

e-HIGHWAY 2050

Modular Development Plan of the Pan-European Transmission System 2050

Contract number	308908	Instrument	Collaborative Project
Start date	1st of September 2012	Duration	40 months
WP 6	Socio economic profitability		
D 6.2	A Toolbox supporting a pan-European technical evaluation of costs and benefits		



Revision: 2.0 FINAL

Due date of delivery: Month 38

		Date & Visa
Written by	Francesco Careri, Venanzio Viscardi, Gianluigi Migliavacca, Stefano Rossi (RSE) Frans Nieuwenhout, Jos Sijm, Cees Volkers (ECN) Luis Olmos, Andres Ramos, Michel Rivier, Jesus La Torre (IIT Comillas)	22.10.2015
Checked by	Gianluigi Migliavacca (RSE)	22.10.2015
Validated by	Nathalie Grisey, Gérald Sanchis (RTE)	22.10.2015

Project co-funded by the European Commission within the Seventh Framework Programme

Dissemination Level

PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Document information

General purpose

The Benefits and Costs Assessment (BCA) methodology developed in WP6 and described in the deliverable D6.1 is then implemented in a toolbox aimed at allowing an automatic application of the methodology starting from the scenario simulation files produced by the WP2 (in the format produced by the ANTARES simulator developed by RTE) and allowing a complete appraisal of the cost/benefit indicators, the elaboration of a scoring parameter and the creation of a final reporting, both in tabular and graphical form.

The toolbox itself is the object of the present deliverable D6.2 and the present manual constitutes a “companion booklet” allowing a practical start-up of a new user.

The e-Highway2050 BCA toolbox is entirely developed in Visual Basic for Applications (VBA) for the MS-Access 2010 platform. The motivation for this choice is for making it easy the testing of the toolbox within off-the-shelf PCs with a basic SW endowment.

The D6.2 (SW and manual) is also conceived a public deliverable of the project, with the aim to allow everybody who can be interested to download and test the BCA toolbox.

Change status

Revision	Date	Changes description	Authors
V1.0	04.09.2015	First Draft	F. Careri, G. Migliavacca S. Rossi V. Viscardi (RSE)
V2.0	22.10.2015	Revision after public consultation	F. Careri (RSE)

EXECUTIVE SUMMARY

The Benefits and Costs Assessment (BCA) developed in the deliverable D6.1 is then implemented in a toolbox aimed at allowing an automatic application of the methodology starting from the scenario simulation files produced by the WP2 (in the format produced by the ANTARES simulator developed by RTE) and allowing a complete appraisal of the cost/benefit indicators, the elaboration of a scoring parameter and the creation of a final reporting, both in tabular and graphical form.

The toolbox itself is the object of the present deliverable D6.2 and the present manual constitutes a “companion booklet” allowing a practical start-up of a new user.

The e-Highway2050 BCA toolbox is entirely developed in Visual Basic for Applications (VBA) for the MS-Access 2010 platform, a widely used software. The motivation for this choice is for making it easy the testing of the toolbox within off-the-shelf PCs with a basic SW endowment.

The D6.2 (SW and manual) is also conceived a public deliverable of the project, with the aim to allow everybody who can be interested to download and test the BCA toolbox.

In Section 1, a generic nomenclature for the document is proposed, for the sake of the reader.

In Section 2, the report shows some clarification on how the D6.1 methodology has been effectively implemented in the toolbox.

In Section 3, the most consistent part of the document, the effective toolbox manual is described: in particular:

- in Section 3.1, a general description of the toolbox is shown;
- in Section 3.2, the description of the toolbox input is proposed;
- in Section 3.3, the user can find practical information on how to use the toolbox in order to calculate BCA indicators;
- in Section 3.4, some information concerning the toolbox outputs is shown.

Annex 1 covers some analytic details on the implementation of socio-environmental indicators, completing the theoretical framework provided in D6.1.

Annex 2 shows some practical details on how the calculation of security of supply indicators is performed inside the toolbox.

TABLE OF CONTENT

Document information.....	ii
EXECUTIVE SUMMARY.....	iv
TABLE OF CONTENT.....	vi
1. Nomenclature.....	8
2. Application of the BCA methodology in the toolbox.....	9
3. Toolbox manual.....	14
3.1. GENERAL DESCRIPTION.....	14
3.2. TOOLBOX INPUTS.....	17
3.2.1. <i>Toolbox file system – Before running the data acquisition</i>	17
3.2.2. <i>Data acquisition</i>	19
3.2.3. <i>Toolbox file system – After running the data acquisition</i>	22
3.2.4. <i>Structure of “DataDB” folder</i>	26
3.2.4.1. AREAS.....	28
3.2.4.2. AVAILDTG_Aij(WOi).....	28
3.2.4.3. BALANCE_Aij(WOj).....	28
3.2.4.4. CO2EMISS_Aij(WOj).....	28
3.2.4.5. CONRENT_Aij(WOj).....	29
3.2.4.6. DBTHERM.....	29
3.2.4.7. ENSHOUR_Aij(WOi).....	29
3.2.4.8. ENSPILL_Aij(WOi).....	29
3.2.4.9. FIXHROR_Sci.....	30
3.2.4.10. FIXSOLR_Sci.....	30
3.2.4.11. FIXWIND_Sci.....	30
3.2.4.12. FLOWLIMFR_Aij(WOi).....	31
3.2.4.13. FLOWLIMTO_Aij(WOi).....	31
3.2.4.14. GENDISP_Aij(WOi).....	31
3.2.4.15. HYDROST_Aij(WOj).....	32
3.2.4.16. LOADVAL_Sci.....	32
3.2.4.17. MGPRICE_Aij(WOi).....	32
3.2.4.18. OPCOSTS_Aij(WOi).....	33
3.2.4.19. PWRFLOW_Aij(WOi).....	33
3.2.4.20. RESANN_Aij(WOi).....	33
3.2.5. <i>Structure of “Manual_Files” folder</i>	34
3.2.5.1. ADDIRES.....	36
3.2.5.2. AVAILDSM.....	36
3.2.5.3. CO2COST.....	36
3.2.5.4. <i>Component_Characteristics</i>	37
3.2.5.5. DNETCST.....	37
3.2.5.6. DNETSZE.....	38
3.2.5.7. DSMCOST.....	38
3.2.5.8. DSMRBTY.....	38
3.2.5.9. DSTOCST.....	39
3.2.5.10. EXTRPRB.....	39
3.2.5.11. LINKS_Aij(WOi).....	39
3.2.5.12. LOADTYPE.....	40
3.2.5.13. OPT3_ij.....	40
3.2.5.14. OPT4_ij.....	41
3.2.5.15. PTDF_Aij.....	42
3.2.5.16. REDFACT.....	42

3.2.5.17.	RESCURT.....	42
3.2.5.18.	RSLCCAP.....	43
3.2.5.19.	Type_of_installation.....	43
3.2.5.20.	ZNLVOLL.....	44
3.3.	CALCULATION OF BCA INDICATORS.....	45
3.3.1.	Calculation of “Social Welfare”.....	46
3.3.2.	Calculation of “CO2 price sensitivity”.....	49
3.3.3.	Market power.....	52
3.3.4.	Additional installed RES.....	55
3.3.5.	Extra distribution investment costs.....	59
3.3.6.	Social Welfare Split.....	63
3.3.7.	Financial and Regulation.....	67
3.3.8.	Social Environmental Aspects.....	75
3.3.9.	Life cycle costs.....	79
3.3.10.	Security of Supply.....	82
3.3.11.	Inter-zonal Transmission Losses.....	87
3.4.	TOOLBOX OUTPUTS.....	90
3.4.1.	Economic results.....	90
3.4.2.	Graph Scenarios.....	93
3.4.3.	Display Scenarios.....	95
	REFERENCES.....	98
	ANNEX 1 – Implementation of social and environmental aspects in the e-Highway2050 BCA Toolbox.....	99
1.	Introduction.....	99
2.	Aggregated cluster approach.....	100
2.1.	METHODOLOGY.....	100
2.2.	TABLES.....	100
2.3.	QUERIES.....	105
2.4.	MACROS AND MODULES.....	108
3.	GIS-based current network approach.....	108
3.1.	METHODOLOGY.....	108
3.2.	OUTCOMES: EXCEL FILES FOR THE COMPENSATION COST MODULE.....	109
4.	Optimal new network approach.....	110
5.	Approximation of approval times depending on ground type.....	110
5.1.	CURRENT SITUATION.....	110
5.2.	AVAILABLE DATA.....	111
5.3.	METHOD.....	111
5.4.	SOURCES (APPROVAL TIMES).....	112
	ANNEX 2 – Technical implementation of security of supply indicators in WP6 Toolbox.....	113
1.	Introduction.....	113
2.	Tools structure overview.....	113
3.	Code modules.....	114
3.1.	TOOLBOX MODULE.....	114
3.2.	DATABASE CLASS MODULE (BASEDEDATOS).....	115
3.3.	TIMER CLASS MODULE (CTIMER).....	115

1. Nomenclature

A suitable nomenclature is added to the present report in order to fix a common language inside the WP6 and, more generally, inside the project.

- BCA indicator:** is one of the cost-benefit component elaborated by the BCA methodology developed by WP6. According to the methodology, for each *case* analyzed by WP2 a set of BCA indicators would be provided. Such indicators are the final elements that summed together will give the cost-benefit quantification.
- Case:** is the set of data and elaboration resulting from each simulation of the WP2. For each *scenario*, a case will be analyzed for the *without* situation and one for each alternative *grid architecture* proposed.
- Cluster:** corresponds to a single equivalent network zone to which the detailed network is reduced in the framework of the project. The network of a single country may be reduced into several clusters.
- Grid architecture:** is a topology of a set of reinforcements (constituted by links to be connected and increased transmission capacities).
- Reinforcement:** is an increase of transmission capacity between interconnected clusters or a creation of new connection between clusters.
- Scenario:** is one of the possible representation of the energy system in the future, defined by the WP1/WP2, in which the network planning has to be performed.
- Strategy:** is the technological framework to implement a given *grid architecture*.
- Variant:** is the set of *BCA indicators* elaborated by the toolbox for all the *cases*, in the framework of the sensitivity analysis. Several variants will be calculated varying a specific sensitivity parameter at a time.
- With case:** is the *case* elaborated for each *scenario*, considering the network reinforcement plan given by the combination of the reference *grid architecture* and with the different *strategies*. Therefore, for a given scenario and grid architecture, the number of with cases
- Without case:** is the reference *case* elaborated for each *scenario* considering no improvement of the network after the 2030 (reference: TYNDP 2014)

2. Application of the BCA methodology in the toolbox

The WP6 toolbox has been designed in the context of the e-Highway2050 research project to be exploited in the ranking of the WP2-WP4 Grid Architectures according to the WP6 BCA methodology: a concrete set of indicators has been selected, among those proposed in the theoretical framework described in [1], in order to retain only those that:

- are **adequately supported by data** in the WP2 simulations. Some extra input parameters may be employed, e.g. split of the VOLL per macro-zone and load typology, only if they can be reliably acquired on the basis of existing sources. Also there, agreement has to be sought with the WP2 scenario hypotheses.
- have a **clear regulatory, technological or economical foundation**. Factors whose importance at 2050 is either not clear or depending on uncertain factors (like un-foreseeable technological evolution or strong regulatory changes that are not evident from the scenario narratives) should not be implemented.
- entail **calculations that are feasible in the toolbox** (ex-post assessment starting from the results provided by WP2-WP4, no additional simulations in WP6). The toolbox should be a simple tool making straightforward evaluations.

On the basis of what is considered above, it is possible to outline what the BCA indicators should be, what the sensitivity factors should be and what BCA indicators should not be implemented.

Therefore, the BCA indicators proposed in D6.1 ([1]) have been split between “core indicators”, that constitute the set of benefits and costs included in the ranking assessment of different Grid Architectures, and “extra indicators”, that do not concur in defining the final ranking of the architectures, but they provide additional information to the study. This categorization is described in Table 1.

With respect to the theoretical framework described in [1], in the WP6 implementation there are some differences, which are justified below:

- the calculation of *variation of the of inter-zonal transmission network losses* is implemented in a simplified way, without taking into account the different approaches due to the presence of branch with imposed flows (i.e. HVDC links) with respect to branch with not imposed flows (i.e. HVAC links). In any case, even if the calculation procedure is implemented, inter-zonal transmission network losses will not effectively be evaluated in the application of the WP6 toolbox in the e-Highway2050 project, due to the lack of values for the losses parameters λ .
- the calculation of the *variation of the Social Welfare due to the exercise of market power* is not performed inside the toolbox, since it requires the possibility to run further zonal system simulations: in any case, the linear regression approach to calculate the updated bid curves for the incumbent GenCo in each cluster (as described in [1]) has been applied externally to the toolbox in order to generate suitable bid

curves. These curves are compatible with the ANTARES simulation tool [2] adopted in the project for zonal system simulations;

- the calculation of *compensation costs due to social and environmental aspects* is implemented according to the revised methodology exposed in Annex 1;
- the evaluation of *time delays in realizing new transmission network assets* is implemented according to the revised methodology exposed in Annex 1;
- scenario flexibility is not calculated anymore, since it should require the simulation of the different Grid Architectures in all the project Scenarios;
- sensitivity to policy pillars is not calculated anymore.

In Table 2, a recap about the indicators, the input files and a short description about calculations behind each indicator are provided. Keep in mind that:

- the set $\{x_{\text{ANTARES}}\}$ is the whole set of information provided by the ANTARES input and output files, described in detail in Section 3.2.4. Other inputs are instead related to user defined input files, described in detail in Section 3.2.5;
- the suffix “i0” identifies the without case for the i -th Scenario;
- the suffix “ij” identifies the j -th with case for the i -th Scenario;
- further methodological details are available in D6.1, [1].

Table 1 - Implementation of BCA indicators in WP6 toolbox

BCA indicators described in [1]	Implemented in WP6 toolbox		Not implemented in WP6 toolbox (explanation)
	Core indicator	Extra indicator	
Total increase of Social Welfare (excluding CO2 emissions)	X		
Total reduction of CO2 emissions	X		
Sensitivity of CO2 price		X	
Total increase of Social Welfare (excluding CO2 emissions) due to market power	X		
Total reduction of CO2 emissions due to market power	X		
Additional installed RES		X	
Reduction of investment costs in distribution networks		X	
Social Welfare split		X	
Life cycle costs - AUTEX		X	X (unavailability of pertinent data)
Life cycle costs - CAPEX = ASSEX + INSTEX	X		
Life cycle costs - OPEX		X	X (unavailability of pertinent data)
Life cycle costs - DECOMMEX		X	X (unavailability of pertinent data)
Life cycle costs - DISPEX		X	X (unavailability of pertinent data)
Reduction of inter-zonal transmission losses	X		
Reduction of intra-zonal transmission losses		X	X (topological limitation and simplified approach)
Social and environmental aspects - Impact on land use - ROW compensation costs		X	
Social and environmental aspects - Impact on biodiversity and landscape		X	X (unavailability of pertinent data)
Social and environmental aspects - Public attitudes and actions		X	X (unavailability of pertinent data)
Social and environmental aspects - Time delays		X	
Impact of innovative transmission technologies - Controllability		X	X (unavailability of pertinent data)
Impact of innovative transmission technologies - Adaptability/relocatability		X	X (unavailability of pertinent data)
Impact of innovative transmission technologies - Enhanced observability		X	X (unavailability of pertinent data)
Security of supply - Reduction of reliability costs (ENS) - European VOLL	X		
Security of supply - Reduction of reliability costs (ENS) - Zonal VOLL		X	
Security of supply - Reduction of reliability costs (ENS) - General methodology		X	
Security of supply - Reduction of resilience costs - General methodology		X	
Security of supply - Reduction of DSM costs - General methodology		X	
Security of supply - Reduction of RES curtailment - General methodology		X	
Financial and regulatory aspects - Common discount rate	X		
Financial and regulatory aspects - Common asset beta		X	
Financial and regulatory aspects - Investment specific asset beta		X	
Financial and regulatory aspects - General methodology		X	
Scenario flexibility		X	X (methodological limitation)
BCA indicators weighting to EU policy pillars		X	X (methodological limitation)

Table 2 – Recap about BCA indicators implemented in WP6 toolbox

BCA indicator	Inputs	Principles of calculation
Total reduction of CO2 emissions	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, CO2 emission tax	A = Reduction of CO2 emissions (with - without) valorized at CO2 emission tax
Total increase of Social Welfare (excluding CO2 emissions)	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, CO2 emission tax, A	B = Difference of variable (fuel) cost of generation (without - with) less A
Sensitivity on CO2 emission tax	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, CO2 emission tax	Interval of values for CO2 emission tax which does not change generation merit order
Total increase of Social Welfare (excluding CO2 emissions) due to market power	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, CO2 emission tax, {bid-up cost curves} $_{i0}$, {bid-up cost curves} $_{ij}$, B	D = $B_{\text{generation curves with bid-up}}$ less $B_{\text{marginal cost curves}}$
Total reduction of CO2 emissions due to market power	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, CO2 emission tax, {bid-up cost curves} $_{i0}$, {bid-up cost curves} $_{ij}$, A	C = $A_{\text{generation curves with bid-up}}$ less $A_{\text{marginal cost curves}}$
Additional installed RES	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, PTDF $_{i0}$, PTDF $_{ij}$, Additional RES potentials in clusters	Iterative procedure: additional RES installed capacity given substitution effect thermal - RES preserving generation merit order and respecting transmission constraints (DC load flow approximation), taking into account RES potential in clusters
Reduction of investment costs in distribution networks	$X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, distribution network consistencies inside each cluster, unitary cost of investment in distribution networks, DSM penetration, average (TOTEX) cost of distributed storage systems	The variation of investment in distribution network is assumed proportional to the variation of the absolute value of the maximum injection inside each cluster. The latter is function of DSM and storage usage (injection peak shaving involves energy shifting)
Social Welfare split	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$	A+B are splitted, at cluster level, in: 1) variation of merchandise surplus 2) variation of producers + consumers surpluses
Life cycle costs - AUTEX	<i>Not implemented in WP6 toolbox</i>	<i>Not applicable</i>
Life cycle costs - CAPEX = ASSEX + INSTEX	Strategy $_{ij}$, Technological information	According to the Strategy, for each corridor of a Grid Architecture the CAPEX cost is computed: discount rate(s) and ROW compensation costs are internalized
Life cycle costs - OPEX	<i>Not implemented in WP6 toolbox</i>	<i>Not applicable</i>
Life cycle costs - DECOMMEX	<i>Not implemented in WP6 toolbox</i>	<i>Not applicable</i>
Life cycle costs - DISPEX	<i>Not implemented in WP6 toolbox</i>	<i>Not applicable</i>
Reduction of inter-zonal transmission losses	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, losses parameters $_{i0}$, losses parameters $_{ij}$,	Variation of losses $_{ij}$ = [Losses_parameter * Length * (Power_flow) 2] $_{ij}$ + - [Losses_parameter * Length * (Power_flow) 2] $_{i0}$
Reduction of intra-zonal transmission losses	<i>Not implemented in WP6 toolbox</i>	<i>Not applicable</i>
Social & environmental aspects - Impact on land use - ROW compensation costs	Strategy $_{ij}$, Technological information, ROW unitary costs (at country level and considering land uses)	According to the Strategy, for each corridor of a Grid Architecture the ROW compensation cost is computed according to the inputs
Social & environmental aspects - Impact on biodiversity and landscape	<i>Not implemented in WP6 toolbox</i>	<i>Not applicable</i>
Social & environmental aspects - Public attitudes and actions	<i>Not implemented in WP6 toolbox</i>	<i>Not applicable</i>
Social & environmental aspects - Time delays	Strategy $_{ij}$, Technological information, time delays (country level historical data)	According to the Strategy, for each corridor of a Grid Architecture the time delay is computed according to the inputs
Impact of innovative transmission technologies - Controllability	<i>Not implemented in WP6 toolbox</i>	<i>Not applicable</i>
Impact of innovative transmission technologies - Adaptability/relocatability	<i>Not implemented in WP6 toolbox</i>	<i>Not applicable</i>
Impact of innovative transmission technologies - Enhanced observability	<i>Not implemented in WP6 toolbox</i>	<i>Not applicable</i>
Security of supply - Reduction of reliability costs (ENS) - European VOLL	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, load type, uniform (at European level) VOLL value	$(ENS_{i0} - ENS_{ij}) \times VOLL$

BCA indicator	Inputs	Principles of calculation
Security of supply - Reduction of reliability costs (ENS) - Zonal VOLL	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, load type, zonal VOLL values	for the k -th cluster: $\sum_k (ENS_{i0k} - ENS_{ijk}) \cdot VOLL_k$
Security of supply - Reduction of reliability costs (ENS) - General methodology	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, load type, zonal VOLL values (differentiated on load type and interruption duration)	for the k -th cluster, h -th hour, t -th load type $E =$ $\sum_k \sum_h \left(\sum_t ENS_{i0kht} - ENS_{ijk} \right) \cdot VOLL_k$ No double counting with resilience and DSM costs
Security of supply - Reduction of resilience costs - General methodology	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, load type, zonal VOLL values (differentiated on load type and interruption duration), E , probability of extreme events, generation and import capacity margins to overcome extreme events	Reduction of ENS due to extreme events achievable thanks to network reinforcements. No double counting with reliability and DSM costs
Security of supply - Reduction of DSM costs - General methodology	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, load type, zonal VOLL values (differentiated on load type and interruption duration), E , interruptible load percentage on total load, interruptible load costs (both capacity and energy component)	Reduction of interruptible load expenses thanks to network reinforcement. No double counting with reliability and resilience costs
Security of supply - Reduction of RES curtailment - General methodology	$\{X_{ANTARES}\}_{i0}, \{X_{ANTARES}\}_{ij}$, RES curtailment valorization	$(RES\ curtailment_{i0} - RES\ curtailment_{ij}) \times RES\ curtailment\ valorization$
Financial & regulatory aspects - Common discount rate	User defined common discount rate (DR)	DR = user defined discount rate
Financial & regulatory aspects - Common asset beta	Common risk free rate (RF), common market premium risk (MP), common asset beta (β)	DR = RF + MP x β
Financial & regulatory aspects - Investment specific asset beta	Common risk free rate, common market premium risk, OPT3_FR_ij: investment specific asset beta values (β_k)	for the k -th corridor: DR _k = RF + MP x β_k
Financial & regulatory aspects - General methodology	Common risk free rate, common market premium risk, OPT_FR4_ij (KPI values): transmission technology TRL values, type of investment regulation, investor type, OPEX regulation, inflation, scenarios uncertainties, interest rate movements, residual asset evaluation, allowed return	for the k -th corridor: DR _k = RF + MP x β_k (inputs)
Scenario flexibility	<i>Not implemented in WP6 toolbox</i>	<i>Not applicable</i>
BCA indicators weighting to EU energy policy pillars	<i>Not implemented in WP6 toolbox</i>	<i>Not applicable</i>

3. Toolbox manual

3.1. General description

The WP6 toolbox has been developed in Microsoft VBA Access 2010. This implementation allows the user to import the pertinent information, run the computation code and display the results in terms of synthetic tables and graphs by a simple mouse click.

The WP6 toolbox has to be applied downstream to the e-Highway2050 zonal system simulations: therefore, it is fully compatible with Antares I/O files.

The main inputs of the WP6 toolbox are provided by WP2 and they are constituted by inputs and outputs of the zonal system simulations performed for each case. Beside this data, the tool receives as input also a set of standard parameters that complete the description of each case. The detailed list of the data needed for the computation of each BCA indicator is reported in Sections 3.2.4 and 3.2.5, with a description of the data format.

For a given e-Highway2050 Scenario and Grid Architecture, the aforementioned data are stored in text files (with extension “.txt”) or in spreadsheet files (“.xls”) that represent the starting point for each BCA evaluation. In particular:

- text files are used to store the needed input and output files from Antares
- spreadsheet files store the user-defined data, in order to be easily managed and modified by the user.

The aforementioned implementation solutions allow an efficient use of memory and computation resources and, at the same time, an easy use.

The information stored in those files are processed independently by computation modules (described in Section 3.3) that implement the BCA methodology. These modules shall elaborate the BCA indicators of its own pertinence for each case and provide the output following the structure described in Section 3.4.

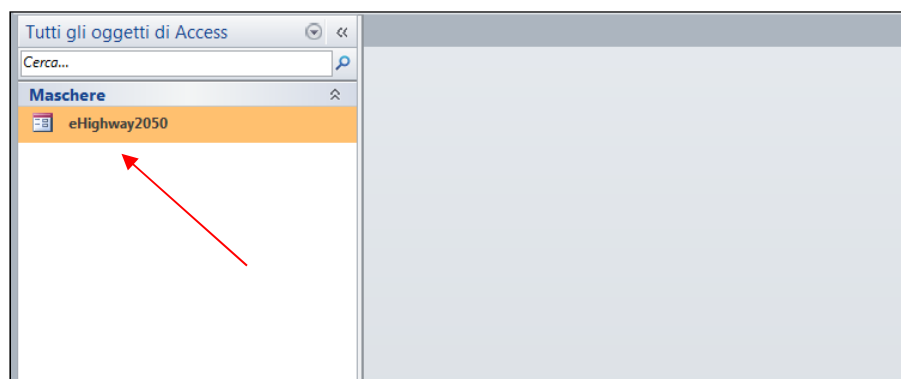


Figure 1 - Open the eHighway2050 mask

The eHighway2050 mask is the Toolbox main mask. To access to it, open the toolbox MS Access file and, double click the mask name, as show in Figure 1.

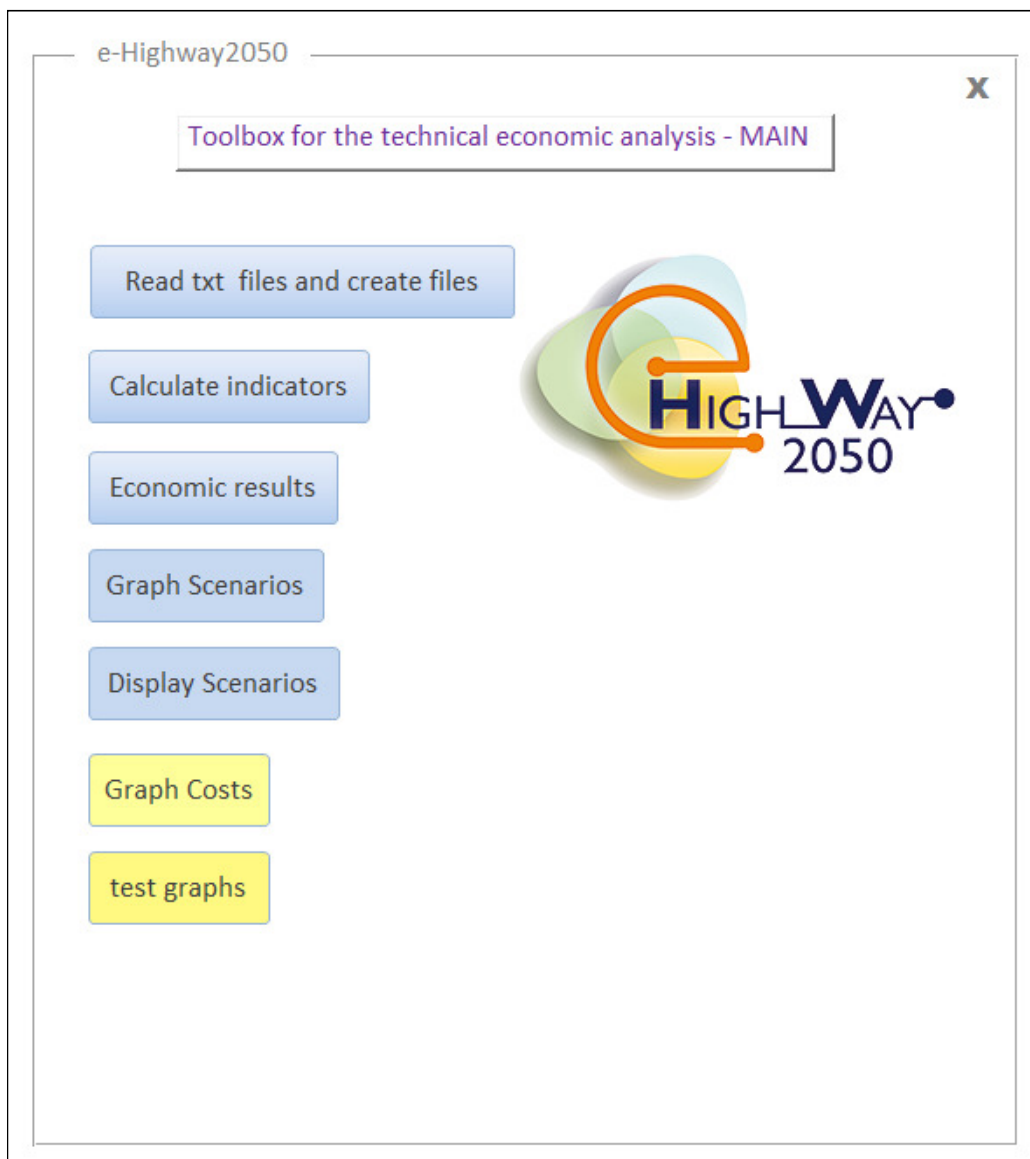


Figure 2 – eHighway2050 mask

The eHighway2050 mask presents a set of buttons (see Figure 2) hereafter described:

- *Read txt files and create files* button: open a mask that allows the user to load ANTARES I/O information needed for BCA and store it in pertinent files.
- *Calculate indicators* button: open a mask that allows the user to calculate the BCA indicators.

- *Economic results* button: open a mask that allows the user display the overall BCA indicators (distinguished in Core and non-Core indicators) to score a specific Grid Architecture.
- *Graph Scenarios* button: open a mask that allows the user display specific BCA indicators in terms of graphs.
- *Display Scenarios* button: open a mask that allows the user to have a synthetic report of the BCA indicators.
- *Graph Costs* and *test graph* buttons have been used for testing further development.

