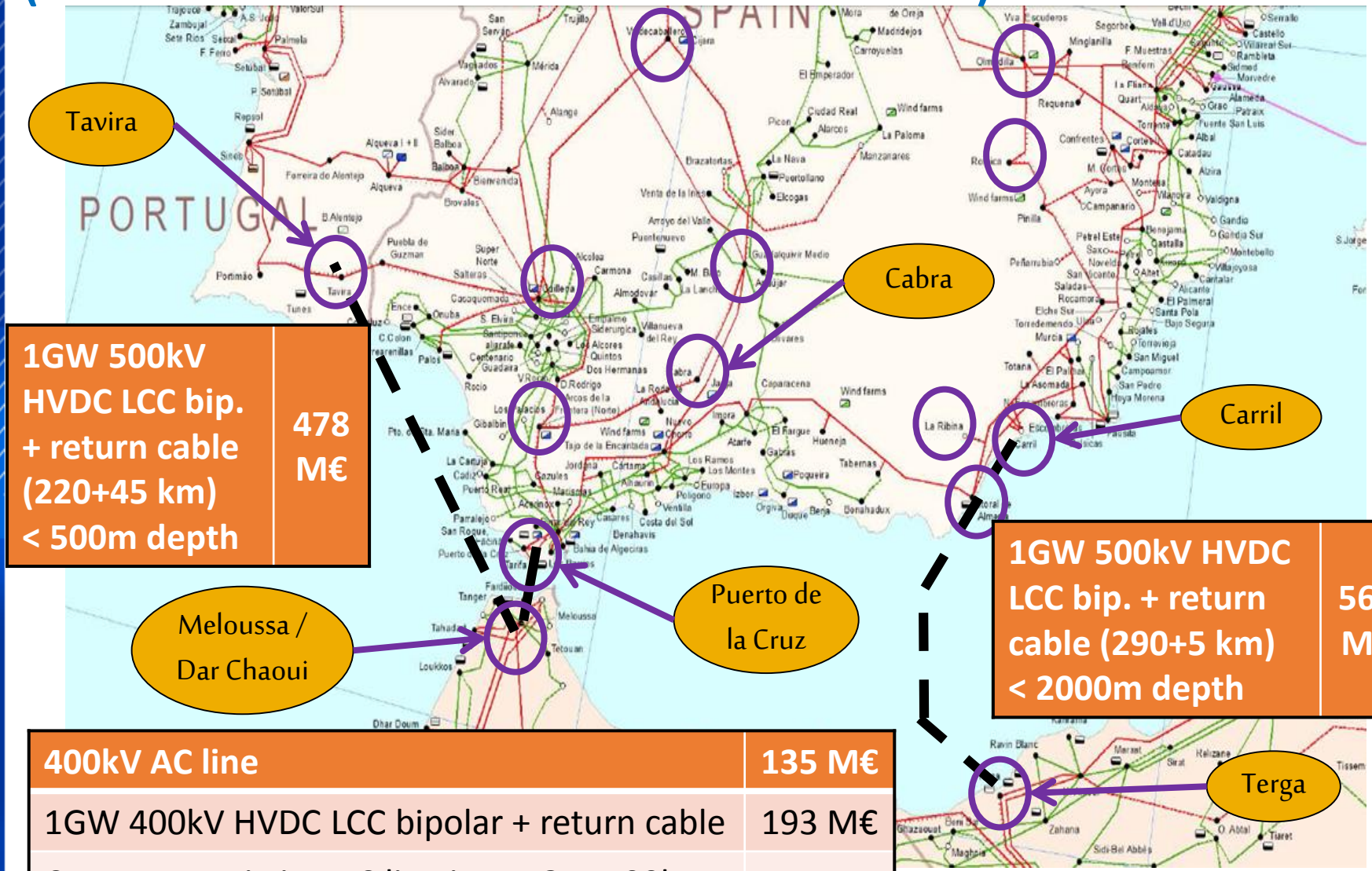
SP-FR INTERCONNECTION

Routes	Length (km)	
	Total	Submarine
Vandellós - Aramon Gatica - Cordemais	540	500

Technology	Invest Costs M€
1GW 500kV HVDC LCC bipolar return cable	871



MAGHREB – IBERIAN PENINSULA INTERCONNECTION OPTIONS (LINKS AND CONNECTIONS POINTS ANALYSED)



1GW 500kV HVDC LCC bip. + return cable (220+45 km) < 500m depth	478 M€

1GW 500kV HVDC LCC bip. + return cable (290+5 km) < 2000m depth	565 M€

400kV AC line	135 M€
1GW 400kV HVDC LCC bipolar + return cable	193 M€
Convert 1 existing AC line into 1GW 500kV HVDC LCC bipolar link + return cable	161 M€

ANALYZED OPTIONS:
EXCHANGE SCENARIOS / TECHNICAL OPTIONS

→ 16 **IB-MA Exchange Scenarios** to cover a wide range of possibilities.

