ENVIRONMENTAL & SOCIAL IMPACT ASSESSMENT (ESIA) FOR PRINOS OFFSHORE DEVELOPMENT PROJECT

Chapter 7 Alternative Solutions

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ABBREVIATIONS

ALARP	As Low As Reasonable Practicable
BT	Buyoant Tower
CAPEX	Capital Expenditure
ERD	Extended Reach Drill
ESIA	Environmental & Social Impact Assessment
FEED	Front End Engineering Design
HAZID	Hazard Identification
HAZOP	Hazard and Operability
NPV	Net Present Value
QRA	Quantitive Risk Assessment
SIP	Self Installing Platform

7 ALTERNATIVE SOLUTIONS

7.1 INTRODUCTION

This section presents details of the alternative development options investigated by Energean when preparing the planned and potential extension projects outlined above. As per international good oilfield practice Energean uses a formal stage gate process through which it progresses its projects. This process commences with Feasibility. In the Feasibility stage the company examined all potential approaches to developing the identified satellite fields. This is undertaken by preparing tables that list for each element of the field development the viable alternatives and then selecting from these to prepare extreme (or end point) development scenarios. These development scenarios are often driven by a theme, which can be technology based ("maximum use of Extended Reach Drilling"), execution related ("maximize potential for local content in the execute stage") or driven by consideration of the existing facilities ("maximize use of existing infrastructure"). With "end points" defined these scenarios are combined and adjusted to give as wide a selection of options as possible.

Based upon this work each potential development option is studied at a high level and then compared on the basis of a number of screening priorities. These priorities include typical fiscal measures ("total capex", "NPV", "annual operating costs"), measures such as "Flexibility" and "Percievd Risk" – that relate to the executability and operability – plus of course "impact" parameters such as "environmental", "manning", "safety" etc. Based upon this analysis between 3 to 6 potential scenarios are carried forward into the next stage (Concept), where they are studied in more detail allowing the best option to be determined. The best option is the one that is seen to be best able to meet the established objectives, namely:

- Minimize potential impact on the environment
- Ensure safety risk levels can be brought to ALARP
- Minimise project risk – focus on simplification of interfaces during installation phase
- Maximise use of existing facilities, and staff resources
- Maximise opportunities for Greek companies

Whilst of course also meeting or exceeding the economic thresholds required to allow the projects to be sanctioned.

When developing fields close to existing infrastructure, particularly where that existing infrastructure has spare capacity, the number of valid "end point" scenarios that can be identified is normally limited. Clearly the most economic approach is to develop these fields as simple satellites. In this case the focus of the Feasibility phase is the optimization of the satellite concept with the same core objectives in mind.

In the context of an Environmental and Social Impact Assessment this early phase of the project is critical as this is the point where the largest opportunity to reduce overall impacts occurs. It is commonly understood that Feasibility and Concept is where "Value" is created. Later stages are about preservation of Value or minimization of Value erosion. The same is clearly true with regards to Environmental (and Safety) impacts. It is much more effective to engineer out Environmental risks at the commencement of a project, than attempt to mitigate these during the Execution and Operations phases.

In this section the alternative development options addressed by Energean in the Feasibility and Concept stages are discussed and contrasted with the baseline option of not developing the fields at all – the so-called "Do Nothing" option.

7.2 'DO NOTHING' OPTION

The "do nothing" option would represent a decision by Energean to make no further development investments in the Prinos Area licenses. New wells would be drilled from the existing Prinos assets and the discovered satellites would not be developed. No new exploration activities would be undertaken. In the "do nothing" option production from the existing well stock would gradually decline until a "break-even" production rate were reached. At current oil prices current production is insufficient to cover ongoing operating costs. Hence if the "do nothing" option had been selected the company would have had to either significantly reduce operating costs to enable the venture to remain economically viable or shut down the facilities immediately.

A decision to significantly reduce operating costs whilst endeavouring to maintain production at profitable levels would have the following consequences:

- Immediate impacts: those expected from the time Energean announces a halt to its planned investments:
  - ⇨ Technical / environmental:
    - Facilities would work under the design capacity, impacting equipment efficiency, operational, safety and environmental performance.
    - Spend on maintenance would be reduced as the facilities are "wound down". This would increase the chance of failures potentially with a negative impact on environmental performance.
  - ⇨ Socioeconomic:
    - Immediate ending of new investments, with knock-on socioeconomic impact to the local market associated (directly/indirectly) with hydrocarbon exploitation;
    - Immediate end to hiring and investing in new people and expertise;
    - Release of personnel to allow operating costs to be reduced and to reflect gradual shut down of operating systems. Staff associated with expansion projects would be laid off immediately
- Long term impacts:

