



ΔΙΑΚΗΡΥΞΗ ΔΑΠΜ- 41702

«ΕΚΠΟΝΗΣΗ ΜΕΛΕΤΗΣ ΣΚΟΠΙΜΟΤΗΤΑΣ, ΜΕΛΕΤΗΣ ΚΟΣΤΟΥΣ ΟΦΕΛΟΥΣ ΚΑΙ ΠΑΡΟΧΗ ΥΠΟΣΤΗΡΙΚΤΙΚΩΝ ΥΠΗΡΕΣΙΩΝ ΓΙΑ ΤΟ ΕΡΓΟ ΔΙΑΣΥΝΔΕΣΗ ΕΡ 150kV 2x200 MVA (~ 2x140 MW) ΚΡΗΤΗ-ΠΕΛΟΠΟΝΝΗΣΟΣ»

ΤΕΥΧΟΣ 8

ΤΕΧΝΙΚΟ ΜΕΡΟΣ

Terms of Reference

Technical Description

For the assignment:

“Feasibility Study, Cost Benefit Analysis (CBA) and provision of Supporting Services for the project 150 kV AC INTERCONNECTION 2x200 MVA (~ 2x140 MW) CRETE-PELOPONNESE”

1. Introduction

The project “150 kV AC Interconnection 2x200 MVA (~ 2x140 MW) Crete-Peloponnese” constitutes the Phase I of the wider project of interconnection of Crete with the Mainland System (HETS). The Phase II is the “DC interconnection, 2x350MW capability, Crete – Attica”.

The project is the cluster 14.26 in the current TYNDP 2017-2026¹ approved by RAE’s Decision 280/2016 (Official Gazette 2534, 17-8-2016). In Annex I the extract of the TYNDP 2017-2026 for the project is provided, while in Annex II the most recent configuration is presented.

The project “150 kV AC INTERCONNECTION 2x200 MVA (~ 2x140 MW) CRETE-PELOPONNESE” is considered as “Major Project” in the framework of EU funds (Article 100 of Regulation (EU) No 1303/2013). Its total eligible cost amounts to approximately € 362,171 million², exceeding the € 75 million financial threshold set by the above regulation and in conformity with the national thematic axis.

IPTO S.A. (the owner and operator of the Hellenic Transmission System), the project’s promoter, aiming to obtain co-financing in the framework of EU Funds, is obliged to prepare and submit the information required, referred to in Article 101 (information necessary for the approval of a major project) of Regulation (EU) No 1303/2013. Important elements of the information required are the Feasibility Study and the Cost Benefit Analysis (CBA).

The aim of this document is to describe the technical specifications for the tendering of the Feasibility Study, Cost Benefit Analysis and the provision of supporting services to IPTO.

2. Feasibility Study

¹ <http://www.admie.gr/to-systima-metaforas/anptyxi-systimatos/dekaetes-programma-anptyxis-systimatos-metaforas-dpa/>

² Annex III provides the estimated budget of the project “150 kV AC INTERCONNECTION 2x200 MVA (~ 2x140 MW) CRETE-PELOPONNESE” and its components

The Feasibility Study focuses on the evaluation of alternative solutions for the future supply of the island of Crete, taking into consideration the environmental constraints set by the EU Directives 75/2010 and 2192/2015 regarding the evolution of the generation mix in the power system of the island.

A feasibility analysis has been performed by IPTO for the preparation and submission of the TYNDP 2017-2026. The Consultant shall review the analysis performed by IPTO and present it in the more rigorous format of a Feasibility Study. IPTO will submit to the Consultant all the available relative information.

3. Cost Benefit Analysis (CBA)

The project “150 kV AC INTERCONNECTION 2x200 MVA (~ 2x140 MW) CRETE-PELOPONNESE” is considered as “Major Project” in the framework of EU funds (Article 100 of Regulation (EU) No 1303/2013). Its total eligible cost amounts approximately to € 362,171 million³, exceeding the € 75 million financial threshold set by the above regulation and certain other provisions.

The CBA is an analytical tool for judging the economic advantages or disadvantages of an investment decision by assessing its costs and benefits in order to assess the welfare change attributable to it and the contribution to EU cohesion policy objectives. The Cost Benefit Analysis is explicitly required, among other elements, as a basis for decision making on the co-financing of major projects included in operational programmes (OPs) of the European Regional Development Fund (ERDF) and the Cohesion Fund.

The CBA, including a financial and economic analysis and a risk assessment, constitutes a crucial part of the information required for the approval of a major project (Article 101 of Regulation (EU) No 1303/2013).

The CBA will be carried out by taking into consideration and complying with:

- a) The **Guide to Cost Benefit Analysis of Investment projects**⁴, Economic appraisal tool for Cohesion Policy 2014-2020” (issued by EC, Directorate General for Regional and Urban policy) for “major projects” (hereinafter referred as “**CBA Guide**”).
- b) the “**Climate Change and Major Projects**”⁵ Outline of the climate change related requirements and guidance for major projects in the 2014-2020 programming period.

³ Annex III provides the estimated budget of the project “150 kV AC INTERCONNECTION 2x200 MVA (~ 2x140 MW) CRETE-PELOPONNESE” and its components

⁴ http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

⁵ https://ec.europa.eu/clima/sites/clima/files/docs/major_projects_en.pdf

Climate change adaptation and mitigation considerations are integrated in the preparation and approval of major projects.

The CBA is structured in the following seven steps:

3.1 Description of the context

Description of the social, economic, political and institutional context in which the project will be implemented.

3.2 Definition of the objectives

From the analysis of all the contextual elements provided from the previous step the regional and/or sectorial needs that can be addressed by the project must be assessed, in compliance with the sectorial strategy prepared by Greece and accepted by the European Commission.

3.3 Identification of the project

Includes:

- the physical elements and the activities (type of infrastructure, type of intervention, service provided, location, etc.) that will be implemented and to achieve a well-defined set of objectives.
- the body responsible for implementation and its technical, financial and institutional capacities
- the impact area and the final beneficiaries

3.4 Technical feasibility & Environmental Sustainability

Technical feasibility and environmental sustainability are among the elements of information to be provided in the funding request for major projects. Although Technical Feasibility and environmental sustainability are not formally part of the CBA, their results must be concisely reported and used as a main data source within the CBA. Detailed information should be provided on: demand analysis, options analysis, environmental and climate change considerations, technical design, cost estimates and implementation schedule.

3.5 Financial Analysis

The **Financial Analysis** is carried out in order to:

- assess the consolidated project profitability
- assess the project profitability for the project owner (IPTO)
- verify the project financial sustainability.

It is carried out in accordance with the Discounted Cash Flow (DCF) method and in compliance with the Commission Delegated regulation 480/2014.

The main parts of the Financial analysis refer to:

- investment cost, replacement costs and residual value
- operating costs and revenues
- sources of financing (EU grant, national public contribution, loans or equity, etc.)
- financial profitability
- financial sustainability

The inflows for the financial analysis include:

- operating revenues from the provision of services (charges paid by the users, ITC revenues, etc.)
- sources of financing
- subsidies and other financial gains

The outflows relate to the following:

- Development costs (e.g. studies, rights of way, environmental planning) and project management costs
- Material and assembly cost, including installation and commissioning
- Other construction costs, including temporary solutions, waste management and environmental costs
- Operating costs (incl. ITC costs)
- Maintenance costs
- Replacement cost
- Reimbursement of loans and interest payment
- Taxes on capital/income and other direct taxes

The **project profitability** is measured by the following key indicators⁶:

- Financial Net Present Value **FNPV (C)** and Financial Rate of Return **FRR (C)** on investment (before EU grant)
- Financial Net Present Value **FNPV (K)** and Financial Rate of Return **FRR (K)** on national capital (after EU grant).

The calculation of the above key indicators contributes to deciding if the project requires EU financial support. The **funding gap rate** quantifies the needed grant (EU and national contribution/grant).

⁶ see Annex IV

The **financial sustainability** of the project will also be verified. The project is considered as financially sustainable when the risk of running out of cash in the future, both during the investment and the operational stages is negligible.

The difference between inflows and outflows will show the deficit or surplus that will be accumulated each year of the analysis. Sustainability occurs if the generated cumulative cash flow is positive for all the years considered.

It is important to ensure that the project does not risk suffering from a shortage of capital. Proof of disposal of sufficient resources to cover future costs should be provided in the sustainability analysis.

3.6 Economic Analysis

An economic analysis should be carried out to appraise the project's contribution to social welfare. The key concept is the use of shadow prices to reflect the social opportunity cost of goods and services, instead of prices observed in the market, which may be distorted.

The standard approach, consistent with international practices, is to move from financial to economic analysis. Adjustments such as fiscal corrections, conversion from market to shadow prices and evaluation of non-market impacts and correction for externalities will be taken into account.

After market prices adjustment and non-market impacts estimation, costs and benefits occurring at different times will be discounted by using the Social Discount Rate.

In the calculation of benefits, applying the "CBA Guide", the consultant could take also into consideration the CBA methodology developed by ENTSO-E (final version approved by the European Commission, 5 Feb 2015) (ENTSO-E CBA methodology)⁷.