- For each one, 2 PT-SP exchange scenarios +-2.5 GW

→ For each one, different **Technical Solutions** (up to 39) are envisaged.

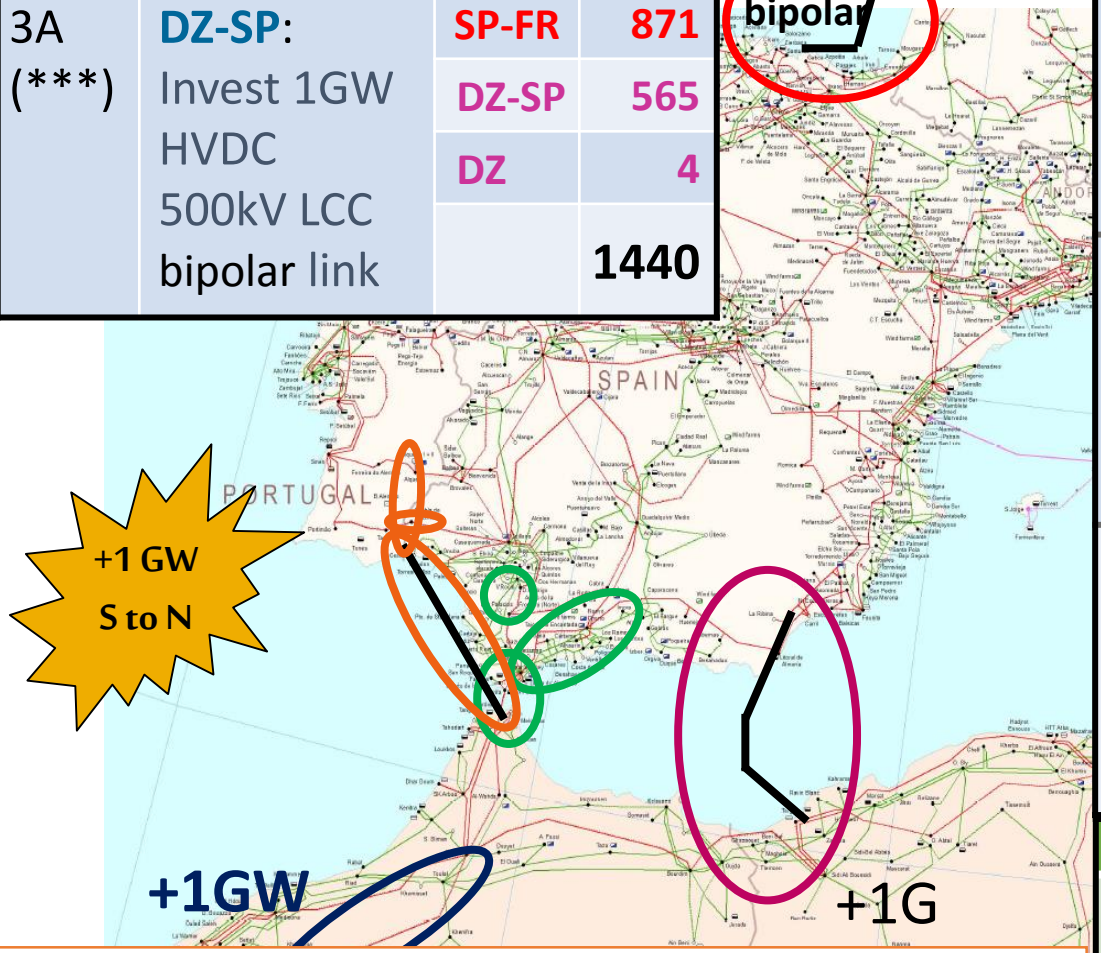
→ 2 **variants** (Puerto de la Cruz and Cabra for MO-SP HVDC link)