- Technical / environmental:
  - A large volume of hydrocarbons would remain unexploited, shutdown and abandonment of the existing facilities would likely mean these discovered volumes would never be produced.
- Socioeconomic:
  - Socioeconomic impacts due to the loss of employment for a significant number of people, mostly employed from the local market;
  - Expertise loss, since the type of facility is unique in the Greek territory, the experienced personnel will not be able to be absorbed by the market and therefore they either have to change career direction or move abroad.
  - Moreover, financial loss resulted from a number of businesses that are dealing either directly (subcontractors, suppliers) or indirectly (service providers), to support the facilities, operations. More specifically, this means that in regional and municipal level there will be a revenue loss (ie. local suppliers, salaries) of about 2,6 m€ per annum (based on data by Energean[1]) and in national level there will a revenue loss (ie. taxes, social insurances, public utilities) of about 3,2 m€ per annum (based on data by Energean[2]).
  - The Project will offer technological, research and educational opportunities both at local and at national levels. A 'do nothing option' would deny the transfer of these opportunities.

Based on the above the '"do nothing" option was not considered as a viable way forward for the assets discussed in the ESIA. Energean has invested substantial capital in demonstrating the further potential of the Prinos Area. Whilst oil prices are currently low the best forward plan for the company is to develop these discovered resources whilst the existing facilities have integrity. This approach is also the most favourable from a socio-economic perspective whilst not introducing unacceptable environmental threats.

7.3 FIELD DEVELOPMENT OPTIONS

7.3.1 Alternative Epsilon field development options

A number of potential development options for the Epsilon field were examined. These include:

- **Option 1** – Minimum facility platform with dry Christmas trees at Epsilon & subsea pipeline to Delta
- **Option 2** – Extended Reach Drilling (ERD) from the Delta platform
- **Option 3** – Subsea installation at Epsilon (wet Christmas trees) and tieback to Delta

[1] It is noted that those data are based on existing financial data (2008 to 2014) and do not include the potential revenues from the exploitation of Epsilon and north Prinos fields, which are expected to increase further the contribution to the local and national economy.
[2] As above.

Option 1 is the preferred solution and is described in section 5 of the ESIA.

Option 2 is considered viable but less optimal than option 1. ERD wells drilled from Prinos would be significantly more expensive and would generate more solid waste whilst presenting more risks (for blowouts) whilst being drilled. The Prinos complex has a limited number of existing well-slots. Use of 5 to 11 of these for the exploitation of Epsilon would have limited options for further drilling at Prinos. Realistically a new drilling platform would have had to be installed at the Prinos complex to allow Epsilon and Prinos infill projects to be executed. It was clearly better to install this platform at the Epsilon field to reduce well complexity at the expense of a small number of short pipelines. The Prinos North Area fields cannot justify the cost of ERD wells and hence under this option these resources would not be developed. By designing and building the Lamda platform the Company has the opportunity to build a second identical unit (Omicron).

Option 3 is to drill conventional wells but dispense with the requirement for a jacket and topsides by installing subsea wellheads, manifold and wet Christmas trees, which are tied back to Delta platform via subsea pipeline (in common with that of the chosen concept). This option is shown in the following figure. This option was rejected as sub-sea wells present significant hazards to the environment compared with surface wells on a new platform, particularly in shallow water. This option would have required the use of two different drilling rigs and would have prevented Energean purchasing its own rig and hence offering additional employment opportunities in the region. The cost of this option was comparable with a surface development but was rejected due to the perceived high environmental risks. Operating costs would have been significantly higher.

7.3.2 Alternative Prinos North field development options

The fields in the Prinos North area will be developed in a future phase after exploitation of Epsilon. Although this subsequent project has yet to be approved Energean has considered three alternatives, similar to the ones examined for Epsilon field development:

- **Option 1 -** Minimum facility platform with dry Christmas trees located between the various discoveries and prospects and subsea pipelines to Delta or to/from Lamda.
- **Option 2 -** Extended Reach Drilling from the Delta platform.
- **Option 3 -** Subsea installation south of Prinos North with individual manifolds (wet Christmas trees) located at each field and a tieback to Delta.

Option 1 is the preferred solution and is described in section 5 of the ESIA.

Option 2 has the same drawbacks as for the development of Epsilon. Clearly a larger platform could have been installed at Prinos to allow all new wells to be drilled from one location. However this would have necessitated a delay in developing Epsilon until the Prinos North area had been further appraised and in any case was shown to be less economic than installing two identical platforms. Design costs are significant compared with fabrication costs and hence the “design one, build two” approach represents significant savings.