Once all projects cost and benefits have been quantified and valued in money terms the economic performance of the project will be measured by calculating the following indicators (Annex V):

- **Economic Net Present Value (ENPV):** is the difference between the discounted total social benefits and costs
- **Economic Rate of Return (ERR):** the rate that produces a zero value for the ENPV.
- **B/C ratio:** the ratio between discounted economic benefits and costs.

3.7 Risk Assessment

The recommended steps for assessing the project risks are:

⁷ www.entsoe.eu/Documents/SDC%20documents/TYNDP/ENTSO-E%20cost%20benefit%20analysis%20approved%20by%20the%20European%20Commission%20on%204%20February%202015.pdf

- **sensitivity analysis**

It enables the identification of the critical variables of the project. Such variables are those whose variations have the greatest impact on a project's financial and economic performance. The sensitivity analysis is carried out by varying one variable at a time and determining the effect of that change on the FNPV and ENPV. As critical variables could be chosen those for which a variation of +/-1% of the value adopted in the base case gives rise to a variation of more than 1% in the value of the FNPV and ENPV.

- **qualitative risk analysis** (incl. risk matrix)

Shall include the following elements:

- a list of adverse events to which the project is exposed
- a risk matrix for each adverse event
- an interpretation of the risk matrix including the assessment of acceptable levels of risk
- a description of mitigation and/or prevention measures.

- **Probabilistic risk analysis** (required where the residual risk exposure is still significant)

- **Risk prevention and mitigation** (incl. Risk Management, which is the identification of strategies to reduce risks and based on risk assessment)

Analytical description of each step is presented in the CBA Guide.

3. Provision of supporting services to IPTO for the submission of the Major Project Dossier to the European Commission.

The Consultant will support IPTO in the submission of the Major Project Dossier to the European Commission with regard to the Feasibility Study and the CBA until their final approval by the Commission (DG Com and DG Regio). In this context the Consultant will answer all possible questions by the Commission related to these studies and will modify them if required, until the final approval by the Commission.

4. Deliverables

- **Feasibility Study**
- **Cost Benefit Analysis (CBA)**, fully applying the "CBA Guide" and the "Climate Change and major projects".
- **Executive Summary of CBA**
- **Provision of supporting services to IPTO up to the final approval of the Feasibility Study and the CBA by the Commission**

5. Time schedule

The deadline for the completion of the Feasibility Study and the CBA and their submission to IPTO is two and a half months (75 calendar days) from the date of signing of the respective contract. The second phase of the project which relates to the support to be given to IPTO with respect to the submission of the above studies to the European Commission, as part of the Major Project Dossier, the time schedule is 8,5 months from the date of signing of the respective contract.

ANNEX I: PROJECT OF INTERCONNECTION OF CRETE WITH THE MAINLAND SYSTEM (HETS)

extract from the national TYNDP 2017-2026 regarding the project of Crete interconnection to the mainland (Phase I and Phase II)

1 Interconnection of Crete with the Mainland System

Crete constitutes the largest autonomous electrical island system in the country. The island's total demand represents 5% of the country's total demand and has historically shown larger increase pace related to that of HETS. Even after 2008, beginning of the economic crisis, the electricity demand in Crete presented lesser average annual rate of demand reduction related to that of HETS (0.7%, contrast to 1.3% at HETS). In 2015 the electricity demand in Crete reached at 2898 GWh, whereas peak annual demand was recorded in 2008 (3047 GWh). In the same time period, the island's hourly average consumption fluctuated from 158 MW (minimum) to 635 MW (peak). The System of Crete is characterized by:

- Very high variable cost of production because of the use of oil in the local power stations, which is reflected as a significant charge on the consumers for the coverage of the Public Service Obligation (PSO) (more than 300 millions € annually).
- Large annual increase rate of the island's load (~5% until 2008 as much for electricity demand, as for the annual peak, which decreases to 1% and 3.9% respectively during the last three years). It must be noted that the demand during the summer months was barely covered by the local stations.
- The big difficulty, almost impossibility to seek locations and to insure permissions for the enhancement of the local stations or the development of new.
- The continuous increase of interest for the exploitation of the enrich local potential of RES, the penetration of which in the island's generation mix is limited due to technical constraints (basically because of important stability issues which the high penetration of RES might create to an autonomous electrical system as such as that of Crete).
- Low level of reliability of supply, especially in cases of power system failure.

The above mentioned characteristics have led to the examination of the island's interconnection with the Mainland System, fact which would contribute excessively to the total or partial settlement of the majority of issues that the electricity system of Crete faces today.

The discussion for the interconnection of Crete with the Mainland System (HETS) began in the 80s, investigating several solutions; due to economic and technical difficulties the interconnection during that period was not implemented.

The subject of the interconnection of Crete returned to the spotlight intensely after 2000, given the fact that the technological advances as much in the construction and in the immersion of cables, as well as in the AC/DC conversion techniques can offer today remarkably favorable and safer conditions concerning interconnection technologies (maximum allowable cable length, immersion depth etc.), while the correlated cost has been significantly reduced. The notable load increase of Crete in relation with the high interest for the exploitation of the island's RES potential were two additional significant factors that contributed in the resurgence of interest for the interconnection of Crete.

The interconnection of Crete with HETS has become a necessary project concerning the expediency of its implementation. In the last approved TYNDP for the 2014 – 2023 period, the interconnection solution of the system of Crete with the area of Attica via DC bipolar link of 700 MW nominal capacity was adopted [1]. As is extensively analyzed in § 1.2, from the investigation which has been carried out by IPTO, it appears that the implementation time required for the interconnection with Attica will be in the order of 9 years due to permission issues, and because of objective barriers which are related to geological conditions throughout the cables immersion route.

In the meantime from the release of the Preliminary Draft Version of the present TYNDP (for which Public Consultation was held from February 9 until March 9 2016), an emerging need to adapt in the new situation stemming from the application of the Directives 2010/75/EU concerning industrial emissions and 2015/2193/EU for the limitation of emissions of certain pollutants into the air from medium combustion plants⁸ appeared. According to the above Directives, the application of these Directives will increase the possibility of generation adequacy problems for the Power System of Crete in the forthcoming years (taking into account the advanced age of most of the existing units). Considering the above (PSO high cost and possible appearance of generation adequacy issues in the near future), **the interconnection subject of Crete appears to acquire an “urgent” character, rendering the implementation time as the most critical parameter for the selection of the technical solution for the interconnection.**

Taking into account the new data which are formed from the application of the Directives 2010/75/EU and 2015/2193/EU, during the former period, different interconnection topologies of the island were examined anew, thoroughly and in depth, and a multi-criteria valuation of pros and cons was made. In this framework, a large number of possible solutions concerning the connection points, the size (transmission capacity) and the type of interconnection network (AC & DC) were examined. The comparative valuation of benefits from the implementation of each interconnection scenario was made taking into account a number of factors and parameters which can be distinguished into

- technical, such as interconnection technology (AC - DC), points of connection to HETS and to Crete, interconnection transfer capacity, operation voltage (150kV – 220kV – 400kV), expected impact on HETS and on the System of Crete (required reinforcements),
- economic, related to the cost, the implementation duration and the achieved savings in PSO
- environmental,
- social, etc.,

valuating the expected investment cost of each solution and the expected benefits from the interconnection. These benefits concern the following:

- contribution to the island’s security of supply improvement

⁸ PPC letter with protocol number ΓρΔ/347/16.02.2016

- important savings in fuel expenditures, resulting in PSO cost reduction
- avoidance of high cost investments for the development and the modernization of the local production stations,
- better exploitation from the existing RES production stations in Crete, which today face limitations due to stability issues,
- active limitation of disturbance that is caused from the continuous operation of the local stations,

Based on preliminary exploration (desk study) which was implemented from the Geology Department of the Laboratory of Marine Geology and Physical Oceanography of the University of Patras [3], resulted the following conclusions:

- The routes from Crete towards Southeast Peloponnese have lesser immersion depth and length display significantly lesser cable burial length and transit from fewer points that need attention due to geological hazards.
- There are positive suitability indications of the submarine route between Southeast Peloponnese and Crete, as results from older studies that were implemented in the framework of the initial attempt of connection of Crete with the Mainland System. Nevertheless, these studies will be updated.

Considering the results of the above exploration, the interconnection of the island was shortlisted into two phases as follows:

- **Phase I:** 150kV AC interconnection, 2×200MVA (~2×140MW) capability, Crete - Peloponnese
- **Phase II:** DC interconnection, 2×350MW capability, Crete - Attica

The analytical description of each phase is forth in the following paragraphs.

1.1 PHASE I: 150KV AC INTERCONNECTION 2X200MVA (~2X140mw) CRETE-PELOPONNESE

The scenario for the interconnection of Crete with Peloponnese using AC technology can be summarized as follows:

- **Voltage - Transfer capacity**

The interconnector between Crete and Peloponnese can be implemented by using two 150kV AC circuits, with a transfer capacity of 200MVA each (maximum transfer capacity that has been used in such projects in Greece).

