MEDITERRANEAN TRANSMISSION SYSTEM OPERATORS

Deliverable 2.1.2
Detailed Project Description
08 - TNLYEY Tunisia-Libya-Egypt

EC DEVCO - GRANT CONTRACT: ENPI/2014/347-006
"Mediterranean Project"
Task 2 "Planning and development of the Euro-Mediterranean Electricity Reference Grid "

Med-TSO is supported by the European Union.
This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of Med-TSO and do not necessarily reflect the views of the European Union.

INDEX

1 Introduction

The present document contains the studies on project TNLYEY, in the context of the Mediterranean Master Plan of Interconnections. Project TNLYEY consists of new interconnections between Tunisia and Libya (+1000 MW AC), and between Libya and Egypt (+1000 MW AC).

The document is structured as follows. Section 2 describes in detail the interconnection project and the different sources for data employed. Section 3 presents the definition of the different snapshots to be considered and the description of the building process followed. Section 4 comprises the criteria and results of the security analysis. Section 5 summarizes the results on security analysis and reinforcements' assessment. Section 6 contains the estimations made for the active power losses. Finally, section 7 comprises the estimation for the different investment costs.

2 Project description and data acquisition

The project consists in a new interconnection across Tunisia, Libya and Egypt.

Project details							
Description	***Substation (from)***	***Substation (to)***	***GTC contribution (MW)***	***Present status***	***Expected commissioning date***	***Evolution***	***Evolution driver***
New interconnection between Tunisia and Libya (AC)	Tunisia (TN) Bouchema	Libya (LY) Sorman	1000	*n.d.*	*n.d.*	*n.d.*	Increase the transfer capacity in the Tunisia - Libya - Egypt transmission corridor
New interconnection between Libya and Egypt (AC)	Libya (LY) Tubrak	Egypt (EY) -	1000	*n.d.*	*n.d.*	*n.d.*	

The system defined for project TNLYEY is described in the table and figure below.

Full models	Boundaries
Tunisia TN	Italy IT
Libya LY	Algeria DZ
	Egypt EY

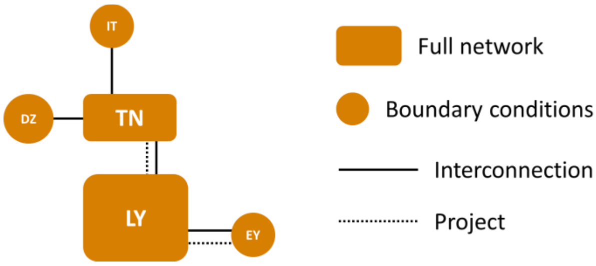

Table 1 – Participation of each of the systems involved in project TNLYEY

For this project, the Tunisian and Libyan systems have been considered as full represented by their transmission network models. Boundary systems, i.e. Algeria, Italy and Egypt, are considered as external buses with loads to simulate energy interchanges.

In the snapshots definition, 4 scenarios (S1, S2, S3 and S4) and seasonality (Winter/Summer) are distinguished. Models provided:

- For the Tunisian system, a set of four models have been provided, corresponding with 4 scenarios (S1, S2, S3 and S4)
- For the Libyan system a unique model has been provided.

Full list of provided files is included in [1].In all models provided interconnected Areas are well identified. Generating technologies are identified in the 'Owner' field for Machines. Concerning merit order list, all generating units are considered with the same rank. Certain particularities in the models provided for the three systems involved in the project are mentioned below:

TN: the file 'Mapping_file_for_TN.XLSX' provided contains information on generating units' characteristics and dispatch for the four scenarios.

Merging process consists of joining the different networks using the connecting buses defined in the next tables. First, Table 2 summarizes the interconnections between systems, which correspond with pairs of modelled systems, thus two interconnection buses must be identified, one for each of the systems in the interconnection.