Option 3 has the same disadvantages as discussed for Lamda. Sub-sea tiebacks are normally only commercially and technically viable in deepwater areas where platform substructure costs are large.

7.3.3 Evaluation of field development options

7.3.3.1 Evaluation of alternative options for Epsilon field development

The criteria for the selection of the best field development option were:

- Safety and Environmental:
  - ⇨ Risk
  - ⇨ Extent of constructions / total coverage of facilities
- Technological:
  - ⇨ Maximum use of existing facilities
  - ⇨ Simplicity
  - ⇨ Flexibility
  - ⇨ Ease in maintenance
- Financial
  - ⇨ Capital costs
  - ⇨ Operating costs

Table 7-1: Evaluation of alternative field development options

Criteria	Option 1 - Minimum facility platform with dry Christmas trees at Epsilon & subsea pipeline to Delta	Option 2 - Extended Reach Drilling (ERD) from the Delta platform	Option 3 - Subsea installation at Epsilon (wet Christmas trees) and tieback to Delta
Environ-mental	A minimum facility platform is a robust and conventional solution that has a minimal environmental risk and a small environmental footprint, due to the fact that: • No fluid process will take place in the new platform. • No production facilities will be installed. • The new facilities cover little area • All production fluids, water injection, gas for	Extended Reach Drilling increases the risk that problems will occur during well construction activities. This leads to an increased risk of blowouts compared with more conventional drilling from a satellite platform. ERD drilling however avoids the need for installing new pipelines. ERD wells produce significantly more solid waste	A subsea development, particularly in shallow water significantly increases the risk of incidents resulting in release of toxic hydrocarbons to the sea. Regular well interventions are required because of scale and asphalt precipitation. These activities are better performed with dry trees. Clearly a subsea development would limit risks to personnel but at the expense of increased

Criteria	Option 1 - Minimum facility platform with dry Christmas trees at Epsilon & subsea pipeline to Delta	Option 2 - Extended Reach Drilling (ERD) from the Delta platform	Option 3 - Subsea installation at Epsilon (wet Christmas trees) and tieback to Delta
	artificial lift, chemicals, and power will be transferred by subsea pipeline and umbilical, which the safest option		danger to the environment.
Technical	It requires minimum structures and has flexibility towards future well maintenance operations (including well intervention requirements). Furthermore this option allows early development and full-field development wells to be drilled with a platform rig, rather than jack-up, hence substantially reducing drilling costs.	The option has many technical complications. More specifically: Drilling extended reach wells represents an increase in length of approximately 50% over their equivalent vertical version and, given the technical complexity involved, the period for delivering each more than doubles from 40 days to 90 days. Drilling extended reach wells also increases risk levels and hence the chance that one or more of the planned wells cannot reach their target. Furthermore, extended reach wells would also have to be completed with an east-west trajectory in the reservoir section, which would appear perpendicular to the ideal orientation (i.e. with respect to fracture orientation).	This option requires the drilling with a jack-up rig. In addition, use of sub-sea wells would make subsequent access to the Epsilon wells only possible via a jack-up, i.e. Energean's own work-over rig could not be employed. Due to expected issues with scale and asphaltene precipitation regular interventions are envisaged.
Financial	It has the potential for further cost optimisation by employing more novel platform types and	The drilling cost will be between 135 MM € and 189 MM €, which is more than the total cost of the platform	Initial capex was comparable but subsequent operating costs greater than either of the other options.

Criteria	Option 1 - Minimum facility platform with dry Christmas trees at Epsilon & subsea pipeline to Delta	Option 2 - Extended Reach Drilling (ERD) from the Delta platform	Option 3 - Subsea installation at Epsilon (wet Christmas trees) and tieback to Delta
	installation techniques.	of option 1.	

The selected solution is option 1 (Minimum facility platform with dry Christmas trees at Epsilon & subsea pipeline to Delta), because:

- It has the smaller environmental footprint;
- It has better economics than the other options considered;
- It presents a robust and conventional solution and hence minimal risk;
- It presents flexibility towards future well maintenance operations (including well intervention requirements);
- It allows early development and full-field development wells to be drilled with a platform rig, rather than jack-up, hence substantially reducing drilling costs;
- It has the potential for further cost optimisation by employing more novel platform types and installation techniques.

7.3.3.2 Evaluation of alternative options for Prinos North field development

Option 1 was also selected for the potential development of the Prinos North area fields for the same reasons as discussed for Epsilon. An additional advantage is that the same design would be used for both platforms. This reduces cost and risk.

