ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

REPRESENTATION OF A MULTIDISCIPLINARY SCENARIO FOR OFFSHORE UPSTREAM, WIND PROJECTS AND APPLICATION OF MONTE CARLO SIMULATION ON EVALUATION OF FEASIBILITY

M. Sc. THESIS

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

DENİZDE PETROL VE RÜZGAR PROJELERİNİN FARKLI MESLEKİ DİSİPLİNLER İÇEREN BİR ÇERÇEVE DAHİLİNDE TARTIŞILMASI VE MONTE CARLO METODU İLE FİZİBİLİTE DEĞERLENDİRMESİ

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ARALIK 2015

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To my wife and children,

FOREWORD

Firstly, I would like to thank my thesis advisor Prof. İsmail Hakkı Helvacıoğlu for his support and guidance throughout this process. I would also like to thank Münir Cansın Özden for encouraging me to enroll in this masters programme, Gökhan Budak for his guidance throughout the past two years and Doruk Küçüksaraç for his immence knowledge and assistance in the financial simulation aspects of this thesis. I am also greatly indebted to my managers Mr. Kubilay Yıldırım and Per Skaug for granting me the opportunity to fulfill my ambitions.
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December 2015

Mahmut Erbil Soylu
(Petroleum Engineer B.Sc.)

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ABBREVIATIONS

USD	: United States Dollars
FT	: Feet
EWEA	: European Wind Energy Association
GW	: Giga-watt
MW	: Mega-watt
YE	: Year End
EU	: European Union
BCF	: Billion Cubic Feet
MMBTU	: Million British Thermal Unit
BOTAS	: Turkish Pipeline Corporation
TPAO	: Turkish Petroleum Corporation
EIE	: Electrical Power Resources Survey Administration
REPA	: Wind Energy Potential Atlas (Turkey)
BCM	: Billion Cubic meter
SCM	: Standard cubic meter
NDT	:Non destructive testing
NPV	:Net present value
TCP	:Tubing conveyed perforation
SASB	:South Akcakoca sub-basin
LIDAR	:Laser imaging detection and ranging
SCM	:Standard cubic meter

LIST OF SYMBOLS

$\mathbf{V_w}$	: Wind speed to be estimated at particular elevation
$\mathbf{V_{wref}}$	: Wind speed at reference height
H	: Elevation of the intended level to be estimated
$\boldsymbol{\mu}$	: Hellman's constant
P(V)	: Power output of wind turbine
$\boldsymbol{\rho}$	: Density of air
A	: Turbine swept area
$\boldsymbol{\beta}$	: Dimensionless factor
$\mathbf{C_d}$	: Drag doefficient
$\mathbf{C_m}$	: Inertia coefficient
$\boldsymbol{\mu_G}$	: Expected rate of return per year for Natural Gas
$\boldsymbol{\mu_C}$	: Expected rate of return per year for Commodity
$\boldsymbol{\sigma_G}$	: Volatility of the rate of returns for Natural Gas
$\boldsymbol{\sigma_C}$	: Volatility of the rate of returns for Commodity
$\mathbf{dW_{t,g}}$	: Price shock on Natural Gas
$\mathbf{dW_{t,g}}$	: Price shock on Commodity
corr()	: Correlation function
$\boldsymbol{\rho}$	: Correlation factor
$\mathbf{u_{m,t}}$	: Random common price shock
$\mathbf{u_{g,t}}$	: Random gas price shock
$\mathbf{u_{c,t}}$	: Random commodity price shock
$\boldsymbol{\varepsilon_{g,t}}$	: Correlated gas price shock
$\boldsymbol{\varepsilon_{c,t}}$	: Correlated commodity price shock
E()	: Expected value function
Var()	: Variance function
$\mathbf{P_t}$	: Price tag at a specific time
$\mathbf{R_z}$	:Torsion around +z axis

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REPRESENTATION OF A MULTIDISCIPLINARY SCENARIO FOR OFFSHORE UPSTREAM, WIND PROJECTS AND APPLICATION OF MONTE CARLO SIMULATION ON EVALUATION OF FEASIBILITY

ABSTRACT

In order to achieve the ultimate goal of accessing abundant, cheap and clean energy for a brighter future for younger generations, investment on offshore energy industry should be considered as a game changer for Turkish Energy policies. Main purpose of this thesis study is to provide necessary background information on different types of offshore energy projects, representation of operational approaches on these projects, offshore structural requirements and considerations related with the operational approaches put forward, development of probabilistic cost and revenue models on represented concepts and application of a cost-revenue based consolidated financial simulation model based on a 10 year quite arbitrary but likely and realistic operational investment scenario. Purpose of application of this arbitrary scenario is to show, if this kind of a projection and will is put forward, what would be the expected results and order of magnitude of the expected monetary earnings and side benefits for the Turkish Energy Industry.

Water depth limitation for the operations to be discussed within the scope of this text is 400ft and this comes from the water depth ratings and limitations of column stabilized offshore mobile units, jackup type of platforms. This limit can be considered as the most distinctive boundary between shallow and deep type of offshore construction and upstream development operations in terms of operating principles, required machinery and types of vessels, structural requirements and hydrodynamic nature of the physical problems to deal with.