Bus	Area	Substation	Bus	Area	Substation
BEN GUERDANE	Tunisia TN	Ben Guerdane	ABOU KAMMECH	Libya LY	Abou Kammech
SAADA	Tunisia TN	Saada	ROUIS	Libya LY	Rouis

Table 2 – Points of merging between systems in the TNLYEY project

Table 3 shows the set of interconnections that correspond with pairs formed by a modelled system and a boundary system, thus only one bus in the modelled system needs to be identified.

Bus	Area (from)	Substation	Area (to)
HAWARIA	Tunisia TN	Hawaria	Italy IT
JENT112	Tunisia TN	Jendouba	Algeria DZ
TAJT211	Tunisia TN	Tajerouine	Algeria DZ
TBO 220A	Libya LY	Tobruk	Egypt EY

Table 3 – Points of merging between systems and external buses in the TNLYEY project

Finally, Table 4 presents the new interconnections associated to the TNLYEY project.

PROJECT	Bus	Area	Subs.	Bus	Area	Subs.	LINK
TNLYEY	BOUCHEMA	Tunisia TN	Bouchema	JENT112	Tunisia TN	Sorman	AC
TNLYEY	TBK 400	Libya LY	Tubrak	-	Egypt EY	-	AC

Table 4 – Points of merging in the Projects in the TNLYEY project

3 Snapshots definition and building process

For the project TNLYEY, a total number of nine Points in Time (PiT) have been defined [2]. Each of the PiT contains, for each of the systems considered, the active power generated, demanded and exported to the other systems. Active power production comes with a breakdown of technologies. Next table shows the power balance for each of the PiTS in TNLYEY project.

project TNLYEY PiT 1 - Power Balance [MW]

sys	PG	PD	Pexport	TN	LY	DZ	IT	EY
Tunisia TN	5667.7	3651.0	2016.6	0.0	1500.0	-83.4	600.0	0.0
Libya LY	15598.5	15561.3	37.3	-1500.0	0.0	0.0	0.0	1537.3

project TNLYEY PiT 2 - Power Balance [MW]

sys	PG	PD	Pexport	TN	LY	DZ	IT	EY
Tunisia TN	4672.6	3472.6	1200.0	0.0	1500.0	-300.0	0.0	0.0
Libya LY	12094.5	15144.5	-3050.0	-1500.0	0.0	0.0	0.0	-1550.0

project TNLYEY PiT 3 - Power Balance [MW]

sys	PG	PD	Pexport	TN	LY	DZ	IT	EY
Tunisia TN	3185.1	2774.5	437.6	0.0	1337.6	-300.0	-600.0	0.0
Libya LY	11324.3	13067.4	-1743.1	-1337.6	0.0	0.0	0.0	-405.5

project TNLYEY PiT 4 - Power Balance [MW]

sys	PG	PD	Pexport	TN	LY	DZ	IT	EY
Tunisia TN	3311.7	2775.7	536.0	0.0	1436.0	-300.0	-600.0	0.0
Libya LY	8164.0	10950.4	-2786.4	-1436.0	0.0	0.0	0.0	-1350.4

project TNLYEY PiT 5 - Power Balance [MW]

sys	PG	PD	Pexport	TN	LY	DZ	IT	EY
Tunisia TN	2620.6	2020.7	600.0	0.0	1500.0	-300.0	-600.0	0.0
Libya LY	5236.9	8286.9	-3050.0	-1500.0	0.0	0.0	0.0	-1550.0

project TNLYEY PiT 6 - Power Balance [MW]

sys	PG	PD	Pexport	TN	LY	DZ	IT	EY
Tunisia TN	3185.2	2585.2	600.0	0.0	1500.0	-300.0	-600.0	0.0
Libya LY	5829.6	8879.6	-3050.0	-1500.0	0.0	0.0	0.0	-1550.0

project TNLYEY PiT 7 - Power Balance [MW]

sys	PG	PD	Pexport	TN	LY	DZ	IT	EY
Tunisia TN	6249.7	5649.7	600.0	0.0	1500.0	-300.0	-600.0	0.0
Libya LY	16431.7	16381.7	50.0	-1500.0	0.0	0.0	0.0	1550.0

project TNLYEY PiT 8 - Power Balance [MW]