- **Connection point in Peloponnese**

In the case of installing AC cables, the minimization of the submarine route is necessary for the project cost optimization and the reduction of the reactive compensation requirements

which are in any case always considerable. Because of these considerations, as the connection point in Peloponnese, the area of cape Maleas has been initially selected. The construction of a 150kV double circuit transmission line with heavy type conductors (T.L. 2B/150kV) is required for the connection to the Mainland System.

Aiming at the acceleration of the permit granting process, part of the terrestrial route in Peloponnese shall be implemented with a double circuit overhead line of 2B/150 kV from Molai s/s to the transition terminal station and from the transition terminal station to a sea shore nearby Neapoli with underground cables of 10 km in length, with two 3-phase cable circuits of 200MVA transfer capacity each. Additionally, it will be necessary to upgrade the existing 150kV light type, single circuit transmission line (T.L. E/ 150kV) Megalopoli-Sparti-Molai, to a T.L. 2B/150kV. These projects can be implemented in a relatively short time compared to similar projects, and their associated cost is considered to be small.

- **Connection point in Crete**

The connection point in Crete shall be located in the west part of the island, at the substation Chania I for the minimization of the submarine route. Such a choice contributes to the reduction of the reactive power compensation requirements and the minimization of the submarine cables cost. Taking into account the transfer capacity of the interconnector as well as the high production cost of the generation units in the thermal power station of Chania, it is concluded that in the short term, no additional reinforcements shall be needed for the transmission network of Crete, a fact that contributes in the acceleration of the project implementation.

A detailed analysis of the projects comprising Phase I is as follows:

- Undergrounding of a small section (1,5 km) of the overhead 150 kV T.L. of Rouf – Ladonas due to upgrading of the 150 kV T.L. Megalopoli – Sparti I.
- Upgrade of the existing T.L. E/150kV Megalopoli I - Sparti II - Sparti I – Skala - Molai, total length of 109.6km, to T.L. 2B/150kV. The project also includes the replacement of the conductors from E to B in the existing T.L. Sparti II – System, 2.6km length. The completion date of this project is estimated at the beginning of 2019.
- Construction of a new 150kV transmission line bay in the existing S/S Megalopoli I, for the connection of the second circuit of the upgraded transmission line mention above. The project shall be ready before the completion of the transmission line upgrade.
- Upgrade of two 150kV simple transmission line bays to fully equipped ones in the existing S/S Sparti II, in the framework of upgrading the existing transmission line Megalopoli I - Molai. The project shall be ready before the completion of the transmission line upgrade.
- Construction of three new 150kV transmission line bays in the existing S/S Molai, for the connection of the second circuit of the upgraded transmission line mentioned above as well as for the connection of the two new circuits of the Crete interconnector. This project shall be ready before the completion of the transmission lines.
- Construction of a new 150kV double circuit transmission line from the S/S Molai to the sea shore next to Neapoli (landing point of the submarine cables). This transmission line will include the following parts:

- An overhead double circuit line, 27,5 km in length, from the Molaoi s/s to the transition terminal station of SE Peloponnese. This project is estimated to be completed at the beginning of 2019.
- An underground double circuit, 10 km in length, from the transition terminal station of SE Peloponnese to the sea shore next to Neapoli. This project is estimated to be completed during the second semester of 2019.
- Construction of a new 150kV transition terminal station in SE Peloponnese. This station will be the connection node for the overhead line towards S/S Molai and the cables towards the S/S Chania I and will be constructed using GIS technology. The new station will include a double 150kV busbar, equipped with a coupler, four 150kV transmission line cable bays for the connection of the lines from and towards the Molai and Chania I substations, and six new 150kV shunt reactors in the new terminal S/S (3 per connection circuit to Crete), for the compensation of the reactive power produced by the cable parts of the 150kV double circuit line SE Peloponnese-Chania I. The nominal capacity of each shut reactor is estimated to be 36MVar, however the finalization of their capacity will be decided later, according to the parameters of the cable circuits. The project is estimated to be completed during 2019.
- Construction of a new 150kV double circuit submarine line between the landing points in SE Peloponnese (near Neapoli) and west Crete, with a total length of 132 km. The project is estimated to be completed during the second semester of 2020.
- Construction of a new 150kV double circuit underground line from the landing point in west Crete to the Chania I S/S, with a total length of 34km. The project is estimated to be completed in-2020.
- Construction of two new 150kV transmission line bays in the existing Chania I S/S, for the connection of the two cable circuits from SE Peloponnese, as well as seven new 150kV shut reactors' bays and shunt reactors (3 per cable circuit from SE Peloponnese and a spare one), for the compensation of reactive power produced by the cables of the 150kV line SE Peloponnese-Chania I. The capacity of each inductor is estimated in the order of 36MVar, but the finalization of their capacity will be decided in a later time, according to the parameters of the cable circuits. The project is estimated to be completed in the second semester of 2019.

Additionally, the installation of a Static Var Compensator (SVC) in Crete will be required for the necessary voltage regulation. The SVC size and installation location will be determined in the future, depending on the evolution of the generation mix in the power system of Crete (taking also into account the EU Directives 75/2010 and 2192/2015).

The entire project cost is estimated to be in the order of 330 million Euros.

The scenario for the interconnection of the island of Crete with Peloponnese, using AC technology, is depicted in Figure 1.

The shunt reactors size ensures compensation up to 70 to 80%. For further compensation the installation of backup reactors (possibly regulated) at Chania and SVC on Crete may be required.

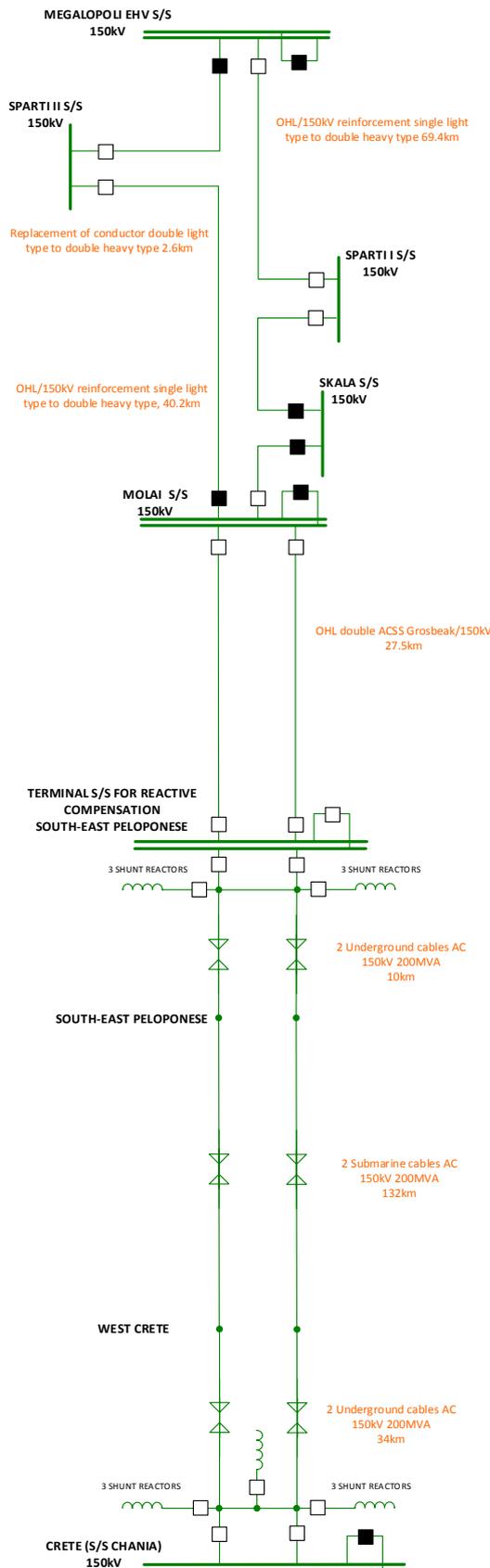


Figure 1: Phase I - AC interconnection 2×200MVA Crete - Peloponnese

1.2 Phase II: Interconnection DC 2×350MW Crete - Attica

It is about the scenario that has been included and analyzed in TYNDP 2014 – 2023. This scenario in general lines contemplates the followings:

- **Technology**

The selection of Voltage Source Converter (VSC) links, compared to Line Commutated DC links are the most reasonable solution as they enable

- the connection of a weak System (as that of Crete) even with a small local production, and also
- rapid change and reverse of power flow without interruption.
- Reactive power regulation and black start-up, capability

The DC interconnection technology with VSC accounts already plenty applications worldwide and is considered to be ripe and reliable, being today available from more than one manufacturers, fact which is important for the tender stage.

For the HVDC link topology, two technical solutions have been examined, both of them including a bipolar link with two high voltage cables, one for each pole. The transfer capability of each cable will be equal to one half of the total, either by using a medium voltage cable for the neutral connection, or with the utilization of a grounding solution and return through the sea (Figure 2).