3.2. Toolbox inputs

3.2.1. Toolbox file system – Before running the data acquisition

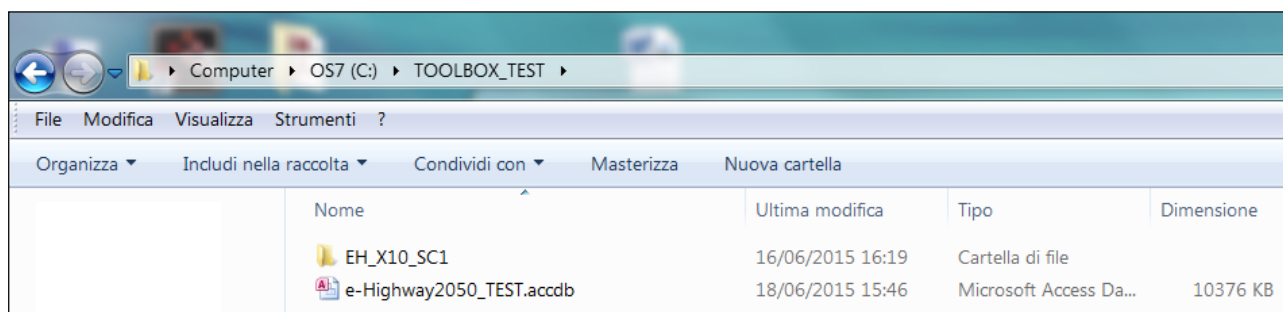


Figure 3 – Toolbox file system – Before running the toolbox

Figure 3 shows how the file system is organized before the Toolbox run:

- a root folder with a generic folder (in the example, “TOOLBOX_TEST”) contains the toolbox file (in the example, “e-Highway2050_TEST.accdb”) as well as the ANTARES files. The toolbox is able to manage more Scenarios: however, since no comparison must be performed between Scenarios, it is suggested to replicate this structure for each Scenario to analyze (i.e. one root folder, one Scenario_folder, one toolbox file);
- a Scenario_folder (in the example, “EH_X10_SC1”) contains the ANTARES I/O files for that specific e-Highway2050 Scenario. The name could be generic, but it must end with a number $i \in [1,9]$. This number is needed in order to identify the Scenario to analyze;
- the Scenario_folder contains others folders where all the ANTARES I/O files Grid Architecture to investigate (see Figure 4): one $W0i$ (the without case, in the example “W01”) and one or more Aij (in the example, “A11”), where $i \in [1,5]$ identifies the specific Grid Architecture to analyze. The use of his syntax for naming the folder is mandatory. The content of $W0i$ and Aij folders is shown in Figure 5 and Figure 6, respectively.

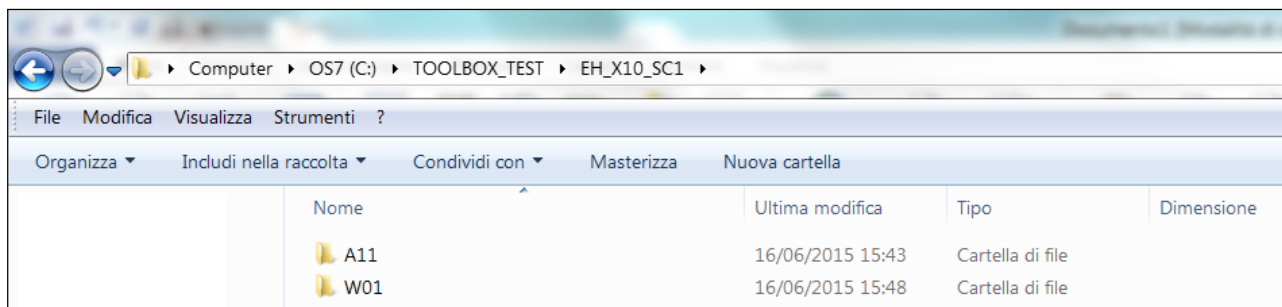


Figure 4 – Scenario_folder: “without” and “with” folders

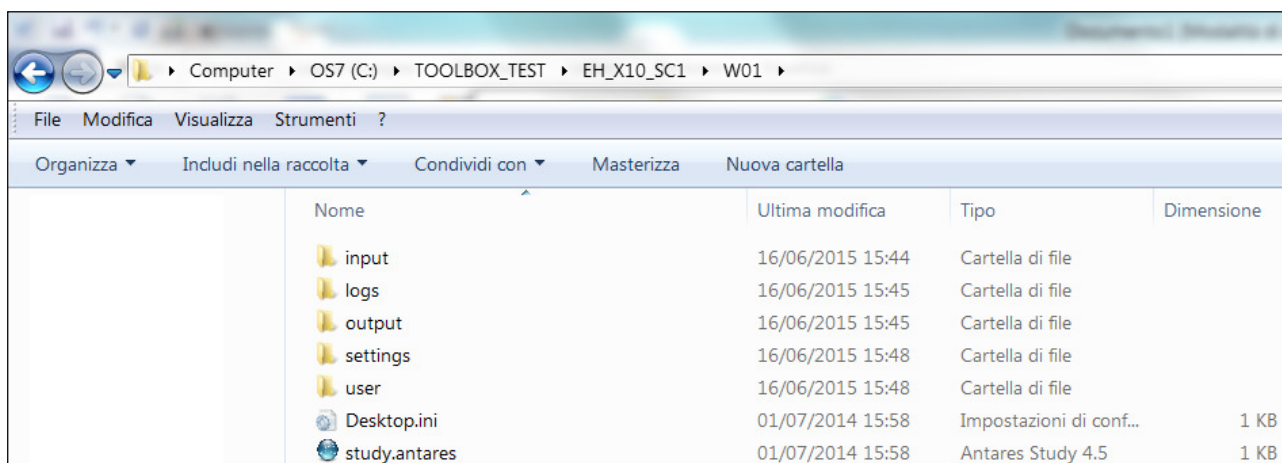


Figure 5 – Scenario_folder: “without” folder content

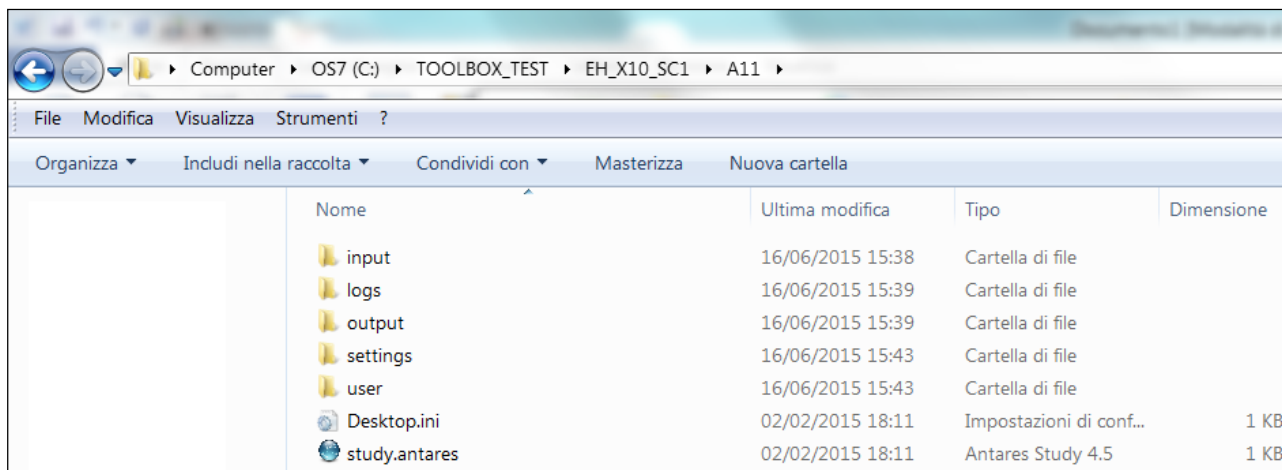


Figure 6 – Scenario_folder: “with” folder content

3.2.2. Data acquisition

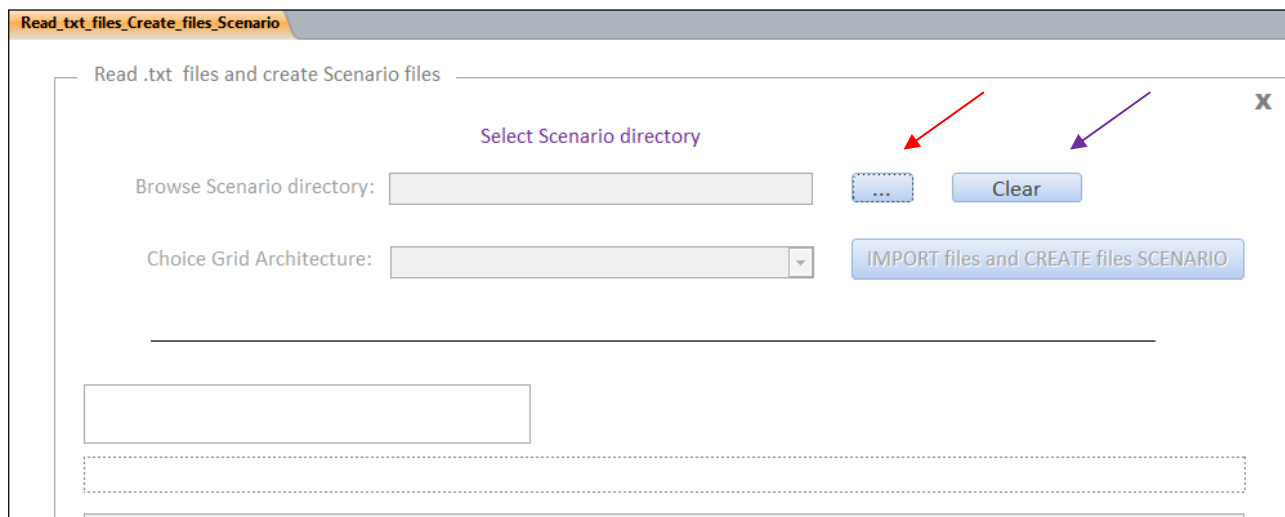


Figure 7 – Reading ANTARES files: browse Scenario directory

- From the eHighway2050 mask, click on *Read txt files and create files*;
- open the menu button, as shown by the red arrow in Figure 7: it will open a folder explorer. Browse until selecting the Scenario_folder (in the example, “C:\TOOLBOX_TEST\EH_X10_SC1”): if you want clear your choice, click on the “Clear” button, highlighted by the purple arrow in Figure 7;
- click on the drop-down menu highlighted by the red circle in Figure 8: you can decide to acquire information for a specific Grid Architecture (in the example, “A11”) or all the available Grid Architectures. In any case, data or the “without” case Grid Architecture is automatically acquired.
- click on the “IMPORT files and CREATE files SCENARIO”, as highlighted by the green arrow in Figure 8.
- data acquisition starts: a short log is available in the page (see Figure 9), but it shows only the first rows: a complete log file (“Highway.log”) is available in root\IN\Scenario_folder (in the example in “C:\TOOLBOX_TEST\IN\EH_X10_SC1”, see Figure 10 and Section Toolbox file system – After running the data acquisition). The toolbox requires about 20 minutes to complete data acquisition for two Grid Architecture (“W01” and “A11” in the example);

- the user is invited to put user defined “Manual_Files” in the pertinent folder (see Section User defined files). To close the box, click “Ok” (blue arrow in Figure 9).
- The close the data acquisition mask, click on the X button in the upper-right corner of the mask (black circle in Figure 9). This action will bring the user to the main mask.

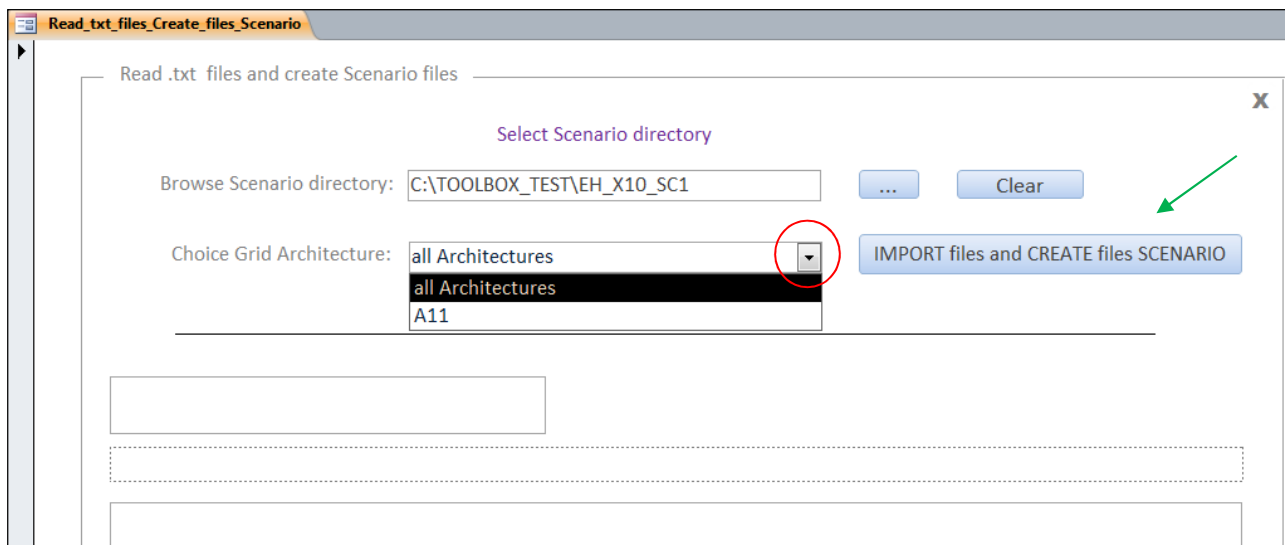


Figure 8 – Reading ANTARES files: import ANTARES file and create toolbox .txt files

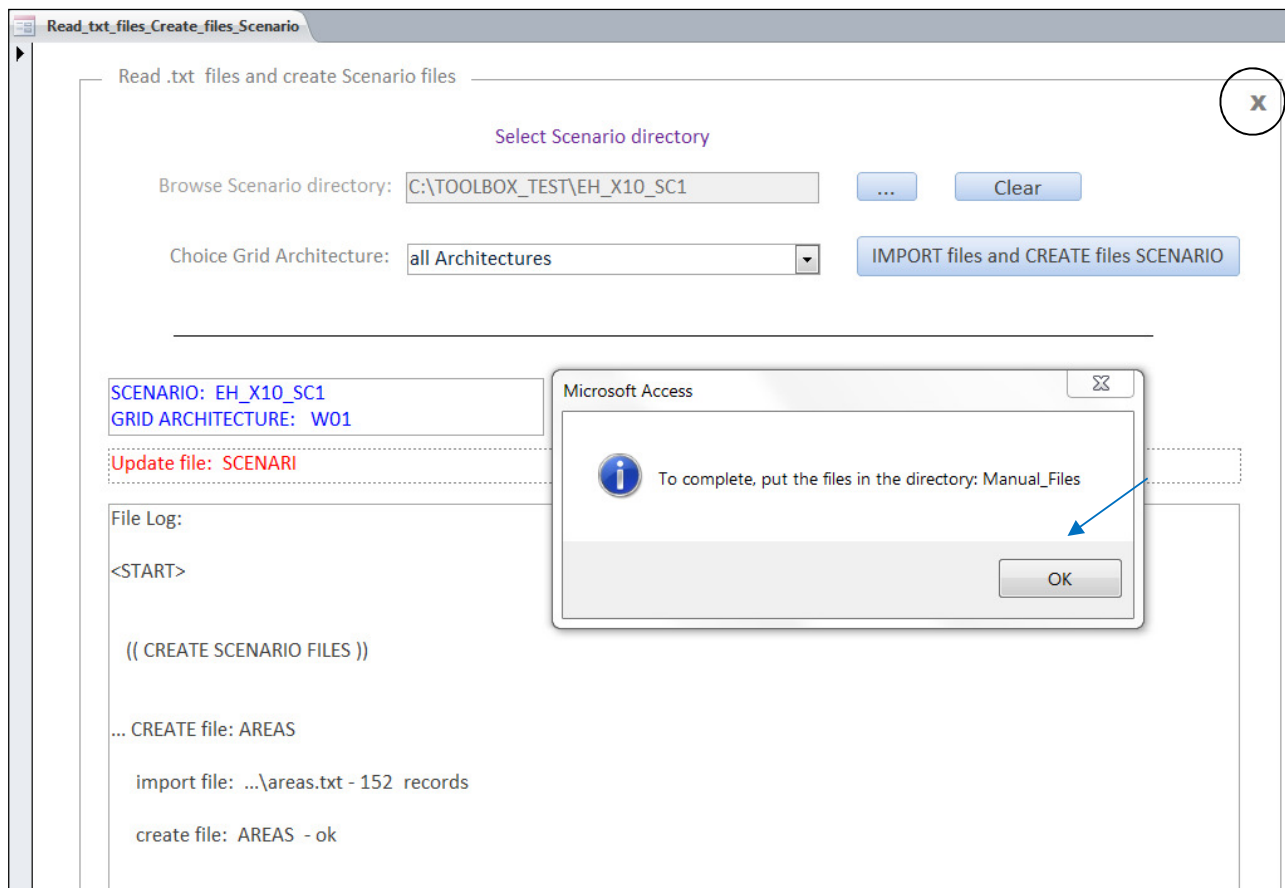


Figure 9 – Reading ANTARES files: end of data acquisition

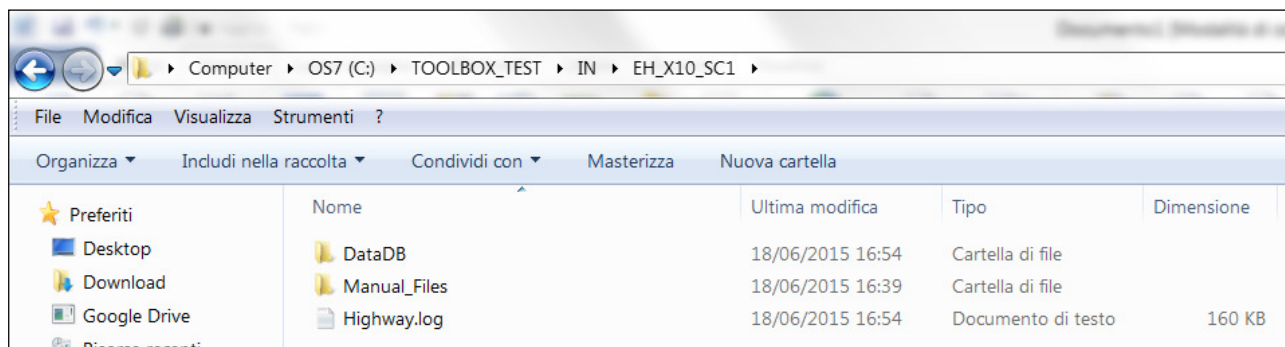


Figure 10 – Reading ANTARES files: data acquisition log file “Highway.log”

3.2.3. Toolbox file system – After running the data acquisition

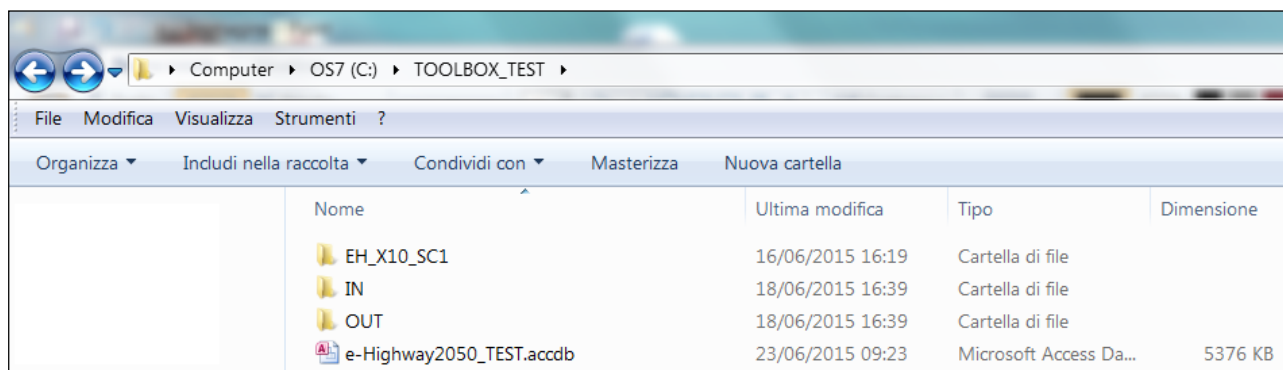


Figure 11 – Toolbox file system – After running data acquisition

Figure 11 shows how the file system is organized before the Toolbox run: in particular, two folders have been created:

- the “IN” folder (Figure 12) is structured as follows:
 - the “Common” folder (Figure 13) contains the file “SCENARI.txt”: this file is used by the Toolbox in order to record what are the Scenarios to analyze:
 - the Scenario_folder (Figure 14, in the example “EH_X10_SC1”) contains:
 - in the “DataDB” folder (Figure 15) information from ANTARES I/O files are stored in text files automatically generated by the Data acquisition procedure (see [Structure of Data DB folder](#) for further information)
 - in the “Manual_Files” folder (Figure 16) , user defined files should be inserted (see [Structure of Manual Files folder](#) for further information)
- the “OUT” folder (Figure 17) content is progressively updated in order to store the output from the Toolbox runs: before starting the indicators calculation, it must include the Excel file (in the example, “Social_Environmental_Aspects_calcsheet.xlsx”) for calculating the effect of Social and Environmental aspects in Life Cycle Costs.

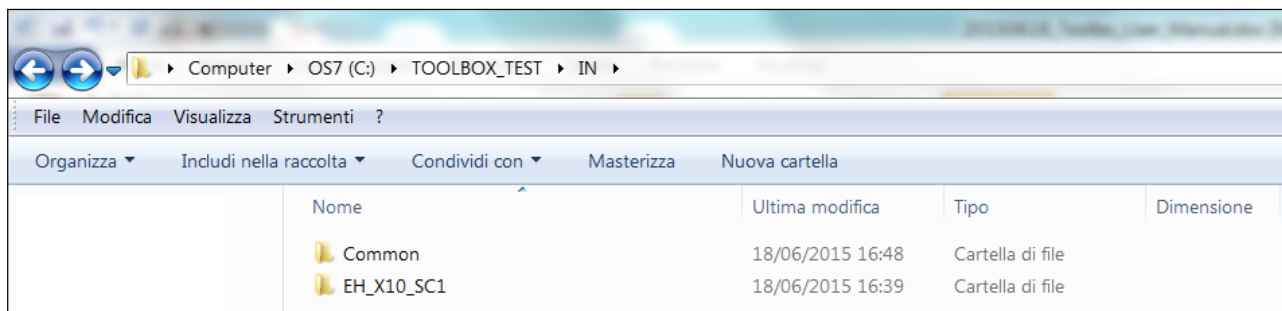


Figure 12 – Toolbox file system – After running data acquisition – “IN” folder

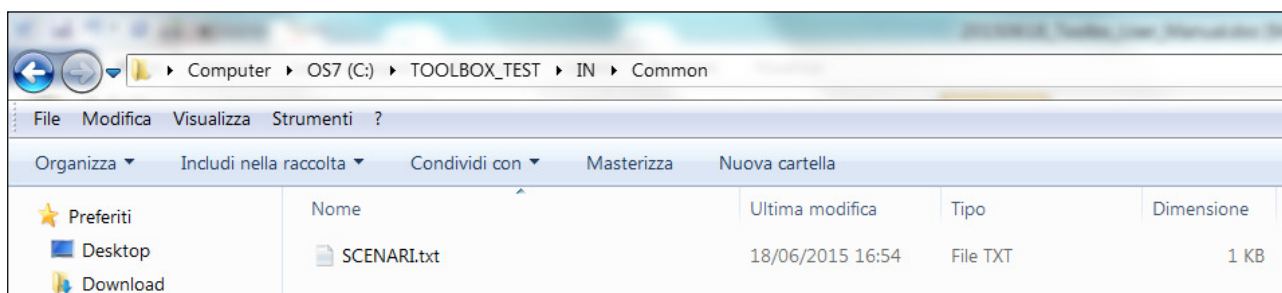


Figure 13 – Toolbox file system – After running data acquisition – “IN\Common” folder

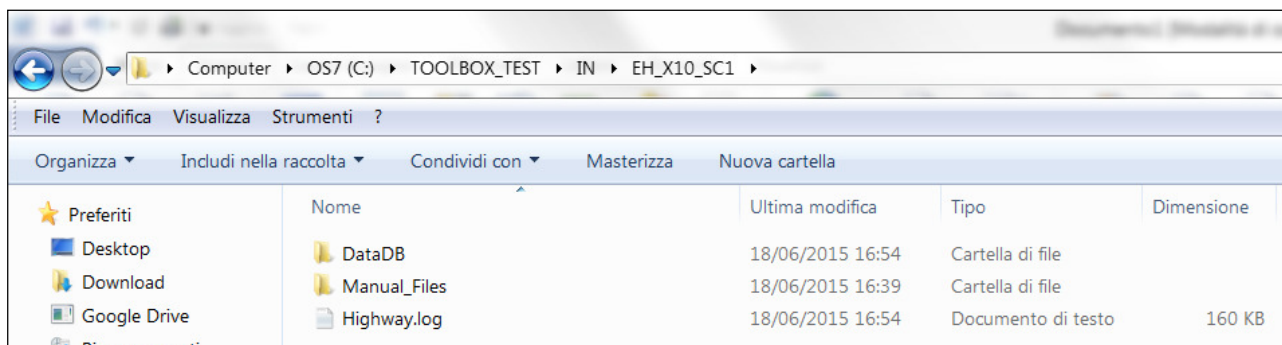


Figure 14 – Toolbox file system – After running data acquisition – “IN\Scenario_folder”

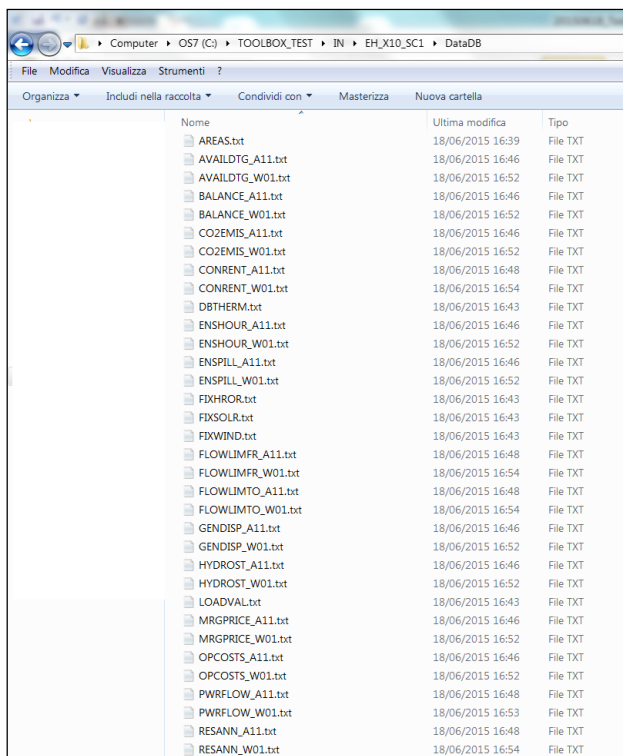


Figure 15 – Toolbox file system – After running data acquisition – “IN\ Scenario_folder\DataDB”

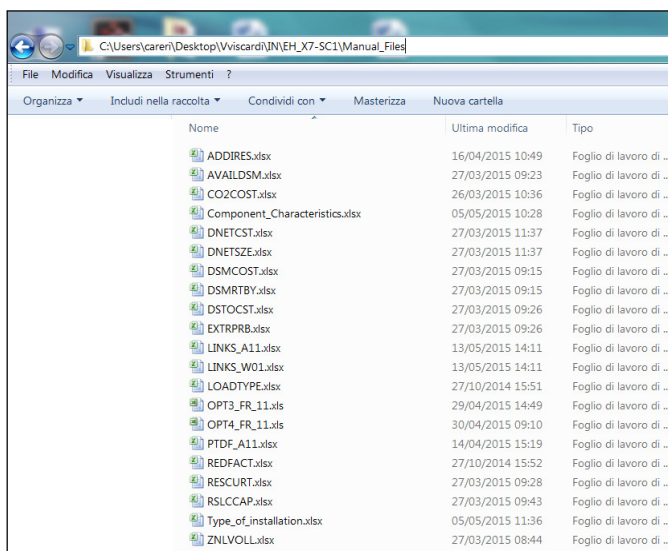


Figure 16 – Toolbox file system – After running data acquisition – “IN\ Scenario_folder\Manual_Files”

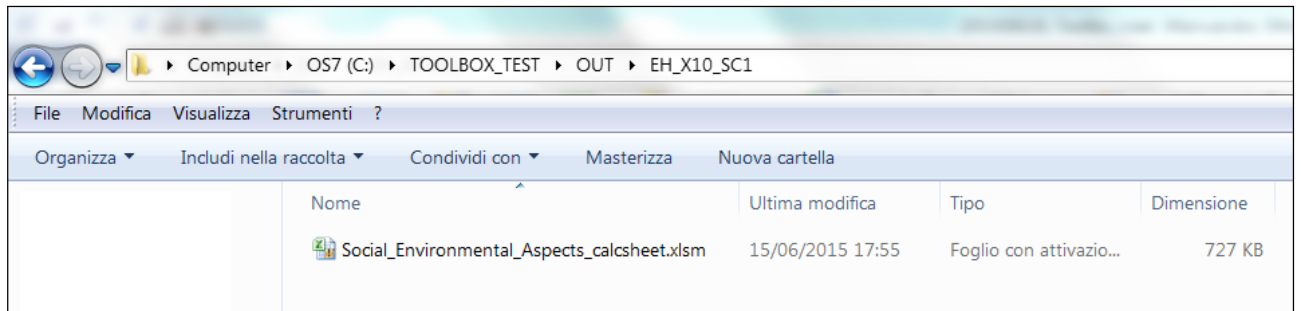


Figure 17 – Toolbox file system – After running data acquisition – “OUT\Scenario” folder

3.2.4. Structure of “DataDB” folder

The information contained in these input files is read from ANTARES I/O files and then it is automatically stored in text files to be used in the BCA assessment. The name of each file (with some exceptions) is structured as follow: *(table name)*_*(case ID)*. The name of the table is constituted by 7 characters, while the case ID entails 3 characters, for identifying the specific case:

- *Aij* Architecture *j* in scenario *i*
- *WOi* Without case in scenario *i*
- *SCi* Scenario *i*

Each table is characterized by:

- **Records** – what data are stored in each row of the table.
- **Fields** – information elements represented by the columns of the table.
- **Referring case** – indicates to which case analyzed the data set refers to.

In the following, the structure of the database is presented, describing in detail for each table, how data are organized. For sake of simplicity, Table 3 shows for each input required by the toolbox the referring file in the DB and the section that describe the structure of the table.

Table 3 – “DataDB” folder content

Data	DB file	Reference
List of areas	AREAS	3.2.4.1
Total dispatchable generation for clusters	AVAILDTG	3.2.4.2
Hourly net balance of clusters	BALANCE	3.2.4.3
Hourly CO2 emissions	CO2EMIS	3.2.4.4
Hourly congestion rents	CONRENT	3.2.4.5
Thermal gen data: marginal cost, Pmax, Pmin	DBTHERM	3.2.4.6
Hourly ENS	ENSHOUR	3.2.4.7
Hourly spilled energy	ENSPILL	3.2.4.8
Hourly run of river generation	FIXHROR	3.2.4.9
Hourly solar generation	FIXSOLR	3.2.4.10
Hourly wind generation	FIXWIND	3.2.4.11
Power flow limits	FLOWLIMFR	3.2.4.12
	FLOWLIMTO	3.2.4.13
Market results: generation scheduling	GENDISP	3.2.4.14
Hourly value of the reservoir hydro generation	HYDROST	3.2.4.15
Hourly load	LOADVAL	3.2.4.16
Hourly market results: zonal prices	MGPRICE	3.2.4.17
Market results: operating costs	OPCOSTS	3.2.4.18
Market results: hourly power flows	PWRFLOW	3.2.4.19
Hourly overall operating costs and CO2 emissions	RESANN	3.2.4.20

3.2.4.1. AREAS

This table contains the list of the clusters.