Transit level	+1GW			+2GW					+3GW							
Exchange Scenario (XS) #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Targeted exchange capacity [GW]															
MO-SP	1			2	2	1	1	1	3	2	2	2	1	1	1	1
MO-PT		1				1	1			1	1				1	1
DZ-SP			1					1				1	2	2	1	1
	Location Extra Production [GW]															
G_{MO}	1	1		2	1	2	1	1	3	3	2	2	1	2	2	1
G_{DZ}			1		1		1	1			1	1	2	1	1	2

Assessment of Technical Options for each Exchange Scenario

South to North

Sc	Description	Investment Costs M€	
3A (***)	**DZ-SP**: Invest 1GW HVDC 500kV LCC bipolar link	SP-FR	871
		DZ-SP	565
		DZ	4
			1440

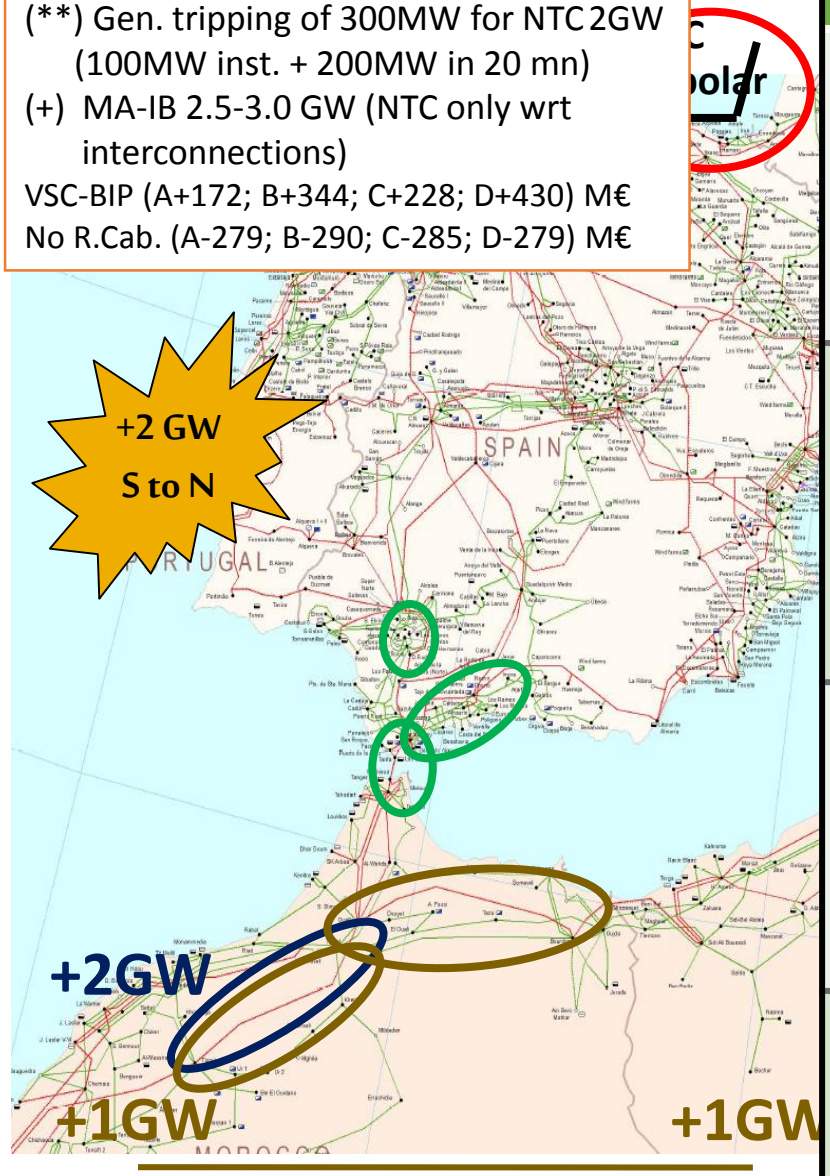


Sc	Description	Invest. Costs M€	
1A (*)	**MO-SP**: Use the current 2x700 MVA AC lines	SP-FR	871
		MO	118
		SP	117
			(#) 0
			1106
			(#) 989
1B (**)	**MO-SP**: Invest 1x700MWVA 400kV AC line	SP-FR	871
		MO	118
		MO-SP	135
		SP	117
			1241
1C (***)	**MO-SP**: Invest 1GW HVDC 400kV LCC bipolar link	SP-FR	871
		MO	118
		MO-SP	193
		SP	117
			1299