Within the first chapter of this thesis, a brief introduction will be given about the current condition and future predictions of the offshore wind energy industry in Europe. In addition to this, brief information will be given on the extent of natural gas storage market, a general descriptive information will be provided on the marginality considerations of offshore hydrocarbon resources and nature of international offshore hydrocarbon ventures will be discussed.

The reason of this quite various portfolio to be brought together and represented under a consolidated scenario comes from the resemblance of the nature of the physical work to be done, similarities within the operational planning, capability of similar installation vessels and fixed steel substructures to be run for these different types of energy projects.

In the second chapter, main considerations regarding offshore wind preliminary prospectivity will be discussed and application of these considerations on Turkish seas will be applied. With regards to the limited available information in hand, preliminary categorization of the wind resources will be done and what needs to be done in order to evaluate the potential further will be discussed. Lidars will be discussed as an

innovative technology in wind resource assessments and a preliminary resource assessment campaign methodology will be introduced. A reference design of a monopile type of platform equipped with lidar device will be introduced. Wind turbine power output estimation and considerations on selection of an applicable turbine and related substructure requirements will be discussed. A reference type of wind development project will be introduced in order to be incorporated into the financial simulation.

Within the third chapter, three different types of upstream offshore projects will be introduced such as a gas storage project, a further development project on a marginal gas field and an arbitrary international offshore development project of the type "buyback contract". Necessary background information will be provided regarding the nature of these projects.

In the fourth chapter, offshore sub-structures required in the aforementioned types of offshore projects will be discussed in detail such as wind measurement monopile platform, steel jacket type wind turbine sub-structure, gas storage jacket, modifications on existing jackets and dynamic behavior of these different types of fixed substructures will be evaluated. The natural frequencies and mode shapes of these substructures under environmental loading conditions will be evaluated in order to verify the validity of the reference designs.

Within the chapter named "Operational Scenario", workflow of the arbitrary scenario will be demonstrated. Sequence of the operations and estimated costs of the operations will be put forward. Additional information will also be provided regarding the site set up for some of the critical operations provided within the operational scenario and requirements of offshore installation vessels will be discussed.

In the sixth chapter, financial simulation methodology, revenue modeling of the previously demonstrated different types of offshore projects, methodology on projection of estimated costs will be introduced and results of the simulations will be tabulated.

Finally, within the last chapter named "conclusions and recommendations", the results achieved within this thesis study will be summarized and recommendations will be put forward in order to achieve the ultimate goal of a developed and competitive offshore energy industry.

DENİZDE PETROL VE RÜZGAR PROJELERİNİN FARKLI MESLEKİ DİSİPLİNLER İÇEREN BİR ÇERÇEVE DAHİLİNDE TARTIŞILMASI VE MONTE CARLO METODU İLE FİZİBİLİTE DEĞERLENDİRMESİ

ÖZET

Yeni nesillere daha parlak bir gelecek bırakmak amacı dahilinde bol, ucuz ve temiz enerji kaynaklarına ulaşmak için açık deniz enerji yatırımları, Türk Enerji Politikaları dahilinde ciddiyetle dikkate alınması gereken oldukça önemli bir husustur. Bu tez çalışmasında farklı tipteki birçok enerji amaçlı deniz projesi hakkında temel bilgiler paylaşılacak olup; akabinde tanıtılan projeler hakkında operasyonel yaklaşımlar aktarılacaktır. Operasyonel yaklaşımlar ile paralel olarak, bu projelerde faydalanılan açık deniz yapıları hakkında bilgiler paylaşılacaktır. Ortaya koyulmuş olan deniz projeleri hakkında olasılıksal yatırım ve gelir modelleri oluşturularak, soyut ancak gerçekçi bir yaklaşım dahilinde oluşturulan 10 yıllık bir yatırım senaryosunun Monte Carlo modeli finansal simulasyonu oluşturulacaktır. Finansal senaryonun oluşturulmasındaki temel amaç, buna benzer bir stratejik plan takip edildiğinde ortaya çıkacak olan maddi kazancın tahmin edilmesi ve Türk Enerji Endüstrisine sağlayacağı katkının derecesinin belirlenmesi olacaktır.

Bu tez çalışması dahilinde su derinliği kısıtlaması olarak 400ft derinlik tercih edilmiştir. Bu su derinliğinin tercih edilmesi arkasındaki temel etmen, 400ft su derinliğinin günümüzde hali hazırda kullanımda olan sütun yardımı ile stabilize mobil deniz platformların büyük bir çoğunluğunun azami çalışılabilir su derinliği değeri olmasıdır. Bu derinlik değeri günümüzde sığ ve derin tip deniz alanlarında gerçekleştirilen enerji projeleri içerisinde operasyon prensipleri, ekipman, makina, deniz araçları, yapısal gereksinimler ve hidrodinamik problemlerin farklılıkları açısından en belirgin limit olarak kabul edilebilir.