sys	PG	PD	Pexport	TN	LY	DZ	IT	EY
Tunisia TN	6859.1	6259.1	600.0	0.0	1500.0	-300.0	-600.0	0.0
Libya LY	16447.6	16397.6	50.0	-1500.0	0.0	0.0	0.0	1550.0

project TNLYEY PiT 9 - Power Balance [MW]

sys	PG	PD	Pexport	TN	LY	DZ	IT	EY
Tunisia TN	3245.1	2645.2	600.0	0.0	1500.0	-300.0	-600.0	0.0
Libya LY	5443.0	8493.0	-3050.0	-1500.0	0.0	0.0	0.0	-1550.0

Table 5 – Power balance for each of the PiTS defined in the TNLYEY project

4 Power flow and security analysis

This section presents the criteria agreed to run the power flow and N-x contingency analysis over the different snapshots built for project TNLYEY. Details on the methodology used for the security analysis are compiled in [3].

Tunisia

For the Tunisian system, the N-1 will be focused on the transmission levels. Therefore, the branches considered for the N-1 analysis are only those at 150 kV, 225 kV and 400 kV. Also, overloads will only be checked for branches at 150 kV, 225 kV and 400 kV.

Concerning rates and tolerances, PSS/E files come with three different values, i.e. rateA, rateB and rateC. For lines and transformers, rateA will be considered all snapshots, thus rateB and rateC will be unused. The tolerance for overload will be 0% for all branches in N, and +20% in N-1 situations.

Regarding the loss of generating units, the energy lost will come first from Italy, via the TNIT interconnection, until rate. Then, if it is necessary, the rest of the energy lost will come from Morocco through Algeria.

Finally, no N-2 situations have considered for Tunisia.

Libya

For the Libyan system, the N-1 will be focused on the transmission levels. Therefore, the branches considered for the N-1 analysis are only those at 220 kV and 400 kV. Also, overloads will only be checked for branches at 220 kV and 400 kV.

Concerning rates and tolerances, PSS/E files come with three different values, i.e. rateA, rateB and rateC. For lines and transformers, rateA will be considered all snapshots, thus rateB and rateC will be unused. The tolerance for overload will be 0% for all branches in N and in N-1 situations.

Regarding the loss of generating units, the energy lost will come from the rest of active Libyan generating units.

Finally, no N-2 situations have considered for Libya.

5 Assessment of reinforcements

The main outcomes of the contingency analysis for each system involved in the project could be summarized to the following:

Tunisia:

The energy interchange with Libya through the projected 400 kV interconnection comes down to the 220 kV network at the Bou Chema substation. This fact may undergo some overloads at the 220 kV network. To overcome this, it is planned to include new 400 kV circuits that takes most of the energy interchanged between the north and the south. Reinforcements considered are:

- New 400 kV circuit between Bou Chema and Oueslatia.
- New 400 kV circuit between Oueslatia and Mornaguia.
- Three (3) new 400 MVA, 220/400 kV transformers at Oueslatia substation.
- Three (3) new 400 MVA, 220/400 kV transformers at Bou Chema substation.

Libya:

Relevant overloads detected at the 220 kV network are due to the fact that those cables have no ampacity enough. To overcome this, the main reinforcement identified is in the 84 km OHL from Tubroc to Saloum.

Next figures show the maps of interconnections, both existing (dashed-yellow line) and planned (yellow line), and corresponding reinforcements (green line).