Sc	Description	Invest. Costs M€	
2A (***)	**MO-PT:** Invest 1GW HVDC 500kV LCC bipolar link	SP-FR	871
		MO-PT	478
		PT	71
		SP	5
		MO	118
			1543

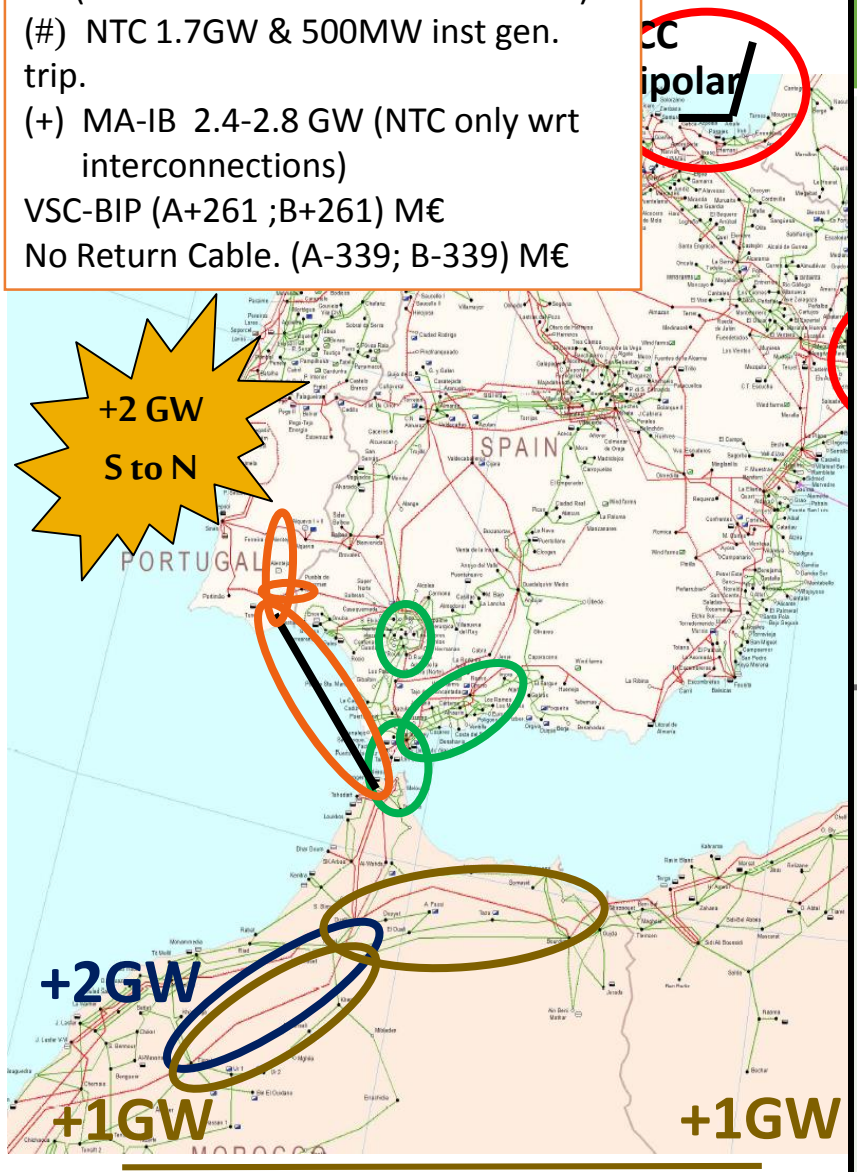
(*) Gen. tripping of 300MW for NTC 1GW (100 instant. + 200 in 20mn)
(#) NTC 0.7GW. No tripping needed.
(**) MA-IB 1.4-1.8 GW (NTC only wrt interconnections)
(***) MA-IB 1.7-1.9 GW (NTC only wrt interconnections)
VSC-BIP (1A+86; 1B+86; 1C+142; 2A+175; 3A+172) M€
No return cable (1A -140; 1B -140; 1C -146; 2A -200; 3A -217) M€

(*) Gen. tripping of 600MW for NTC 2GW (200MW inst. + 400MW in 20 mn)
(**) Gen. tripping of 300MW for NTC 2GW (100MW inst. + 200MW in 20 mn)
(+) MA-IB 2.5-3.0 GW (NTC only wrt interconnections)
VSC-BIP (A+172; B+344; C+228; D+430) M€
No R.Cab. (A-279; B-290; C-285; D-279) M€