Giriş bölümünde, ilerleyen bölümlerde değinilecek olan farklı tipteki projeler hakkında genel bilgiler verilmiştir. Bu bölüm dahilinde, yenilenebilir enerji kaynakları içerisinde rüzgar enerjisinin Avrupa'daki durumu ve gelecekle ilgili beklenir projeksiyonları, deniz alanlarında gerçekleştirilen rüzgar projelerinin günümüzdeki durumu ve yakın gelecekteki beklenir durumu hakkında bir takım istatistiki bilgiler paylaşılmıştır. Bu paylaşımdaki temel amaç deniz alanlarında gerçekleştirilecek olan rüzgar enerjisi projelerinin çok önemli bir gelişim evresine girdiğinin tespitidir. Ayrıca, 2015 yılında gerçekleştirilen Avrupa rüzgar enerjisi beklenir gelişim senaryosunda deniz alanlarında gerçekleştirilecek olan projelerin toplam kapasite içerisindeki pay artışına da değinilmiştir.

Buna ek olarak doğal gaz depolama konusu ilerleyen bölümlerde tartışılacak proje ile ilgili bir takım kavramların tanımları verilmiş olup buna ek olarak birçok farklı ülkenin doğal gaz depo hacimleri ve doğal gaz tüketimleri ile ilgili oransal bilgiler paylaşılarak, Türkiye'nin durumu ve hedefleri karşılaştırılmıştır.

Giriş bölümünde değinilen diğer bir konu ise hidrokarbon rezervlerinin geliştirilmesi ve ekonomiye kazandırılması konusunda gerçekleştirilen fizibilite çalışmalarının değişken pazar koşulları ve teknik zorluklar nedeni ile zamana bağlı olarak oldukça farklı sonuçlar vermesi ve bu tür değerlendirmeler gerçekleştirilirken ön planda tutulması gereken parametreler ile ilgili bilgiler verilmiştir.

Tez çalışmasının ikinci bölümünde deniz alanlarından rüzgar enerjisi üretimi konusu detaylı olarak ele alınmıştır. Bölüm dahilinde denizde rüzgar enerjisi üretiminin karadaki üretime nazaran avantaj sağladığı koşullar, Türkiye'deki potansiyel rüzgar alanlarının tespiti ve kategorizasyonu yapılmış olup birçok prospektif alan tanımlanmıştır. Öncül prospekt tanımlamalara ek olarak, deniz alanlarında rüzgar kaynaklarının değerlendirilmesi maksatlı ölçüm sistemleri ile alakalı bilgiler paylaışlmış olup, konu ile ilgili yeni geliştirilmiş olan bir laser teknolojisi hakkında bilgiler verilmiştir.

Deniz alanlarında rüzgar enerjisi projelerinde ilk ölçümler sonucu uygun olan yerlerin projelendirilmesi için gerekli olan esaslar üzerine tartışılmış olup, Türk deniz alanlarında ölçüm yapılması önerilen 33 deniz alanı ve önerilen 42 ölçüm lokasyon kordinatı listelenmiştir. Farklı potansiyele sahip görünen deniz alanları 3 kategori altında toplanmış olup bu noktadaki temel amaç farklı potansiyele sahip yörelerin farklı tarife politikalarına tabi tutularak projelerin ulusal enerji stratejisi dahilinde şekillendirilmesi ve yönlendirilmesi için bir enstrüman olarak düşünülmesi gerekliliğidir. Bu noktada tarife Avrupa birliğindeki açık deniz rüzgar enerji fiyat politikaları hakkında bilgiler paylaşılmıştır.

İkinci bölümün devamında, açık deniz rüzgar alanlarında gerçekleştirilecek olan rüzgar enerjisi projeleri hakkında genel bir projelendirme çalışması gerçekleştirilmiştir. Bu noktada, Akçakoca yöresinden bir rüzgar ölçüm örneği üzerinden yıllık ortalama rüzgar hızı hesaplanmış olup, elde edilen ortalama hız Hellman'ın bağıntısı ile kullanılmak istenilen rüzgar türbininin rotor yüksekliğindeki ortalama hız kestirimi yapılmıştır. Yapılan kestirim, seçilmiş olan türbinin karakteristik rüzgar hızı, güç verimi eğrisi ile kesiştirilerek, bahsi geçen alanda, seçilmiş olan türbin ve spesifik rotor yüksekliğindeki kapasite faktörü belirlenmiştir.

Üçüncü bölüm genel olarak deniz alanlarında gerçekleştirilen petrolcülük projelerinin tanıtılması ile ilgili olarak kurgulanmıştır. Konu ile alakalı olarak Türkiye Petrolleri Anonim Ortaklığının Kuzey Marmara doğal gaz depolama sahası üçüncü faz geliştirme projesi ile ilgili platform ve sondaj gereksinimleri tanımlanarak ileriki bölümlerde tanıtılan finansal simulasyon içerisine hangi varsayımlar dahilinde yerleştirildiği tarif edilmiştir. Bölüm dahilinde tartışılan geliştirme projesi iki adet sabit çelik platform üzerinden kazılacak olan 12'şer adet kuyu vasıtası ile doğal gaz depo rezervuarına yapılan enjeksiyon ve geri üretim miktarlarının arttırılarak, yerel pazarda herhangi bir kapasite fazlası ya da kısıt halinde devreye girerek doğal gaz ağının dengelemesinin gerçekleştirilmesidir.