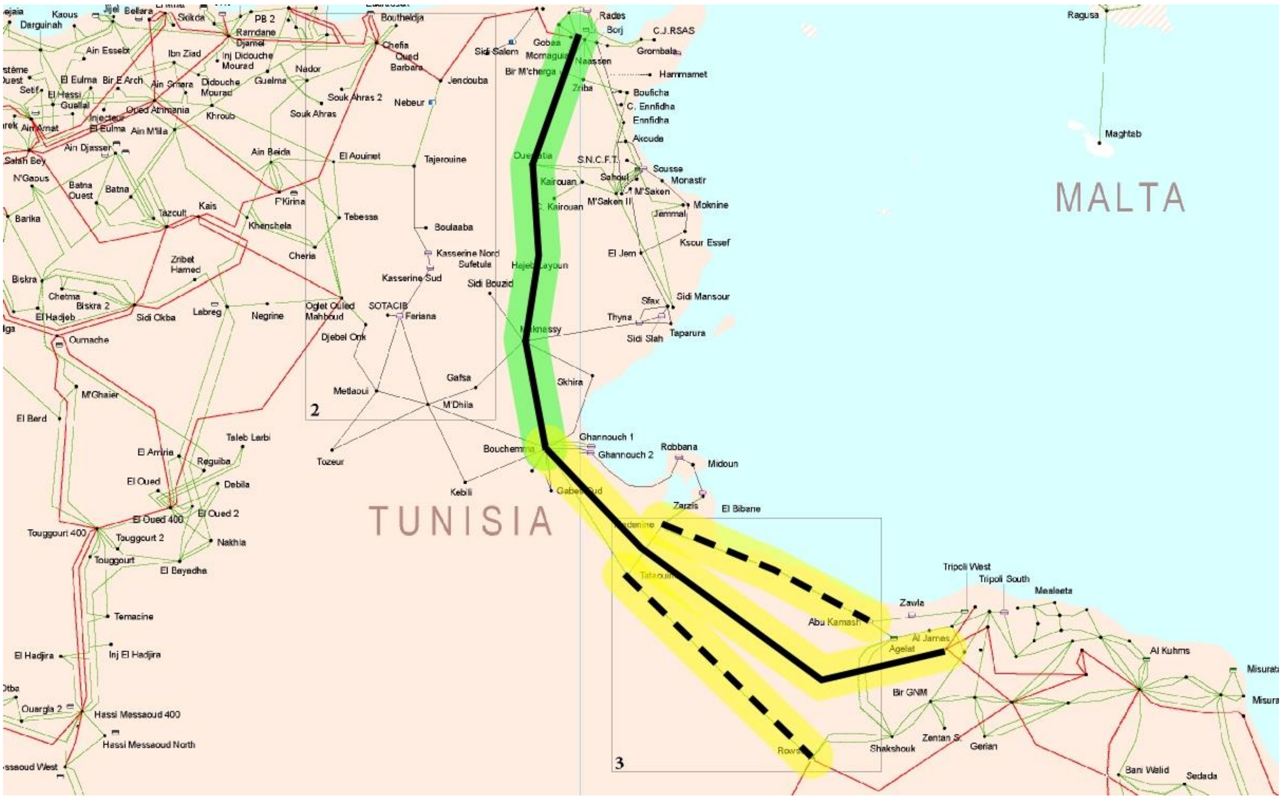

Figure 1 – Map of interconnections and reinforcements for project TNLYEY, detail of TNLY interconnection area