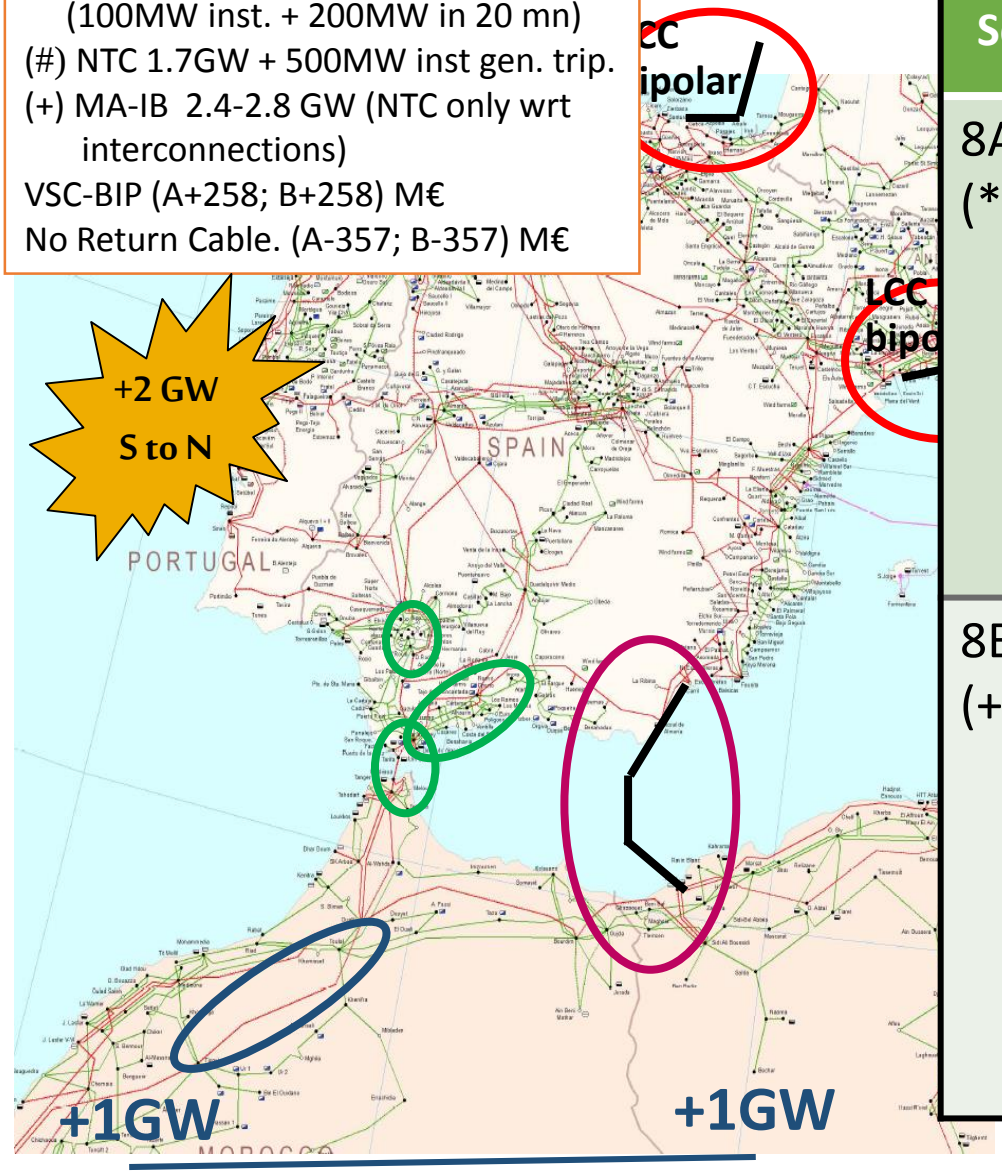
Sc	Description	Investment Costs M€		
			Sc 4	Sc 5
4A 5A (*)	MO-SP: Invest 1x700MW AC additional line	SP-FR	1742	
		MO-SP	135	
		MO+DZ	550+0	389+4
		SP	117	
			2544	2387
4B 5B	MO-SP: Convert 2x700 MW AC in 1x700 MW AC + 2GW 500 kV HVDC LCC bipolar	SP-FR	1742	
		MO-SP	321	
		MO+DZ	550+0	389+4
		SP	117	
			2730	2573
4C 5C (**)	MO-SP: Invest 1GW 400kV HVDC LCC bipolar link	SP-FR	1742	
		MO-SP	193	
		MO+DZ	550+0	389+4
		SP	117	
			2602	2445
4D 5D (+)	MO-SP: Convert 2x700 MW AC in 3GW 500kV HVDC LCC bipolar	SP-FR	1742	
		MO-SP	465	
		MO+DZ	550+0	389+4
		SP	117	
			2874	2717