Üçüncü bölümde tartışılan diğer bir konu ise faaliyete başladığı tarihten günümüze ekonomik olarak başarı getirmeyen Akçakoca açık deniz doğal gaz sahasının yenilikçi bir bakış açısı dahilinde tekrar değerlendirilmesidir. Bakış açısı dahilinde üçüncü geliştirme safhası ile üretilebilir rezervlerin arttırılmasıdır. Akçakoca sahası'nın geçmişteki geliştirme faaliyetleri hakkında bilgiler verilmiş olup, sahada hali hazırda keşfedilmiş ancak geliştirilmemiş olan rezervler tablolanmıştır. Saha geliştirme konsepti dahilinde önceki geliştirme fazlarında inşaa edilmiş ve kullanımda olan 4 adet üretim platformunda bulunan proses ekipmanı ve sistemlerinden faydalanılması esas alınmıştır. Üretim platformlarının yüzey lokasyonlarından, geliştirilmek istenilen rezervlerin yatay ve düşey uzaklıkları belirtilmiş olup, yönlü sondaj teknolojisinin erişime el verdiği rezervlerin tercihi yapılmıştır. Bununla birlikte bahsi geçen geliştirme operasyonlarını gerçekleştirmek için temin edilmesi gereken sütun stabilize sondaj platformunun gerekli minimum sütun uzunluğu ve sondaj platformunda bulunması gereken teknik özellikler listelenmiştir.

Dördüncü bölüm dahilinde önceki iki bölümde tartışılan denizde rüzgar ve petrolcülük projeleri ile ilgili kullanılması muhtemel olan sabit deniz yapıları ile ilgili yapısal analiz sonuçları paylaşılmıştır. Bölüm dahilinde gerçekleştirilen analizin metodolojisi tartışılmış, analizlerde kullanılan rüzgar, dalga ve akıntı yükleri ve diğer çevresel etmenlerin tanımları yapılmış olup birçok farklı tipteki sabit açık deniz yapısının dinamik davranışları ve doğal frekansları tespit edilmiştir. Analiz edilen deniz yapıları; rüzgar ölçümleri için kullanılması planlanan monopile tip açık deniz yapısı, rüzgar türbininin taşıyıcısı olan 4 bacaklı sabit yapısı, Akçakoca projesi içerisinde modifikasyonlara tabi tutulması planlanan üretim platformlarının, olası bir modifikasyon sonucunda dinamik davranışının ne şekilde değişmesinin beklendiği tartışılmıştır.

Gerçekleştirilen yapısal analiz çalışmaları dahilinde öncelikle planlanan yapının üç boyutlu modeli oluşturulmuş olup, yapının taşıması beklenen harici yükler ve çevresel yükler belirlenmiştir. Harici ve çevresel yükleri farklı kombinasyonlarda yapı üzerine uygulayarak her bir durumda yapı elemanları üzerinde oluşan stres miktarları hesaplanmıştır. Güvenlik katsayısı haricinde stres değerleri olan yapısal elemanların çapları ve malzeme et kalınlıkları arttırılarak daha mukavim hale getirilmiştir. Değiştirilen model tekrar üzerinde oluşan stresler tekrarlanmış ve bütün yapısal elemanlar stresleri istenilen düzeye eriştiği aşamada mukavim statik model tamamlanmıştır.

Statik model, zemin özellikleri ve zemine sabitleme elemanlarının da modele eklenmesi sonrası tekrar analiz edilerek, yapının temel mukavemeti kontrol edilmiştir. Zemin analizinde Ayazlı doğal gaz üretim platformu tasarımında kullanılan karot analizi sonuçlarından faydalanılmış olup, tez çalışması dahilinde tartışılan 7 farklı modelin her birinde aynı zemin modeli kullanılmıştır. Açık deniz yapısının taban geometrisi, su derinliği, harici yüklerin büyüklüğü ve çevresel yüklerin çeşitliliği bir arada değerlendirilmiş olup yapı üzerinde oluşan maksimum toplam moment tespit edilmiştir.

Bundan sonraki aşamada dalga yükleri belirli periyotlar ve dalga yüksekliklerinde yapısal model üzerinde uygulanarak, sabit yapıda oluşan hareketlerin doğal frekansları belirlenmiştir. Tespit edilen doğal frekansların kabul edliebilir aralıklarda olup olmadığı tartışılmış ve uygun olmadığı belirlenen modeller üzerinde tasarımın ilk aşamasına geri dönülerek, model geometrisi ve yapı elemanlarının özellikleri değiştirilmiştir. Yapılan analiz çalışmalarında SACS isimli analiz yazılımı kullanılmıştır.

Beşinci bölümde, 10 yıllık soyut ancak önceki bölümlerde gerçekçiliği tanıtılmış olan deniz enerji projelerin tek bir operatör tarafından gerçekleştirildiği varsayımı dahilinde finansal simulasyona esas operasyon sıralaması ve planlaması tartışılmıştır. Bu tanımlama dahilinde farklı tip projelerdeki benzer operasyonlar gruplanarak detaylı planlama gerçekleştirilmiştir.