Sea return is widely used in DC technology, especially in long distance applications, as it contributes to the limitation of the project cost, compared to the utilization of a medium voltage cable for the neutral connection. Nevertheless, for the implementation of a sea return solution, the creation of a lagoon or sea electrode conductor may be necessary for the installation of the grounding electrodes, fact that increases significantly the difficulty in locating the proper areas for the project and to obtain the necessary permissions for the grounding system installation, especially in touristic areas such as Crete, as well as close to harbors or industrial zones like in the case of the landing area in Attica, where the installation of sea return electrodes may cause damages in adjacent metal constructions in the industrial zone of Elefsis. In conclusion, the cost associated to the environmental impacts of such a solution is not negligible and must be taken into account during the final decision.

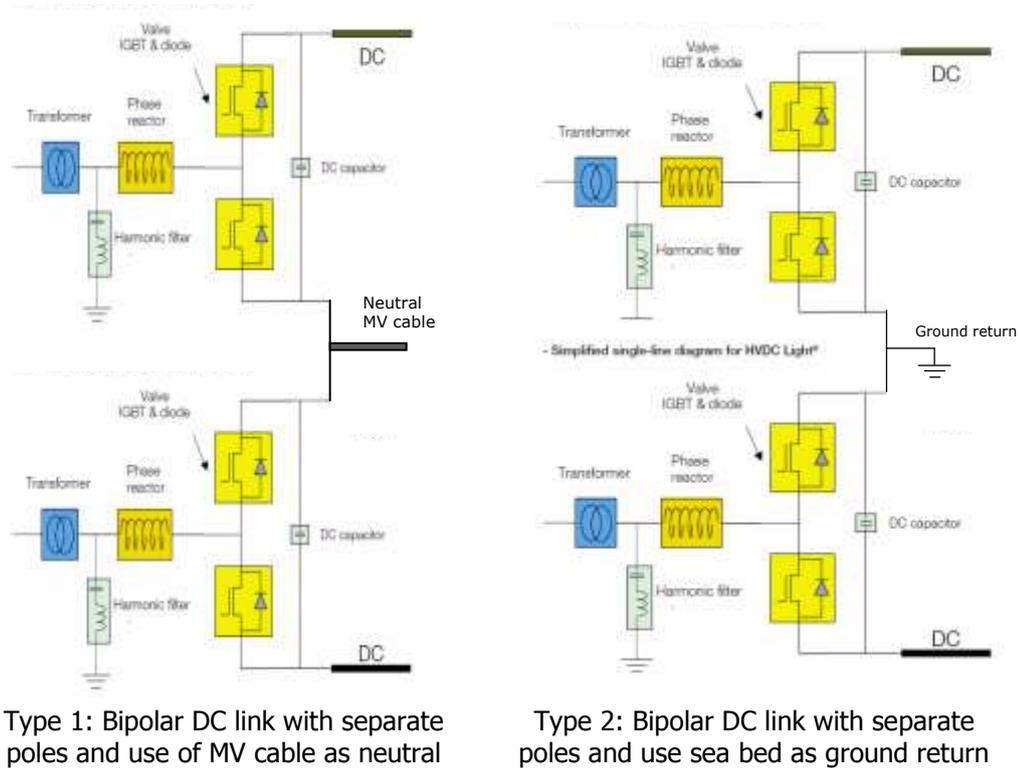


Figure 2: DC schemes under consideration

The operation voltage selection of the HVDC links depends on their length and their nominal power. High power (e.g. 2x500MW), with the current technical capabilities for VSC Converter stations and submarine cables leads to operating voltages in the order of ≥ 320 kV. IPTO estimates that according to the current technological prospects, operating voltage of the DC link should be confined between 300 and 350kV.

- **Transfer capability**

Concerning the transfer capability of the HVDC link and taking into account the total demand in Crete, international practice, and the results of a relevant dynamic stability study performed by IPTO[2], the selection of a 700MW (2x350MW) transfer capability seems to be the safer solution. This conclusion is aligned with the outcome of a sensitivity study performed in order to define the optimal size of the interconnector. Nevertheless, **depending on the technical developments in the next years** (operating voltage, unitary cost elements, etc.) and especially **the evolution of large RES projects in Crete, the final size of the interconnector could be re-examined for a possible revision (up to 1000MW) according to the emerging needs.**

- **Connection point in Attica**

The size of the interconnector as well as the achievement of the security of supply of the island along with the need to increase the capability to absorb RES electricity production, are the main reasons to select a strong connection point for the interconnection with HETS. In this respect an appropriate place coterminous to Koumoundouros EHV substation has been identified, for the development of the AC/DC conversion station and space has been

reserved for the construction of two 400kV bays⁹. A short route with an easy access exists between the converter station and the seaside (considering a landing point in the Elefsis bay, and an underground route of few kilometers).

However, as mentioned earlier, submarine access to Attica, through the Perama area, is difficult because of the existing fishing areas, fact that may lead to cable burial up to 400m depth (with an associated interconnection cost increase). Furthermore, a preliminary investigation would be required in the landing area in Attica which will aim to locate shipwrecks, the position of abandoned metal objects, to define anchors immersion depths, and to identify the difficulties in construction during the immersion which could potentially further increase the cost of the interconnection with Attica.

Other possible connection points have been investigated as well, such as the Acharnes EHV S/S and the future EHV S/S in Rouf. Connection in the EHV S/S Acharnes requires long underground cable routes which cross densely populated areas, while the available space in EHV S/S Rouf is marginally sufficient and long delays of the project's development are noticed.

- **Connection point in Crete**

The connection point in Crete must be the center point of the island's load and adjacent to a strong local network, in order to minimize the needs for new transmission projects. The Linoperamata area fulfils these criteria (Korakia location), as the local transmission network is strong and capable to supply with safety the power provided by the Mainland System, and in the short term, no new projects will be necessary. However, the choice of this point results in an increase of the submarine route and as a consequence, the project's cost.

A detailed analysis of the projects comprising Phase II, is as follows:

- Construction of a new AC/DC bipolar converter station as well as the connection projects (2 400kV bays, 2 autotransformers, etc.), at the 400kV side of Koumoundouros EHV S/S.
- Construction of a new 150kV coupling substation in Crete. This substation shall be constructed using GIS technology, and will include a double 150kV busbar with a coupler, and six 150kV transmission line bays of the connection to the 150kV transmission network circuit of Crete and 2 transformer bays for the converter substation connection.
- Construction of a new AC/DC bipolar converter substation in Crete.
- Construction of a DC cable network, connecting the conversion stations of Attica with Crete. This cable network shall include:
 - An underground DC circuit (two cables \pm plus electrode cable) , ~33km length, from the converter station (EHV Koumoundouros) to the landing point in Attica region (most likely Pachi Megara) .
 - A submarine DC circuit (two cables, \pm) , with an approximate length of 340km, from the landing point in Attica to the landing point in Crete (Korakia).

⁹ This space was intended to be used for the connection of a large natural gas power station. However, this project is stagnant.

- An overhead DC circuit, ~6 km length (two cables ± plus an electrode conductor), from the landing point in north Crete (Korakia) to the converter station AC/DC in Crete (Damasta).
- Upgrade and undergrounding of very small parts in the 150kV network (sections of two 150 kV overhead transmission lines) of Crete shall be needed for the connection to the 150kV coupling substation in Crete to Linoperamata S/S. The required projects shall be determined in close collaboration with the Operator for the non-Interconnected Islands, and will be ready before the implementation of the DC interconnector
- Installation of sea grounding electrodes or lagoons in the appropriate location.
Adding two 150 kV transmission line bays in the existing Linoperamata substation.
- A transmission terminal station in Korakia (Crete) for the transition of the submarine DC cables to overhead DC transmission line
- Sea bottom survey of the DC submarine cable route

The above mentioned are depicted in Figure 3.

Estimated year for the project commissioning is 2024 or early 2025. However, taking into account that the most possible reasons for significant delays will be the exploration of an appropriate location, permitting and implementation of the relative projects for the installation of grounding electrodes in a lagoon or electrode conductor, it is estimated that the project could finish earlier (up to 2022) without the grounding electrodes (i.e. only with the two DC cables). At a later stage, the project can be completed by installing the electrodes in a lagoon or in the sea in the form of a grounding electrode conductor.

Total cost of the project is estimated in the order of 700 to 1000 million Euros.