Records: single value

3.2.4.2. AVAILDTG_Aij(WO*i*)

This table contains the hourly value of dispatchable thermal generation available in each cluster.

Records: hourly values

Fields: one record for each cluster

Referring case: one table for each without case *i* and for each architecture *ij*

Data format: Text file

3.2.4.3. BALANCE_Aij(WO*j*)

This table contains the hourly value of the net balance (*generation - load*) resulting from simulations in each cluster.

Records: hourly values

Fields: one record for each cluster

Referring case: one table for each without case *i* and for each architecture *ij*

Data format: Text file

3.2.4.4. CO2EMISS_Aij(WO*j*)

This table contains the hourly value of the CO2 emissions [t] resulting from simulations in each cluster.

Records: hourly values

Fields: one record for each cluster

Referring case: one table for each without case *i* and for each architecture *ij*

Data format: Text file

3.2.4.5. **CONRENT_Aij(WOj)**

This table contains the hourly algebraic value of congestion rent.

Records:	hourly values
Fields:	one record for each corridor
Referring case:	one table for each without case <i>i</i> and for each architecture <i>ij</i>
Data format:	Text file

3.2.4.6. **DBTHERM**

This table contains data of thermal generators of the system.

Records:	4 x n°cluster+2 (see sample of the table)
Fields:	16 (see sample of the table)
Referring case:	single table
Data format:	Text file

3.2.4.7. **ENSHOUR_Aij(WOi)**

This table contains the hourly value of Energy Not Supplied [MWh] in each cluster.

Records:	hourly values
Fields:	one record for each cluster
Referring case:	one table for each without case <i>i</i> and for each architecture <i>ij</i>
Data format:	Text file

3.2.4.8. **ENSPILL_Aij(WOi)**

This table contains the hourly value of energy spilled [MWh] in each cluster.

Records:	hourly values
Fields:	one record for each cluster
Referring case:	one table for each without case <i>i</i> and for each architecture <i>ij</i>
Data format:	Text file

3.2.4.9. *FIXHROR_S*i**

This table contains the hourly value of energy from run-of-river hydro [MWh] in each cluster.

- Records:** hourly values
- Fields:** one record for each cluster
- Referring case:** one table for each scenario *i*
- Data format:** Text file

3.2.4.10. *FIXSOLR_S*i**

This table contains the hourly value of energy from PV solar [MWh] in each cluster.

- Records:** hourly values
- Fields:** one record for each cluster
- Referring case:** one table for each scenario *i*
- Data format:** Text file

3.2.4.11. *FIXWIND_S*i**

This table contains the hourly value of energy from wind [MWh] in each cluster.

- Records:** hourly values
- Fields:** one record for each cluster
- Referring case:** one table for each scenario *i*
- Data format:** Text file

3.2.4.12. *FLOWLIMFR_Aij(WOi)*

This table contains the network architectures for the case $Aij(WOi)$, in terms of power flow limit. This is the flow limit of the direct way of the link (from A to B). In the table are reported all the possible links among clusters. If a link actually does not exist the flow limit is zero.

Records:	for each corridor of the network
Fields:	one record for the case
Referring case:	single table (it contains all case data)
Data format:	Text file

3.2.4.13. *FLOWLIMTO_Aij(WOi)*

This table contains the network architectures for the case $Aij(WOi)$, in terms of power flow limit. This is the flow limit of the opposite way of the link (from B to A). In the table are reported all the possible links among clusters. If a link actually does not exist the flow limit is zero.

Records:	for each corridor of the network
Fields:	one record for the case
Referring case:	single table (it contains all case data)
Data format:	Text file

3.2.4.14. *GENDISP_Aij(WOi)*

This table contains the hourly generation dispatch [MWh] resulting from market simulations in each cluster, divided per technology. Results of each cluster are staked in succession as records (see sample below).

Records:	hourly values x n° clusters
Fields:	one record for each technology
Referring case:	one table for each without case i and for each architecture ij
Data format:	Text file

3.2.4.15. *HYDROST_Aij(WOj)*

This table contains the hourly value of the reservoir hydro generation resulting from simulations in each cluster.

Records:	hourly values
Fields:	one record for each cluster
Referring case:	one table for each without case <i>i</i> and for each architecture <i>ij</i>
Data format:	Text file

3.2.4.16. *LOADVAL_SCi*

This table contains the hourly value of load [MWh] in each cluster.

Records:	hourly values
Fields:	one record for each cluster
Referring case:	one table for each scenario <i>i</i>
Data format:	Text file

3.2.4.17. *MGPRICE_Aij(WOi)*

This table contains the hourly value of marginal price [€/MWh] resulting from simulations in each cluster.

Records:	hourly values
Fields:	one record for each cluster
Referring case:	one table for each without case <i>i</i> and for each architecture <i>ij</i>
Data format:	Text file

3.2.4.18. **OPCOSTS_Aij(WOi)**

This table contains the hourly value of operation costs [€] resulting from simulations in each cluster.

Records:	hourly values
Fields:	one record for each cluster
Referring case:	one table for each without case <i>i</i> and for each architecture <i>ij</i>
Data format:	Text file

3.2.4.19. **PWRFLOW_Aij(WOi)**

This table contains the hourly value of power flows [MW] resulting from simulations in each corridors.

Records:	hourly values
Fields:	one record for each corridors
Referring case:	one table for each without case <i>i</i> and for each architecture <i>ij</i>
Data format:	Text file

3.2.4.20. **RESANN_Aij(WOi)**

This table contains the hourly values of the overall operating costs [€/h] and CO2 emissions [t]

Records:	hourly values
Fields:	two record for each clusters
Referring case:	one table for each without case <i>i</i> and for each architecture <i>ij</i>
Data format:	Text file

3.2.5. Structure of “Manual_Files” folder

The information contained in these input files is prepared by the toolbox user in terms of spreadsheet (Excel) files to be used in the BCA assessment. The name of each file (with some exceptions) is structured as follow: *(table name)*_*(case ID)*. The name of the table is often constituted by 7 characters, while the case ID entails 3 characters, for identifying the specific case:

- *Aij* Architecture *j* in scenario *i*
- *WOi* Without case in scenario *i*
- *SCi* Scenario *i*

Each table is characterized by:

- **Records** – what data are stored in each row of the table.
- **Fields** – information elements represented by the columns of the table.
- **Referring case** – indicates to which case analyzed the data set refers to.

In the following, the structure of the database is presented, describing in detail for each table, how data are organized. For sake of simplicity, Table 4 shows for each input required by the toolbox the referring file in the DB and the section that describe the structure of the table.

Table 4 – “Manual_Files” folder content

Data	DB file	Reference
Additional RES installed capacity	<i>ADDIRES</i>	3.2.5.1
Available DSM	<i>AVAILDMS</i>	3.2.5.2
CO2 emission tax	<i>CO2COST</i>	3.2.5.3
Transmission technologies data	<i>Component_Characteristics</i>	3.2.5.4
Unitary investment costs in distribution network	<i>DNETCST</i>	3.2.5.5
Distribution network consistencies	<i>DNETSZE</i>	3.2.5.6
DSM costs	<i>DSMCOST</i>	3.2.5.7
Amount of DSM for reliability purposes	<i>DSMRTBY</i>	3.2.5.8
Average cost of storage in distributin network	<i>DSTOCST</i>	3.2.5.9
Probability of occurrence of extreme events	<i>EXTRPRB</i>	3.2.5.10
Data for evaluating transmission losses	<i>LINKS</i>	3.2.5.11
Percentage of load demand for economic activity	<i>LOADTYPE</i>	3.2.5.12
Input file for F&R - Option 3	<i>OPT3_FR</i>	3.2.5.13
Input file for F&R - Option 4	<i>OPT4_FR</i>	3.2.5.14
PDF matrix	<i>PTDF</i>	3.2.5.15
Reduction factors on interconnection capacity	<i>REDFACT</i>	3.2.5.16
RES curtailment cost	<i>RESCURT</i>	3.2.5.17
Reduction of generation capacity on extreme events	<i>RSLCCAP</i>	3.2.5.18
Type of installation for transmission technologies	<i>Type_of_installation</i>	3.2.5.19
Zonal VOLL	<i>ZNLVOLL</i>	3.2.5.20

3.2.5.1. *ADDIRES*

This table contains the additional amount of RES [MW] that can be further installed in each cluster.

<i>Records:</i>	single value
<i>Fields:</i>	one record for each cluster
<i>Referring case:</i>	one table
<i>Data format:</i>	Spreadsheet file

3.2.5.2. *AVAILDSM*

This table contains the amount of DSM [% of Load] assumed to be available in each cluster.

<i>Records:</i>	one value for electric vehicles (ID 1) and one value for electric heating (ID 2)
<i>Fields:</i>	one record for each cluster
<i>Referring case:</i>	one table
<i>Data format:</i>	Spreadsheet file

3.2.5.3. *CO2COST*

This table contains the CO2 price assumed in scenario *i*.

<i>Records:</i>	single value
<i>Fields:</i>	single value
<i>Referring case:</i>	one table
<i>Data format:</i>	Spreadsheet file

3.2.5.4. *Component_Characteristics*

This table contains the technological data on transmission technologies from WP2.

Records:	n° of transmission technologies x 11 <ul style="list-style-type: none">- #1: Technology name- #2: Technology type<ul style="list-style-type: none">o Refurbishmento AC OHLo AC cableo DC OHLo DC Cableo DC subsea cable- #3: Kilometric investment cost [k€/km]:- #4: Kilometric investment lifetime [y]:- #5: Concentrated investment cost [k€/MW]- #6: Concentrated investment lifetime [y]- #7: Maximum power of ne circuit [MW]- #8: Kilometric OPEX cost [k€/(km*y)]- #9: Concentrated OPEX cost [k€/(MW*y)]- #10: Kilometric DECOMMEX+DISPEX cost [k€/km]- #11: Concentrated DECOMMEX+DISPEX cost [k€/MW]<ul style="list-style-type: none">o HIGH
Referring case:	one table
Data format:	Spreadsheet file

3.2.5.5. *DNETCST*

This table contains the average cost [€/km] assumed for reinforcing the distribution network in scenario *i*.

Records:	single value
Fields:	single value
Referring case:	one table for each scenario <i>i</i>
Data format:	Spreadsheet file

3.2.5.6. *DNETSZE*

This table contains the average size [km] assumed for the distribution network of each cluster in scenario *i*.

Records:	single value
Fields:	one record for each cluster
Referring case:	one table for each scenario <i>i</i>
Data format:	Spreadsheet file

3.2.5.7. *DSMCOST*

This table contains the costs [€/MW] for contractualizing interruptible loads and the costs [€/MWh] for using it during the operation, assumed for each cluster.

Records:	first record is the cost of contractualization [€/MW], the second record is the cost for using the interruptible load.
Fields:	one record for each cluster
Referring case:	one table for each scenario <i>i</i>
Data format:	Spreadsheet file

3.2.5.8. *DSMRBTY*

This table contains the values of DSM in each cluster available for reliability purpose.

Records:	single value
Fields:	one record for each cluster
Referring case:	one table for each scenario
Data format:	Spreadsheet file

3.2.5.9. *DSTOCST*

This table contains the average cost [€/MWh] assumed for the installation of distributed storage in scenario *i*.

Records:	single value
Fields:	single value
Referring case:	one table for each scenario <i>i</i>
Data format:	Spreadsheet file

3.2.5.10. *EXTRPRB*

This table contains the probability of occurrence of an extreme event for each cluster.

Records:	single value
Fields:	one record for each cluster
Referring case:	single table
Data format:	Spreadsheet file

3.2.5.11. *LINKS_Aij(WOi)*

This table is partially generated as a black file when the calculation of the variation of interzonal transmission losses is launched. It must be filled by the user with the pertinent data for the aforementioned calculation.

Records:	n° corridor x 5 - #1: Corridor (automatically filled) - #2-#3: Cluster from-to (automatically filled) - #5: length of the corridor [km] - #5: loss parameter [MW/(km*MW ²)]
Referring case:	one table for each without case <i>i</i> and for each architecture <i>ij</i>
Data format:	Spreadsheet file

3.2.5.12. **LOADTYPE**

This table contains the percentage of load demand corresponding to each type of economic activity for each cluster.

Records: single value x n° of load type (3 load type assumed)

Fields: one record for each cluster

Referring case: single table

Data format: Spreadsheet file

3.2.5.13. **OPT3_ij**

This table contains the input data for calculating the role of financial and regulatory aspects assuming Option 3: *Investment specific asset betas*.

Records: n° of reinforced links x 3:

- #1-#2: Cluster from - to
- #3: Asset beta value

Referring case: one table for each without case *i* and for each architecture *ij*

Data format: Spreadsheet file

3.2.5.14. OPT4_{ij}

This table contains the input data for calculating the role of financial and regulatory aspects assuming Option 3: *General Methodology*.

- Records:** n° of reinforced links x 12:
- #1-#2: Cluster from-to
 - #3: Technology Readiness Level (TRL). $TRL \in [1,9]$
 - #4-#5: Investment regulation scheme cluster from-to:
 - o IB: Incentive Based
 - o CB: Cost based
 - o CONC: Concession
 - #6: Investor type
 - o TO: Transmission Owner
 - o TSO: Transmission System Operator
 - #7: Operation cost scheme
 - o IB: Incentive base
 - o CB: Cost base with ex-post check
 - #8: Inflation level
 - o LOW
 - o MEDIUM
 - o HIGH
 - #9: Scenario Uncertainties
 - o LOW
 - o MEDIUM
 - o HIGH
 - #10: Residual asset evaluation
 - o RC: Replacement cost
 - o NRC: Non-replacement cost
 - #11: Interest rate movement
 - o LOW
 - o MEDIUM
 - o HIGH
 - #12: Allowed return
 - o LOW
 - o MEDIUM
 - o HIGH

Referring case: one table for each without case *i* and for each architecture *ij*

Data format: Spreadsheet file

3.2.5.15. *PTDF_Aij*

This table contains the PTDF matrix for the modeled AC network.

Records:	n° of clusters x n° of AC links
Referring case:	one table for each without case <i>i</i> and for each architecture <i>ij</i>
Data format:	Spreadsheet file

3.2.5.16. *REDFACT*

This table contains the reduction factors for accounting the interconnection capacity in the resilience calculation. The first factor regards the neighboring clusters, while the second one regards the third clusters.

Records:	single value
Fields:	one record for “neighboring” and one record for “third”.
Referring case:	single table
Data format:	Spreadsheet file

3.2.5.17. *RESCURT*

This table contains the RES curtailment cost [€/MWh] assumed in each cluster.

Records:	single value
Fields:	one record for each cluster
Referring case:	one table for each scenario <i>i</i>
Data format:	Spreadsheet file

3.2.5.18. *RSLCCAP*

This table contains the factors for reducing the existing generation capacity to compute the amount of generation capacity lost due to the occurrence of an extreme event in each cluster.

Records:	one value for “Non-usable capacity”, one for “Maintenance overhauls outages” and one for “System service reserve”
Fields:	one record for each cluster
Referring case:	single table
Data format:	Spreadsheet file

3.2.5.19. *Type_of_installation*

This table contains further data about the type of installation for each transmission technology

Records:	n° of transmission technologies x 3 <ul style="list-style-type: none">- #1: Technology name- #2: Technology type<ul style="list-style-type: none">○ Refurbishment○ AC OHL○ AC cable○ DC OHL○ DC Cable○ DC subsea cable- #3: Type of installation<ul style="list-style-type: none">○ Overhead lines○ Underground cables○ Sub sea cables
Referring case:	one table
Data format:	Spreadsheet file.

3.2.5.20. **ZNLVOLL**

This table contains the values of VOLL [€/MWh] assumed for each cluster, differentiated for 3 load type.

Records: single value x n° of load type (3 load type assumed)

Fields: one record for each cluster

Referring case: one table for each scenario *i*

Data format: Spreadsheet file

3.3. Calculation of BCA indicators

Keep in mind that, since the effect of some indicators is internalized in other, some indicators should be calculated before others. In particular:

- “CO2 price sensitivity” and “Market Power” (in this order) should be calculated after “Social Welfare”;
- “Financial and Regulation” and “Social Environmental Aspects” (in this order) should be calculated before “Life-cycle Costs”.

3.3.1. Calculation of “Social Welfare”

- From the eHighway2050 mask, click on *Calculate indicators*;
- Select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 18, respectively);
- Click on “Social Welfare” (blue arrow in Figure 18): a new windows opens (Figure 19);
- If the marginal costs of generation include the costs of CO2 emission, click on the pertinent checkbox (red arrow in Figure 19). This option must always be selected in the e-Highway2050 project activities;
- Click on “Calculate button” (purple arrow in Figure 19): the indicator is usually calculated in mere seconds;
- After the calculation, close the mask clicking “Ok” in the textbox (red arrow in Figure 20) and clicking on the upper right “X” symbol (black circle in Figure 20).

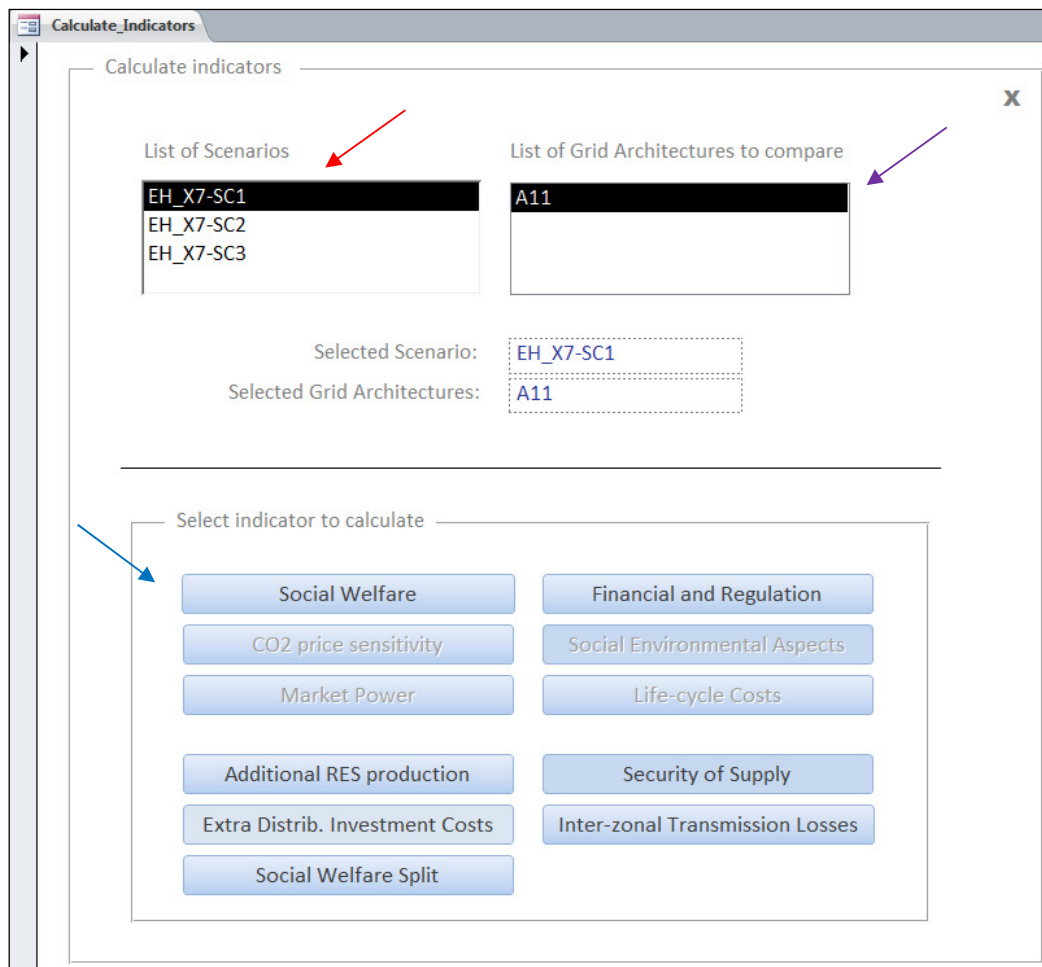


Figure 18 - Calculate indicators - Social Welfare

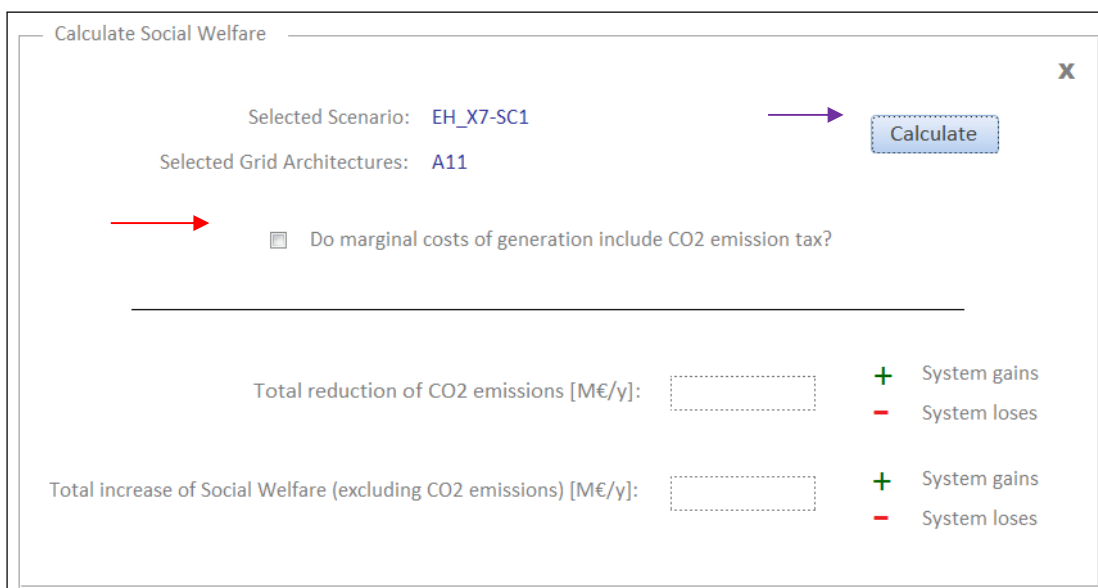


Figure 19 -Social Welfare calculation

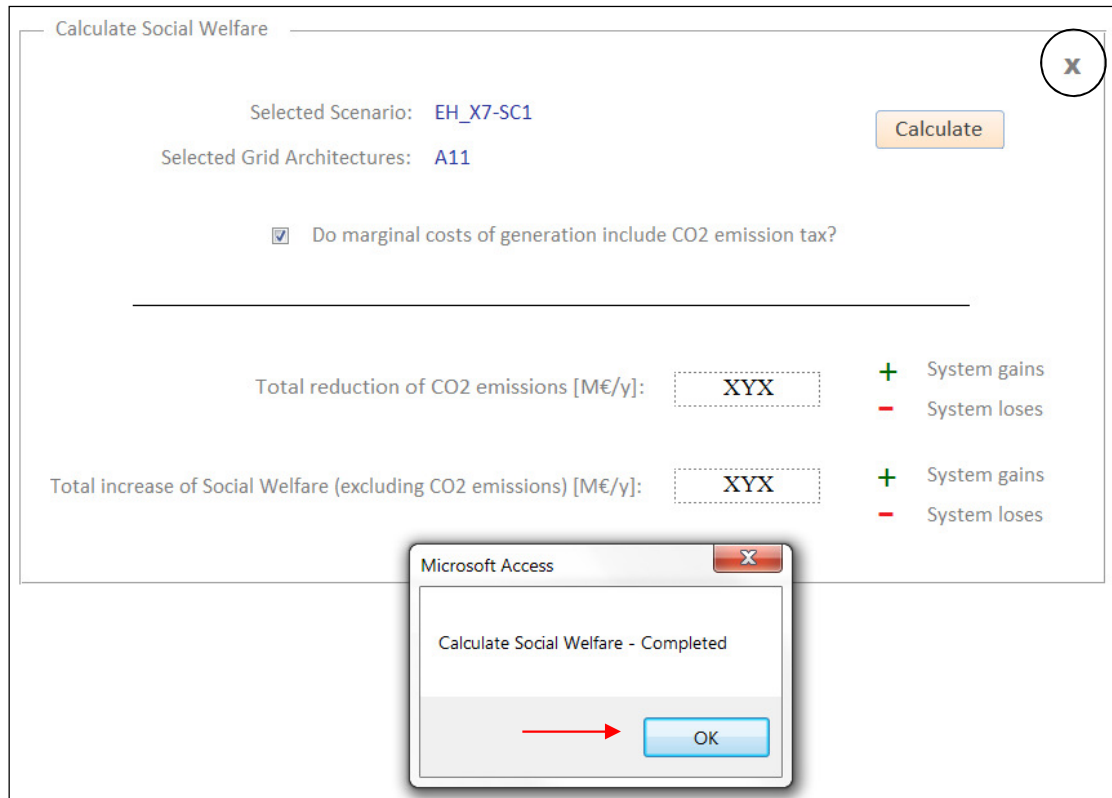


Figure 20 –Social Welfare - Closing the mask

3.3.2. Calculation of “CO2 price sensitivity”

- From the eHighway2050 mask, click on *Calculate indicators*;
- Select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 21, respectively);
- Click on “CO2 price sensitivity” (blue arrow in Figure 21): a new windows opens (Figure 22);
- the Toolbox remembers the choice relative to the inclusion of the costs of CO2 emission into marginal cost of generation made in the calculation of “Social Welfare” indicator (see red arrow in Figure 22);
- the sensitivity analysis on CO2 price starts from an initial value (see purple arrow in Figure 22). This value is stored in the “CO2COST.xlsx” in \IN\Scenario_folder\Manual_Files;
- Click on “Calculate button” (blue arrow in Figure 22): the indicator is usually calculated in mere seconds. The values given as output (“CO2 Price Limit max/min”) represents the interval of CO2 prices that do not involve a change in the merit order used in the ANTARES simulation: therefore, this interval spans from “0” (lower bound) to “+Inf” (upper bound);
- After the calculation, close the mask clicking “Ok” in the textbox (red arrow in Figure 23) and clicking on the upper right “X” symbol (black circle in Figure 23).