Altıncı bölümde, bir önceki bölümde tanımlanmış olan operasyon senaryosuna uygun olarak farklı tiplerdeki açık deniz projelerinin, proje ömürleri, gelir modelleri, işletme giderleri ve buna benzer maliyetleri ve gelirleri etkileyen birçok parametre tanımlanarak projelerin ayrı ayrı gelir varsayımları yapılmıştır. Gelir varsayımları içerisinde olasılık metodu ile uyumlu sonuçlar vermesi amacı ile gelirler farklı tahmini fonksiyonlarla tanımlanarak gelecek dönemler için fiyat ve gelir tahminleri gerçekleştirilmiştir. Monte Carlo simulasyonu ile belirlenmiş parametre aralıklarından gelişigüzel çekilen değişkenler ile net günümüz değer hesaplamaları 1000 defa yapılarak %10 yıllık enflasyon değerine göre olasılık dağılım fonksiyonu oluşturulmuştur. Bu yapılan çalışma sonucunda net günümüz değerin histogramı çizilmiş olup birçok olasılıkta 2 milyar dolar üzerinde net günümüz değer hesaplanmıştır.

Sonuç ve öneriler bölümünde ise yapılan çalışma sonucunda Türk denizcilik sektörü içerisinde rüzgar enerjisi ve petrol, doğal gaz projeleri alanına yatırımların arttırılması, sabit deniz yapılarının rüzgar enerjisi projelerinin popülerliğinin artmasına bağlı olarak yeniden önemli bir araştırma ve geliştirme konusu haline geldiği aktarılmıştır.

1. INTRODUCTION

Current picture of the world energy market seems to be extremely complex because of the random distribution of different types of natural resources worldwide, differences in the nature of engineering and technological requirements for exploitation , distance of the resources to the consumption points, transportation, distribution and storage capability and physical mechanisms of these various resources. If political border barriers are also included on top this complex equation, political and international relations among the governments, nations becomes the most important factor on determining energy supply, prices and reliability. To say that, most of the disputes and clashes today, are mostly related with the access to natural resources.

For a nation to provide problem free, brighter future projections for younger generations, improve the quality of life of the public in various aspects such as transportation, household heating and electricity, industrial production and agricultural activities, access to abundant, cheap and clean energy is extremely important. Since all these mentioned activities require access to reliable energy in terms of supply and cost for the stability, sustainability and development of the economy, governments set national energy strategies in order to create a balanced and sustainable portfolio among different sources of energy supply, rules and regulations in order to provide support to energy industry in terms of engineering, safety, exploration and development of natural resources and environmental protection.

If Turkey's current consumption portfolio, market growth predictions and geopolitical risks are considered together, it can be said that, a proactive and innovative strategy needs to be set in order to secure the supply of abundant energy and minimize the geopolitical risks related with the supply of energy. In addition to this, within this strategy, the ultimate purpose should be to create a self sufficient energy market and import - export balance shall be achieved.

At this point, for achieving the aforementioned purposes, supporting the development of offshore energy sector might be a game changer for Turkish energy dynamics in various aspects such as offshore wind energy, offshore exploration and development of hydrocarbon resources, development of offshore natural gas storage fields and entering into offshore hydrocarbon ventures in different parts of the world.

Within the scope of this chapter, It will be tried to discuss the importance and current condition of the offshore wind energy, importance of natural gas storage for the national natural gas markets, marginality considerations for hydrocarbon resources and importance of entering into international offshore hydrocarbon ventures.

1.1 Wind Energy in Europe

European Union, as being the leading political actor in continental Europe, literally is enforcing the member states to invest in exploitation of renewable energy resources for the last 2 decades. According to "Wind energy scenarios for 2030" report published by the European Wind Energy Association states that in the year of 2030; the target set for each member state is to provide a minimum 27% (which corresponds to 46% of electricity consumption) of the total energy consumed shall be extracted from renewable resources and wind industry will take the "lion's share" [1].

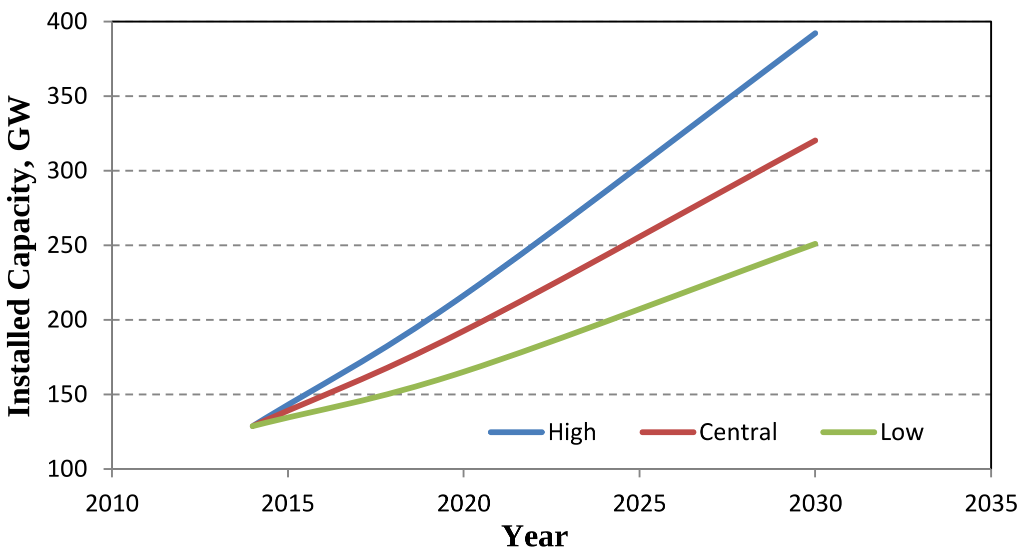

Figure 1.1: Wind power scenarios for 2030 in Europe.