(*) Gen. tripp. of 300MW for NTC 2GW (100MW inst. + 200MW in 20 mn)
(#) NTC 1.7GW & 500MW inst gen. trip.
(+) MA-IB 2.4-2.8 GW (NTC only wrt interconnections)
VSC-BIP (A+261 ;B+261) M€
No Return Cable. (A-339; B-339) M€



Sc	Description	Investment Costs M€		
			Sc 6	Sc 7
6A 7A (*)	**MO-SP**: use current 2x700MW AC **MO-PT**: invest 1GW 500kV HVDC LCC bipolar link	SP-FR	1742	
		MO-PT	478	
		MO+DZ	550+0	389+4
		PT	71	
		SP	123 (#) 5	
			2964 (#)2846	2807 (#)2689
6B 7B (+)	**MO-SP**: Invest 1x700MW AC additional line 2x700MW AC **MO-PT**: invest 1GW 500kV HVDC LCC bipolar link	SP-FR	1742	
		MO-PT	478	
		MO-SP	135	
		MO+DZ	550+0	389+4
		PT	71	
		SP	123	
			3099	2942

(*) Gen. tripp. of 300MW for NTC 2GW (100MW inst. + 200MW in 20 mn)
(#) NTC 1.7GW + 500MW inst gen. trip.
(+) MA-IB 2.4-2.8 GW (NTC only wrt interconnections)
VSC-BIP (A+258; B+258) M€
No Return Cable. (A-357; B-357) M€



Sc	Description	Investment Costs M€	
8A (*)	MO-SP: use current 2x700MW AC DZ-SP: invest 1GW HVDC 500kV LCC bipolar link	SP-FR	1742
		DZ-SP	565
		MO+DZ	118+4
		SP	117 (#) 0
			2546 (#) 2429
8B (+)	MO-SP: Invest 1x700MW AC additional line DZ-SP: invest 1GW HVDC 500kV LCC bipolar link	SP-FR	1742
		DZ-SP	565
		MO-SP	135
		MO+DZ	118+4
		SP	117
			2681