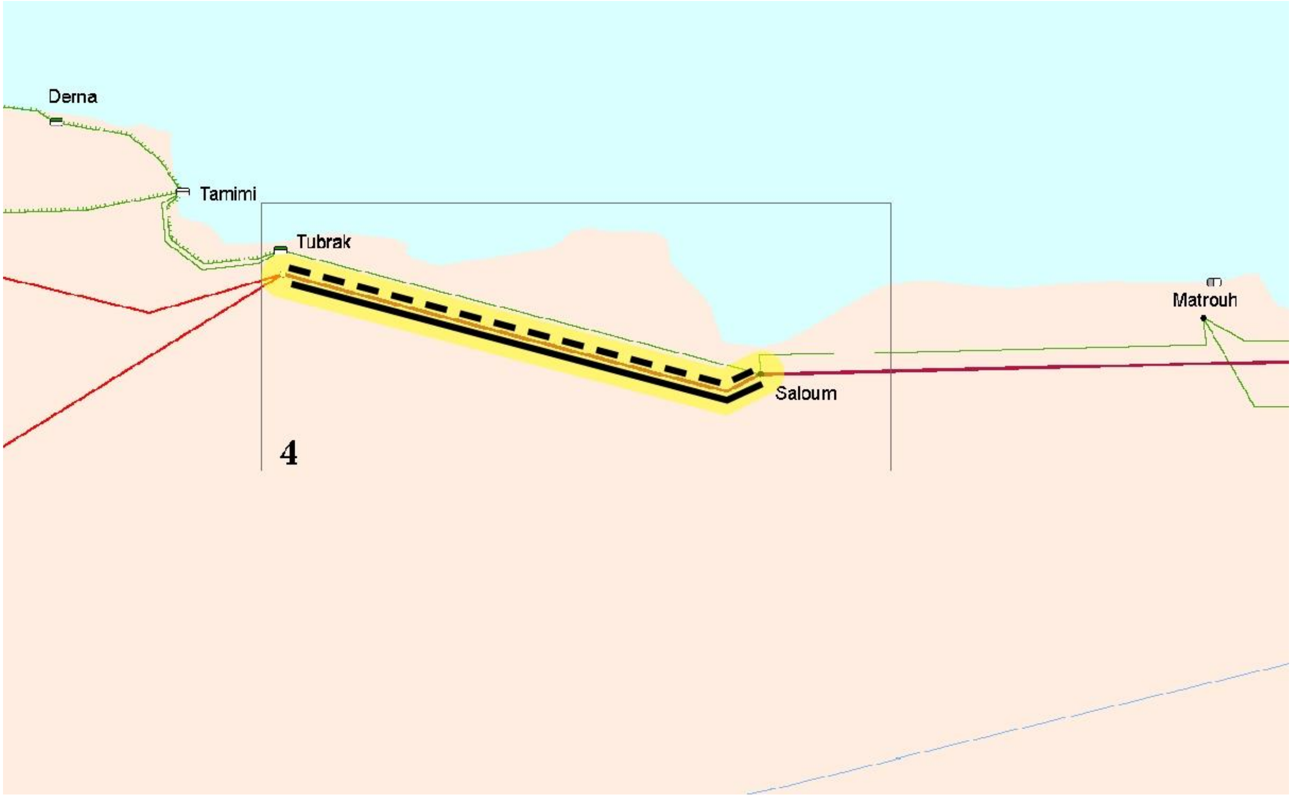

Figure 2 – Map of interconnections and reinforcements for project TNLYEY, detail of LYEY interconnection area

6 Estimation of Active Power Losses

Internal losses in each country

To evaluate the performance of the new interconnection projects plus the planned reinforcements, the active power losses have been computed for 1) the snapshots built with the specified reinforcements considered, and for 2) the snapshots without interconnection projects and without reinforcements. Next tables show the active power losses summary for each of the PiTs, Table 6 with the results for the Tunisian system and Table 7 with the results for the Libyan system.

	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
1	72.5	169.4	96.9
2	27.9	80.0	52.2
3	43.6	59.9	16.3
4	22.7	59.1	36.3
5	80.9	117.0	36.1
6	63.3	139.6	76.3
7	57.0	102.3	45.3
8	70.8	113.3	42.6
9	49.7	103.8	54.1

Table 6 – Comparison of the active power losses for each snapshot, with and without interconnection projects and reinforcements, for the Tunisian system

	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
1	186.7	315.0	128.3
2	142.8	223.4	80.5
3	129.4	135.3	5.9
4	79.4	129.0	49.6
5	73.5	112.2	38.7
6	81.5	116.7	35.2
7	163.7	267.2	103.5
8	194.9	365.6	170.7
9	75.5	111.5	35.9

Table 7 – Comparison of the active power losses for each snapshot, with and without interconnection projects and reinforcements, for the Libyan system

Considering the time percentile (hours of the year) that each PiT represents, internal active power losses with and without the new interconnection project computed for each PiT have been converted to annual energy losses for each one of the 4 scenarios.

Losses in the new AC interconnection project

Based on the hourly time series of exchange among countries provided by Market studies for each one of the 4 scenarios, with and without the new interconnection project, yearly losses on the interconnection have also been computed.