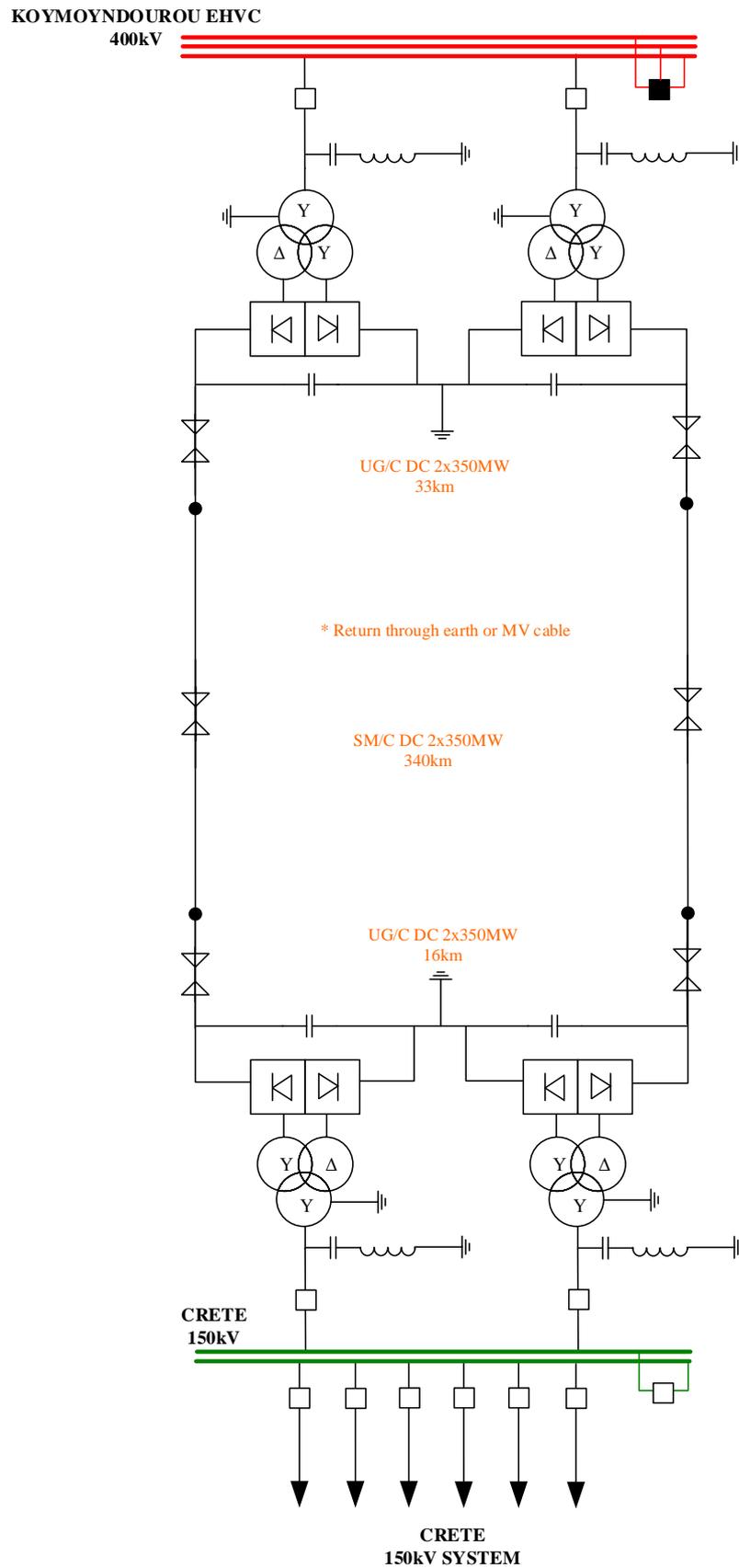


Figure 3: Phase II - DC interconnection 2x350MW Crete - Attica

1.3 IPTO final design for the Crete interconnection scheme

The corresponding technical solution for the second phase of the Crete interconnection project had been included in the approved TYNDP 2014-2023 as well. The choice of this solution had been mainly decided for the following reasons:

- The interconnection of Crete with Attica is independent from the progress of the 400kV transmission network extension to Peloponnese, which is considerably delayed due to difficulties in the permitting and expropriation procedures.
- The long length of the underground and submarine route (in the order of 400km) necessitates the use of a DC link.

A recent investigation conducted by IPTO concluded that in contrary to the estimations reported in TYNDP 2014-2023, the implementation of this interconnection scenario requires a larger implementation time period around 9 years. This conclusion has been based on the following critical findings:

- A preliminary study performed by the Laboratory of Marine Geology and Physical Oceanography of the Geology Department in the University of Patras, resulted in the following conclusions:
 - The potential solutions to reach the area of Koumoundouros are either east of Salamina (Perama channel), either in the west towards Megara. Between these two directions:
 - The areas of Perama, Piraeus, Keratsini and Megara are characterized by intense human activity which is considered unsafe for the landing and route of the cables, and will require special interventions. If they finally be selected, additional measures for the cables safe operation are recommended.
 - The solutions towards Megara include submarine route of ~13km longer from the corresponding towards Perama and require underground cables from Megara up to Koumoundouros EHV S/S.
 - The approach from the Perama channel may yet have lesser length from that towards Megara, but is characterized from intense human activity, feature which applies in general for the entire Elefsis bay.
 - Some general issues that need to be investigated further are the following:
 - The volcano activity (hydrothermal solutions) in the marine area of Milos island is intense and extends to an area of 35km². For this reason, additional research is recommended in the marine area between Milos and Antimilos island and possibly a partial re-design of the cable route.
 - Taking into account fishing activities in the areas of Attica, Agios Georgios island and Chania, it is recommended to bury the cables in depths up to 400m.
 - A detailed investigation is required for the potential landing point in Attica before the final selection, in order to locate the position of shipwrecks, abandoned metal objects, and to define the anchors immersion depths which could potentially constitute the cable burial up to the depth contour of 50 or 100m extremely expensive.

- Unusual Geological phenomena in the cable route area under examination do not seem to jeopardize their safe operation. Nevertheless, it is recommended to perform detailed investigations relevant to possible landslides.
 - Possible crossings with other cables in any case must be addressed by communicating with the involved companies and organizations.
- From the above mentioned it becomes obvious that detailed depth studies are required for the optimal selection of the submarine cables immersion route, to avoid areas with large depths, as there are still important technical uncertainties related to immersions in such large depths.
 - A worldwide survey of similar projects concluded that the associated cost is high and presents large fluctuations. Indicatively, according to the current estimations this will range between 700 and 1000 million Euros.
 - Finally, due to the already mentioned extensive requirements for research related to the determination of the optimal route, the overcome of environmental issues and the potential for Research & Development, as results from the initial findings, an extensive time period for the project implementation is foreseen as much for the permitting, as for the project construction as well (estimation: 9 years).

Considering the above and especially **the emerging need to cope with the generation adequacy problem** that arises due to the implementation of the Directives EU/75/2010 and EU/21983/2015, IPTO chose to proceed starting with the AC 2x200MVA solution (Phase I), given that is characterized by lesser delays and uncertainties. The DC interconnection shall be implemented in a later stage (Phase II). The expected benefits due to the implementation of Phase II are analytically presented in the TYNDP 2014-2023. The assessment of these benefits shall be made in the near future and be updated on a constant basis, taking into account the evolution of the generation mix in HETS and Crete, the technological advancements, especially regarding DC submarine cables and their cost, environmental issues, etc.

Beyond the undeniable benefits related to the implementation of Phase II, it is worthwhile to mention those related to Phase I. Specifically, the assessment of the benefits related to the implementation of Phase I (AC interconnection with a double circuit) shows that in a **relatively short time frame**, this project will contribute in the active improvement of the system of Crete from a technical as well as from an economic aspect. The most important findings of this assessment can be summarized as follows:

- ***Implementation Duration:*** Based on the detailed analysis of all processes and work implementations the expected implementation time frame (assuming that no judicial or other implications will occur) is in the order of 4 years and the project is expected to operate during the first semester of 2020, **converging in the acceleration of the Crete interconnection implementation.**
- ***Technical assessment:*** Detailed network studies have been performed for the analysis of the interconnection in operation of the system of Crete to HETS, including the projects in Phase I. System operation analysis in steady state (N and N-1 conditions), as well as

dynamic analysis in cases of major disturbances and under different scenarios of load and RES penetration was conducted. The conclusions of this analysis shown that the transfer capacity in the direction from HETS to Crete will be in the order of 200 to 270MW (depending on the system operating conditions in HETS and Crete). It must be also noted that the **operational security in Crete will be especially high** compared to the current situation, as the system will not necessarily need to apply load shedding measures in cases of generation loss in the island, while a considerable reduction in needs of expensive spinning reserve is expected (as is the relative cost as well), as the interconnection can simultaneously provide the largest proportion of reserve needs. Transmission system losses in the interconnector from Molai to Chania, it is estimated to be in the order of 90 to 160GWh per year, depending on the generation mix and the installed capacity of the production units in Crete (see Table 1).

- *Contribution to the reduction in the “Public Service” Obligation costs.* Detailed simulation studies of the production system operation in Crete have been carried out as well as a sensitivity analysis with respect to the future generation mix, considering both conventional and renewable generation. Table 1 summarizes indicative results related to the achievement of generation cost reduction as well as the improvement of the security of supply in Crete after the implementation of Phase I. The contribution of the interconnection in the supply of electricity demand is expected to be from 1200 to 1850GWh/year (that is 40% to 60% of the island’s total annual electricity demand). This substitution will result in a considerable reduction of the operational costs that are necessary to serve electricity demand in the island of Crete.