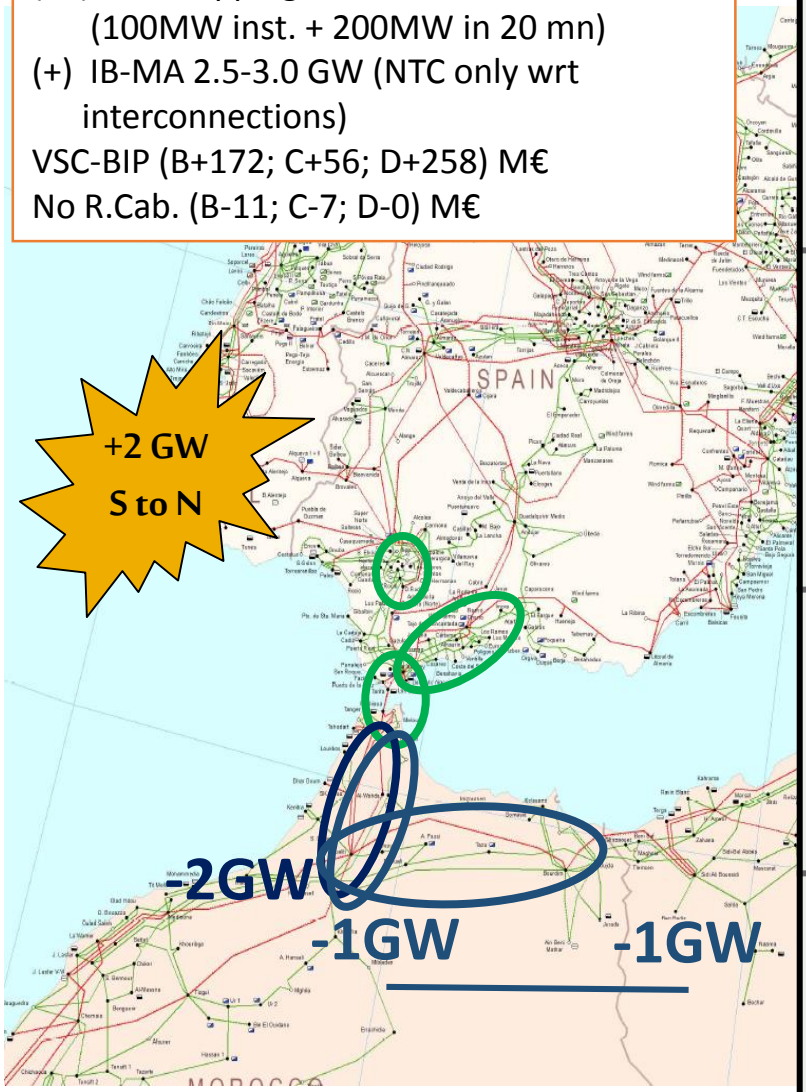
North to South transit

METHODOLOGY – NORTH TO SOUTH

→Total investment costs assessment for a **+2GW** NtoS transit level.

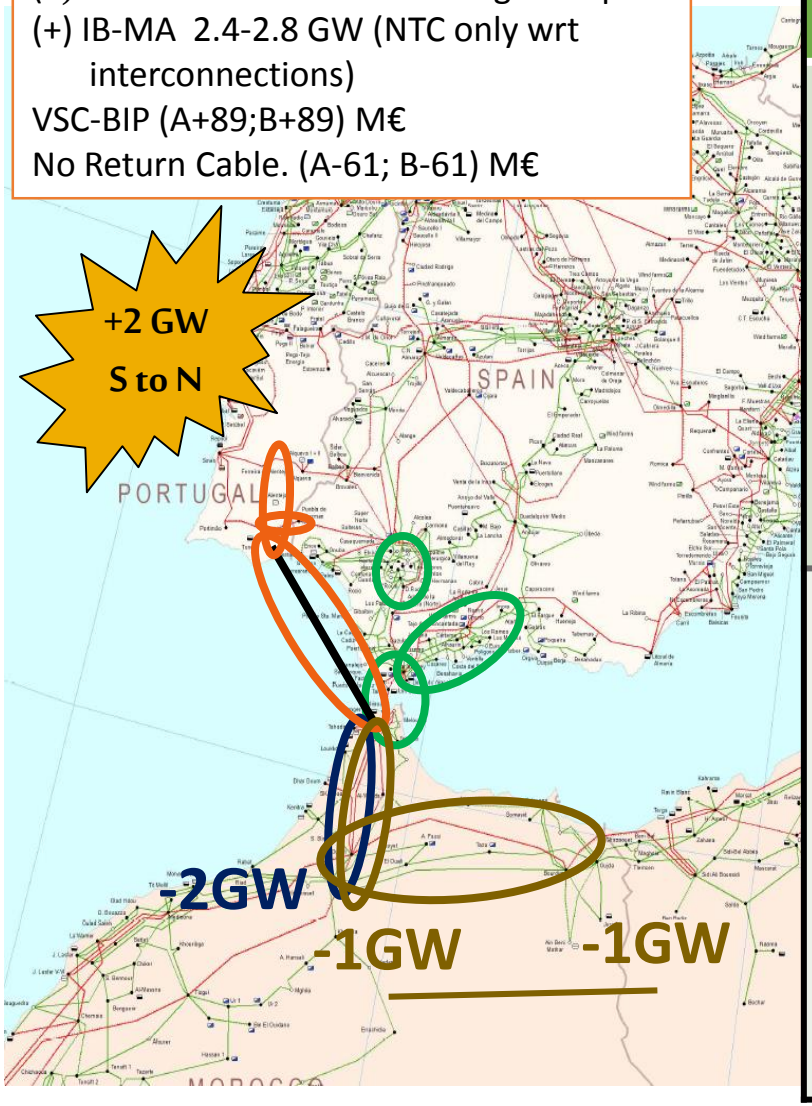
- During course of the project, it appears that most probably flows will first be North to South
- From technical point of view, it was checked:
  - Internal reinforcements identified within SP and PT needed for a StN allow NtS flow
  - The level of investment required in Morocco and Algeria.
- Decoupled from the SP-FR interconnection, so that the investment costs associated to that link are not included in the main results.