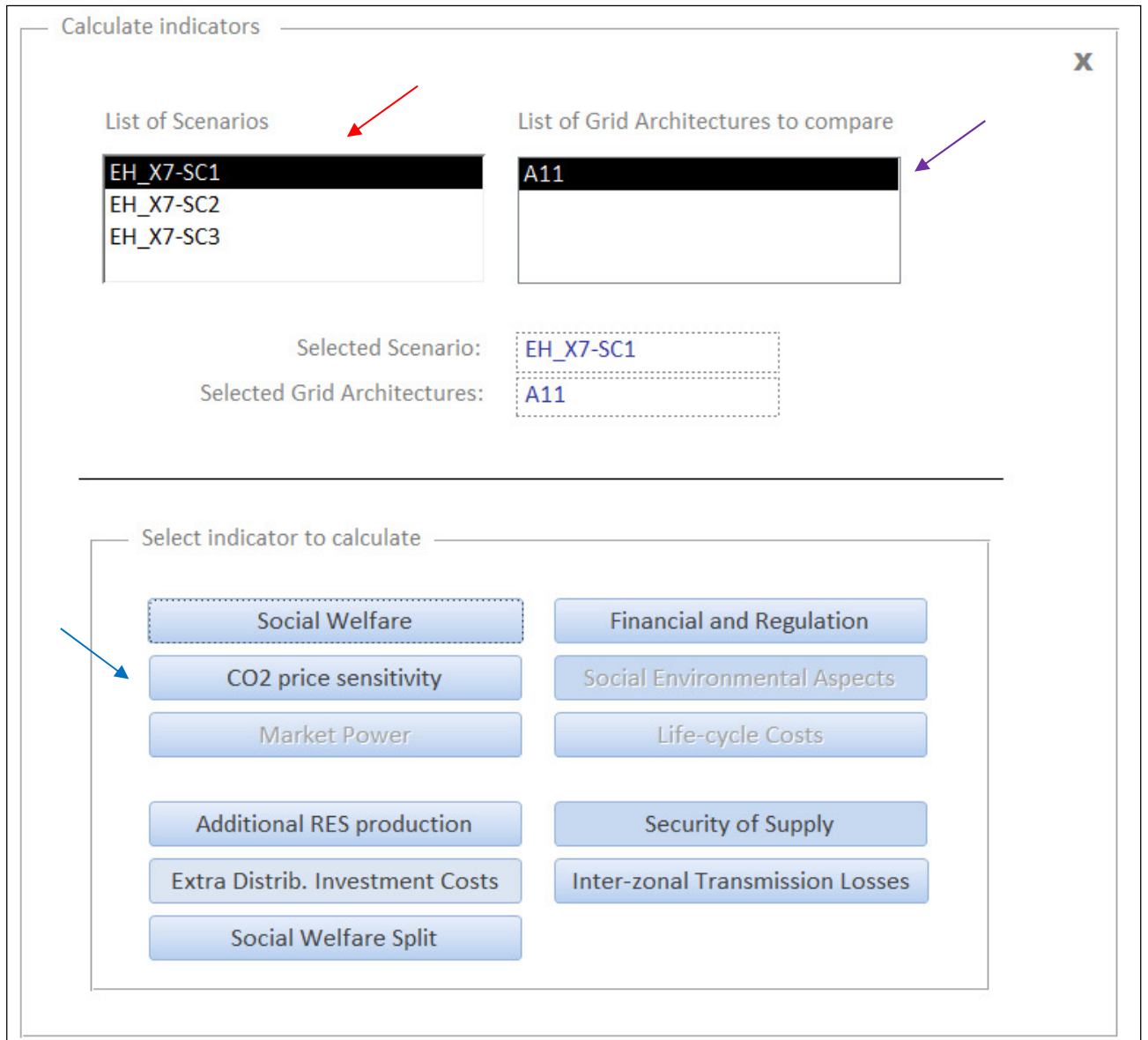


Figure 21 – Calculate indicators – CO2 price sensitivity

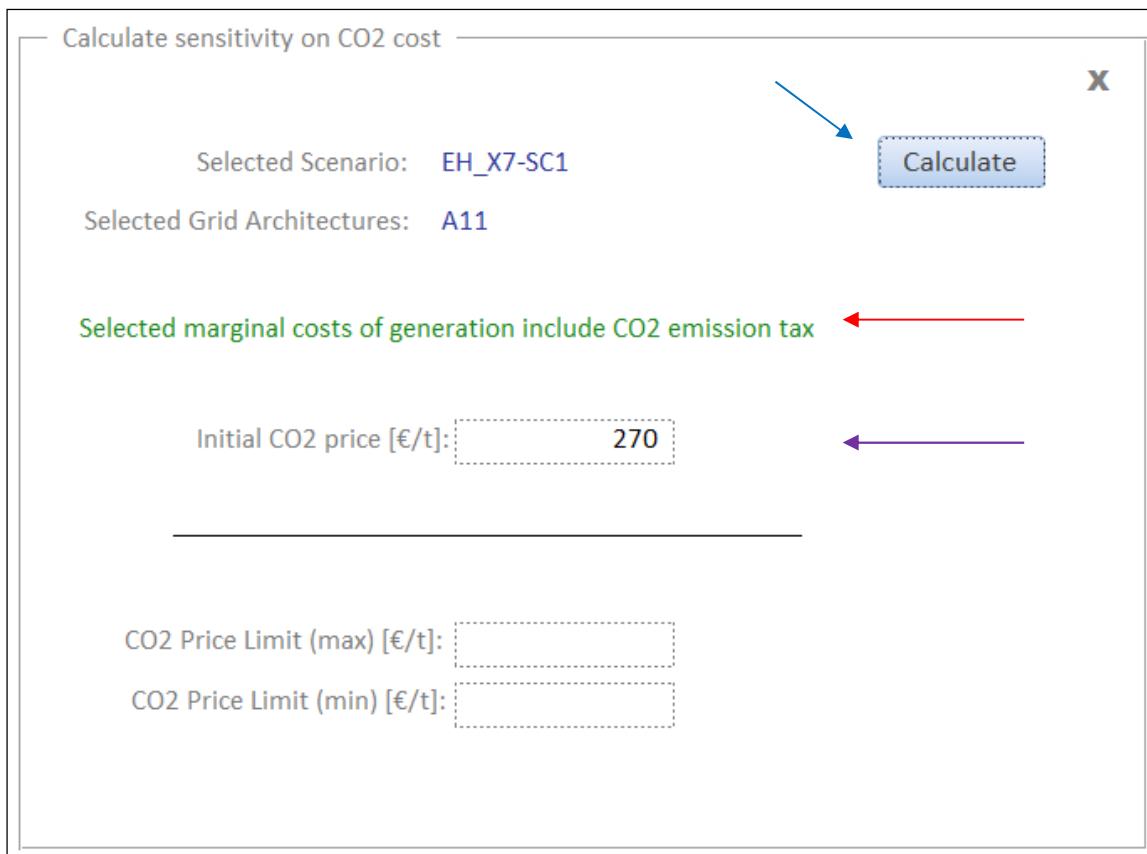


Figure 22 – CO2 price sensitivity calculation

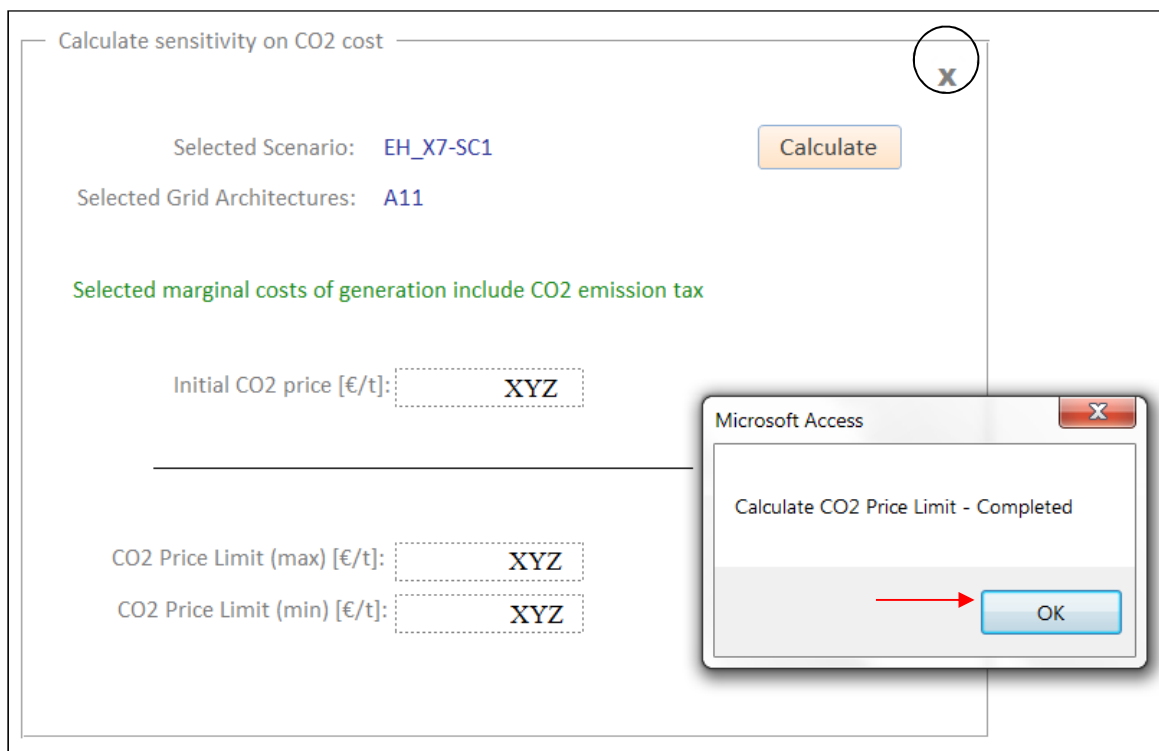


Figure 23 – CO2 price sensitivity - Closing the mask

3.3.3. Market power

- From the eHighway2050 mask, click on *Calculate indicators*;
- Select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 24, respectively);
- Click on “Market Power” (blue arrow in Figure 24): a new windows opens (Figure 25), similar to the one relative to the “Social Welfare” indicator. In fact, the objective of this indicator is to calculate the differential effect on Social Welfare and cost of CO2 emissions (with respect the system marginal price case) that arises from the imposition of strategic bid-up on generators bid curves in ANTARES;
- the Toolbox remembers the choice relative to the inclusion of the costs of CO2 emission into marginal cost of generation made in the calculation of “Social Welfare” indicator (see red arrow in Figure 25);
- select the path where ANTARES simulations considering market power are stored (see purple arrow in Figure 25). A folder tree opens (brown arrow in Figure 25): then, select the pertinent path, stored in the “Browse directory” textbox. To clear the selection, click on “Clear” button (see black arrow in Figure 25),
- Click on “Calculate button” (green arrow in Figure 25): the indicator is usually calculated in mere seconds.
- After the calculation, close the mask clicking “Ok” in the textbox (red arrow in Figure 26) and clicking on the upper right “X” symbol (black circle in Figure 26).

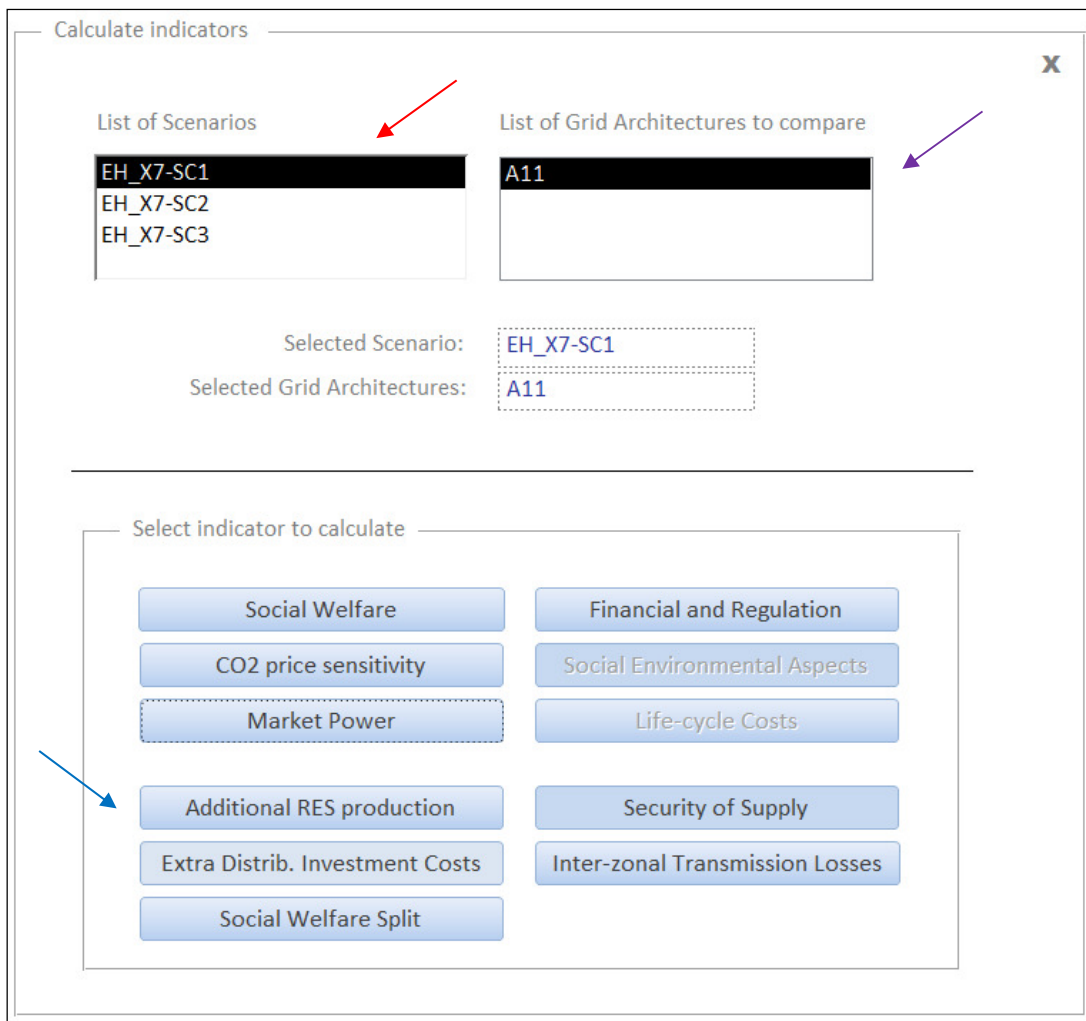


Figure 24 – Calculate indicators – Market power

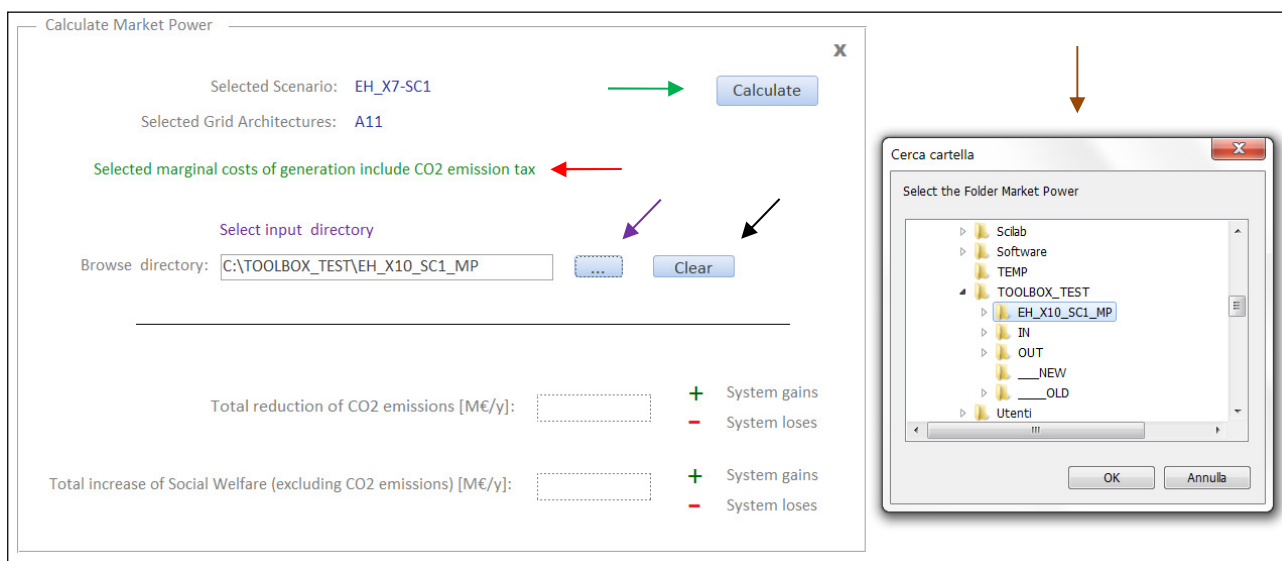


Figure 25 – Market power calculation

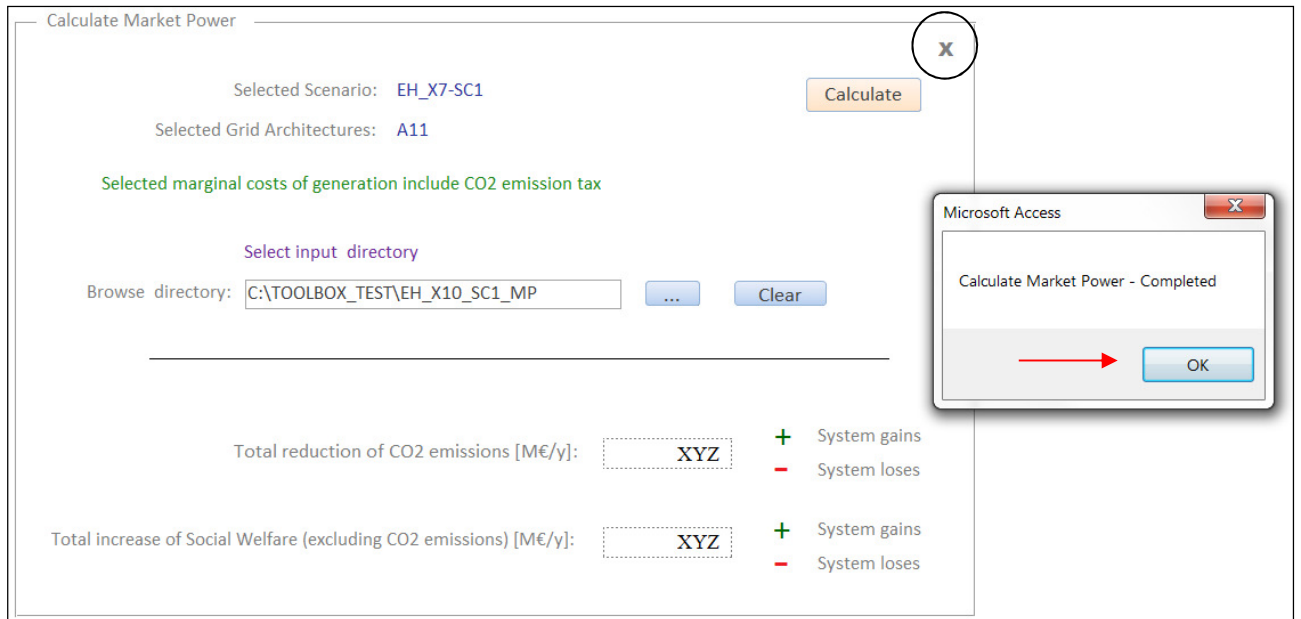


Figure 26 – Market power – Closing the mask

3.3.4. Additional installed RES

- From the eHighway2050 mask, click on *Calculate indicators*;
- Select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 27, respectively);
- Click on “Additional installed RES” (blue arrow in Figure 27): a new windows opens (Figure 28);
- To calculate the indicator, click on “Calculate” (red arrow in Figure 28): the indicator is calculated in dozens of seconds. A report on areas is provided, as well an overall result for the system;
- After the calculation, close the mask clicking “Ok” in the textbox (red arrow in Figure 29) and clicking on the upper right “X” symbol (black circle in Figure 29).

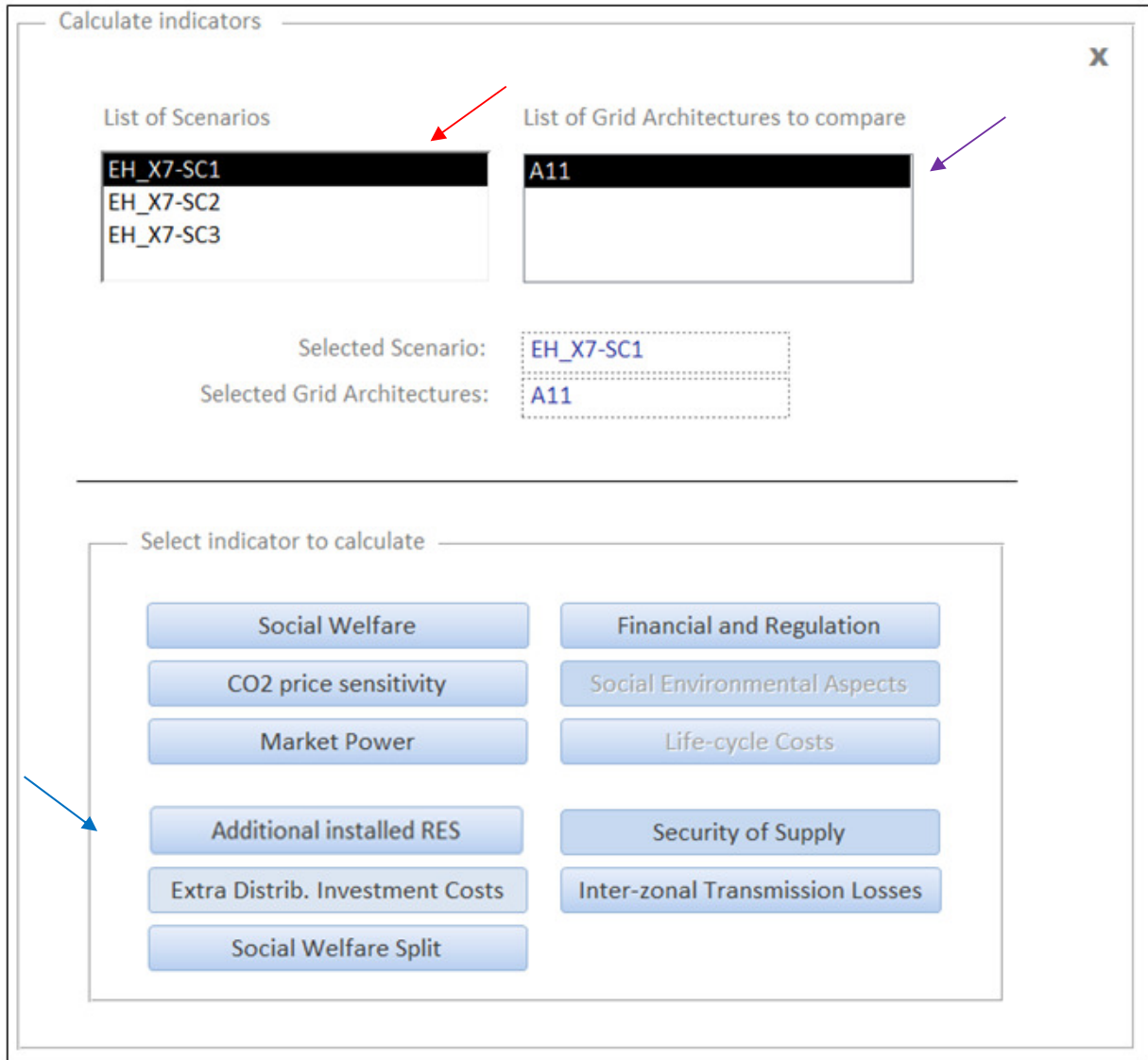


Figure 27 - Calculate indicators - Additional RES production

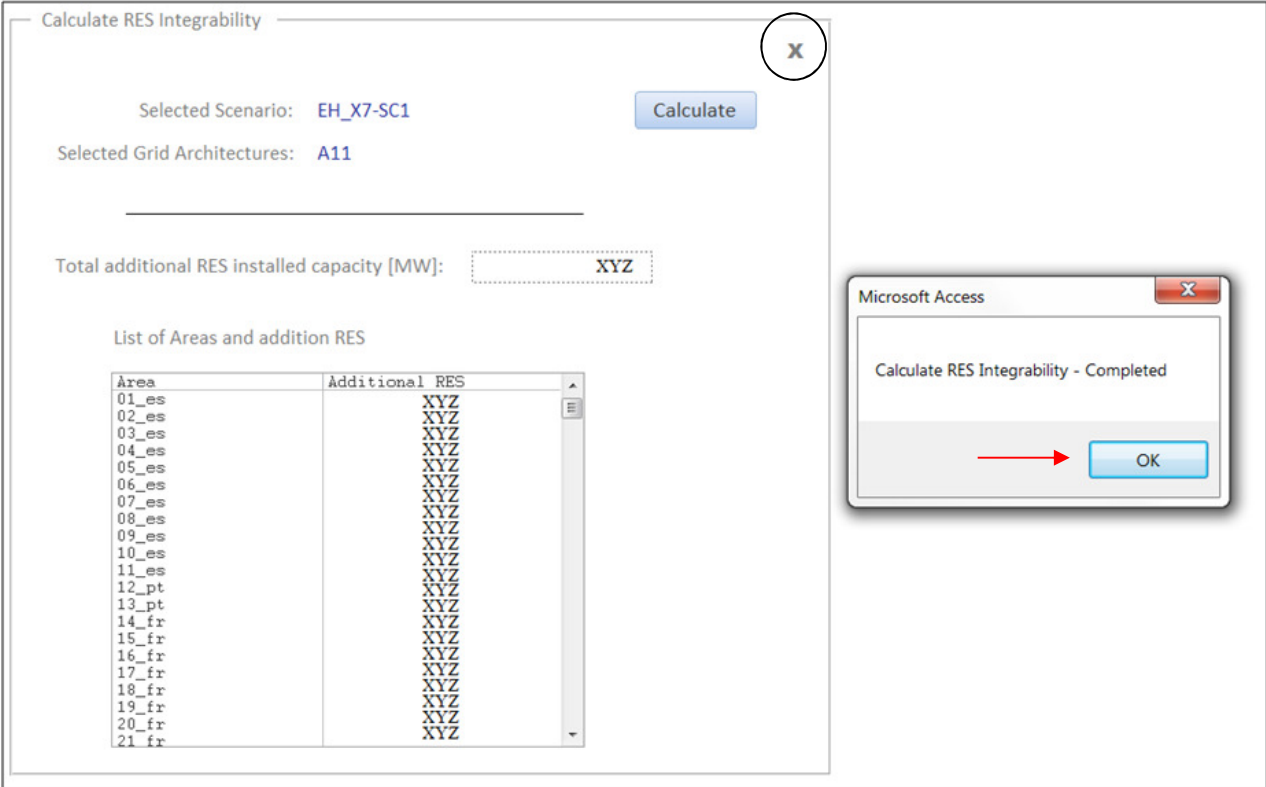


Figure 29 - Additional installed RES - Closing the mask

3.3.5. Extra distribution investment costs

- From the eHighway2050 mask, click on *Calculate indicators*;
- Select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 30, respectively);
- Click on “Extra Distrib. Investment Costs” (blue arrow in Figure 30): a new windows opens (Figure 31);
- To calculate the indicator, click on “Calculate” (red arrow in Figure 31): the indicator is calculated in dozens of seconds. A report on areas is provided, as well an overall result for the system;
- After the calculation, close the mask clicking “Ok” in the textbox (red arrow in Figure 32) and clicking on the upper right “X” symbol (black circle in Figure 32).