Table 1: Indicative results of the simulation of the generation system of Crete (reference year 2020)

Scenario		Local thermal generation	Imports	EUE	LOLP	Losses	Savings*				
							From fuel substitution	From avoided EUE	From losses	TOTAL	
							(GWh)		(h/year)	(GWh)	(mil. €)
Isolated System	1	No unit retirements	2572.6	0.0	1.019	33.360	-				
	2	Retirement of units whose generation license is expiring	2333.7	0.0	239.923	3079.116	-				
Interconnected system	3	No unit retirements	1312.0	1261.6	0.002	0.128	90	122.5	3.1	-5.1	120.5
	4	Retirement of units whose generation license is expiring	720.6 – 1011.7	1558.9 – 1850.1	2.951	86.560	160	156.8 – 240.9	710.9	-9.1	858.6 – 942.7

* Assuming the average generation cost for the interconnected (mainland) system equals 57€/MWh

- Contribution to the generation adequacy. The contribution of the interconnector in the generation adequacy and the reliability of supply is expected to be considerably high. From a reliability analysis of the generation system in Crete, based on the availability characteristics of the existing generation units, it appears that the reliability level is low, since a loss of load likelihood (LOLE, Loss of Load Expectation) in the order of 13 hours/year appears for the year 2016 (when worldwide the acceptable levels of LOLE are in the order of 2.4 to 3 hours/year). Figures 4 and 5 depict the evolution of stochastic reliability indicators LOLE and EUE (Expected Unserved Energy) of the forthcoming decade, assuming that no decommissioning of generation units will take place.

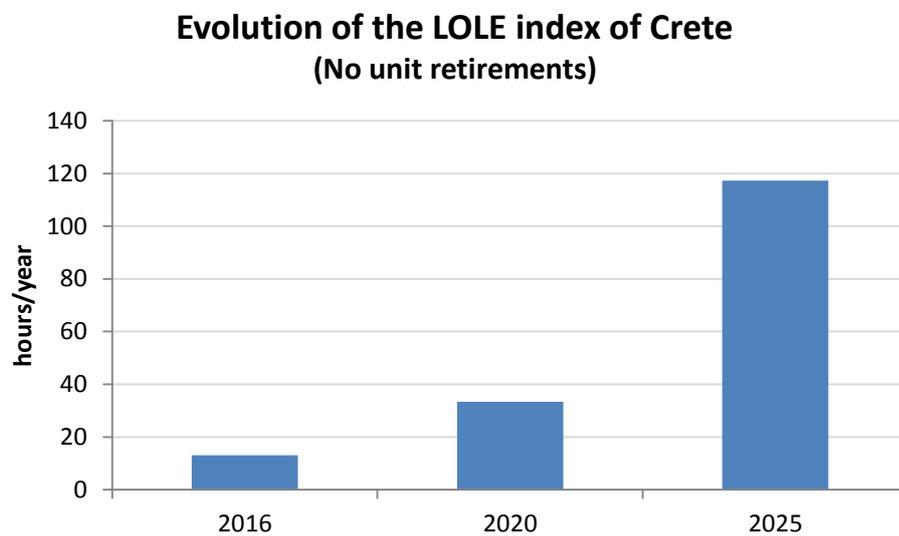


Figure 4: Evolution of the LOLE index of Crete, assuming that all existing units remain operational

**Evolution of the EUE index of Crete
(No unit retirements)**

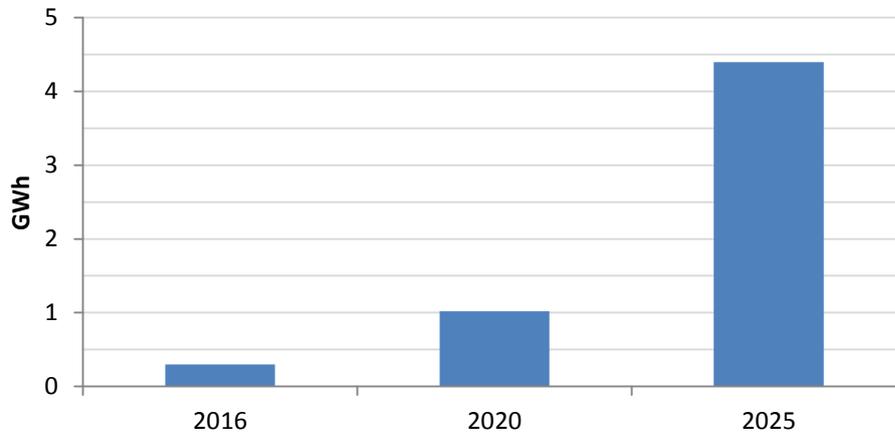


Figure 5: Evolution of the EUE index of Crete, assuming that all existing units remain operational

The impact of the generation units decommissioning on the reliability indicators of Crete is depicted in Figures 6 and 7, for the cases which their production permission dues in 2020, without the examination of further restrictions that might derive from the according Directive, combined with the implementation of Phase I. It is obvious that the application of the Article 34 of the Directive EU/75/2010 will dramatically affect the already reduced capability of the production system in Crete for the next decade.

**Evolution of the LOLE index of Crete
(Retirement of units whose generation license is expiring)**

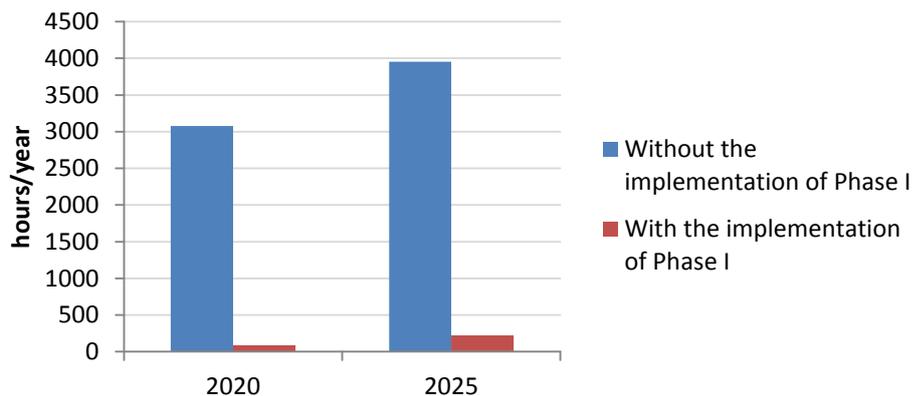


Figure 6: Impact of the implementation of Phase I projects on the evolution of the LOLE index of Crete

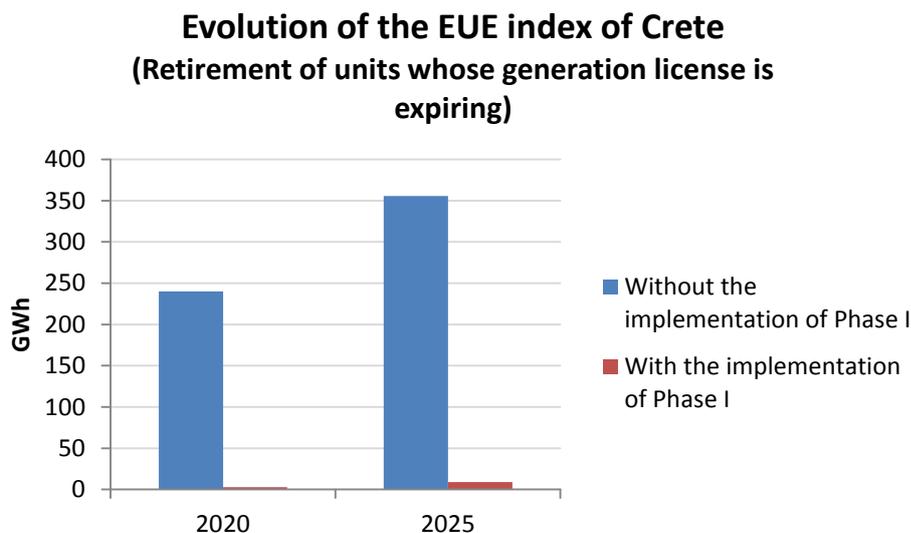


Figure 7: Impact of the implementation of Phase I projects on the evolution of the EUE index of Crete

The implementation of the Phase I projects, although does not provide a solution to the generation adequacy problem of Crete for the next decade (LOLE indicator will be equal to 86hours/year for 2020 and 222hours/year for 2025), it significantly contributes to the improvement of the system's reliability. It should be mentioned indicatively that the annual benefit due to the monetization¹⁰ of the unserved energy (comparing Crete with and without the interconnection) is estimated to be 710 million Euros for the year 2020 and 1 billion Euros for the year 2025.

- Avoidance of very important investments in new generation units in Crete (which is necessary due to the aging of the existing generation units and for the application of EU Directives 75/2010 and 2193/2015).
- Reinforcement of the 150kV network in Lakonia and its extension towards North Lakonia Congestion problems in Lakonia region necessitate the construction of new transmission projects in order to be relieved. In addition, HEDNO plans to construct a new S/S in Neapoli and the T.L. 150kV for his connection to the System, which will significantly improve the security of supply of the region. It is obvious that these projects can be aligned with the projects that will be constructed in the framework of Phase I for the interconnection of Crete, aiming to achieve simultaneously multiple objectives (interconnection of Crete, security of supply in Lakonia region, increase of the RES penetration in the area), minimizing the projects in total.

An incidental benefit expected from the interconnection of Crete with Peloponnese is related to the contribution of this project to the partial relieve of the congestion in the 150kV network of Peloponnese, until the completion of the 400kV transmission lines in this area. It is obvious that during the first years of the interconnection operation, the power flow will be in the direction from Peloponnese to Crete.