According to the same report, three different scenarios given in figure 1.1 have been put forward and those scenarios indicate that, in 2030, the market share of wind power will be somewhere in between 19%-31% of total electricity consumption of European Union. Some of the other important figures extracted from this report are as follows: 251GW - 392 GW is the range of expected total installed capacity of power generation, €367bn - €591bn is the expected range of total investment, 307,000 - 366,000 expected range of jobs to be created and 76,000 - 114,000 is the expected range of turbines on-line. In addition to these figures, 339 - 554 Million Tons of Carbon dioxide emission will be prevented.

As can obviously be seen from the figures presented on the previous two paragraphs, one can certainly say that, Europe has selected wind industry as the primary renewable energy resource for achieving sustainable growth. Europe is considering wind industry as a catalyst for the improvement economical growth performance, a key industry for creating significant amount of jobs, a technology to help reviving the atmosphere and environment.

In addition to these benefits, with regards to the wind power, total amount of hydrocarbons import will be lowered down, monetary value spent for import will stay within the local economy, international price volatility on conventional resources will be less, economical growth will be more sustainable. Also, pressure on developed economies of accessing to strategically hydrocarbon resources will be less. This also can contribute to significant benefits on achieving world peace.

If all these reasons are considered together, One can clearly understand why Europe is extensively investing on wind power and setting up ambitious targets. The overall picture is quite obvious and apart from the electric power generated, there are a lot of significant side benefits exist.

As a comparative information to be provided for Turkish wind industry, related information is derived from the annual statistical report of Turkish Wind Energy Association. According to this report, the total wind energy generation capacity (YE 2014) is 3,42GW, total capacity of projects under construction is 1,16 GW and total of licensed projects not yet started is 5,44GW [2]. As of date; Turkish Wind Industry installed capacity corresponds to 2.7% of European Union and if all the awarded licenses are assumed to be available and connected by 2020 and mid-scenario applies for EU, this ratio might come up to 5,1%.

After reviewing these statistical figures and projections, it can be said that, development of the Turkish wind market is quite parallel to Europe so far and further development rate will possibly be higher than EU averages. This is an encouraging information for Turkish Energy Portfolio.

1.2 Future of European Offshore Wind

According to the same report, ratio of offshore wind installations to total wind installed capacity by 2030 is expected to be 3/8, which corresponds to 150GW of 400GW. According to EWEA's Wind in power statistical report, (YE 2014) the total installed wind power capacity is 128GW and 8GW is the amount of offshore wind so far [3].

With regards to the statistical and probabilistic information taken from two different EWEA reports, it can be concluded that offshore wind capacity is expected to grow 1600% within 2014-2030 period, whereas onshore wind capacity will grow only 100%.

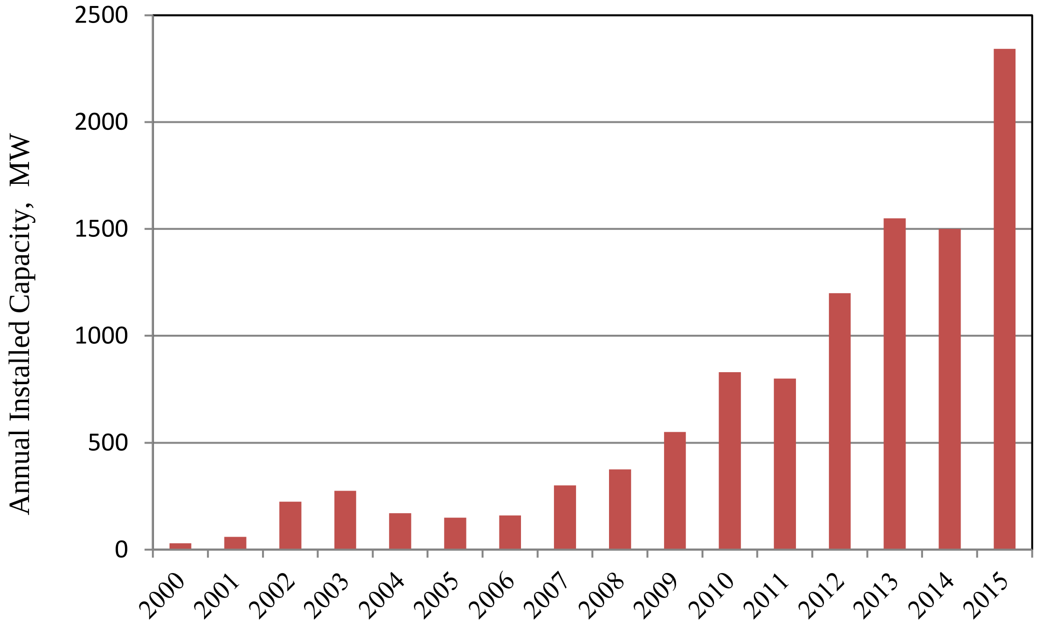

Figure 1.2: Annual installed offshore capacity.