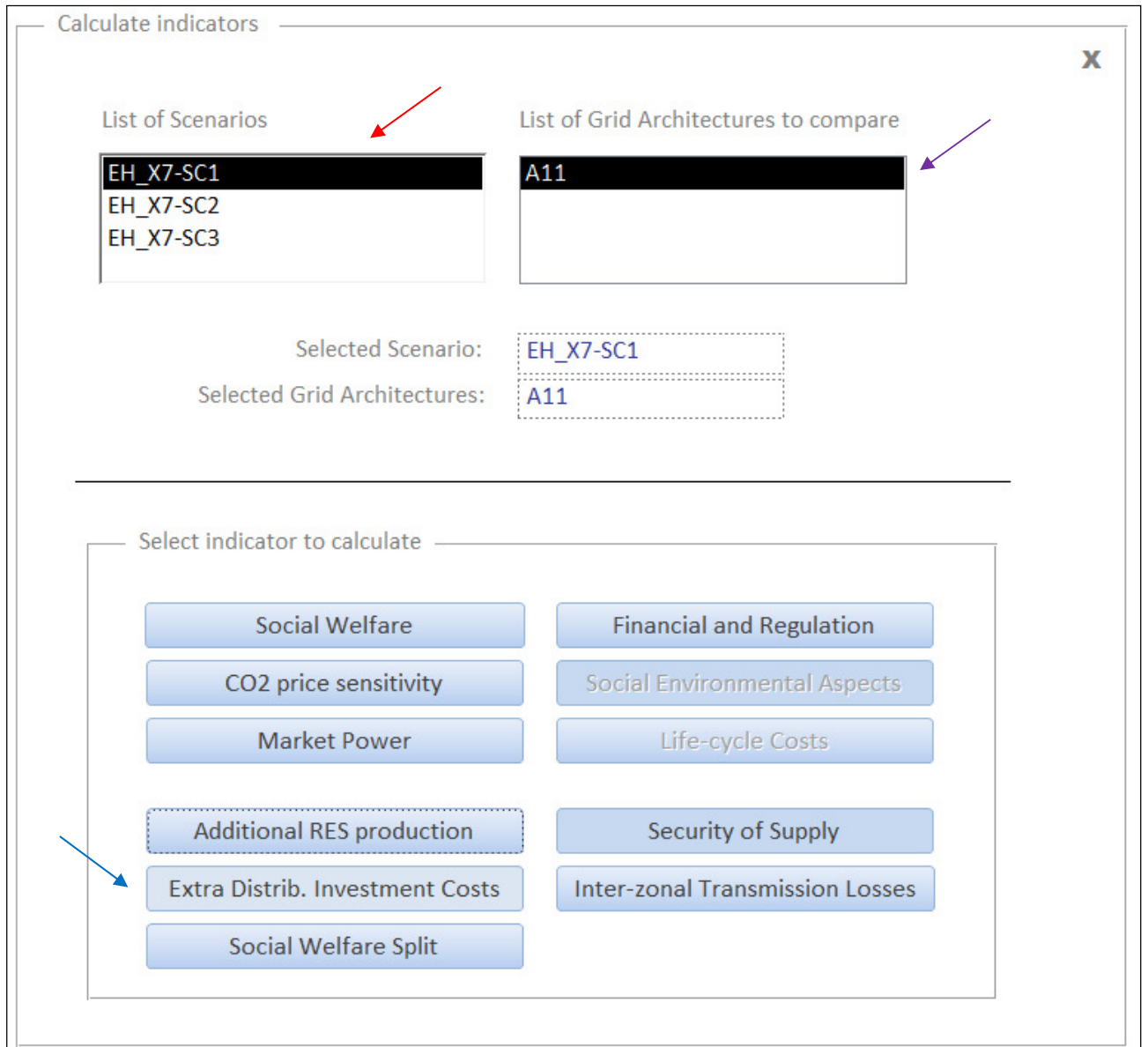


Figure 30 – Calculate indicators – Extra distribution investment costs

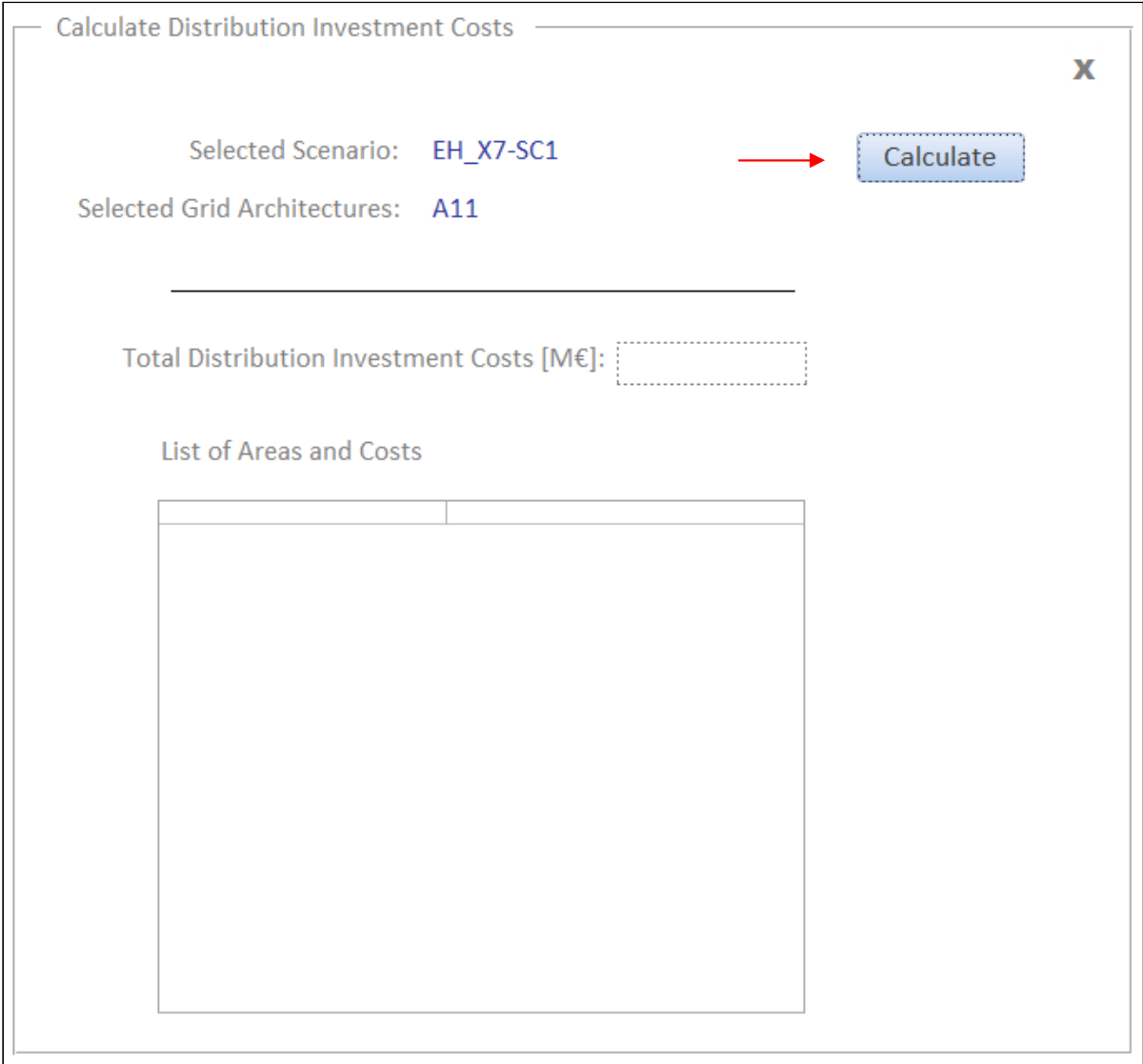


Figure 31 – Extra distribution investment costs calculation

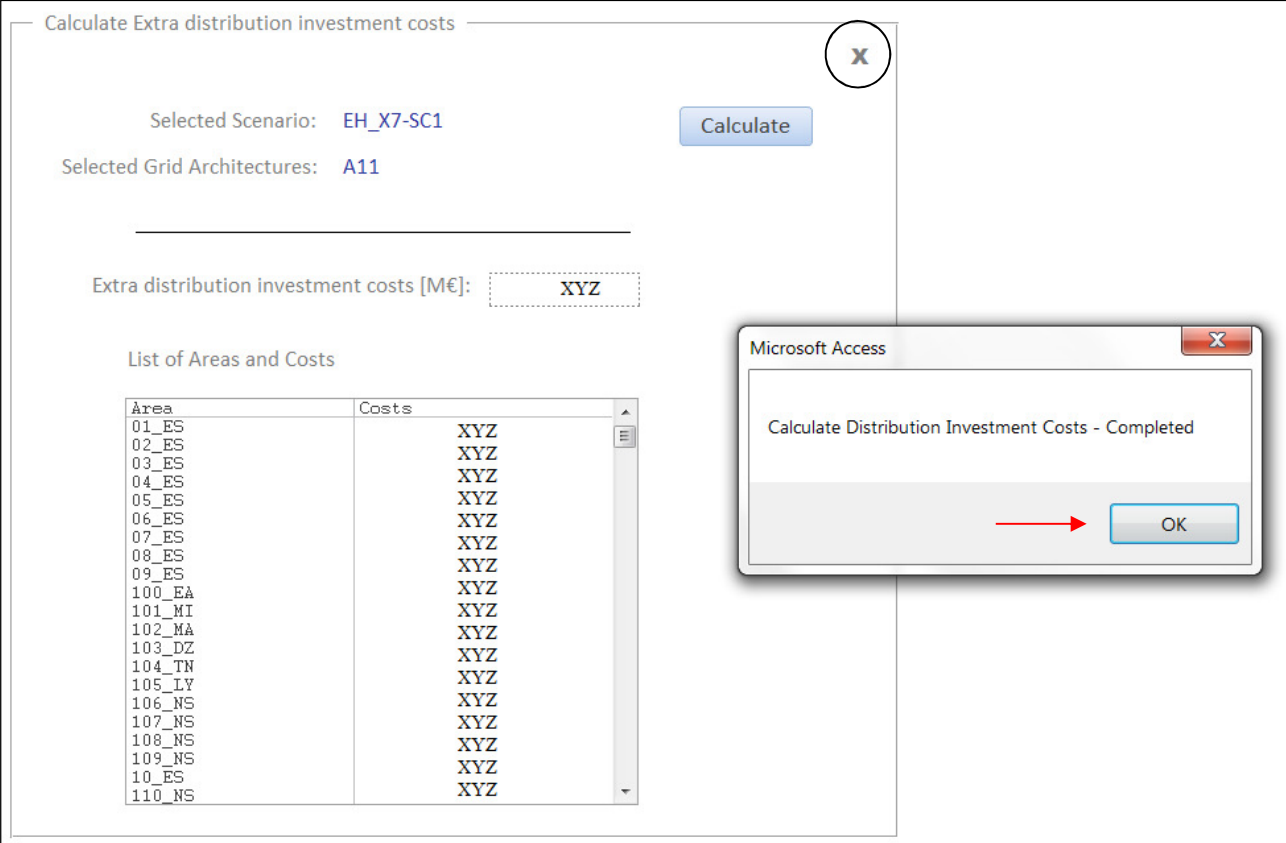


Figure 32 – Extra distribution investment costs - Closing the mask

3.3.6. Social Welfare Split

- From the eHighway2050 mask, click on *Calculate indicators*;
- Select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 33, respectively);
- Click on “Social Welfare Split” (blue arrow in Figure 33): a new windows opens (Figure 34);
- To calculate the indicator, click on “Calculate” (red arrow in Figure 34): the indicator is calculated in dozens of seconds. A report on areas is provided, as well as overall results (variation of social welfare, variation of congestion rent, variation of the sum of consumers and producers surpluses) for the system;
- After the calculation, close the mask clicking “Ok” in the textbox (red arrow in Figure 35) and clicking on the upper right “X” symbol (black circle in Figure 35).

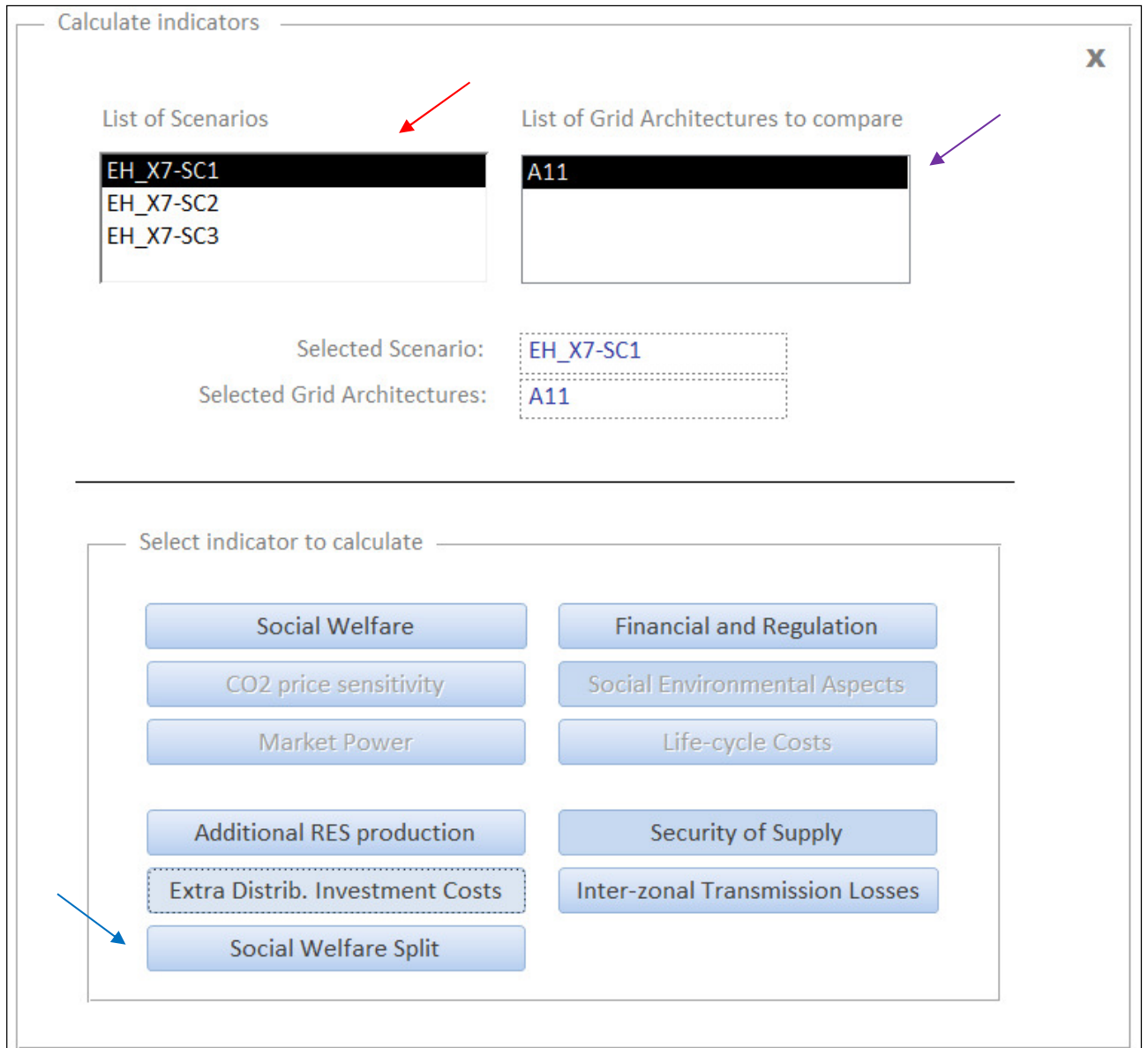


Figure 33 – Calculate indicators – Social Welfare Split

Calculate Social Welfare Split X

Selected Scenario: EH_X7-SC1 →

Selected Grid Architectures: A11

Delta SW (System) [M€/yr]:

Delta CR (System) [M€/yr]:

Delta CS + PS (System) [M€/yr]:

List of Areas and Split:

Figure 34 – Social Welfare Split calculation

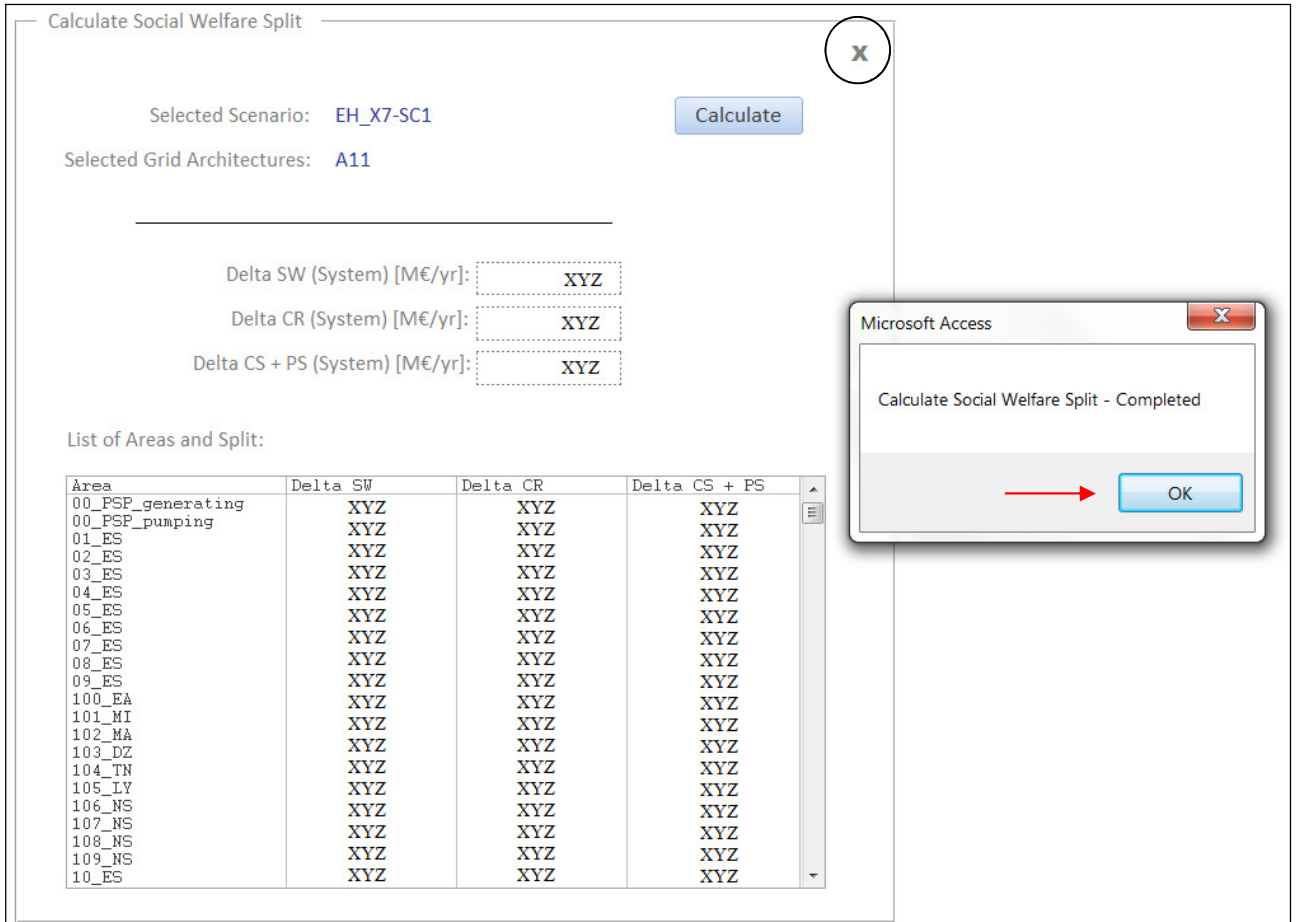


Figure 35 – Social Welfare Split – Closing the mask

3.3.7. Financial and Regulation

- From the eHighway2050 mask, click on *Calculate indicators*;
- Select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 36, respectively);
- Click on “Financial and Regulation” (blue arrow in Figure 36): a new windows opens (Figure 36);
- Click on the button shown by the red arrow in Figure 37: a tree structure opens. Then, select the Strategy input Excel file (in e-Highway2050, provided by WP2). The path of this file is reported in the textbox highlighted by the purple arrow in Figure 37. To clear this selection, click on “Clear”, (blue arrow in Figure 37);

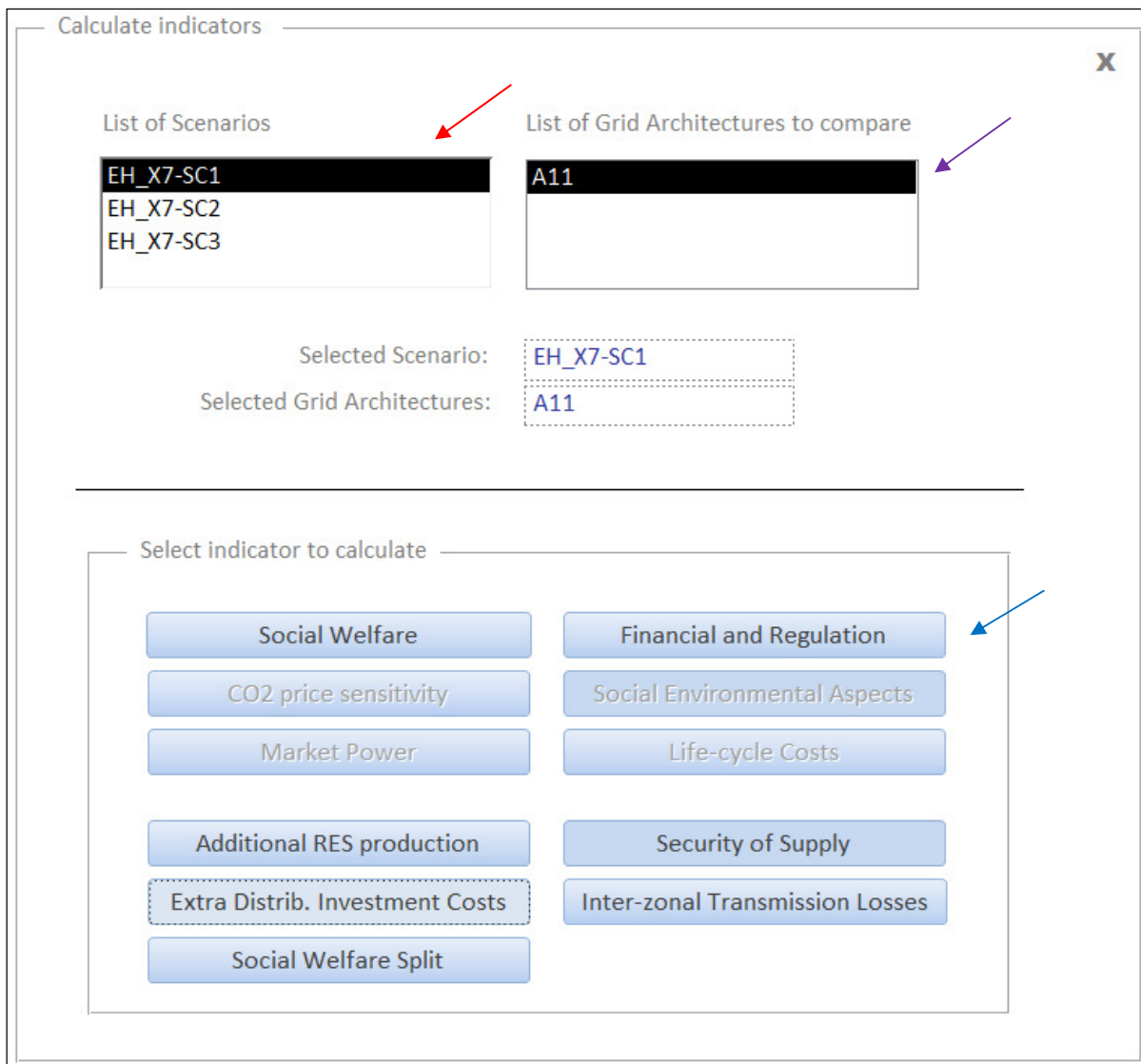


Figure 36 – Calculate indicators – Financial and Regulation

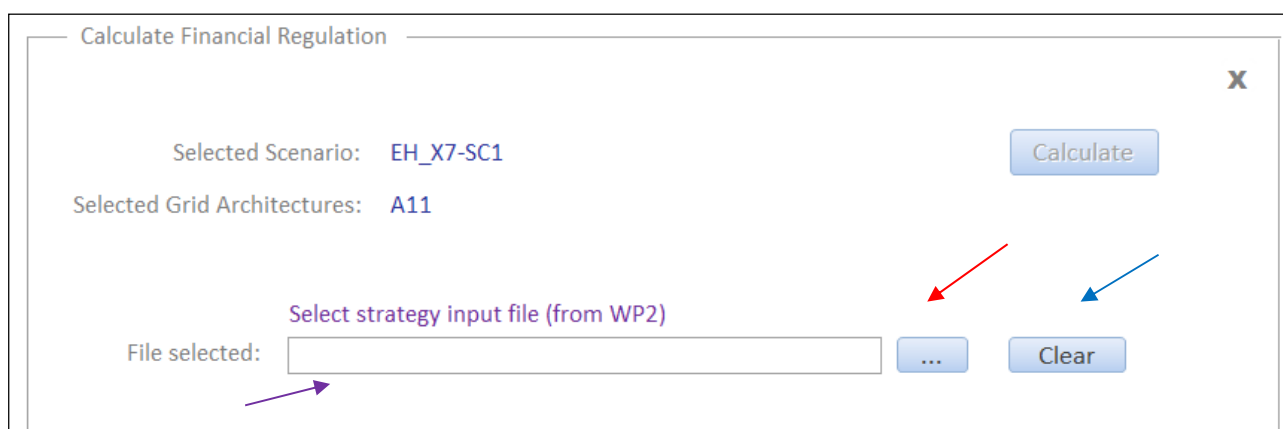


Figure 37 – Financial and Regulation – Selecting strategy input file

- From the drop-down menu highlighted by the red circle in Figure 38, select one of the four available methodology to calculate financial and regulation aspects:

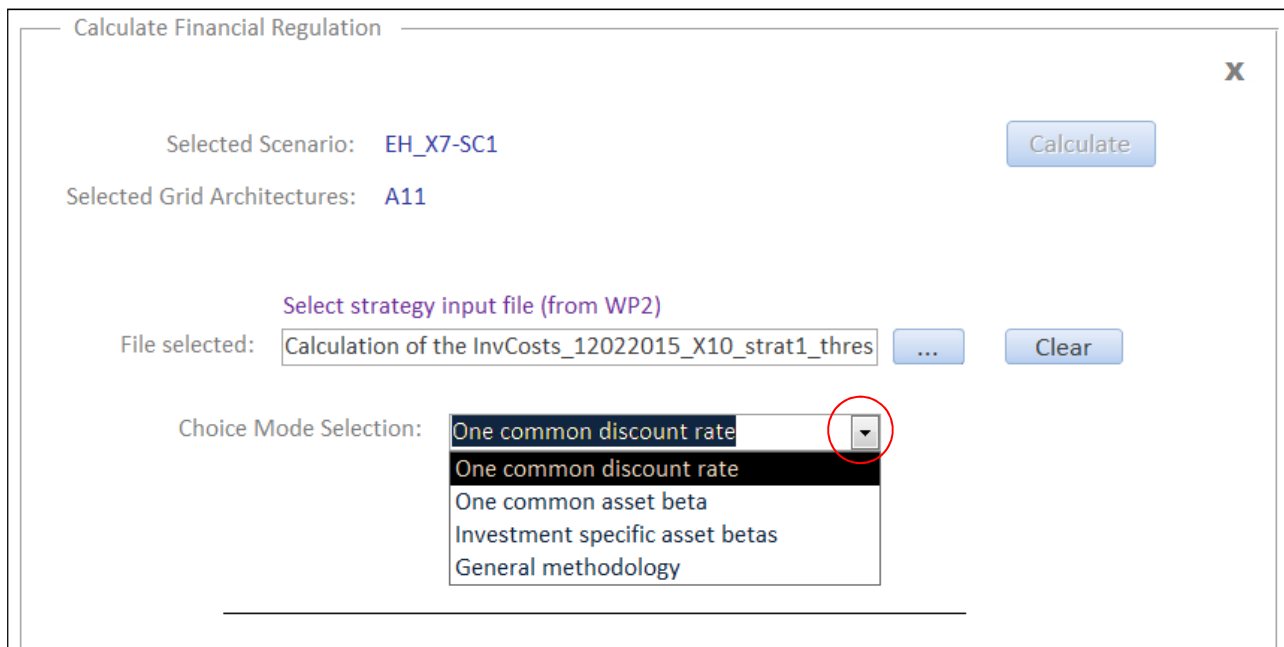


Figure 38 – Financial and Regulation – Selecting methodology

- *One common discount rate*: one user-defined discount rate is adopted for all the network reinforcements:
 - insert this value in the box (see blue arrow in Figure 39) as a percentage (e.g., to consider a 5% discount rate, insert “5”);
 - press “Enter”: then the “Calculate” button (see red arrow in Figure 39) becomes visible;
 - click on “Calculate”.

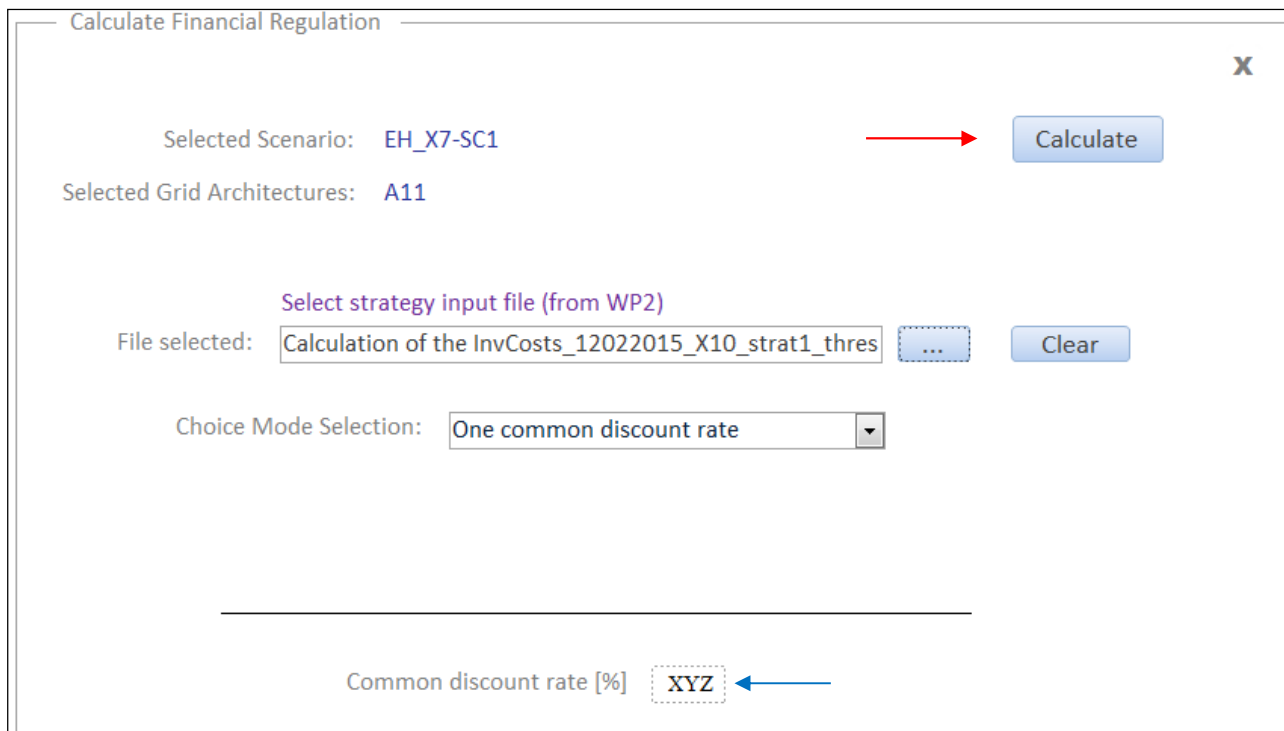


Figure 39 – Financial and Regulation – One common discount rate

- *One common asset beta*: a (common) discount rate is calculated starting from a common risk free discount rate, a common market premium risk and a common asset beta:
 - insert the risk free and market premium discount rates value in the boxes (see blue and purple arrows in Figure 40, respectively) as a percentage (e.g., to consider a 5% discount rate, insert “5”);
 - insert the common asset beta (see brown arrow in Figure 40) as a decimal number (e.g. “0.2”)
 - press “Enter”: then the “Calculate” button (see red arrow in Figure 40) becomes visible;
 - click on “Calculate”.

Calculate Financial Regulation

Selected Scenario: EH_X7-SC1

Selected Grid Architectures: A11

Select strategy input file (from WP2)

File selected: Calculation of the InvCosts_12022015_X10_strat1_thres

Choice Mode Selection: One common asset beta

Common risk free discount rate [%] XYZ

Common market premium risk [%] XYZ

Common asset beta XYZ

Figure 40 – Financial and Regulation – One common asset beta

- *Investment specific asset beta*: discount rate values are calculated starting from a common risk free discount rate, a common market premium risk and specific asset beta values for particular investments:
 - click on the selection button highlighted by the red circle in Figure 41: a tree folder structure opens. Then, select the user defined Excel file (in the example, “OPT3_FR_11.xls”) with asset beta values;
 - insert the risk free and market premium discount rates value in the boxes (see blue and purple arrows in Figure 41, respectively) as a percentage (e.g., to consider a 5% discount rate, insert “5”);
 - press “Enter”: then the “Calculate” button (see red arrow in Figure 41) becomes visible;
 - click on “Calculate”

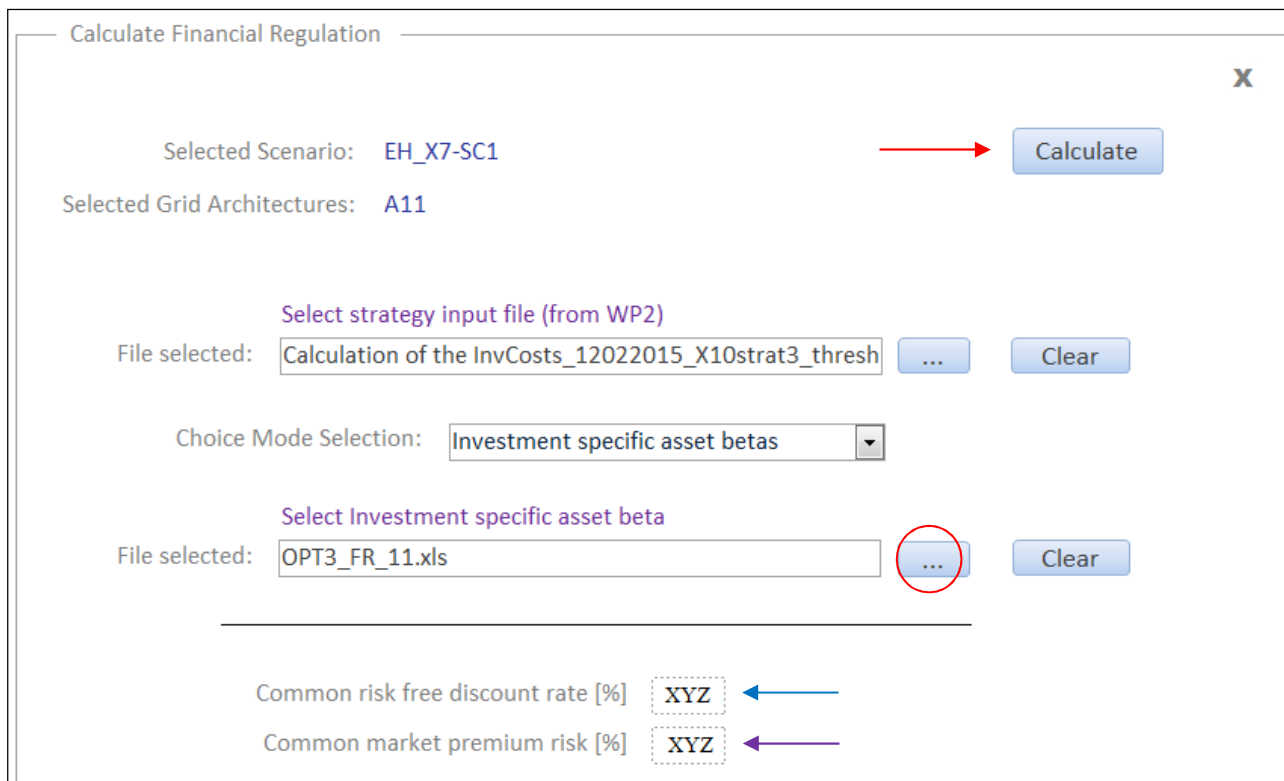


Figure 41 – Financial and Regulation – Investment specific asset beta

- *General methodology*: discount rate values are calculated starting from the methodology described in D6.1:
 - click on the selection button highlighted by the red circle in Figure 42: a tree folder structure opens. Then, select the user defined Excel file (in the example, “OPT4_FR_11.xls”) with input parameters;
 - insert the risk free and market premium discount rates value in the boxes (see blue and purple arrows in Figure 42, respectively) as a percentage (e.g., to consider a 5% discount rate, insert “5”);
 - press “Enter”: then the “Calculate” button (see red arrow in Figure 42) becomes visible;
 - click on “Calculate”

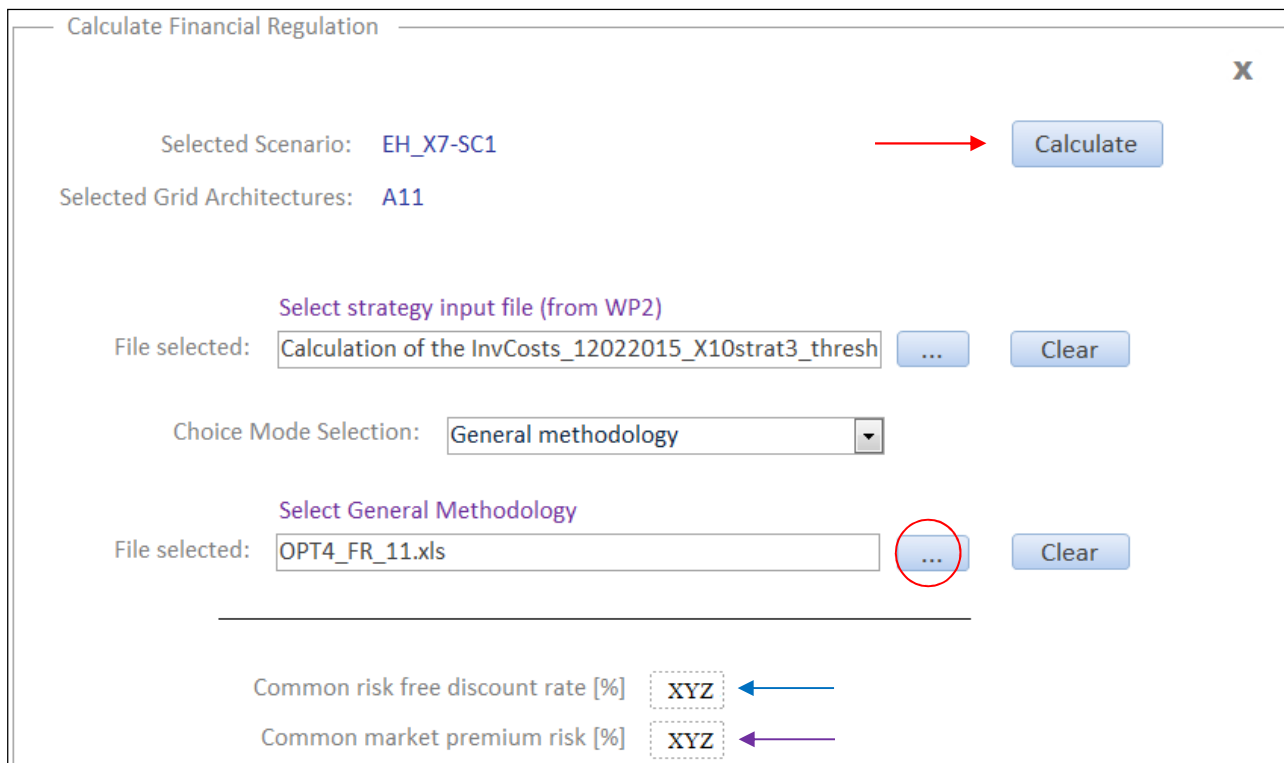


Figure 42 – Financial and Regulation – General methodology

- Calculation is performed in mere seconds. A report is provided, in terms of average discount rate for the whole system and in terms of discount rate for the specific corridors;
- After the calculation, close the mask clicking “Ok” in the textbox (red arrow in Figure 43) and clicking on the upper right “X” symbol (black circle in Figure 43).