Computation of the losses in the new AC interconnection has been carried out for the four scenarios S1 to S4 and 8760 hours of estimated flows through the interconnections. The following table summarizes the values used for this estimation exercise:

link	r_l [pu]	NTC_{new} [MW]	NTC_{total} [MW]
TN-LY	0.004600	1000	1500
LY-EY	0.003918	1000	1500

Table 8 – Parameters for the losses estimation in the TNLYEY interconnections

The following table shows the annual losses estimate on the interconnection project for each scenario:

Scenario	Annual Losses (GWh)	
	LY-EY	TN-LY
S1	66.7	89.9
S2	67.7	88.4
S3	66.3	85.8
S4	64.6	89.3

Table 9 – Annual losses estimate for the TNLYEY new interconnection

7 Estimation of Investment Cost

The new AC link between Tunisia and Libya consists of 300 km of AC OHL. Using 0.5 M€/km for the cost of the AC cables including installation, the estimate for the cable cost is 150 M€. The cost of the end substations is estimated to be 1.5 M€, each one including one AIS bay. Finally, the total investment cost in the new AC interconnection is 153 M€.

The new AC link between Libya and Egypt consists of 350 km of AC OHL. Using 0.5 M€/km for the cost of the AC cables including installation, the estimate for the cable cost is 175 M€. The cost of the end substations is estimated to be 1.5 M€, each one including one AIS bay. Finally, the total investment cost in the new AC interconnection is 178 M€.

The following tables provide an estimate for the investment cost for the internal reinforcements, and the Cost Benefit Analysis (CBA) carried out based on the results of EES and TC1 activities of the Mediterranean Project. It should be noted that this is an estimation of the cost based on the best practices in the region.

P8 - TNLYEY - Investment Cost								
New Interconnections								
Description	**Type**	**Countries Involved**	**Length/number**		**Total Investment Cost**	**GTC Contribution**	**Location**	**Status**
			OHL [km]	**Cable [km]**	**M€**	**MW**		
New Interconnection TN-LY	AC 400kV OHL	TN-LY	300		150	1000		
	OHL 400kV Circuit breaker (AIS bay)	TN-LY	1		1.5			
	OHL 400kV Circuit breaker (AIS bay)	LY	1		1.5			
New Interconnection LY-EY	AC 400kV OHL	LY-EY	350		175	1000		
	OHL 400kV Circuit breaker (AIS bay)	LY	1		1.5			
	OHL 400kV Circuit breaker (AIS bay)	EY	1		1.5			
Total Cost of New Interconnections (M€ / %total)					**331**	**61%**		
Internal Reinforcements								
Description	**Type**	**Countries Involved**	**Length/number**		**Total Investment Cost**	**Capacity**	**Location**	**Status**
			OHL [km]	**Cable [km]**	**M€**	**MW / MVA**		
Reinforcement of a 84 km OHL from		LY	84		33		Tubroc - Saloum	
OHL 400 kV		TN	250		102		Bouchemma -Oueslatia	
OHL 400 kV		TN	140		57		Mornaguia-Oueslatia	
Bays for OHL 400 kV		TN	4		6		Bouchemma, Oueslatia, Mornaguia	
AutoTransformer 400/225 KV-400 MVA		TN	1		3		Oueslatia	
AutoTransformer 400/225 KV-400 MVA		TN	1		3		Bouchemma	
Bay AutoTransformer 400 kV		TN	2		3		Bouchemma, Oueslatia	
Bay AutoTransformer 225 kV		TN	2		3		Bouchemma, Oueslatia	
Total Cost of Internal Reinforcements (M€ / %total)					**209**	**39%**		
Total Project Investment Cost					**540**			