Having two identical platforms reduces the chance that operators make errors due to confusing operating procedures for one facility with the other.

7.4 DRILLING OPTIONS

7.4.1 Environmental criteria for drilling locations

According to MD 170225/14 (Annex 4.5 / par. 8.1.1.10) the evaluation of drilling locations needs to take into consideration environmental factors, on top of any technical / financial parameters.

An initial assessment showed that there would be very little or no variation in the environmental parameters in possible alternate drilling locations, for the following reasons:

- Drilling associated with the Epsilon and Prinos North area field developments will take place in the same marine area that the existing offshore facilities are located;
- The new infrastructure will be connected to the existing offshore facilities;
- The baseline analysis showed that the adjacent marine areas of the fields exploited (in present and in future) by Energean are contiguous and very similar;

- The physiochemical analyses and the use of benthic bioindicators (as part of the ESIA) did not show any disturbances from existing facilities;

The planned drillings satisfies all criteria set by the law, as shown in the following table:

Table 7-2: Environmental criteria for drillings, according to MD 170225/14

Environmental criterion	
1) Environmental sensitivity (ecological significance, water quality, benthos, protected areas etc)	The physiochemical analyses and the use of benthic bioindicators (as part of the ESIA) did not show any disturbances from existing facilities. The wells are far from protected areas. The benthic and marine communities are common, without any significant ecological importance.
2) Correlation of the planned wells with present wells, so as to avoid cumulative impacts in the marine environment	The criterion is fully satisfied
3) Important culture heritage findings	There are no marine antiquities
4) Offshore pipelines and other infrastructures	There drillings will take place outside of the offshore pipeline safety zones
5) Minimization of impacts to other activities, i.e. fishery, navigation	There is a safety zone of 500 m around the existing facilities where fishing is prohibited. Navigation routes and fishing grounds are not in the direct vicinity of the project.

7.4.2 Drilling options for Epsilon field

7.4.2.1 Alternative options

The development of the Epsilon field has introduced the opportunity to revisit the way drilling operations in the Prinos area are undertaken. The number of wells required for an effective development of Epsilon ruled out the use of extended reach wells from Prinos.

Three drilling options were examined:

- Jack-up drilling rig
- Tender assisted drilling rig
- Modular platform drilling rig

Jack-up drilling rigs have been used for Prinos drilling to date. These have been mobilized to drill small batches of wells from the existing Prinos drilling platforms – including medium-reach ERD wells to both Prinos North and Epsilon. Jack-up drilling can only be achieved with small jackets with no more than twelve (12) well slots.

Tender assisted rigs are barge based mobile drilling units where the heaviest equipment (tanks, pumps, accommodation) are located on the barge and the remaining equipment on the platform. They include a heavy lift crane, which erects the drilling equipment set on the platform where wells are to be drilled. The barge and platform are connected together by hoses and cables. The area on the barge used to transport the drilling equipment acts as a lay down area once the drilling equipment is erected on the platform. There is no limit to the number of well slots that can be accessed from a tender rig. The required platform sub-structure is comparable with that needed for jack-up drilling.

Modular platform drilling rigs are platform-drilling rigs that are designed so that they can be moved from location to location. Once fully erected on a platform they are fully self-contained needing no support from a barge or tender. This type of rig necessitates the use of a larger/heavier platform substructure, as all weight has to be supported.

7.4.2.2 Evaluation of alternative drilling options for Epsilon field

The criteria for the selection of the best field development option were:

- Environmental: mainly in terms of extent of constructions / total coverage of facilities;
- Technical;
- Financial.

The number of wells required for an effective development of Epsilon ruled out the use of extended reach wells from Prinos. Not only were the costs prohibitive compared with wells drilled from a satellite platform but there were insufficient spare slots available at Prinos. Extended Reach Drilling would have required a new well jacket to be installed at Prinos. In shallow water depths a satellite platform and associated pipelines is normally cheaper and more effective than just two to three (2-3) ERD wells. Field development studies undertaken for Energean confirmed this.

The rig selection was driven by the need to keep overall weights within the limits of what could be accommodated on the existing platforms, in order to:

- Avoid large expansions and
- Have the minimum structures in the marine environment

Prinos area reservoir fluids contain significant quantities of wax and ashphaltenes and formation waters have high salt contents. Well completions therefore need regular interventions involving the ability to pull installed completions. Whilst the Epsilon wells could have been drilled by a jack-up, minimizing the size of the substructure, the platform had to be sufficiently large so that it could accommodate both a work-over rig and coiled-tubing equipment to facilitate routine interventions. A platform designed for a jack-up normally contains no more than 12 wells. Fifteen (15) well slots were considered as optimal for the Epsilon development.