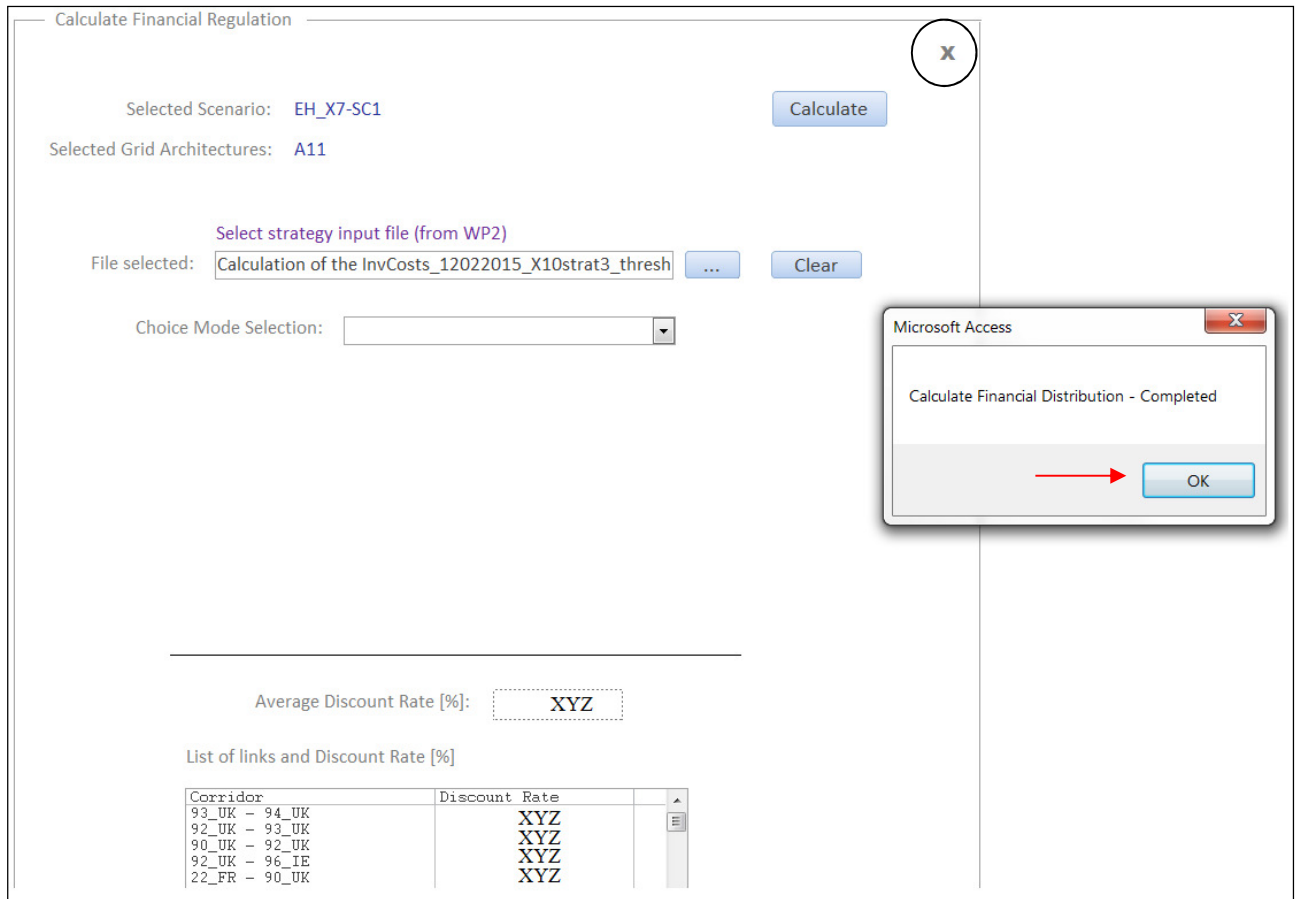


Figure 43 – Financial and Regulation – Closing the mask

3.3.8. Social Environmental Aspects

- From the eHighway2050 mask, click on *Calculate indicators*;
- Select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 44, respectively);
- Click on “Social Environmental Aspects” (blue arrow in Figure 44): a new windows opens (Figure 45);
- Be sure that all Microsoft Excel files are closed;
- Click on the button highlighted by the red circle in Figure 45: the, select the Social and Environmental calculation Excel file with macro (“Social_Environmental_Aspects_calcsheet.xlsm” in the example) located in “root\OUT\Scenario_folder”. If you what clear you choice, click on the “Clear” button, highlighted by the purple arrow in Figure 45.
- Then, the “Calculate” button highlighted by the red arrow in Figure 45 becomes visible. Click on the “Calculate” button.
- Switch on the Excel file opened;
- In the yellow cell shown in Figure 46, write the name of the “Input_Grid_Arch_ij.xls” (in the example, Input_Grid_Arch_11.xls) generated by the *Financial and Regulation* procedure and located in “root\OUT\Scenario_folder”. Then, press the “Calculate all corridors” button (red arrow in Figure 46).
- If a warning message highlighting that a particular connection is not available in the sheet “LandUsePerCorridor”, press “Ok”.
- After the calculation, click “Ok”;
- Save both opened Excel files (the Social and Environmental calculation Excel file with macro and the Input_Grid_Arch_ij file) and close them;
- Switch to the Toolbox and click “Yes” (red arrow in Figure 47);
- Calculation is performed in mere seconds. A report is provided, in terms of compensation costs and time delay for the specific corridors (see Figure 48);
- After the calculation, close the mask clicking “Ok” in the textbox (red arrow in Figure 48) and clicking on the upper right “X” symbol (black circle in Figure 48).

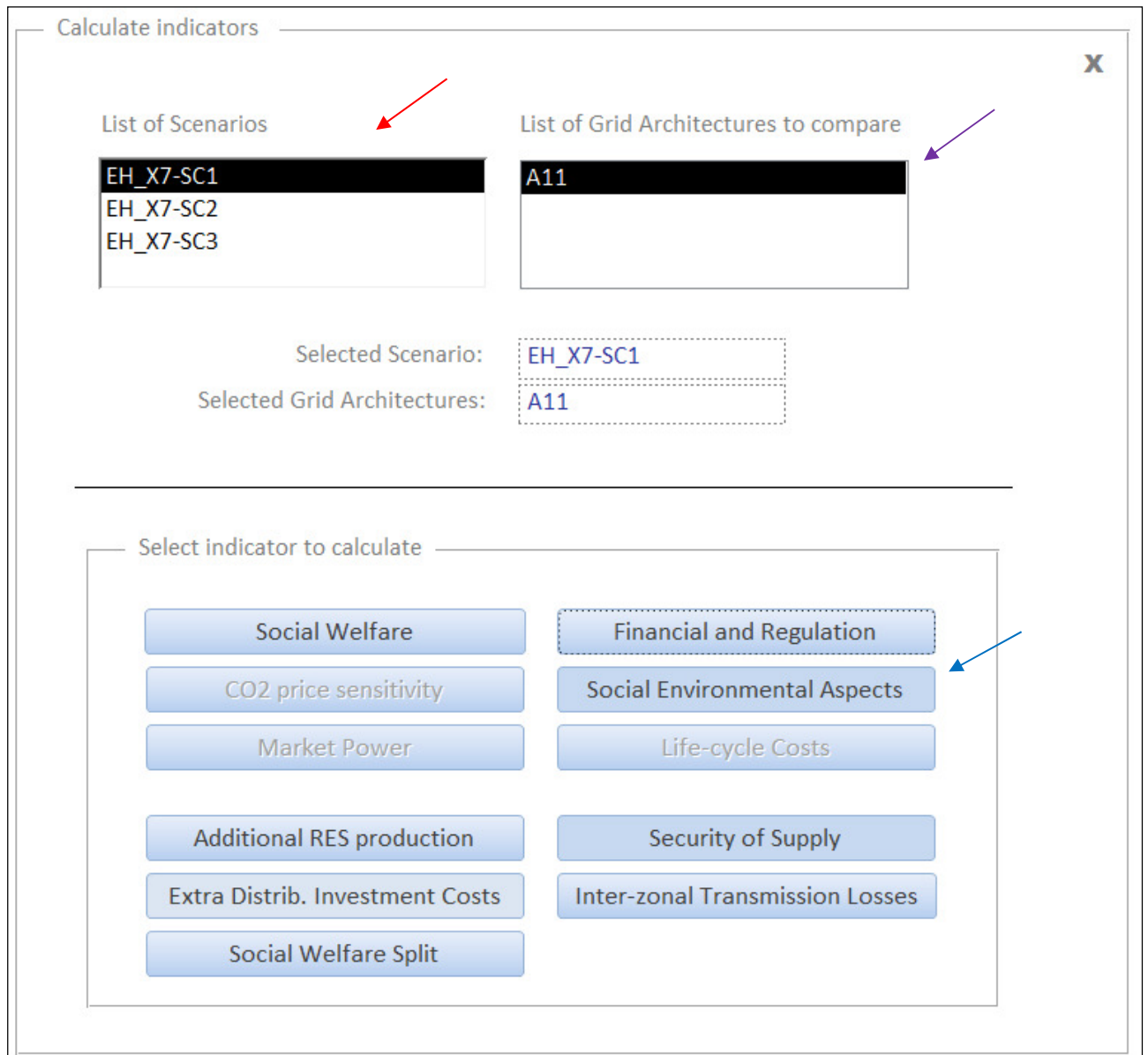


Figure 44 - Calculate indicators - Social Environmental Aspects

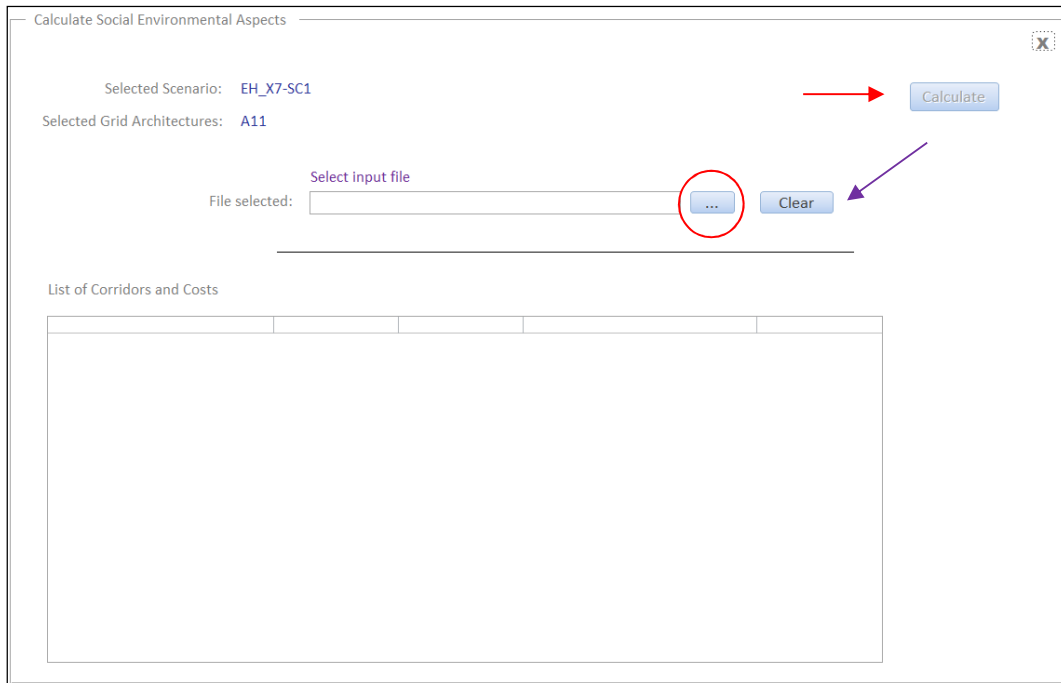


Figure 45 –Social Environmental calculation

Output file	Input_Grid_Arch_11.xlsx	
Columns	13	Delay [year]
	12	Compensation costs [€]
Corridor Nr	52	Calculate all corridors
Cluster from	dc01_ES	
Cluster to	dc12_PT	
Cluster from in LandUsePerCorridor	31_DE	Find clusters for given corridor
Cluster to in LandUsePerCorridor	79_NO	

Figure 46 - Input for Social Environmental calculation

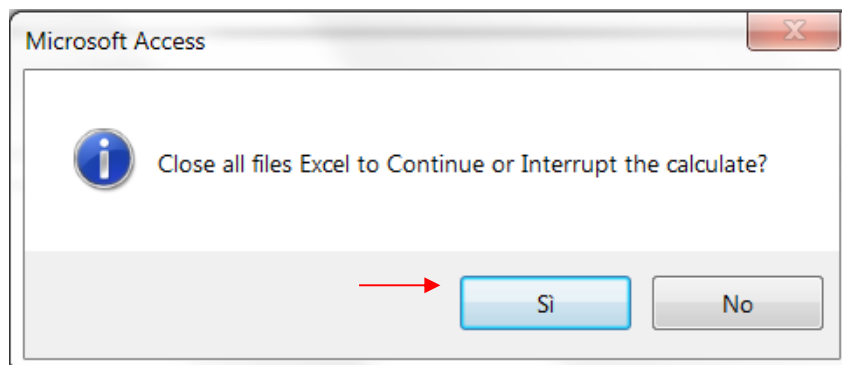


Figure 47 – Social Environmental Aspects - Calculation confirmation

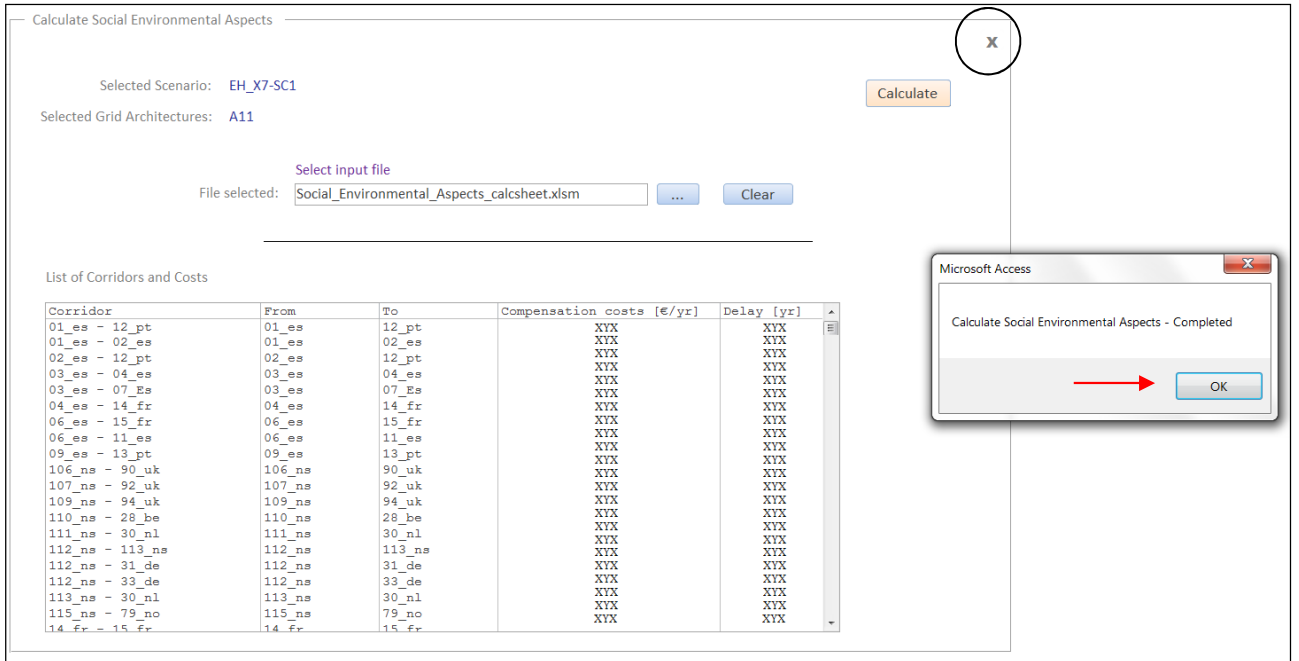


Figure 48 – Social Environmental Aspects – Closing the mask

3.3.9. Life cycle costs

- From the eHighway2050 mask, click on *Calculate indicators*;
- Select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 49, respectively);
- Click on “Life-cycle Costs” (blue arrow in Figure 49): a new windows opens (Figure 50);
- Click on the “Calculate” button (red arrow in Figure 50);
- The calculation is performed in mere seconds: the output is provided in terms of total LCC costs and annuity costs (blue and purple arrows in Figure 51, respectively);
- After the calculation, close the mask clicking “Ok” in the textbox (red arrow in Figure 51) and clicking on the upper right “X” symbol (black circle in Figure 51).

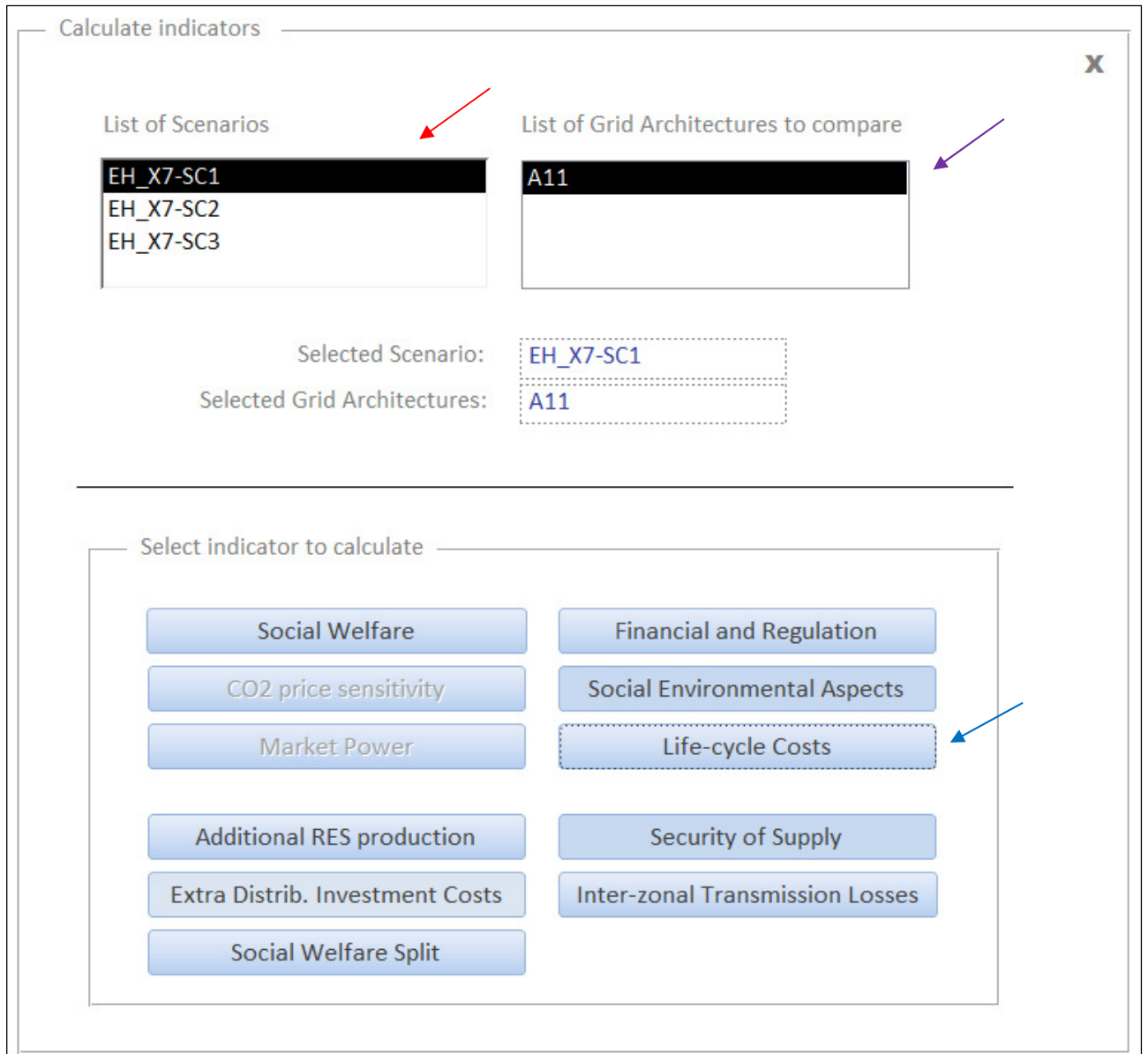


Figure 49 – Calculate indicators – Life-cycle Costs

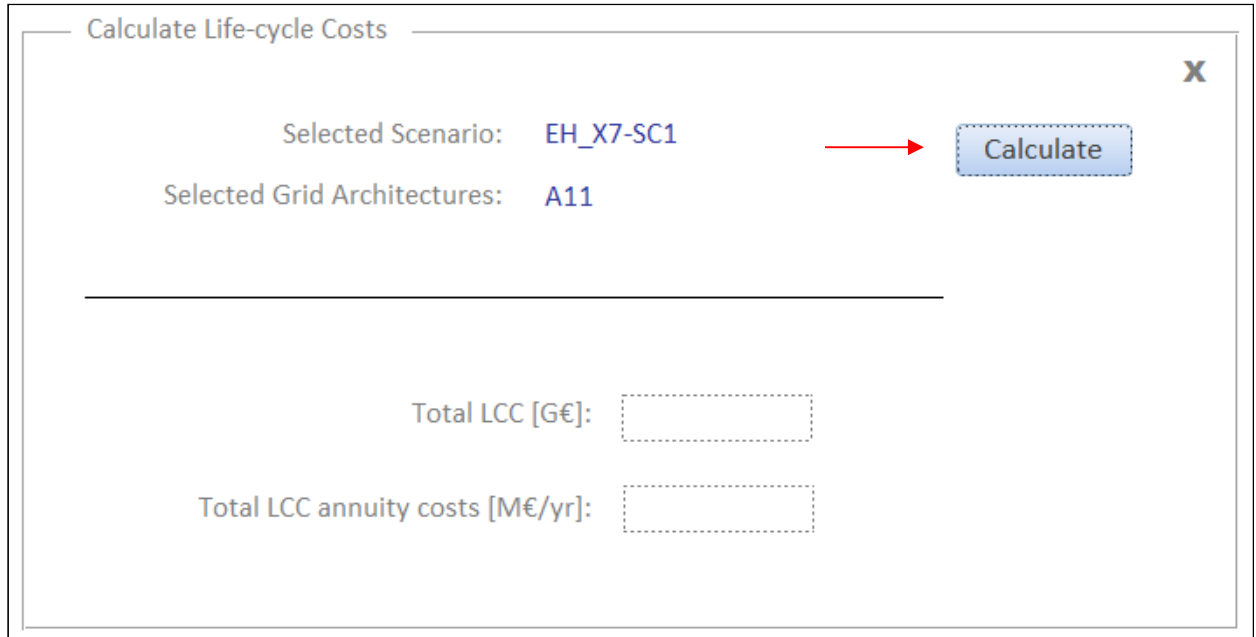


Figure 50 - Life-cycle Costs calculation

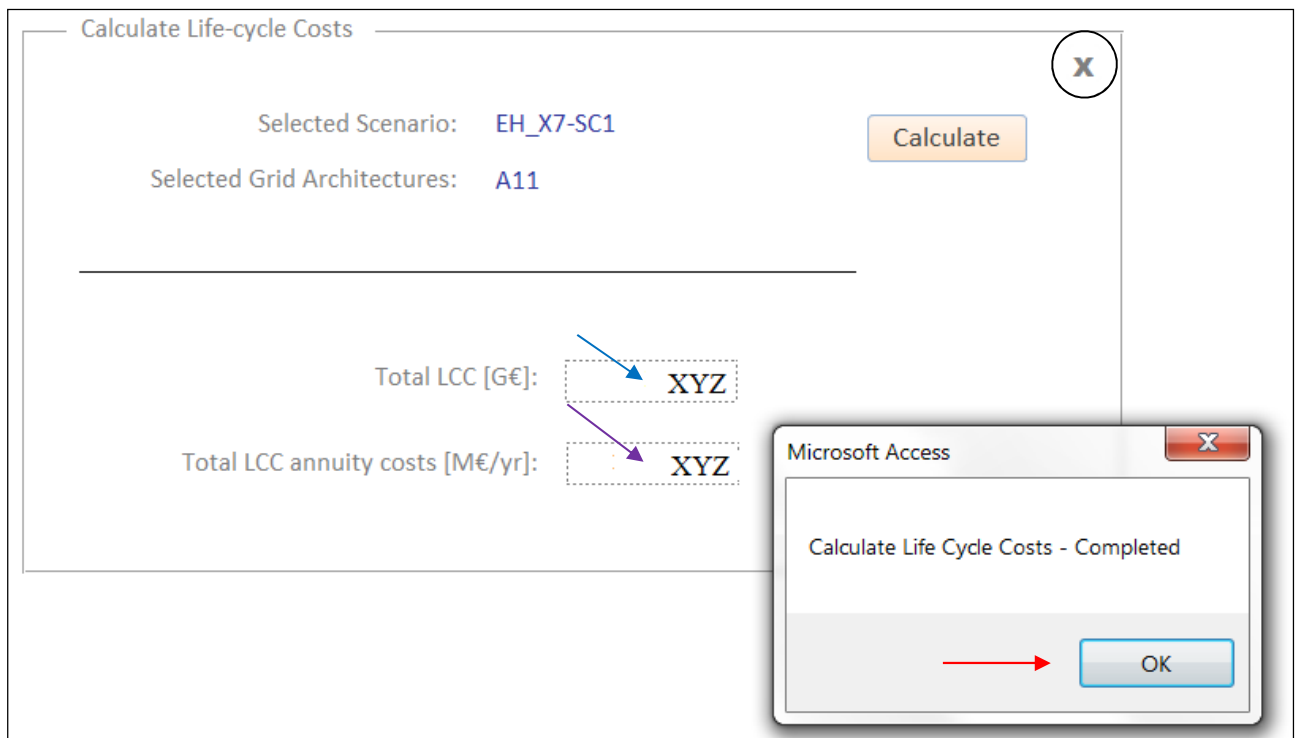


Figure 51 - Life-cycle Costs - Closing the mask

3.3.10. Security of Supply

- From the eHighway2050 mask, click on *Calculate indicators*;
- Select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 52, respectively);
- Click on “Security of Supply” (blue arrow in Figure 52): a new windows opens where is possible to select the different calculation methodologies from the drop-down menu highlighted by the red circle in Figure 53;
 - *Antares ENS – Global VOLL* (Figure 54): the reduction of reliability costs is provided valorizing the Energy Not Served values given as output in ANTARES simulation with a global VOLL chosen by the Toolbox user: in e-Highway2050, this value is equal to 10000 [€/MWh]. The value must be inserted in the textbox highlighted by the red arrow in Figure 54: then press “Enter”;
 - *Antares ENS – Zonal VOLL* (Figure 55): the reduction of reliability costs is provided valorizing the Energy Not Served values given as output in ANTARES simulation with a zonal VOLL provided in the “ZNLVOLL.xls” located in root\IN\Scenario_Folder\Manual_Files;
 - *WP6 Methodology* (Figure 56): the reduction of reliability, resilience, DMS (energy component) and RES curtailment costs are evaluated according to the methodology included in D6.1
- After the selection of the calculation methodology, the “Calculate” button (purple arrows in Figure 54, Figure 55 and Figure 56) becomes visible;
- If the user selects *Antares ENS – Global VOLL* or *Antares ENS – Zonal VOLL*, the calculation is in general performed in mere seconds: if the users selects *WP6 Methodology*, the methodology usually requires 30 minutes;
- According to the selected methodology, the output is provided in different ways, as depicted in Figure 54, Figure 55 and Figure 56;
- After the calculation, close the mask clicking “Ok” in the textbox (red arrow in Figure 57) and clicking on the upper right “X” symbol (black circle in Figure 57).