At this point, validity of these estimations on offshore wind power development might be questioned and can be considered as highly optimistic, but the recent statistical information given in figure 1.2 shows that the expected trend on growth rate of offshore wind installations has already been started. Only within the first 6 months of 2015, 584 commercial offshore wind turbines have been connected to grid, the total capacity installed being 2.34GW [4]. 2.34GW of installed offshore capacity corresponds to 30% of the total capacity installed within years 2000-2014.

With regards to the information provided above, it can be clearly stated that; European Union has already initiated the massive investment program on offshore wind industry and era of rapid growth on this sector has started.

At this point, to note the condition of Turkish offshore wind energy as a background information, unfortunately, there is no ongoing projects or license has been awarded yet. Some actions are urgently needed to be taken by government authorities in order to catch this rapid growth period of offshore wind industry. The preliminary actions for investors to evaluate the offshore wind potential of Turkish seas would probably be to provide the definitions on the rules and regulations of offshore wind prospectivity and clarification on the tariff approach.

Within the second chapter of this thesis work, further information will be provided regarding the preliminary evaluation on offshore wind prospective resources of Turkey, comparative information will be provided on tariff's currently being applied in Europe, offshore wind resource assessment, turbine and substructure selection. A reference offshore project will be demonstrated for incorporating into the Monte Carlo financial simulation in order to provide a base of understanding for overall project feasibility.

1.3 Natural Gas Storage

A second point of discussion as another important industrial sector regarding the energy politics presented within the introductory part of this study is to provide some descriptive and statistical information on the main motivations and operational dynamics of natural gas storage.

Natural gas storage reservoir is a volume that is being used for storing excess natural gas which has already been produced from some other natural gas reservoir. There are five different types of natural gas storage reservoirs being used worldwide today. These reservoirs are salt caverns, old mine shafts, aquifers, depleted natural gas reservoirs and hard-rock caverns. [5].

Some of the important definitions regarding natural gas storage are; total natural gas storage capacity is the maximum volume of gas that can be stored within a storage reservoir as per the physical characteristics of the reservoir. Total gas in storage indicates the amount of gas at a particular time. Cushion gas volume is the minimum level inside the reservoir, that will permanently stay inside in order to sustain the pressure inside the reservoir to provide the deliverability. Working gas capacity refers to the volume difference between total storage capacity and cushion volume while working gas volume refers to the total volume minus cushion gas volume at a particular time [6]. Working gas volume changes in the US is given in figure 1.3.

In addition to the general definitions about the volumetric and capacity considerations about natural gas storage, there are two other important parameters to be mentioned are : Deliverability refers to the amount of total capacity of natural gas to be provided to the gas grid per day and injection rate is the capacity of the excess natural gas to be restored in the storage and those parameters are important in terms of the flexibility and operability of natural gas supply grid.

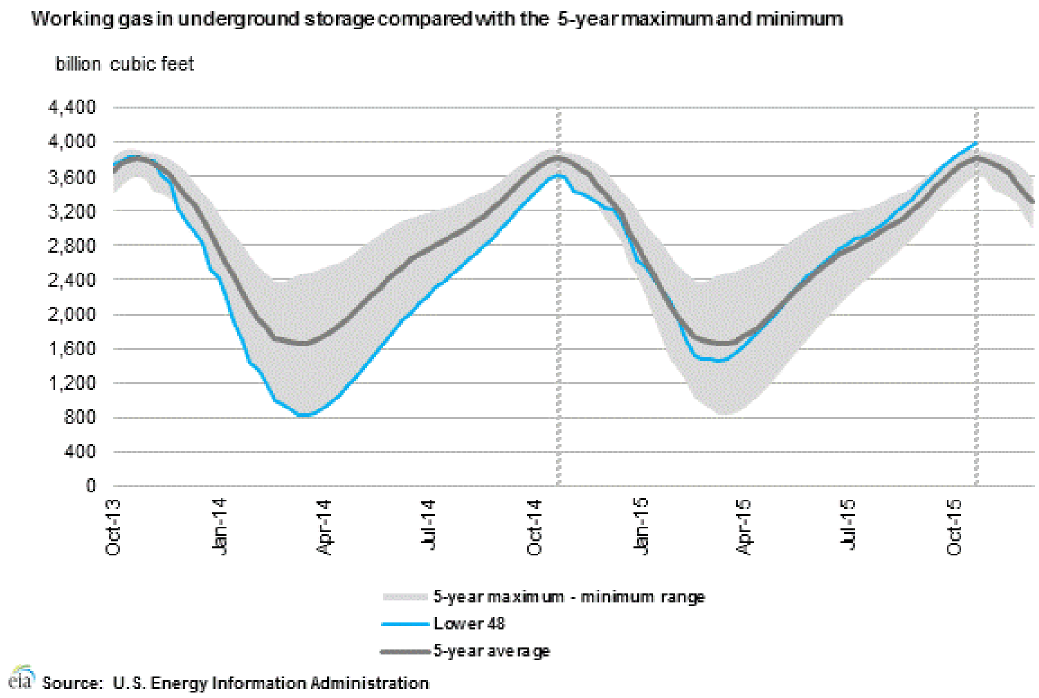

Figure 1.3 : Working Gas Storage Volumes in the USA [6].