In shallow water, benign-weather, offshore areas with multiple medium sized drilling centres a tried and tested alternative is the use of tender assisted drilling barges. After analysis it became clear that such an approach would be ideal offshore Northern Greece, because it satisfies several criteria:

- Environmental: The use of a modular drilling rig at Epsilon would not increase structure size over that required and could be applied at the existing Prinos platforms with minimal modifications. There is no interaction between the rig and the sea bed in the vicinity of the platform
- Technical: Metocean data for the Prinos area shows that wind and sea conditions are ideally suited to this type of drilling technology. The modular drilling equipment sets employed in tender assisted drilling are of similar weight to the medium rig already employed on Prinos Alpha and re normally designed to operate on platforms with a similar deck space as that required to accommodate a work-over rig.
- Financial: The costs of a jack-up drilling rig are significantly higher than the ones of a tender assisted drilling.

As an alternative to the use of a tender assisted barge the Company also investigated the use of a modular platform rig. The use of this technology would have necessitated use of a large structure for the Lamda platform. The existing Prinos Alpha and Beta platforms could not be upgraded to support such a rig.

Based on the above, Energean purchased a tender assisted drilling asset (‘Energean Force’ drilling rig) and refurbished this to internationally recognised standards during the winter of 2014/15.

7.4.3 Drilling options for future Prinos North field development

7.4.3.1 Alternative options

The intent of the Company is to use the same approach for Prinos North as selected for Epsilon. Both areas are virtually identical (water depth, distance from Prinos and the coast and number of wells required). Therefore whatever was demonstrated to be ideal for Epsilon would be employed for Prinos North.

7.4.3.2 Evaluation of alternative drilling options for future field development

As discussed previously, similar drilling options to Epsilon field development will be applied and therefore the same assessment of alternatives applies.

7.5 PLATFORM TYPES

7.5.1 Alternative options

As discussed previously, a minimum facility platform was selected as the best solution for the development of the new fields. There are a variety of such structures, used worldwide and the following platform types were examined:

- Monopile: Monopiles comprise a single (approximately 2.0 m to 3.0 m) column supported on a 4.0 m to 5.0 m diameter pile driven into through the column into the seabed. It normally is used in shallow locations, typically in 20m - 40m of water.
- Monotower: This platform is similar to a Monopile, but supported on a suction anchor rather than driven pile.
- Vierendeel Tower: This structure type is commonly used for small platforms without wells in relatively benign shallow water environments. It comprises a square-legged jacket with external bracing for strength.
- Conductor supported platform: installed with and only usable with a jack-up rig. Would not support weight of existing work-over rig and hence not investigated in detail
- Self-installing platforms: a variety of self-installing platforms have been applied world wide. These designs avoid the need for using a crane barge during installation. They can be broken into two sub-classes: designs that self float (are buoyant); designs that require use of a temporary installation/transportation barge.

Examples of installed aforementioned solutions are shown in the following photos:

Photo 7-1: Vierendeel tower

Photo 7-2: Monotower

Photo 7-3: Monopile

Self-installing platforms were investigated in some depth to determine whether they could be applied in the place of a typical steel jacket. Self-installing platforms do not require the large marine spread needed to install a typical piled jacket. Greece is relatively remote from offshore support infrastructure and mobilizing specialist barges from the North Sea or Persian Gulf represented a large cost and increased environmental impacts (emissions due to consumption of fuel during transportation and installation). The following two-competing designs were selected and addressed during FEED. One was considered the best buoyant sub-design and the other the best non-buoyant design:

- Buoyant Tower or Self – Installing Floating Tower (BT/SIFT)
- Self Installing Platform 2 (SIP2)

More specifically:

The Buoyant Tower (BT) concept was developed to install a platform in a seismically active offshore location in Peru. It was enhanced and modified for application in the North Sea and renamed the SIFT. The BT is buoyant before, during and after installation. It "floats" in the seabed allowing it to withstand severe earthquakes. The SIFT is buoyant before installation but is upended and sunk to the seabed during installation. Post installation it functions as a traditional gravity based structure.

The design incorporates a combination of existing and proven technologies from deep-water Spars and compliant structures, together with shallow foundations, to provide a cost effective alternative to conventional fixed steel platforms.

Installation can be effected without the use of a derrick crane vessel and negates the need for heavy duty piling and grouting of the foundations. In addition, the simple design and fabrication principles optimize opportunities for regional fabrication and construction.