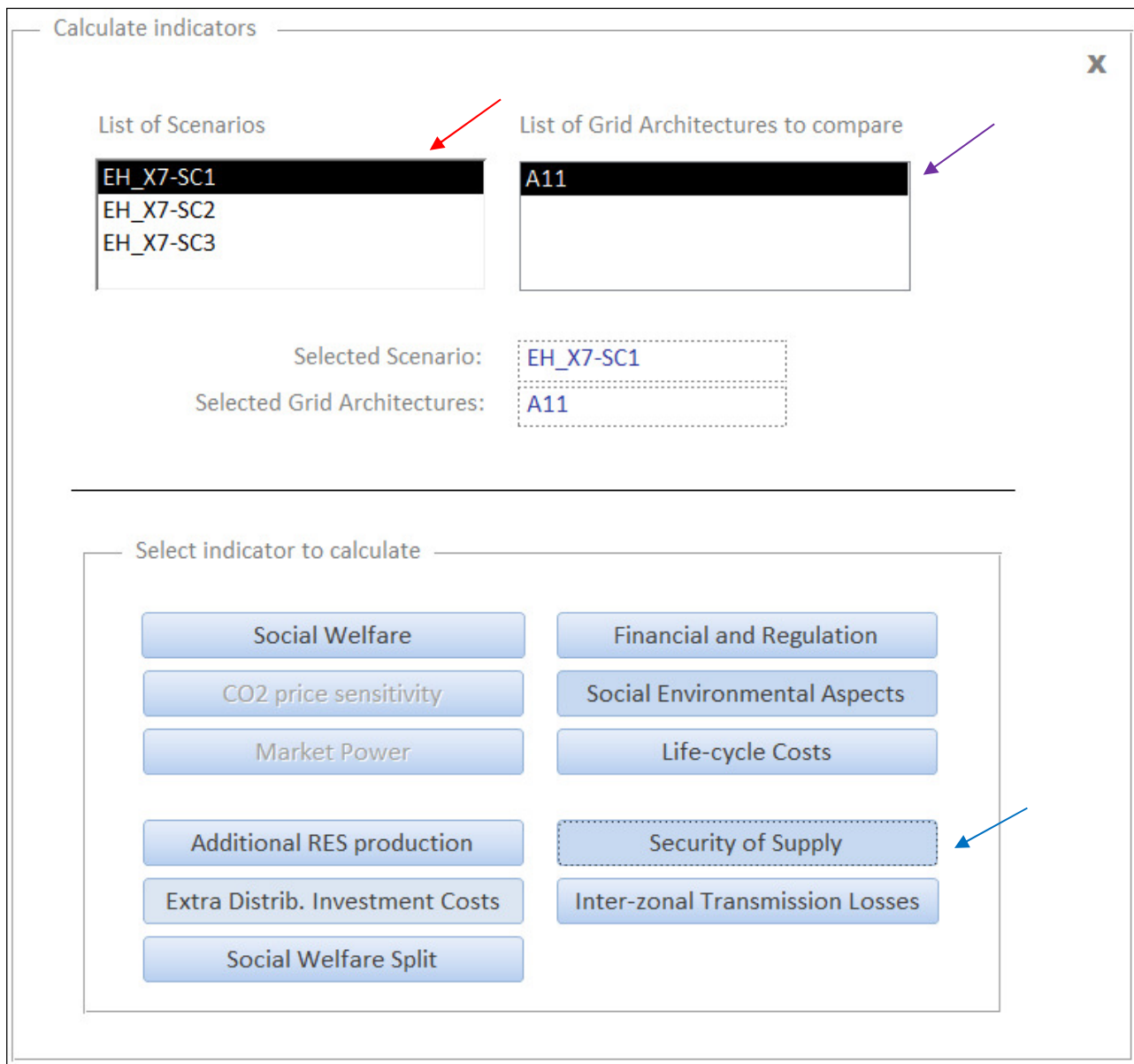


Figure 52 – Calculate indicators – Security of Supply

Calculate Security Supply

Selected Scenario: EH_X7-SC1

Selected Grid Architectures: A11

Calculate

Choice Method Selection: Antares ENS - Global VOLL

Antares ENS - Global VOLL

Antares ENS - Zonal VOLL

WP6 Methodology

Redution of reliability cost [M€/yr]:

Figure 53 – Security of Supply – Selecting the methodology

Calculate Security Supply

Selected Scenario: EH_X7-SC1

Selected Grid Architectures: A11

Calculate

Choice Method Selection: Antares ENS - Global VOLL

European VOLL [€/MWh]: XYZ

Redution of reliability cost [M€/yr]:

Figure 54 – Security of Supply – Antares ENS – Global VOLL

The screenshot shows a dialog box titled "Calculate Security Supply" with a close button (X) in the top right corner. The "Selected Scenario" is "EH_X7-SC1" and the "Selected Grid Architectures" is "A11". A blue "Calculate" button is positioned to the right of these fields, with a purple arrow pointing towards it. Below this, the "Choice Method Selection" dropdown menu is set to "Antares ENS - Zonal VOLL". A horizontal line separates the input fields from the output field, which is a dashed box labeled "Redution of reliability cost [M€/yr]:".

Figure 55 – Security of Supply – Antares ENS – Zonal VOLL

The screenshot shows a dialog box titled "Calculate Security Supply" with a close button (X) in the top right corner. The "Selected Scenario" is "EH_X7-SC1" and the "Selected Grid Architectures" is "A11". A blue "Calculate" button is positioned to the right of these fields, with a purple arrow pointing towards it. Below this, the "Choice Method Selection" dropdown menu is set to "WP6 Methodology". A horizontal line separates the input fields from the output fields, which are four dashed boxes labeled: "Redution of reliability cost [M€/yr]:", "Redution of resilience cost [M€/yr]:", "Reduction of DSM cost (energy component) [M€/yr]:", and "Reduction of RES curtailment [M€/yr]:".

Figure 56 – Security of Supply – WP6 methodology

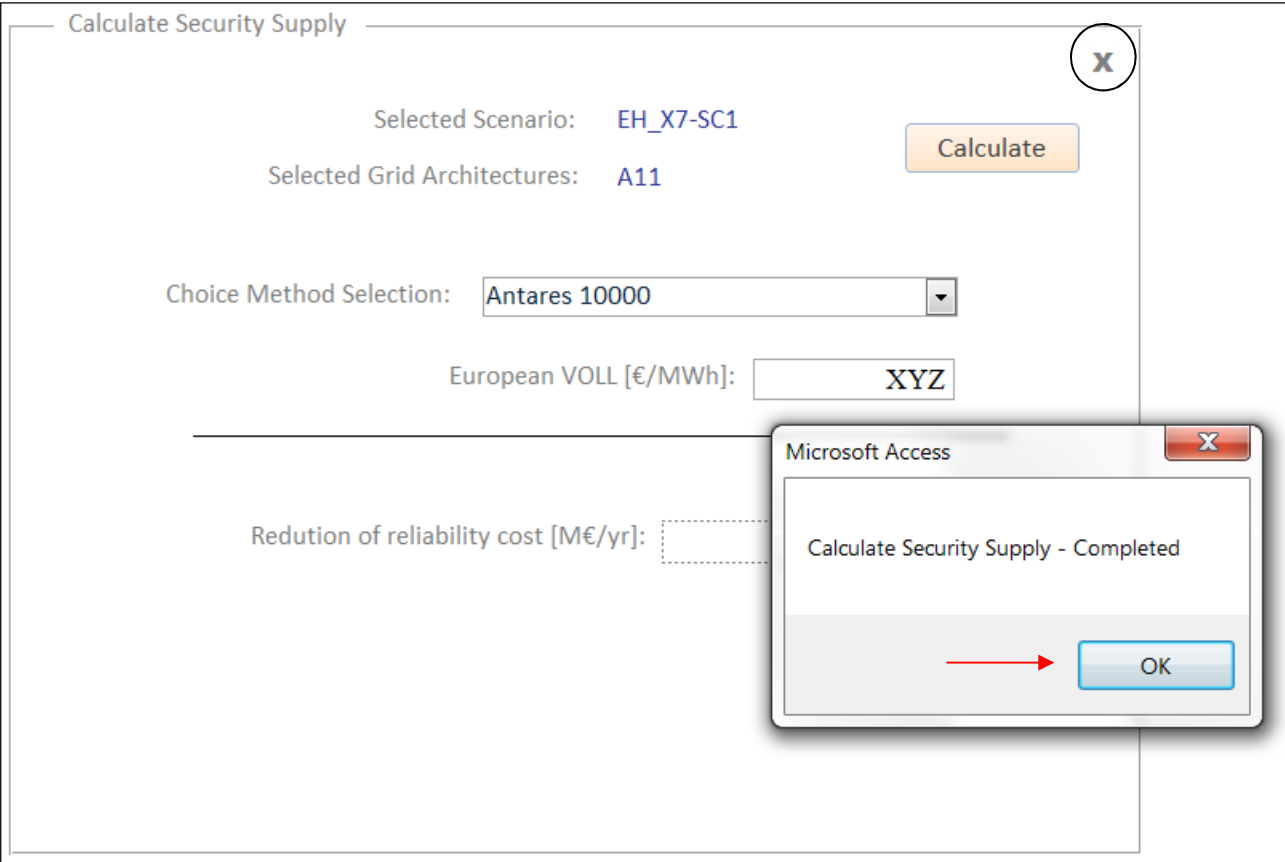


Figure 57 - Security of Supply - Closing the mask

3.3.11. Inter-zonal Transmission Losses

- From the eHighway2050 mask, click on *Calculate indicators*;
- Select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 58, respectively);
- Click on “Inter-zonal Transmission Losses” (blue arrow in Figure 58): then a new windows opens (Figure 59);
- Click on the “Calculate” button (red arrow in Figure 59);
- A textbox opens, warning the user on the opportunity to regenerate the user defined Excel files (LINKS_ij). Click on “Yes”;
- After the calculation, close the mask clicking “Ok” in the textbox (red arrow in Figure 60) and clicking on the upper right “X” symbol (black circle in Figure 60).
- Please keep in mind that, in e-Highway2050, the value of this indicator is always “0” due to the unavailability of reliable losses parameters inside the project. Nevertheless, the calculation methodology is implemented: therefore, if proper input values are provided, the indicator can be calculated.

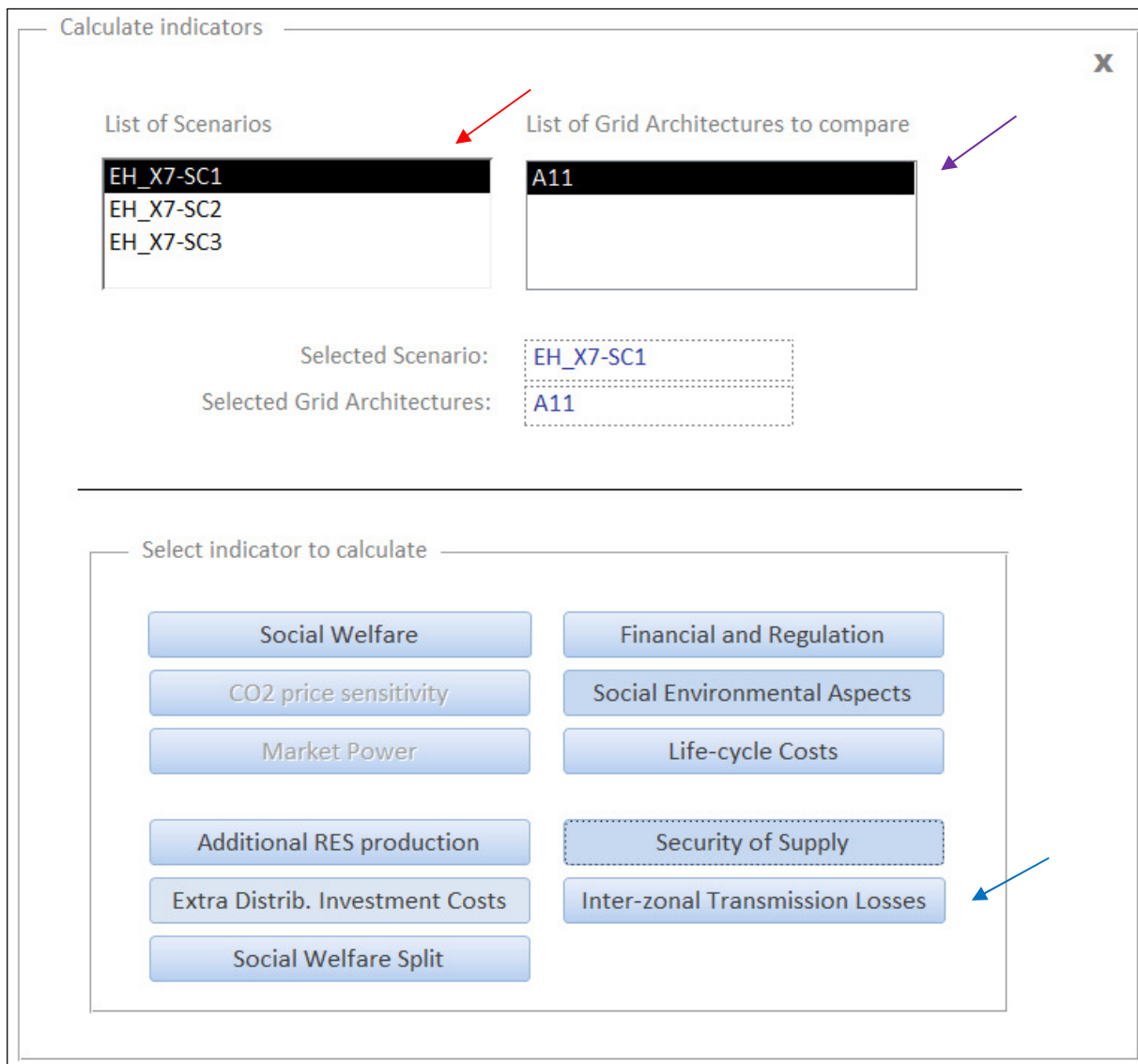


Figure 58 - Calculate indicators - Inter-zonal Transmission Losses

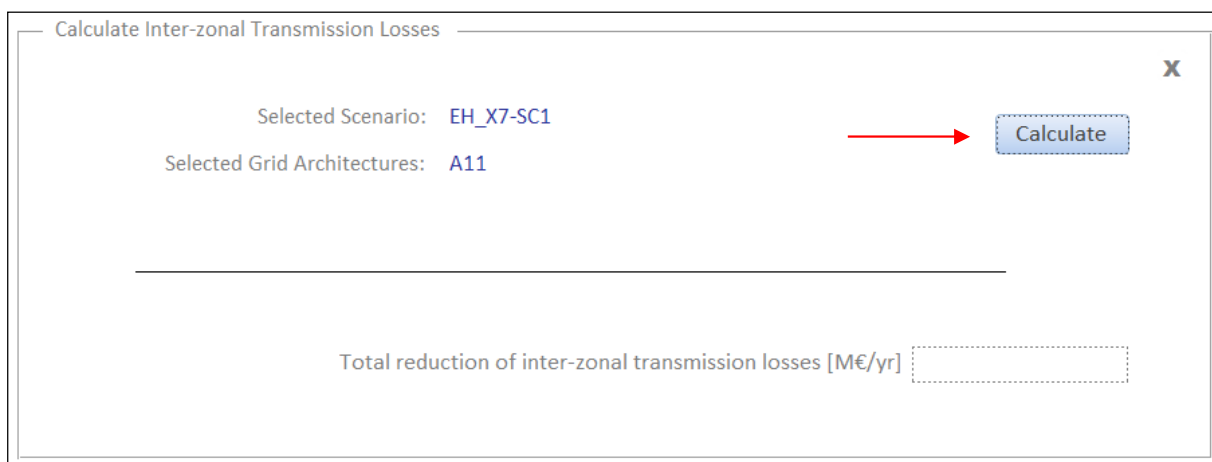


Figure 59 - Inter-zonal Transmission Losses calculation

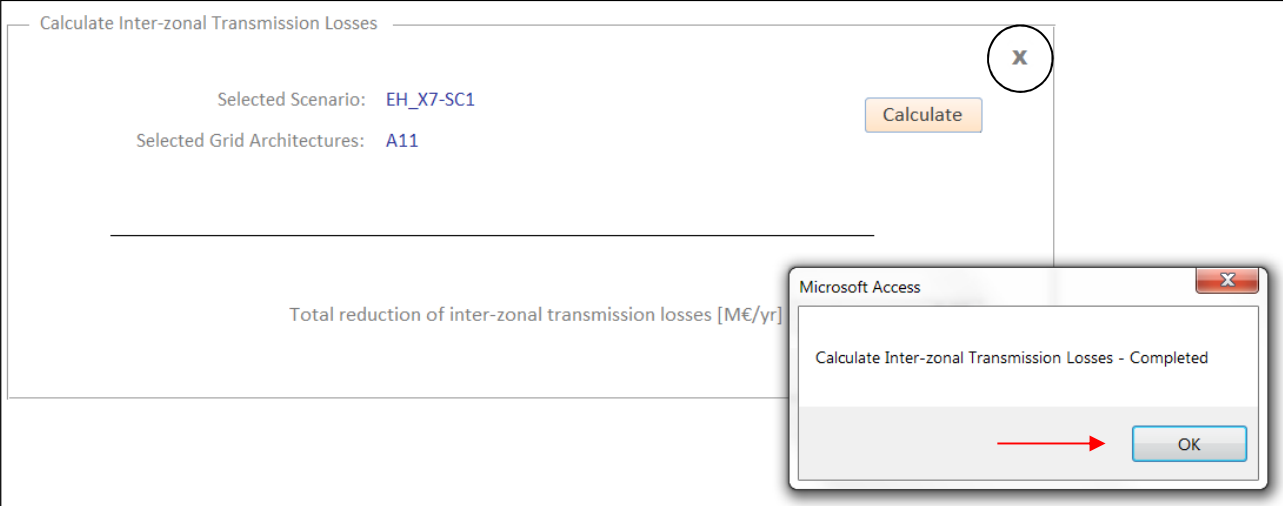


Figure 60 – Inter-zonal Transmission Losses – Closing the mask

3.4. Toolbox outputs

3.4.1. Economic results

- From the eHighway2050 mask, click on *Economic results*;
- Select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 61, respectively). It is possible to select one Scenario and up to 5 Grid Architectures to compare: clicking two times Grid Architecture a means to deselect it. In the red ellipse in Figure 61, the synthesis of the selected options is reported;
- There are two options in selecting indicators:
 - selecting what indicators to display by means of the pertinent check box (see vertical continuous brown arrow in Figure 61);
 - selecting all the indicators clicking on the “All selected” button (see horizontal dashed brown arrow in Figure 61);
- After the selection, there are two ways to displaying indicators:
 - displaying cost-benefit core indicators (see green arrow in Figure 61) “Display Cost/Benefit Core indicators”. This option must be selected in order to score specific Grid Architectures and to sum the pertinent economic indicators (see Figure 62);
 - displaying cost-benefit non-core indicators (see black arrow in Figure 61) clicking on the “Display Cost/Benefit non-Core indicators”. Since not all the non-core indicators are expressed by means of homogeneous metric, they cannot be summed (see Figure 63);
 - the yellow button “Display Cost/Benefit Overall indicators” have been used for testing further development and it is currently disabled.
- To close the mask clicking “Ok” on the upper right “X” symbol (black circles in Figure 62 and Figure 63).

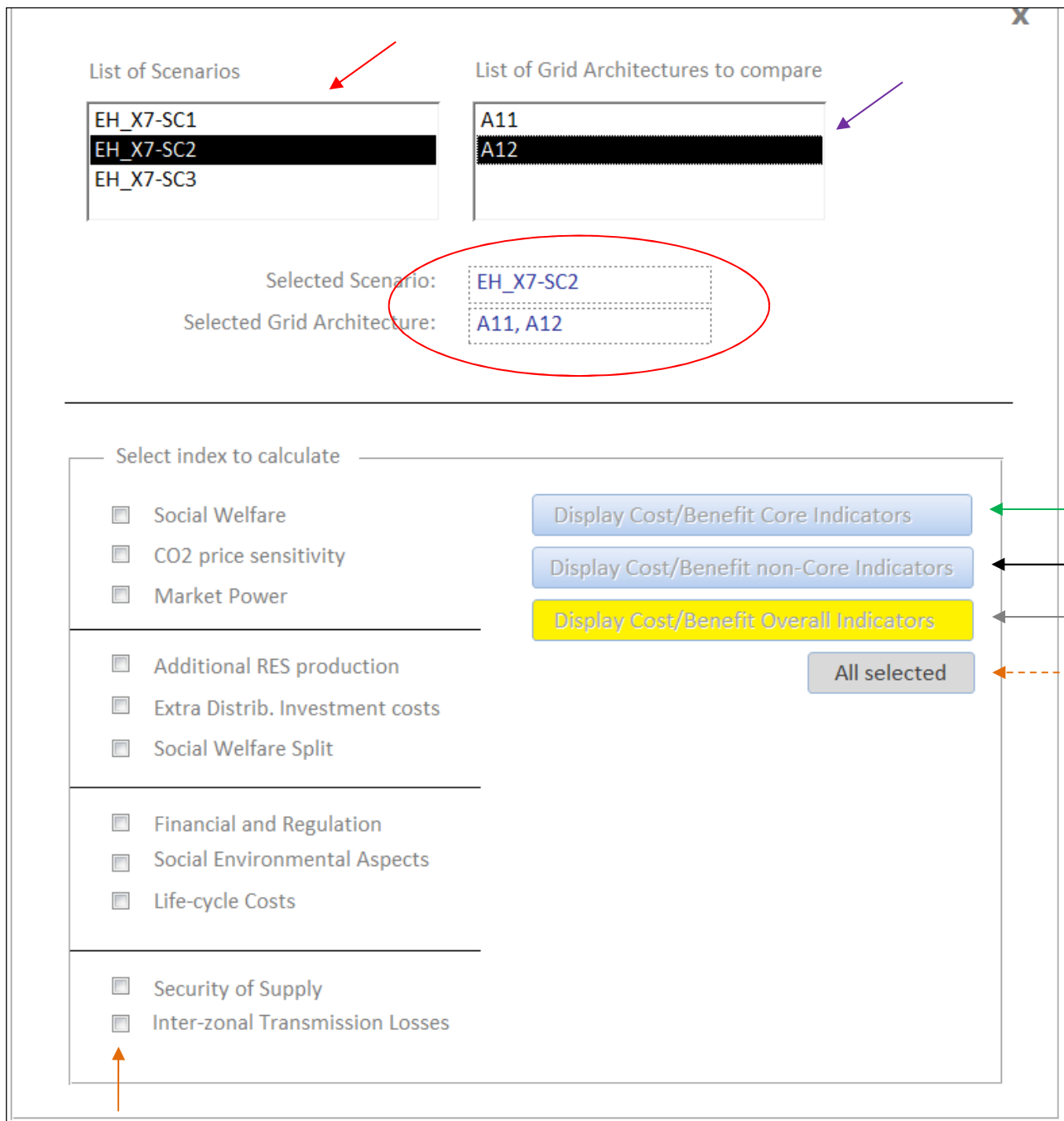


Figure 61 – Economic results – main mask

Display Cost/Benefit Core Indicators

Selected Scenario: EH_X7-SC1

List of Indicators Cost and Architectures:

Indicators	A11	A12				
<LCC> Total LCC - Annuity [M€/yr]	XYZ	XYZ				
Total	XYZ	XYZ				

List of Indicators Benefit and Architectures:

Indicators	A11	A12				
<SW> Increase SW [M€/yr]	XYZ	XYZ				
<SW> Reduc. CO2 emissions [M€/yr]	XYZ	XYZ				
<MP> Increase SW due to MP [M€/yr]	XYZ	XYZ				
<MP> Reduc. CO2 emissions due to MP [M€/yr]	XYZ	XYZ				
<SS> Reduc. Reliability Costs [M€/yr]	XYZ	XYZ				
<SS> Reduc. of Resilience Cost [M€/yr]	XYZ	XYZ				
<SS> Reduc. DSM Cost (energy comp.) [M€/yr]	XYZ	XYZ				
<SS> Reduc. RES Curt. [M€/yr]	XYZ	XYZ				
<ITL> Reduc. Inter-zonal Trasm. Losses [M€/yr]	XYZ	XYZ				
Total	XYZ	XYZ				

Figure 62 – Economic results – Display Cost/Benefit Core Indicators mask

Display Cost/Benefit non-Core Indicators

Selected Scenario: EH_X7-SC1

List of Indicators Cost and Architectures:

Indicators	A11	A12				
<CO2> CO2 Price Limit (max) [€/t]	XYZ	XYZ				
<CO2> CO2 Price Limit (min) [€/t]	XYZ	XYZ				

List of Indicators Benefit and Architectures:

Indicators	A11	A11				
<DIC> Addit. Distrib. Inv. Cost [M€]	XYZ	XYZ				
<SWS> Delta SW [M€/yr]	XYZ	XYZ				
<SWS> Delta CR [M€/yr]	XYZ	XYZ				
<SWS> Delta CS + PS [M€/yr]	XYZ	XYZ				
<RES> Addit. RES generation [MWh/yr]	XYZ	XYZ				
<FR> Average Disc. Rate [%]	XYZ	XYZ				

Figure 63 – Economic results – Display Cost/Benefit non-Core Indicators mask

3.4.2. Graph Scenarios

- From the eHighway2050 mask, click on *Graph Scenarios*;
- Select the pertinent Scenario to analyze (red arrow in Figure 64).
- Select the indicator to graph (purple arrow in Figure 64): the a new window opens with graphs for the specific indicator (see Figure 65)
- The Toolbox provide the visualization of the selected indicator in all the Grid Architectures evaluated: double clicking on a graph allows to access to a table where numeric values reported in the graphs are stored (see Figure 66);
- For closing the pertinent mask, click on the upper right buttons highlighted by black circles (see Figure 64 Figure 65 and Figure 66)

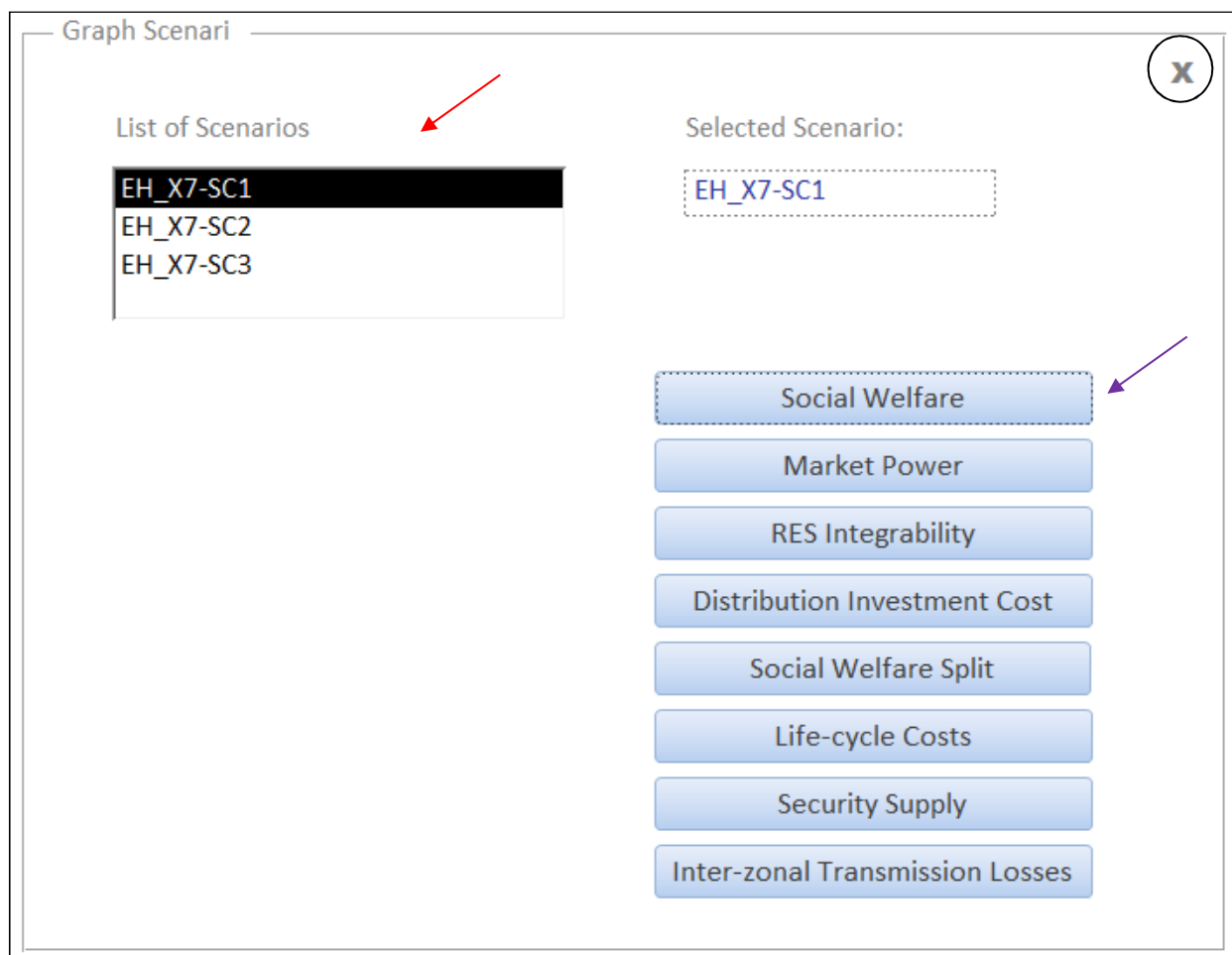


Figure 64 - Graph Scenario mask

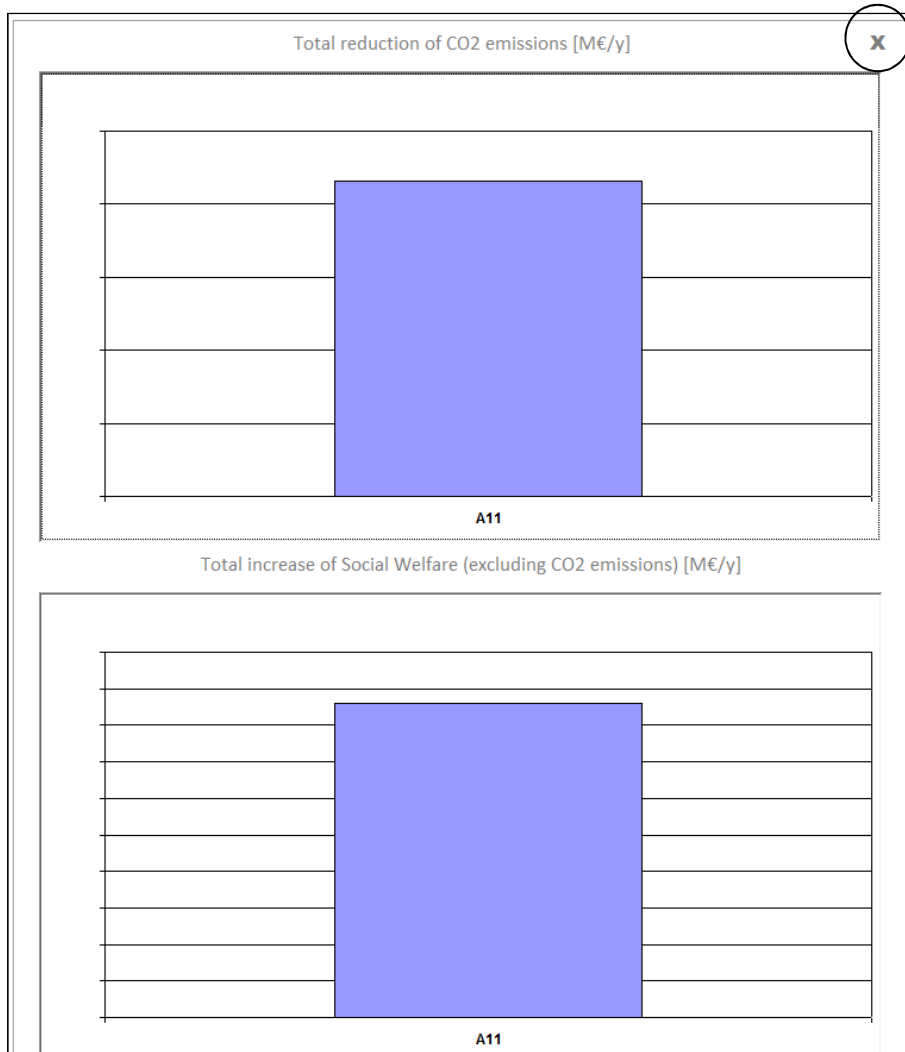


Figure 65 - Graph example

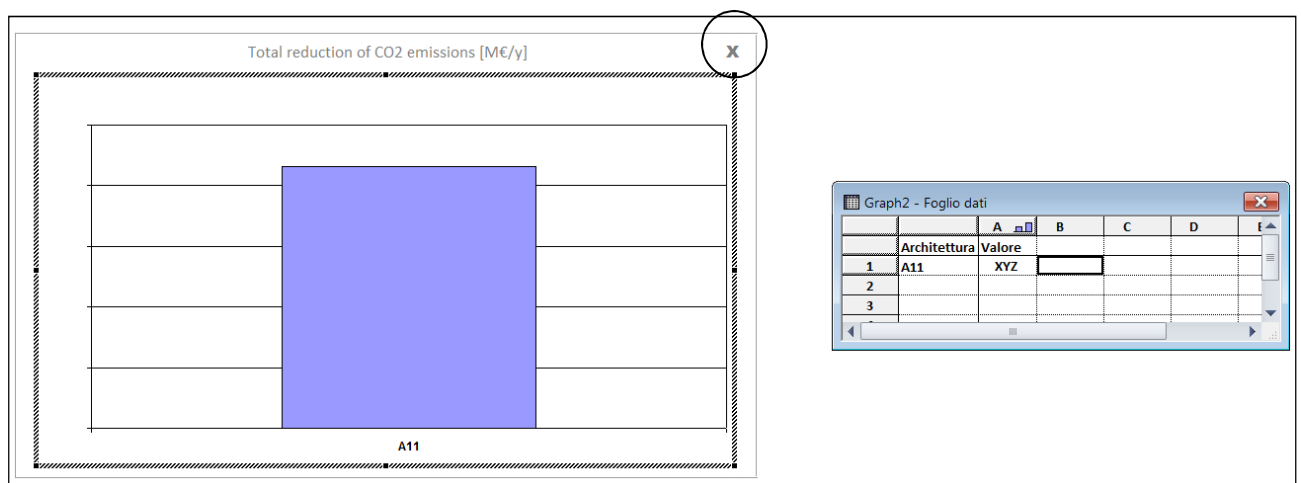


Figure 66 - Graph and table example

3.4.3. Display Scenarios

- From the eHighway2050 mask, click on *Display Scenarios*;
- select the pertinent Scenario and Grid Architecture to analyze (red and purple arrows in Figure 67, respectively);
- click on the “Display” button: a short report about the calculated indicators is provided (see Figure 68);
- To clear the displayed values, click on the “Clear button” (black arrow in Figure 68);
- to close the mask, click on the upper right buttons highlighted by black circle in Figure 68.