¹⁰ Considering a Value of Lost Load (Voll) equal to 3000Euro/MWh

But if in the future Crete becomes an exporter due to high RES development, export capabilities from Crete to the Mainland System will be limited due to the considerable interest for RES development in Peloponnese as well. The completion of the 400kV network extension in Peloponnese will relieve this situation but without eliminating the power flow restrictions from Crete and Peloponnese towards the Mainland System. This issue will be resolved with the implementation of Phase II.

In conclusion, it is expected that the projects of Phase I **will have a very short payback period** (depending on the evolution of oil prices). In principle, Phase I resolves significantly the current problems of Crete (reduced reliability and high production cost). The estimated cost is relatively safe and its implementation is not expected to face important technical/environmental problems compared to the corresponding DC solution. As a result, **the design of Phase I achieves in the best possible way and with considerably less risks the initial target of the minimization of the implementation time of the Crete interconnection to HETS.**

With the completion of both Phases I and II will be achieved a bidirectional transfer capacity of about 1000MW to and from Crete, guaranteeing the security of supply of Crete for a time horizon of several decades, providing in this way not only the capability to radically reduce the local conventional electricity production, but to also decommission older units that effect the environment. Simultaneously, it will be possible for the installed RES capacity in Crete to be developed and to exceed 1000MW. Such a capability provides the perspective for a future extension of the Crete interconnection towards Karpathos and Rhodes islands and is more than enough to justify the necessity to implement both phases of the mentioned project.

1.4 Implementation of the Crete interconnection projects

The design and permit granting processes for both phases are implemented simultaneously¹¹. The permit granting process for the Phase I projects has started. The relevant process for Phase II will start soon, and will progress simultaneously with the continuous re-examination of all the technical issues and by keeping up with the evolutions related to the HVDC technology.

In any case, the immersion of cables shall be implemented after the finalization of the permitting processes and the land acquisition that are necessary for the terrestrial parts of the project.

Finally, IPTO in close cooperation with the Operator for the non-Interconnected Islands will perform additional technical studies for the determination of the necessary reinforcements in the System of Crete in the following years. These reinforcements shall be determined according to the following parameters:

- Interconnection points
- Nominal capacity of the interconnectors
- Loading of the interconnectors
- Different scenarios for the required operation of the local generation units

¹¹ The places for the landing of submarine cables have been determined and the permit granting process will follow soon.

Concerning the existing development plan for the transmission network in Crete (according to the TYNDP of islands 2014-2018), it is not expected in general to change, however will be reviewed soon in collaboration with the Operator for the non-Interconnected Islands.

REFERENCES

- [1] *'Ten Year Network Development Plan 2014 - 2023'*, IPTO, December 2013.
- [2] *'Operation of the Electrical System of Crete in Interconnection with the Mainland Grid: A Stability Study'*, M. Karystianos, Y. Kabouris, A. Koronides, S. Sofroniou, 2013 IREP Symposium-Bulk Power System Dynamics and Control -IX, Rethymnon, Greece, August 25-30, 2013
- [3] *'Interconnection of Crete with the National Interconnected Transmission System- Desk Study'*, G. Ferentinos, G. Papatheodorou, D. Christodoulou, Laboratory of Marine Geology and Physical Oceanography, University of Patras, March 2014

ABBREVIATIONS

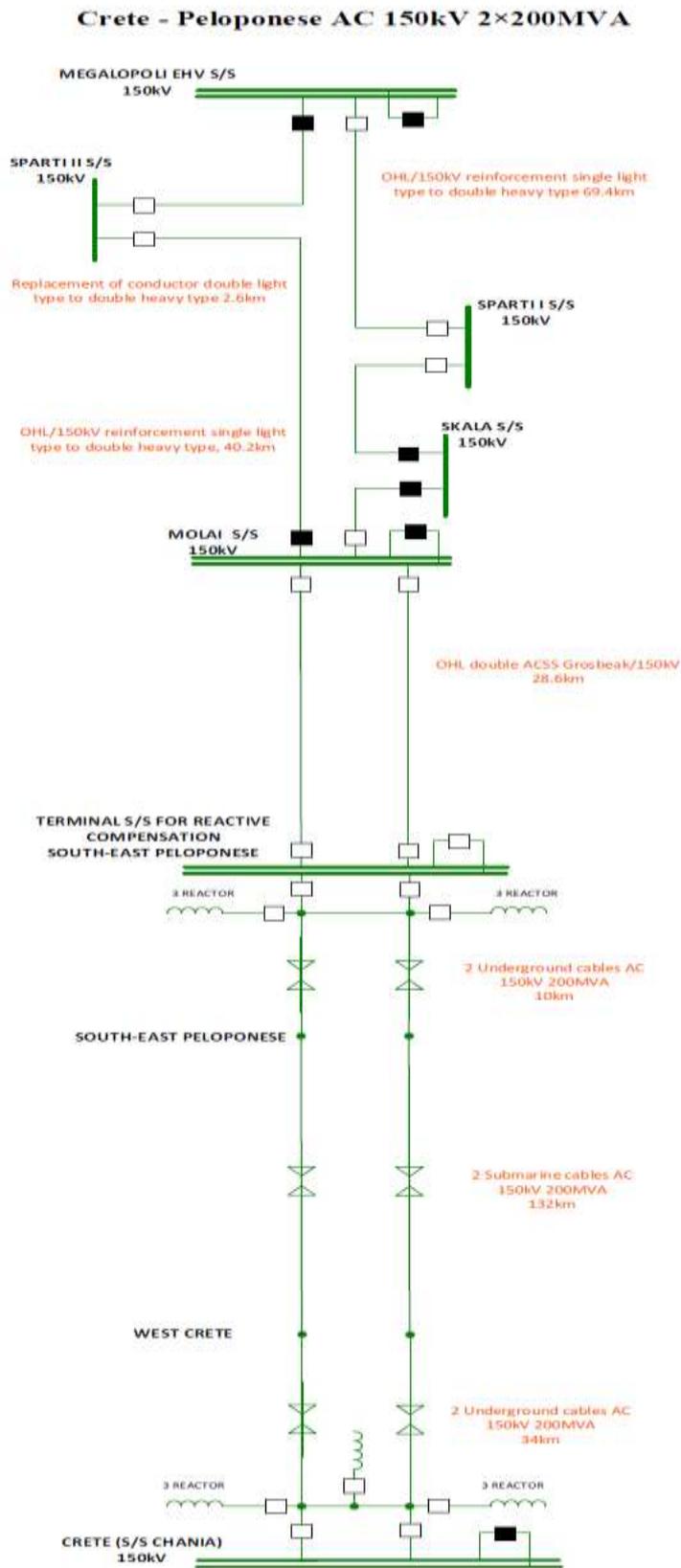
2B	: Double circuit heavy type transmission line
2B'B'	: Double circuit double conductor transmission line
AC	: Alternating Current
APS	: Autonomous Power Station
AT/F	: Autotransformer
B	: Single circuit heavy type transmission line
B'B'	: Single circuit double conductor transmission line
B'B'B'	: Single circuit triple conductor transmission line
C.C.	: Combined cycle
CHP	: Combined heat and power station
DC	: Direct Current
D/C	: Distribution Center
E	: Single circuit light type transmission line
EHV	: Extra-high voltage
EHV S/S	: Extra-high voltage center
GIS	: Gas Insulated Substation
HETS	: Hellenic Electricity Transmission System
H.V.	: High Voltage
HPP	: Hydroelectric Power Plant
HV	: High Voltage
HVDC	: High Voltage Direct Current (direct current connections)
IPTO	: Independent Power Transmission Operator
M.D.	: Ministerial Decision
M.V.	: Medium Voltage
MV	: Medium Voltage
N conditions	: Normal operation with all System components available
N-1 conditions	: Loss of one System component, such as T.L., production unit, AT/F
N-1 criterion	: Loss of one System component, such as T.L., production unit, AT/F
N-2 conditions	: Loss of two System components
NEPC	: National Energy Policy Council
Network	: Distribution Network
NG	: Natural gas
NTUA	: National Technical University of Athens
OEM	: Operator of Electricity Market
PCC	: Power Control Center
PEIAE	: Preliminary Environmental Impact Assessment and Evaluation
PEIS	: Preliminary Environmental Impact Study
PP	: Power Plant
PPC	: Public Power Corporation SA

INDEPENDENT TRANSMISSION SYSTEM OPERATOR

Interconnection of Crete with the Mainland System (extracted from National Transmission Development Plan 2017 – 2026 / to be approved by the Regulator)

PV	: Photovoltaic
RAE	: Regulatory Authority for Energy
RES	: Renewable Energy Sources
S/C	: Submarine Cable
S/S	: Substation
SGI	: Services of General Interest
SHP	: Small Hydroelectric Plant
System	: Transmission System
T.L.	: Transmission Line
T/F	: Transformer
T.M.	: Technical Minima
TPP	: Thermal Power Plant
TSDP	: Transmission System Development Study
TYNDP	: Ten-Year Network Development Plan
U/C	: Underground Cable
VSC	: Voltage Source Converters
W/F	: Wind Farm