The SIFT, examined for the new fields, consisted of four cellular legs with each leg comprised of tank compartments whose design would account for hydrostatic pressure and axial load, free flooding and ballast tanks. The four cellular legs were structurally connected through horizontal tubular frames.

The SIFT is grounded by suction piles, which protrude from the bottom of each cellular leg and penetrates into the seafloor.

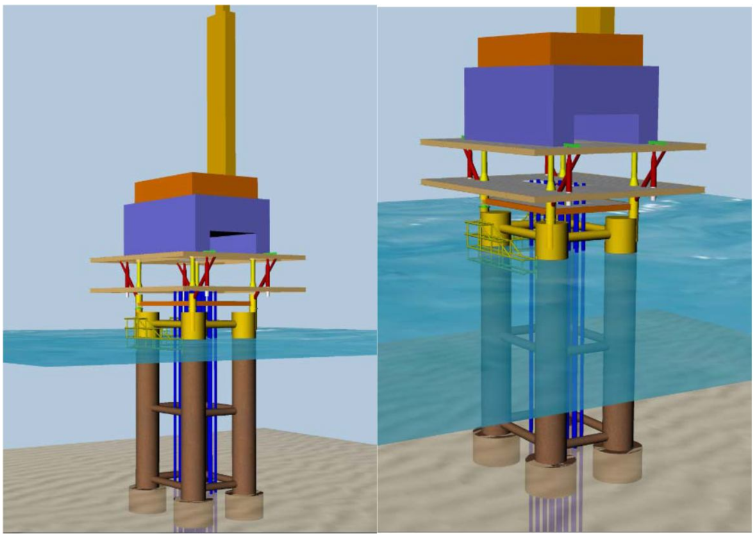


Figure 1: General view of the assessed BT/SIFT platform as alternative platform

The Self Installing Platform 2 (SIP2) chosen for the development of Epsilon and the Prinos North area fields is fully described in section 5 of the ESIA.

7.5.2 Evaluation of Alternative Platform types

The solution of monopole / monotower was rejected for technical reasons. More specifically:

- Monopile: Single legged jackets can only accommodate a limited number of wells that would be drilled from a jack-up rig. In a monopole the column is used to contain the pile and hence wells have to be positioned externally. A maximum of 2 wells can normally be accommodated. Risers are exposed. Use of a driven pile was not seen as desirable due to the need to mobilise specialized equipment.
- Monotower: Soil conditions were idea for a suction pile, however a one-legged platform was not large enough to accommodate the planned number of well slots. Wells are normally drilled through the central column. A SIP2 is effectively 4 mono-towers linked by the topsides.

- Vierendeel Tower: This platform type is not strong enough to support a platform based drilling rig.

For the selection between the SIFT and SIP2 concepts the environmental and technical/economical parameters considered were:

- Environmental:
  - ⇨ Minimum scale structure
  - ⇨ Quick and small scale construction
  - ⇨ Minimal risk
- Technological: / economical:
  - ⇨ Flexibility
  - ⇨ Ease of maintenance
  - ⇨ Costs

Table 7-3: Evaluation of BT/SIFT and SIP2

Criteria	BT/SIFT	SIP2
Environmental	• Mobilization of a small fleet (2-3 barges, 1 supporting ship). • Some external resources, ie. extended spreads might be required. • Operational risks requires an offshore float-over that increases installation risk and hence impact on environment. • Environmental footprint from operation: Irrelevant to type of platform.	• Mobilisation of a small fleet of tugs plus a transportation barge. • No need for external resources, such as crane barges, piling spreads etc. This option has a minimum risk to environment. • Operational risks: identical for any type of self-installing platform. • Environmental footprint from operation: Irrelevant to type of platform.
Technical / economical	• Installed in approximately a week. • Minimal external resources are required. • Flexibility: can be moved to another location although would need to topsides to be removed. • Maintenance: Irrelevant to type of platform • Costs: Similar.	• Installed in a few days, rather than a few weeks • No need for external resources, such as crane barges, piling spreads etc. • Requires rental of strand jacks • Flexibility: the structure can very be transferred to another location • Maintenance: Irrelevant to type of platform • Costs: Similar.

The SIFT and SIP2 technologies are both similar as can be seen from the above analysis. The SIP2 sub-structure was finally chosen as it was perceived to offer less installation risk due to the avoidance of an offshore float over. Whilst both approaches use similar quantities of steel the SIP2 leg fabrication is slightly simpler offering minor cost advantages.