Display Scenarios
X

List of Scenarios

- EH_X7-SC1
- EH_X7-SC2
- EH_X7-SC3

List of Grid Architectures to compare

- A11

Selected Scenario:

Selected Grid Architecture:

Display

Clear

Total reduction of CO2 emissions [M€/y]:	<input type="text"/>	<SW>
Total increase of Social Welfare (excluding CO2 emissions) [M€/y]:	<input type="text"/>	<SW>
CO2 Price Limit (max) [€/t]:	<input type="text"/>	<CO2>
CO2 Price Limit (min) [€/t]:	<input type="text"/>	<CO2>
Total reduction of CO2 emissions due to market power [M€/y]:	<input type="text"/>	<MP>
Total increase of Social Welfare (excluding CO2 emissions) due to market power [M€/y]:	<input type="text"/>	<MP>
Additional RES production [MWh/yr]:	<input type="text"/>	<RES>
Extra Distribution Investment Costs [M€]:	<input type="text"/>	<DIC>
Delta SW (System) [M€/yr]:	<input type="text"/>	<SWS>
Delta CR (System) [M€/yr]:	<input type="text"/>	<SWS>
Delta CS + PS (System) [M€/yr]:	<input type="text"/>	<SWS>
Average Discount Rate [%]:	<input type="text"/>	<FR>
Total LCC [G€]:	<input type="text"/>	<LCC>
Total LCC annuity costs [M€/yr]:	<input type="text"/>	<LCC>
Reduction of Reliability costs [M€/yr]:	<input type="text"/>	<SS>
Reduction of Resilience costs [M€/yr]:	<input type="text"/>	<SS>
Reduction of DSM costs (energy component) [M€/yr]:	<input type="text"/>	<SS>
Reduction of RES curtailment [M€/yr]:	<input type="text"/>	<SS>
Reduction of inter-zonal transmission losses [M€/yr]:	<input type="text"/>	<ITL>

Figure 67 – Display Scenarios mask

Display Scenarios
X

List of Scenarios

EH_X7-SC1
 EH_X7-SC2
 EH_X7-SC3

Selected Scenario: EH_X7-SC1

List of Grid Architectures to compare

A11

Selected Grid Architecture: A11

Display

Clear

Total reduction of CO2 emissions [M€/y]:	XYZ	<SW>
Total increase of Social Welfare (excluding CO2 emissions) [M€/y]:	XYZ	<SW>
CO2 Price Limit (max) [€/t]:	XYZ	<CO2>
CO2 Price Limit (min) [€/t]:	XYZ	<CO2>
Total reduction of CO2 emissions due to market power [M€/y]:	XYZ	<MP>
Total increase of Social Welfare (excluding CO2 emissions) due to market power [M€/y]:	XYZ	<MP>
Additional RES production [MWh/yr]:	XYZ	<RES>
Extra Distribution Investment Costs [M€]:	XYZ	<DIC>
Delta SW (System) [M€/yr]:	XYZ	<SWS>
Delta CR (System) [M€/yr]:	XYZ	<SWS>
Delta CS + PS (System) [M€/yr]:	XYZ	<SWS>
Average Discount Rate [%]:	XYZ	<FR>
Total LCC [G€]:	XYZ	<LCC>
Total LCC annuity costs [M€/yr]:	XYZ	<LCC>
Reduction of Reliability costs [M€/yr]:	XYZ	<SS>
Reduction of Resilience costs [M€/yr]:	XYZ	<SS>
Reduction of DSM costs (energy component) [M€/yr]:	XYZ	<SS>
Reduction of RES curtailment [M€/yr]:	XYZ	<SS>
Reduction of inter-zonal transmission losses [M€/yr]:	XYZ	<ITL>

Figure 68 – Display Scenarios mask – Show indicators

REFERENCES

- [1] Migliavacca, G., Rossi, S., Careri, F., Olmos L., Ramos A., Rivier M., Sijm J., Van Hertem D., Huang D., “A comprehensive cost-benefit approach for analysing pan-European transmission highways deployment”, e-Highway2050 Deliverable D6.1, February 2014;
- [2] M. Doquet, C. Fourment and J. Rouderges, “Generation & Transmission Adequacy of Large Interconnected Power Systems: A contribution to the renewal of Monte-Carlo approaches,” IEEE Trondheim PowerTech, 2011.

ANNEX 1 – Implementation of social and environmental aspects in the e-Highway2050 BCA Toolbox

1. Introduction

The costs of future networks is determined to a large extent by the precise routes which can be followed as well as the type of network components which can be applied, such as the distinction between overhead lines and the much more expensive underground cables. The aim of this component of the e-Highway project is to develop an approach for quantifying the additional costs and benefits of future grids apart from the direct investment costs. Three widely differing alternative approaches have been assessed. These are :

1. Aggregated cluster approach
2. Detailed current network approach
3. Optimal new network approach

In the **aggregated cluster approach**, all relevant parameters affecting the network connections between clusters are averaged per cluster. This allows straightforward assessment but at a very crude level

The **detailed current network approach** starts with the assumption that the location of the future network is determined by the existing network. Part of the existing network will be strengthened to allow for future increases in transmission capacity that are needed. This stresses the evolutionary character of network development.

In the third alternative, **the optimal new network approach**, the trajectories are chosen which leads to the lowest cost connections between loads and generators. This 'greenfield approach' does not take into account the location of the current network.

Official permission procedures for electricity networks differ substantially between the different EU countries. This can lead to substantial delays which might affect future network choices. This aspect is further assessed in chapter 5 on approval times.

2. Aggregated cluster approach

2.1. Methodology

In the aggregated cluster approach, WP6 received data about the distance between neighbouring clusters from the centre of a cluster being available from WP2. The distance was calculated based on straight lines. Because the actual length between the clusters will always be longer than the straight line between the centre points, an additional detour of 30% was added.

For most of the clusters, data about the land use from the LUCAS database has been obtained. For some non-EU countries this data was not available. For these countries the data was taken from the worldstat.info website.

The methodology for calculating the compensation costs by the aggregated cluster approach starts with taking the distance between the 2 clusters connecting to each other. 50% of the distance is imputed to cluster A and 50% of the distance is imputed to cluster B. 50% of the distance combined with the average land use data gives the starting point for calculating the compensation costs.

For the aggregated cluster approach an Access database has been developed. In the next paragraph, a detailed description of the tables, queries, macros, modules within the database is given.

2.2. Tables

In the database the TECDATA table is a special table. It is not necessary to copy this table to the toolbox DB, because this table is already there. All the other tables has to be copied into the e-Highway2050 toolbox. In the next part a description is provided of all the tables.

AssexInstex

This table will be filled with the macro 'Fill AssexInstex Table' which runs the function ImportAssexInstex from the ReformatData module. This function takes all the data from the table TECDATA.

Description of the fields

Name field	Description	Refers to
TransmissionTechnology	Generic transmission technology. These are the same as the fieldnames in the TECDATA table.	θ
CapitalCost	Unitary capital costs of the assets. This is taken from the record with 'Asset capital expenses ASSEX [€/km]' in the field 'Tec data' from the TECDATA table.	ASSEX
InstallationCost	Unitary installation costs of the capital goods. This is taken from the record with 'INSTEX [€/km]' in the field 'Tec data' from the TECDATA table.	INSTEX

ClusterCombination

In this table, information about which clusters can connect to each other is provided. The information is stored in 2 directions for example 01ES is connected to 02ES but also 02ES is connected to 01ES.

Description of the fields

Name field	Description	Refers to
ClusterFrom	Are the same as the fieldnames in the TECDATA table	h, k
ClusterTo	The record with 'INSTEX [€/km]' in the field 'Tec data'	h, k

ClusterInfo

In this table some information about the clusters is stored. As default, all parameters are filled with the default value 0.

Description of the fields

Name field	Description	Refers to
Cluster	Code of the cluster	h, k
FactorSenisitiveBioland	Percentage of km in sensitive areas related to biodiversity and landscape	β
FactorSenisitiveHealthWell	Percentage of km in sensitive areas related to health and wellbeing	η
FactorSuperimposition	Superimposition parameter, parameter to avoid double counting β and η	ρ
DelayRerouting	Time delay in years due to reroute the interconnection	Δt_{BTHW_1}
DelayUnderground	Time delay in years due to underground the interconnection	Δt_{BTHW_2}
DelayCompensation	Time delay in years due to making compensations	Δt_{BTHW_3}
DelayPublicAttitude	Time delay in years due to public attitude and actions	Δt_{PA}

ClusterLandUseTypeInfo

In this table the information is stored the distribution of the land use types for each cluster.

Description of the fields

Name field	Description	Refers to
Cluster	Code of the cluster	h, k
LandUseType	Code of the type of land use	u
FactorLandUse	Land use factor per land use type and cluster	LU

ClusterLandUseTypeTransmissionTechnologyInfo

In this table, some information about the cluster, land use type and used transmission technology is stored.

Description of the fields

Name field	Description	Refers to
Cluster	Code of the cluster	h, k
LandUseType	Code of the type of land use	u
TransmissionTechnology	Generic transmission technology. If the names of the technologies changes in the TECDATA table, the information in this table has to be changed too.	θ
ROWCost	Unitary compensation costs for ROW	Cost_ROW
CostValLoss	Unitary compensation costs for loss of value. In this database a default factor of 0 is implemented.	Cost_ValLoss

ClusterTransmissionTechnologyCouplingInfo

In this table, information is stored about the coupling between the transmission technologies for which technology can be used when putting an interconnection from overhead lines to underground lines. If the information in the TECDATA table will change, also this table has to be changed.

Description of the fields

Name field	Description	Refers to
Cluster	Code of the cluster	h, k
TransmissionTechnologyFrom	Generic transmission technology which will be replaced	θ
TransmissionTechnologyTo	Generic transmission technology in which it will be replaced	θ
UndergroundFactor	This factor is a multiplication factor on the length of a corridor. So a factor of 1 says that there is no change in the length of the corridor. By default the factor 1 is implemented in the database.	k_{ζ}

ClusterTransmissionTechnologyInfo

In this table is some information stored about the cluster and transmission technologies.

Description of the fields

Name field	Description	Refers to
Cluster	Code of the cluster	h, k
TransmissionTechnology	Generic transmission technology	θ
WidthROW	Average width of ROW. In this database a default factor of 1 is used because the unitary compensation costs for ROW are available per meter instead of square meter.	\overline{w}
DelayROWAcquisition	Time delay in years due to the ROW acquisition. In this database a default factor of 0 is used.	Δt_{ROW}
ReroutingFactor	Extra km in rerouting necessary to avoid sensitive areas. In this database a default factor of 0 is used.	$k_{rerouting}$
BLHWCompensationCost	Extra compensation costs for biodiversity, landscape, health and wellbeing in order to mitigate the crossing of sensitive areas.	BLHW_CompCosts

CorridorTransmissionTechnologyInfo

In this table is information stored about which transmission technology is used between 2 clusters. The combination of the fields ClusterFrom and ClusterTo has to be the same as in the table LengthCorridor.

Description of the fields

Name field	Description	Refers to
ClusterFrom	Code of the cluster	h, k
ClusterTo	Code of the cluster	h, k
TransmissionTechnology	Generic transmission technology used	θ
Share	How much of the corridor is used by the specified transmission technology.	not mentioned in referring document

LengthCorridor

In this table is information stored about which transmission technology is used between 2 clusters. The entries and connections in the fields ClusterFrom and ClusterTo has to be the same as in the table LengthCorridor.

Description of the fields

Name field	Description	Refers to
ClusterFrom	Code of the cluster	h, k
ClusterTo	Code of the cluster	h, k
Length (km)	Distance in km between the centre of 2 clusters. This field is not used in the database.	
Length+detour (km)	Distance in km between the centre of 2 clusters, including a potential detour.	1

TransmissionTechnologyInfo

In this table is specific information stored about the available transmission technologies.

Description of the fields

Name field	Description	Refers to
TransmissionTechnology	Generic transmission technology used	θ
WidthReduction	reduction coefficient for width from time to t_0 time t_f .	k_w

2.3. Queries

Only the query qryCheckLandUse100% is used as a check to see if the distribution of the land uses adds up to 100% for each cluster. For this query it is not necessary to make a copy into the e-Highway2050 toolbox. For all the queries it is necessary to make a copy to the e-Highway2050 toolbox. The final query which will deliver the final compensation costs is the query qryCostCompensationTotal. This query has only 1 record and 1 output field (SumOfCostCompensation).

Here below all the queries and assumptions are explained with a short description.

qryCostCompensationTotal

This query calculates the total compensation costs. This query takes the data from the query *qryCostCompensation*.

qryCostCompensation

This query calculates the total compensation costs for each corridor between 2 clusters. This query takes data from the queries *qryCostBLHW*, *qryCostROW* and *qryCostValLoss*.

qryCostBLHW

This query calculates for each corridor between 2 clusters the compensation costs for biodiversity, landscape, health and wellbeing. This query takes the minimum costs from the queries *qryBLHWMitigation*, *qryBLHWRerout* and *qryBLHWUnderground* and uses this as output.

qryBLHWMitigation

This query calculates for each corridor between 2 clusters the costs for BLHW when there is mitigation. This is done by adding up the costs for mitigation in the first cluster and the costs for mitigation in the second cluster. The length between the 2 clusters is used to determine the distance of the corridor in each cluster. By default we say that 50% of the length is in the first cluster and 50% is in the second cluster. This query takes data from the query *qryLengthCorridor* and the tables *CorridorTransmissionTechnologyInfo*, *ClusterTransmissionTechnologyInfo* and *ClusterInfo*.

qryBLHWRerout

This query calculates for each corridor between 2 clusters the costs for BLHW when there is rerouting. This is done by adding up the costs for rerouting in the first cluster and the costs for rerouting in the second cluster. The length between the 2 clusters is used to determine the distance of the corridor in each cluster. By default we say that 50% of the length is in the first cluster and 50% is in the second cluster. This query takes data from the query *qryLengthCorridor* and the tables *CorridorTransmissionTechnologyInfo*, *ClusterTransmissionTechnologyInfo*, *AssexInstex* and *ClusterInfo*.

qryBLHWUnderground

This query calculates for each corridor between 2 clusters the costs for BLHW when there is undergrounding the transmission line. This is done by adding up the costs for undergrounding in the first cluster and the costs for undergrounding in the second cluster. The length between the 2 clusters is used to determine the distance of the corridor in each cluster. By default we say that 50% of the length is in the first cluster and 50% is in the

second cluster. This query takes data from the query `qryLengthCorridor` and the tables `CorridorTransmissionTechnologyInfo`, `ClusterTransmissionTechnologyInfo`, `ClusterTransmissionTechnologyCouplingInfo`, `AssexInstex` and `ClusterInfo`.

qryCostROW

This query calculates for each corridor between 2 clusters the costs for ROW. This is done by adding up the costs for ROW in the first cluster and the costs for ROW in the second cluster. The length between the 2 clusters is used to determine the distance of the corridor in each cluster. By default we say that 50% of the length is in the first cluster and 50% is in the second cluster. This query takes data from the queries `qryLengthCorridor` and `qryCostROWClusterTransmissionTechnology` and the tables `CorridorTransmissionTechnologyInfo`, `ClusterTransmissionTechnologyInfo` and `TransmissionTechnologyInfo`.

qryCostRowClusterTransmissionTechnology

This cluster calculates for each possible combination of cluster and transmission technology the costs for ROW. This query takes data from the tables `ClusterLandUseTypeTransmissionTechnologyInfo` and `ClusterLandUseTypeInfo`.

qryCostValLoss

This query calculates for each corridor between 2 clusters the costs for value losses. This is done by adding up the costs for value loss in the first cluster and the costs for value loss in the second cluster. The length between the 2 clusters is used to determine the distance of the corridor in each cluster. By default we say that 50% of the length is in the first cluster and 50% is in the second cluster. This query takes data from the queries `qryLengthCorridor` and `qryCostValLossClusterTransmissionTechnology` and the table `CorridorTransmissionTechnologyInfo`.

qryCostValLossClusterTransmissionTechnology

This cluster calculates for each possible combination of cluster and transmission technology the costs of value losses. This query takes data from the tables `ClusterLandUseTypeTransmissionTechnologyInfo` and `ClusterLandUseTypeInfo`.

qryLengthCorridor

This query calculates the distances between the clusters only for the defined possible corridors. This query uses the tables `ClusterCombination` and `LengthCorridor`.

qryCheckLandUse100%

This query makes a check to see if for all the clusters the distribution of the land uses add up to 100%. This query uses only the table ClusterLandUseTypeInfo.

2.4. Macros and Modules

The database contains 1 macro and 1 module. The macro 'Fill AssesInstex Table' calls the function ImportAssexInstex which is in the module ReformatData. The function ImportAssexInstex looks in the table TECDATA and search for the records with 'INSTEKX [€/km]' and 'Asset capital expenses ASSEX [€/km]' in the field 'Tec data'. The data from 'INSTEKX [€/km]' is stored in the table AssexInstex in the field InstallationCosts and the data from 'Asset capital expenses ASSEX [€/km]' is stored in the field CapatitalCosts. Each field with technology data in the table TECDATA gets its own record in the table AssexInstex.

Be aware that when the technology format in the table TECDATA needs to be changed (new and changed field names), also the format of the data in all the tables with TechnologyInfo in the name has to be changed manually. In the table ClusterLandUseTypeTransmissionTechnologyInfo the fields ROWCost and CostValLoss are different for unground line technologies and overhead lines technologies. In the table ClusterTransmissionTechnologyCouplingInfo is information which overhead line technology can be replaced by which unground line technology. Also the data in the table ClusterTransmissionTechnologyInfo and TransmissionTechnologyInfo are depending on the type of the available technologies.

3. GIS-based current network approach

3.1. Methodology

In the GIS based current network approach the shortest way between 2 connecting clusters has been calculated using the existing grid of power lines. At the same time

GIS maps were used to calculate the shortest distance between 2 connecting clusters. The maps used for these calculation are:

- Grid 400 225 KV: Map with the available grid in Europe with distinctions about the capacity of each line.
- Clusters_Borders: Map with the clusters which has to be taken into account.
- CLC_Complet.tif: Map with the land use data.



Figure : Map displaying the basic used maps.

Starting from these base maps the actions for calculating the shortest way between 2 clusters and combine this with the land use data the actions are described in the next paragraph.

3.2. **OUTCOMES: Excel files for the Compensation Cost module**

In the accompanying Excel file with the results of the above described activities are 5 worksheets:

1. **Summary:** in this sheet a summary of all available data is presented. In the first table the length of all connections are presented divided per type of land use. In the second table you will find the compensation costs for all connections with only underground cables and for all connections with almost only overhead lines (because it is not likely that in areas with artificial land use overhead lines will be used, the assumption has been made that here underground cables are used).
2. **ConnectionPoints:** in this sheet you will find the Latitude and Longitude of the chosen connection points per cluster. These points were chosen via a procedure explained in action 1 above.
3. **LengthPerRoute:** here you will find the total length in km between the connection points in 2 adjacent clusters. How this length was calculated is described in action 2 above. For some pairs of clusters no connections by the current grid were available. For these clusters a new connection was created by hand (see the comment column). Also all connection between non-adjacent clusters were not taken into account. If we would take this connections into account a lot of connections were using the same route.

4. **LandUsePerRoute:** in this sheet you will find per connection, and per cluster through which this connection is going and per type of land use the length in km of each part of the connection and the compensation costs for both an underground cable or an overhead line.
5. **CostsPerCluster:** in the last sheet you will find the compensation costs in euro/km. These compensation costs are given per cluster for the 7 land use types for both underground cables as well as for overhead lines.

4. Optimal new network approach

The last approach is the optimal new network approach. This approach looks like the GIS based current network approach, but instead of following the existing grid a completely new grid will be developed. The route of this new grid will be decided given the cheapest way to create a connection between 2 connecting clusters. This approach has been investigated as option but it has not been implemented due to the lack of time.

5. Approximation of approval times depending on ground type¹

5.1. Current Situation

Currently data on approval times for the construction of overhead and underground high voltage lines and their corresponding poles is rather limited. The most detailed document publicly available in English is provided by etso in 2006. However it only differentiates the approval times by member countries. No further differentiation by type of intervention nor by typology of the ground is performed. Hence a methodology based on the available data has to be defined to generate ground typology dependent data.

¹ Version 4, submitted by TU Berlin on 27 January 2015

5.2. Available Data

To determine possible durations of easements and expropriation publicly available data has been considered. The resulting durations can be found in the subsequent table.

[months]	easement		expropriation		additional lawsuit	max total
	lower	upper	lower	upper		
Austria		24				24
Belgium	0	0	inf			NA
Czech Republic	3	6				6
France				3		3
Germany			6	12	60*	18
Greece				12		12
Luxemburg		6		24		30
Portugal				24		24
Average:						15.5

Unfortunately the data is rather incomplete. Except for Germany no data was found on the possible duration of an additional lawsuit, nor its possibility. As this would result in a country specific bias for Germany, the figure was excluded for the calculation of the average approval time. If additional data can be delivered by national TSOs, this column will be considered for the calculation of the average approval time.

5.3. Method

We assume a positive linear correlation between the approval times and the monetary cost for the right of the way (ROW). As a starting point we use a European wide average approval time and adjust it depending on the ROW for each topology.

Our analysis showed an average approval time for easement or expropriation of 15.5 months.

According to different experts approval times mostly vary between +/- 50%. Therefore we assume that in the best case an approval time of 7.75 months can be reached, whereas in the worst case an approval time of 23.25 months must be tolerated.

As we assume a positive linear correlation, the typology with the lowest ROW cost will also have the shortest approval time of 7.75 months. Similar the typology with the highest ROW cost will have the longest approval time of 23.25 months. These two points are defining the linear curve of our regression. Hence for all ROW besides the lowest and highest, approval times are a linear interpolation between these two points.

5.4. Sources (Approval times)

Eurelectric (2003): Public Acceptance for new transmission overhead lines and substations

<http://www.eurelectric.org/Download/Download.aspx?DocumentID=12983>

Etso (2006):

https://www.entsoe.eu/fileadmin/user_upload/_library/publications/etso/others/procedures%20400%20kv%20lines.pdf

ANNEX 2 – Technical implementation of security of supply indicators in WP6 Toolbox

1. Introduction

This document briefly explains the general structure of the part of the toolbox dedicated to security of supply indicators. The next section provides a general view of the structure of the tool, followed by a section that describes each of the modules and functions within the computer tool.

2. Tools structure overview

The tool is aimed at computing the reliability measures of electric network systems. For this purpose, it is designed as a set of VBA modules inside the main Access database. This structure derives from a previous design of the tool where data were stored in an Access database. It is not the case anymore, and now the Access database serves only as a mean to hold the executable VBA modules.

The VBA modules involved in the computation are:

- *Toolbox*: This is the main core module that contains the functions to compute the reliability measures.
- *BaseDeDatos*: This class module encapsulates the functions needed to access an external database and launch the queries to retrieve the information from it. Since the toolbox is now not based on an Access database anymore, this module has no use. It is left just in case it is needed again.
- *CTimer*: This class module is used to measure the elapsed time in the computations.

The only form that can be found in the database is just used for launching the computations and showing the results in a simple way. Since these computations are going to be integrated in a larger toolbox, this form has no use for the final tool, and hence it is not described in this document.

3. Code modules

3.1. Toolbox module

This class holds the principal functions to launch the reliability measures computation. The set of functions that provide the functionality are the following ones:

- *Function Main*: This function organizes the computations to be carried out by this part of the toolbox. It assumes that there is a base folder for the input data, inside of which a “DataDB” subfolder contains text input files, and a “Manual_files” folder contains the Excel input files. The base path is built with the structure BasePath + ScenarioIndex + InfixPath (for instance “C:\ Toolbox\File data\IN\SC1-Dry-run”). In this example, the variables BasePath and InfixPath must take the following values for the tool to successfully read input data:

BasePath = “C:\ Toolbox\File data\IN\SC”

InfixPath = “-Dry-run”

- *Functions ComputeSystemReliability, ComputeSystemResilience, ComputeDemandSideManagement and ComputeRESCurtailmentCompensation*: These functions perform the computations described in the methodology developed in the working package and already discussed-
- *Function ReadNodes*: Reads and returns the set of nodes considered in the problem being solved.
- *Function ReadNodeConnections*: Reads and returns the connections between the nodes in the problem, that represent the electric lines.
- *Function ReadScenarioCount*: Returns the scenario count. Since this information is not available at the moment of writing this, this function just returns the value of 1. When the scenario count is finally established, it should be returned by this function (maybe by reading to some configuration data).
- *Function ReadArchitectureCount*: Returns the architecture count. As in the previous item, this is not yet available at the moment of writing this, so it merely returns a value of 1. When this value is finally included in the dataset, this value should be returned by this function.
- *Function ReadTableDB*: Reads some information table from an Access database.
- *Function ReadTableTXT*: Reads some information table from an Access database. It assumes the text file is located under the text data file folder.
- *Function ReadTableXLS*: Reads some information table from an Access database. It assumes the Excel file is located under the Excel data file folder.
- *Function QuickSort*: This function sorts a set of values by using the general quicksort method, by calling itself recursively.

3.2. Database class module (BaseDeDatos)

This class provides access to an external database, and the ability to query its contents. As it was previously said, currently it is not used anymore, but it is left in case it is needed again. Its functionality is based on the following functions:

- *Function ModificaRutaAcceso*: It sets the path of the database to be used for the following queries. It expects and ACCDB database for use with Access.
- *Function ConsultaBaseDeDatos*: This function launches a SQL query to the database indicated by the previous function call. If the query contains an error, it will signal that on return. But it does not return the results from that query.
- *Function DevuelveResultado*: This function returns the results of a query previously launched to the database. Note that the results from a query cannot be read more than once.
- *Function Consulta*: This function combines the two previous functions, by launching a query and returning the results, if the query is successful.

3.3. Timer class module (CTimer)

This module can be used to measure time elapsed during some process executed in Windows. For this purpose, the class holds the information for a Windows timer and uses the Windows API functions to handle this information. The public interface to use this class consists on the following function and properties:

- *Function StartCounter*: Must be called at the beginning of the process whose execution time is to be measured. It stores an initial time reference for subsequent measures, so it should be called again to restart the measurement.
- *Property TimeElapsed*: Returns the time (measured in milliseconds) that has passed through since the last call to the function StartCounter.
- *Property TimeElapsedFormatted*: Returns the time (as a string with the format “MM min. SS sec.”) that has passed through since the last call to the function StartCounter.