ANNEX II: UPDATED CONFIGURATION OF THE PROJECT (December 2016)



ANNEX III: ESTIMATED PROJECT BUDGET AND ITS COMPONENTS

Table 1. Estimated Project Budget (indicative)

ΔΙΑΣΥΝΔΕΣΗ ΚΡΗΤΗΣ (ΦΑΣΗ Ι) Ενδεικτικός Προϋπολογισμός	(€)
Εκτιμώμενο επενδυτικό κόστος (Υποέργα)	329.110.000,00
Απρόβλεπτα	29.619.900,00
Δαπάνες Δημοσιότητας	150.000
Project Management (PM)	3.291.100,00
	362.171.000,00

Table 2. Subprojects and estimated investment cost

ΔΙΑΣΥΝΔΕΣΗ 150 kV Ε.Ρ. ΠΕΛΟΠΟΝΝΗΣΟΥ - ΚΡΗΤΗΣ	
ΠΕΡΙΓΡΑΦΗ ΑΝΤΙΚΕΙΜΕΝΟΥ ΥΠΟΕΡΓΟΥ	ΚΟΣΤΟΣ (€)
1. Υ/Σ Μεγαλόπολης Ι ΑΗΣ, επέκταση με μια (1) νέα πλήρη πύλη Γ.Μ. 150 kV σε διπλό ζυγό	492.000,00
2. Αναβάθμιση Γ.Μ. 150 kV Μεγαλόπολη Ι - Σπάρτη ΙΙ από Ε σε 2Β, μήκους 56 Km	10.080.000,00
3. Υπογειοποίηση τμήματος Γ.Μ. 150 kV Ρουφ – Λάδωνας, απλού κυκλώματος 1,7 km.	550.000,00
4. Υ/Σ Σπάρτη ΙΙ, επέκταση με Αναβάθμιση 2 απλών πυλών Γ.Μ. 150 kV σε πλήρεις πύλες, σε μονό ζυγό.	593.000,00
5. Αναβάθμιση Γ.Μ. 150 kV Σπάρτη ΙΙ – Σκάλα από Ε σε 2Β, μήκους 27 Km	4.750.000,00
6. Αναβάθμιση Γ.Μ. 150 kV Σκάλα – Μολάοι από Ε σε 2Β μήκους 27 Km	4.750.000,00
7. Υ/Σ Μολάων επέκταση με μια (1) νέα πλήρη πύλη Γ.Μ. 150 kV σε διπλό ζυγό, αναβάθμιση δυο (2) απλών πυλών Γ.Μ. 150 kV σε πλήρεις πύλες, σε διπλό ζυγό	1.195.000,00
8. Μελέτη βυθού για όδευση υποβρυχίων καλωδίων Πελοποννήσου – Κρήτης	550.000,00
9. Νέα ΓΜ 150kV Υ/Σ Μολάων – Τερματικού αντιστάθμισης, μήκους 27,5 km, βαρέως τύπου διπλού κυκλώματος, με αγωγό ACSS/TW.	5.650.000,00
10. Νέος Υ/Σ Τερματικού αντιστάθμισης, διπλού ζυγού (GIS) με τέσσερις (4) πλήρεις	9.000.000,00

<p>πύλες Γ.Μ. 150 kV σε διπλό ζυγό, έξι (6) πλήρεις πύλες με τα πηνία αντιστάθμισης 36 MVar έκαστο, μια (1) πλήρη πύλη διασύνδεσης ζυγών 150 kV.</p>	
<p>11. Καλωδιακό τμήμα σύνδεσης 150 kV Υ/Σ Μολάων – Χανιά Ι</p> <ul style="list-style-type: none"> · Δύο υπόγεια καλωδιακά κυκλώματα 10 km Πελοποννήσου (200 MVA έκαστο κύκλωμα). · Δύο υποβρύχια καλωδιακά κυκλώματα 132 km Πελοποννήσου – Κρήτης (200 MVA έκαστο κύκλωμα). · Δύο υπόγεια καλωδιακά κυκλώματα 34 km Κρήτης (200 MVA έκαστο κύκλωμα). 	275.000.000,00
<p>12. Υ/Σ Χανίων, επέκταση με δυο (2) πλήρεις πύλες Γ.Μ. 150 kV σε διπλό ζυγό, επτά (7) πλήρεις πύλες 150 kV με τα πηνία αντιστάθμισης 36 MVar έκαστο.</p>	6.500.000,00
<p>13. Υ/Σ Αγίας Κρήτης (εντός του Υ/Σ) ή σε νέο χώρο στην περιοχή Κορακιάς / Λινοπεραμάτων και σύνδεση στον Υ/Σ Λινοπεραμάτων</p> <p>1 πλήρης SVC ± 100 MVar .</p>	10.000.000,00
ΣΥΝΟΛΟ	329.110.000,00

ANNEX IV: CALCULATION OF FINANCIAL PERFORMANCE INDICATORS

Financial Net Present Value (FNPV)

This indicator represents the discounted economic cash-flow of the project. It shall be calculated according to the following formula:

$$FNPV = \sum_{t=f}^{c+T} \frac{R_t - C_t}{(1+i)^{(t-n)}}$$

Where:

- c is the first full year of operation
- R_t : is the revenue from the operation in year t (in the revenues of year $t+T$ the residual value of the project is included)
- C_t is the sum of CAPEX and OPEX on the year t
- n is the year of analysis
- i is the Financial Discount Rate (FDR) of the project
- f is the first year of revenue or cost

If FNPV is positive the project generates a net profit. The FNPV reflects the financial viability of a project in absolute values and it is considered the main financial performance indicator.

Financial Internal Rate of Return (FIRR)

This indicator represents the financial viability of the project being its ability to generate revenues higher than its investment and operational costs. The indicator is defined as the discount rate that produces a zero FNPV.

Therefore a project is considered financially desirable if the FIRR exceeds its Financial Discount Rate.

The Financial Benefit/Cost ratio (FB/C)

This indicator is the ratio between the discounted benefits and the discounted costs.

$$FB / C = \frac{\sum_{t=f}^{c+T} \frac{R_t}{(1+i)^{t-n}}}{\sum_{t=f}^{c+T} \frac{C_t}{(1+i)^{t-n}}}$$

Where:

- c is the first full year of operation
- R_t : is the revenue from the operation in year t (in the revenues of year $t+T$ the residual value of the project is included)
- C_t is the sum of CAPEX and OPEX on the year t

- n is the year of analysis
- i is the Financial Discount Rate (FDR) of the project
- f is the first year of revenue or cost

If FB/C exceeds 1, the project is considered as financially efficient as the revenues outweigh the costs on the time horizon.

These performance indicators should be seen as complementary to FNPV.

ANNEX V: CALCULATION OF ECONOMIC PERFORMANCE INDICATORS

Economic Net Present Value (ENPV)

This indicator represents the discounted economic cash-flow of the project. It shall be calculated according to the following formula:

$$ENPV = \sum_{t=f}^{c+T} \frac{R_t - C_t}{(1+i)^{(t-n)}}$$

Where:

- **c** is the first full year of operation
- **R_t** is the social benefit induced by the project on year *t*. The benefit on year *c+T* also includes the Residual Value of the project.) The benefit refers mainly to Socio-Economic Welfare, SEW, which is the benefit indicator B2. Moreover, other monetized benefits, such as benefits from variation of losses (benefit indicator B4), should be taken into account.
- **C_t** is the sum of CAPEX and OPEX on the year *t*
- **n** is the year of analysis
- **i** is the Economic Discount Rate of the project
- **f** is the first year of induced social welfare ($\Delta SWEU$) or cost

If ENPV is positive the project generates a net benefit. The ENPV reflects the performance of a project in absolute values and it is considered the main performance indicator.

Economic Internal Rate of Return (EIRR)

This indicator represents the economic viability of the project being its ability to generate social welfare higher than its investment and operational costs. The indicator is defined as the discount rate that produces a zero ENPV.

Therefore a project is considered economically desirable if the EIRR exceeds its Social Discount Rate.

The Economic Benefit/Cost ratio (EB/C)

This indicator is the ratio between the discounted benefits and the discounted costs.

$$EB / C = \frac{\sum_{t=f}^{c+T} \frac{R_t}{(1+i)^{t-n}}}{\sum_{t=f}^{c+T} \frac{C_t}{(1+i)^{t-n}}}$$

Where:

- **c** is the first full year of operation
- **R_t** is the social benefit induced by the project on year *t*. The benefit on year *c+T* also includes the Residual Value of the project.) The benefit refers mainly to Socio-Economic Welfare, SEW, which is

the benefit indicator B2. Moreover, other monetized benefits, such as benefits from variation of losses (benefit indicator B4), should be taken into account.

- C_t is the sum of CAPEX and OPEX on the year t
- n is the year of analysis
- i is the Economic Discount Rate of the project
- f is the first year of induced benefit or cost

If EB/C exceeds 1, the project is considered as economically efficient as the benefits outweigh the costs on the time horizon.

These performance indicators should be seen as complementary to ENPV and as a way to assess/compare projects of different sizes (different level of costs and benefits).