7.6 TOPSIDE FACILITIES

7.6.1 Alternative options

With processing capacity for oil, produced water, gas and water injection available on Delta it was clear that the topsides of Lamda and Omicron should be designed with minimal facilities. There were therefore few topsides alternatives to be investigated. The only decision to be made was whether to invest in equipment that would minimize manned operations at the new facilities. As this was a way to minimize risk levels to staff it was decided to link the new platforms to Delta with an umbilical cable. This would avoid the need for power generation on the satellites (hence emissions and maintenance), provide remote control via fibre optics (avoid the need for a local control room) and to store, bunker and pump chemicals locally (reduced chance of spillage, lower manpower, lower emissions).

The topside design described in section 5 was developed based upon this philosophy of minimizing manned interventions. Energean has completed all design and safety studied for the topside facilities. The design follows standards, regulations and good industry design practices. It has been designed to reduce the inherent risk to staff of managing hydrocarbons with significant toxic potential. ALARP techniques were used at the start of concept design to achieve the lowest possible risk levels. Hazards were identified by using well-known techniques, such as HAZID and HAZOP. It must be mentioned, that part of the ESIA was the QRA for the topside facilities.

7.6.2 Evaluation of Alternative Topside Facilities

No viable alternatives to the chosen concept could be identified without increasing risk levels to staff.

7.7 PIPELINES

7.7.1 Alternative options

The routing and mechanical aspects of the required pipelines were determined according to the field development option and platform type selected.

The alternative options investigated were:

- Buried or unburied pipelines
- Installation by towing or by S-Lay.

7.7.2 Evaluation of Pipelines

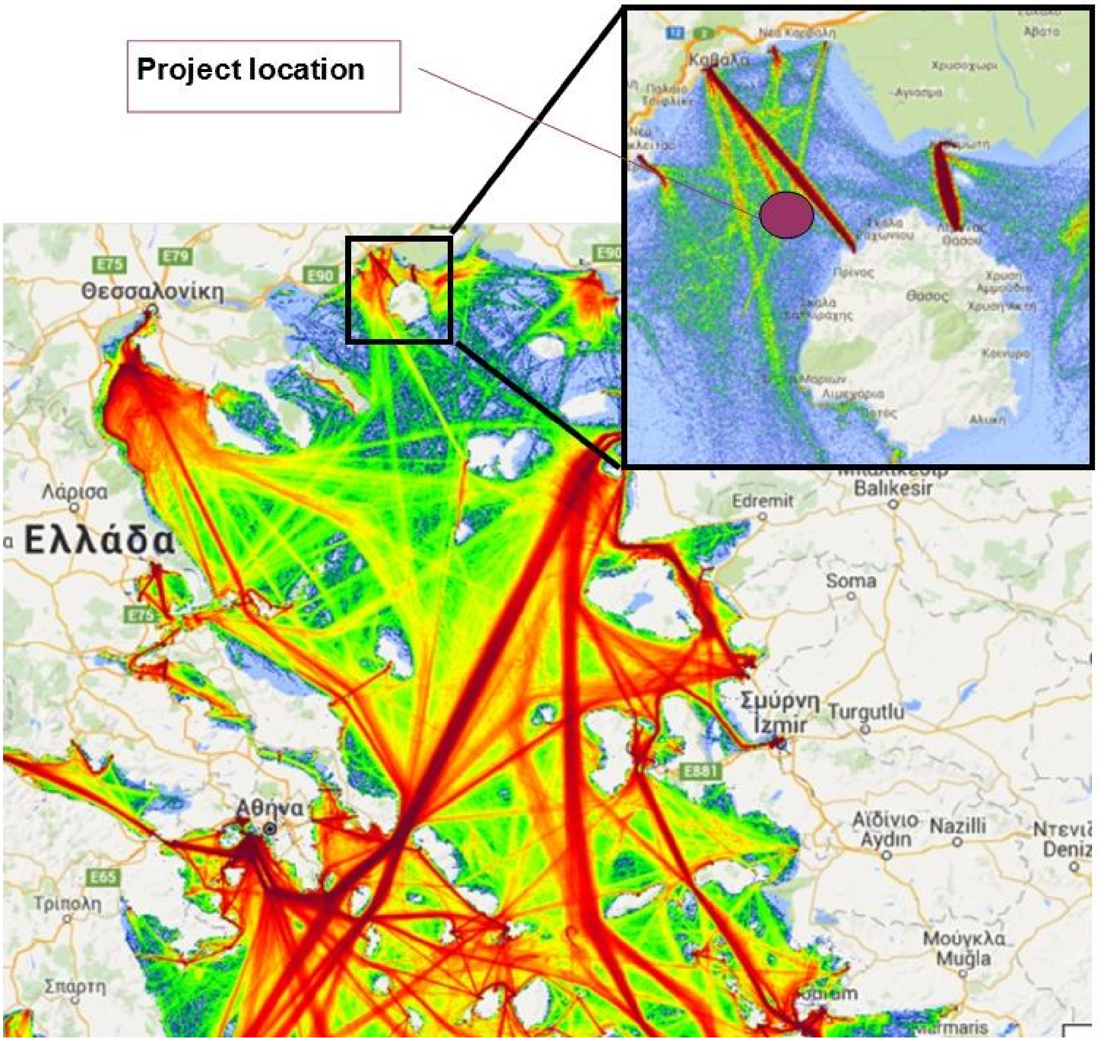
The evaluation of pipelines was based on environmental and safety parameters / criteria. Energean has elaborated detailed studies for:

- The best solution for protection by navigation and fishing gear;
- The construction option provided the highest on-bottom stability

More specifically:

Criterion 1 – protection by navigation and fishing gear:

Mediterranean region is well known by high marine traffic. The shipping traffic in Aegean Sea is presented in the following figure:



Map 7-1: Recorded marine traffic in Aegean Sea (source: www.marinetraffic.com)

As shown in the figure, there are several shipping lanes falls next to Prinos field (north Aegean Sea). The concern is that statistically, around 50% of ships travelling under a "flag of convenience" and do not stick to designated shipping lanes.

But, the most critical issue is the intense fishing activities around the project area. Special protection measures have to be taken against fishing gear interaction. The best solution is all pipelines to be trenched for permanent protection from fishing gear (and navigation).

Criterion 2 – on-bottom stability:

Pipelines were checked for on-bottom stability based on available metocean data. The analysis considered the installation sequence lay the pipeline flooded on seabed and then trench it. The design cases considered relying on mechanical and natural backfill. Minimum pipeline wall thicknesses (for production and gas lift pipelines) were considered in this analysis. The following table summarizes the analysis results:

Table 7-4: On-bottom Stability Analysis Results

Location	Design Case	Duration	Current Return Period	Waves Return Period	Pipeline		
					Production Pipeline	Water Injection	Gas Lift
					10inch ×15.88mm	6inch ×11mm	6inch ×9.5mm
Lamda	Flooded on Seabed	≤3 days	1 year	1 year	Stable	Stable	Stable
Delta					Stable	Stable with CWC or Mattresses (250m @ Delta)	Stable with CWC or Mattresses (500m @ Delta)
Lamda	Flooded on Seabed	1 month	1 year	10 year	Stable	Stable with CWC or Mattresses	Stable with CWC or Mattresses
Delta					Stable with CWC or Mattresses (750m @ Delta)	Stable with CWC or Mattresses	Stable with CWC or Mattresses
Lamda	Flooded on Seabed	1 month	100 year	1 year	Stable	Stable	Stable
Delta					Stable	Stable with CWC or Mattresses (250m @ Delta)	Stable with CWC or Mattresses (750m @ Delta)
Lamda	Operating in open trench	12 months	1 year	10 year	Stable	Stable	Stable
Delta					Stable	Stable	Stable

Lamda	Operating in open trench	12 months	100 year	1 year	Stable	Stable	Stable
Delta					Stable	Stable	Stable
Lamda	Operating in open trench	20 years	100 year	100 year	Stable	Stable	Stable
Delta					Stable in 1.5m trench (without backfill) or in 1m trench (with backfill)	Stable	Stable in 1.25m trench (without backfill) or in 1m trench (with backfill)

The general conclusion is that pipeline is stable in a trench and unstable on seabed in many cases particularly near Delta platform (shallower water depth ~28m).

Pipeline was assessed flooded on seabed, from results above it is expected that operational condition on seabed will be unstable (due to lower weight and higher loading conditions). Further sensitivities and modifications could enhance the stability of pipe on seabed (actual water depths after tie-in confirmation, more recent survey, final corrosion rate and type, additional metocean data investigation and geotechnical. investigation, increasing the wall thickness, lower safety factor and reduction in wave velocity due to spreading). These parameters could make the pipe stable in many cases.

Apart from stability issue, trenching and backfilling are beneficial for protection and buckling aspects.

The overall conclusion of the evaluation of pipeline connections option is that the buried pipelines are the best solution. The option of unburied pipelines is rejected.

Finally, an installation assessment took place, also, for towing and S-Lay methods. The analysis showed that, although the two methods are technically feasible and have the same environmental footprint, the preferred option is towing, due to lower cost.