Table 10 – Investment cost of the project TNLYEY

Assessment results for the Cluster P8 - TNLYEY														
non scenario	GTC increase direction 1 (MW)		1000 (TN-LI) - 1000 (LI-EY)											
	GTC increase direction 2 (MW)		1000 (LI-TN) - 1000 (EY-LI)											
scenario specific			MedTSO scenario											
			1			2			3			4		
			Ref. Scenario	with new project	Delta	Ref. Scenario	with new project	Delta	Ref. Scenario	with new project	Delta	Ref. Scenario	with new project	Delta
GTC / NTC (import)		TN	800	1800	1000	800	1800	1000	800	1800	1000	800	1800	1000
		LY	1050	3050	2000	1050	3050	2000	1050	3050	2000	1050	3050	2000
		EY	1250	2250	1000	1250	2250	1000	1250	2250	1000	1250	2250	1000
Interconnection Rate (%)*		TN	8.8%	19.9%	11.0%	8.4%	18.8%	10.5%	7.7%	17.3%	9.6%	6.2%	14.0%	7.8%
		LY	4.5%	13.0%	8.5%	4.5%	13.0%	8.5%	4.5%	13.0%	8.5%	4.5%	13.0%	8.5%
		EY	1.4%	2.6%	1.1%	1.4%	2.6%	1.1%	1.3%	2.4%	1.1%	1.4%	2.5%	1.1%
Benefit Indicators	B1-SEW	(M€/y)	270			290			290			340		
	B2-RES	(GWh/y)	0			0			0			0		
	B3-CO_2	(kT/y)	-1600			-1000			-1600			-1500		
	B4 - Losses	(M€/y)	47.1			140.5			130.8			144.7		
		(GWh/y)	580			1466			1477			1625		
	B5a-SoS Adequacy	(MWh/y)	0			60			60			40		
	B5b-SoS System Stability													
Residual Impact Indicators	S1- Environmental Impact													
	S2-Social Impact													
	S3-Other Impact													
Costs	C1-Estimated Costs	(M€)	540											

* considering the GTC for 2030 , the Install generation for 2030 and the GTC for importation (the same criteria used in the ENTSO-E)

Rules for sign of Benefit Indicators

B1- Sew [M€/year] =	Positive when a project reduces the annual generation cost of the whole Power System
B2-RES integration [GWh/Year] =	Positive when a project reduces the amount of RES curtailment
B3-CO_2 [kt/Year] =	Negative when a project reduces the whole quantity of CO_2 emitted in one year
B4-Losses - [M€/Year] and [GWh/Yea	Negative when a project reduces the annual energy lost in the Transmission Network
B5a-SoS [MWh/Year] =	Positive when a project reduces the risk of lack of supply

Assessment	Color code
negative impact	red
neutral impact	light beige
positive impact	green
Not Available/Not Available	grey
monetized	yellow

Table 11 – Results of the Cost Benefit Analysis for the TNLYEY project

8 References

1	Snapshots building process	Share point
2	Guide for setting up grid models for Network studies V 5.0	Share point
3	Network Analysis and Reinforcement Assessment	Share point

DISCLAIMER

This document contains information, data, references and images prepared by the Members of the Technical Committees "Planning", "Regulations and Institutions"; "International Electricity Exchanges" and Working Group "Economic Studies and Scenarios", for and on behalf of the Med-TSO association. Whilst the information contained in this document and the ones recalled and issued by Med-TSO have been presented with all due care, the Med-TSO Members do not warrant or represent that the information is free from errors or omission.

The information are made available on the understanding that the Med-TSO Members and their employees and consultants shall have no liability (including liability by reason of negligence) to the users for any loss, damage, cost or expense incurred or arising by reason of any person using or relying on the information and whether caused by reason of any error, negligent act, omission or misrepresentation in the information or otherwise.

Whilst the information is considered to be true and correct at the date of publication, changes in circumstances after the time of publication may impact on the accuracy of the information. The information may change without notice and the Med-TSOs Members are not in any way liable for the accuracy of any information printed and stored or in any way interpreted and used by a user.

The information of this document and the ones recalled and issued by Med-TSO include information derived from various third parties. Med-TSOs Members take no responsibility for the accuracy, currency, reliability and correctness of any information included in the information provided by third parties nor for the accuracy, currency, reliability and correctness of links or references to information sources (including Internet Sites).