(*) Gen. tripping of 600 MW for NTC 2 GW (200MW inst. + 400MW in 20 mn)
(**) Gen. tripping of 300 MW for NTC 2 GW (100MW inst. + 200MW in 20 mn)
(+) IB-MA 2.5-3.0 GW (NTC only wrt interconnections)
VSC-BIP (B+172; C+56; D+258) M€
No R.Cab. (B-11; C-7; D-0) M€



Sc	Description	Investment Costs M€		
			Sc 2-4	Sc 2-5
2-4A 2-5A (*)	**MO-SP**: Invest 1x700MW AC additional line	MO-SP	135	
		MO	64	178
		SP	117	
			316	430
2-4B 2-5B	**MO-SP**: Convert 2x700 MW AC in 1x700 MW AC + 2GW 500kV HVDC LCC bipolar	MO-SP	321	
		MO	64	178
		SP	117	
			502	616
2-4C 2-5C (**)	**MO-SP**: Invest 1GW 400kV HVDC LCC bipolar link	MO-SP	193	
		MO	64	178
		SP	117	
			374	488
2-4D 2-5D (+)	**MO-SP**: Convert 2x700 MW AC in 3GW 500kV HVDC LCC bipolar	MO-SP	465	
		MO	64	178
		SP	117	
			646	760

(*) Gen. tripping of 300MW for NTC 2GW (100MW inst. + 200MW in 20 mn)
(#) NTC 1.7GW & 500MW inst gen. trip.
(+) IB-MA 2.4-2.8 GW (NTC only wrt interconnections)
VSC-BIP (A+89;B+89) M€
No Return Cable. (A-61; B-61) M€



Sc	Description	Investment Costs M€		
2-6A 2-7A (*)	**MO-SP**: use current 2x700MW AC **MO-PT**: invest 1GW 500kV HVDC link LCC bipolar	MO-PT	478	
		MO	64	178
		PT	71	
		SP	123 (#) 5	
			736 (#) 618	850 (#) 732
2-6B 2-7B (+)	**MO-SP**: Invest 1x700MW AC additional line 2x700MW AC **MO-PT**: invest 1GW 500kV HVDC link LCC bipolar	MO-PT	478	
		MO-SP	135	
		MO	64	178
		PT	71	
		SP	123	
			871	985

CONCLUSIONS

SOUTH TO NORTH (i)

→The **majority of investment costs** (870M€ per GW) correspond to the **SP-FR link**

- long distance HVDC submarine links have been considered.

→The internal grid reinforcement needs are

- Relatively **small in SP**: 120M€(1&2GW)-160M€(3GW)
- Relatively **small in PT**: 70M€ (scenarios with 1GW through PT)
- Quite **large in MO**: 120M€ (1GW), 389-650M€ (2GW), 784-966M€ (3GW)
  - Large flows from the South-Western part to the Northern part.
- Almost **non existent in DZ**: 4M€

→In terms of total network investments, the **MO-SP interconnection corridor is the less costly option**.

- Expected due to its shorter length.
- Converting the current AC ones into HVDC links raise the issue of synchronism between EU and Maghreb.

SOUTH TO NORTH (ii)

→DZ-SP interconnection link is the most expensive one, closely followed by the MO-PT one.

- **MO-PT advantage**: interconnection will not need to cross areas where the sea depth is above 500m, while the DZ-SP one needs to cross some areas where the sea-depth is above 1500m.
- **DZ-SP advantage**: no internal grid reinforcements required neither in SP nor in DZ, making it, overall, less costly (in terms of total network investment costs) than the MO-PT interconnection option (this is no longer true if part of the internal network reinforcements in Morocco are not associated to the transit).

→**Costs** computed for solutions analyzed are **very much conditioned by** the size of internal grid **reinforcements required in MO**.

→**N-1 criteria** and automatic tripping mechanisms associated to interconnection failures, **heavily condition the network investment needs** to reach the targeted transit levels.

NORTH TO SOUTH

- The uncoupling with the FR-SP interconnection reduces very much the network investment costs
- Total network investment costs when power imported is consumed both in MO (+1GW) and in DZ (+1GW) are about
  - 500 M€ when using only the MO-SP interconnection
  - 730 M€ when using both the MO-SP interconnection and the MO-PT one.
- If all power imported from SP and PT is consumed in MO (+2GW), the cost of reinforcements decreases in about 110 M€
  - the internal MO grid corridor connecting MO to DZ should not be reinforced.