After providing informative descriptions about the natural gas storage reservoirs, some statistical information will be given in this section regarding the size of the natural gas storage capacities in the U.S. According to U.S. Energy Information Administration's weekly report on natural gas storage released on November 16th, 2015, the total volume of natural gas stored within the storage reservoirs across United States is 3985BCF, which corresponds to 8.95 Billion USD of monetary value if total volume is multiplied with current price of 2.33 USD/MMBtu. [7]. If last 3 years average gas price is multiplied with the stored volume the monetary value of this gas goes up to 15.5 Billion USD. This huge difference is represented here in order to provide a rough idea about the profit margin of storage traders.

According to annual industry report published by BOTAS (YE-2014) [8] the ratio of storage capacity over annual natural gas consumption of some countries are tabulated in table 1.1 as follows and it can be seen that for Turkish natural gas market, in order to secure supply, this ratio should be increased.

Table 1.1: Comparison of storage capacities among different countries. [8]

State	Storage Capacity / Overall Consumption	Storage Capacity / Household Consumption
USA	18	48
Russia	27	61
Ukraine	49	109
Germany	19	105
France	20	52
Italy	30	65
Turkey	5	20

The current storage capacity of Turkey is 74 BCF and projected to be increased to 151 BCF by the end of 2019, 205BCF by the end of 2022 and the ratio of storage over annual consumption is planned to be increased to 9% by 2019 and over 10% by the end of 2022. Turkish natural gas storage sector will meet the requirement of 10% capacity target by the end of 2022. In addition to this, apart from the total volume of storage, the deliverability target is 2.65BCF/day by the end of 2019, which corresponds to 65% of estimated daily market consumption [8].

At this point, for increasing the deliverability rate up to the targeted levels, one of the most important projects is the capacity increase phase-3 development project on Silivri offshore gas storage field. Since this offshore project is planned to be realized within the upcoming 4 years, it will be discussed in further detail in chapter 3 and will be introduced into the operational scenario and financial simulation model.

1.4 Marginality Considerations on Offshore Hydrocarbon Assets

As a third point of discussion put into the financial model comes from the marginality of offshore hydrocarbon fields. By legal definition, marginal field refers to an oil or gas field that may not produce enough net income to make it worth developing at a given time [9]. As can be seen within the definition itself, the assessment of a field whether it is profitable or not, might change with time and conditions. To say that, if the profitability of a field is highly dependent on the market and operational conditions and goes to negative on some likely cases, than it can be referred as marginal.

There are a series of elements that has effect on marginality considerations of a hydrocarbon field. First, and most important factor is the sales price of the commodity. Since the nature of the oil and gas prices are quite volatile, price shocks are being observed quite frequently. Marginal fields are affected from this price volatilities dramatically. Within the periods of low prices, investments on these kind of fields slow down or even some cases, operating company stops production operations because of the less volatile behavior of the operating expenses.

Another important factor on marginality consideration is the investment and technological requirements in order to reach these resources. If accessing the resource requires high technological machinery or equipment, careful considerations should be made regarding the operational planning and execution. If those are not planned in detail and executed strictly as per plan, the financial results might be catastrophic.

Apart from these two factors, process requirements such as elimination of sand content in production, presence of hydrogen sulphide or some other unwanted chemicals within the product, difficulties in transportation regarding the chemical and physical properties of the product such as high viscosity, paraffinic and wax content of oil, separation requirements among different types of products are also some of the technical aspects in evaluation of marginality.

As a final category marginality evaluation, distance and marketing options, the government regulations on environmental protection, the level of the government share on production, taxation regime and presence of financial benefits on oil and gas exploration and production activities also plays important role on determination of profitability and evaluation of marginality.

For offshore fields on top of these general factors, marginality considerations are even more critical with regards to the nature of the operations, planning of the interfaces between types of different operations such as drilling, construction and installation of offshore structures, design and maintenance of offshore production equipment and systems, installation of offshore pipelines, interconnections and connections to the offshore structures.

Within the third chapter of this thesis, Akcakoca offshore natural gas field will be discussed in detail regarding the marginality of the field and a preliminary development concept will be introduced to show that the field profitability can be on the positive side. The represented concept will be included into the financial model and simulation will be run including an offshore marginal development project.

1.5 International Offshore Hydrocarbon Ventures

In order to eliminate the import-export deficit for countries without abundant hydrocarbon reserves, one of the most important strategy is to become an international player within upstream industry. By this way, the deficit amount of that particular country can be covered up from a series of producing assets in other parts of the world.

By entering into such ventures in foreign countries, there are several advantages can be achieved such as not being affected from sharp price changes in oil and gas, securing hydrocarbon reserves for the stability of the internal economy and creating new jobs for local people to work overseas. In addition, some other political and trade benefits can also be achieved.

Some of the major countries with significant reserves lacks in funding of the development of oil and gas assets. The problem of those countries comes from the fact that, the government relies on the earnings from oil and gas mainly and leaves insufficient funds for the oil industry to sustain and develop such as Iran, Russia, Nigeria or some other cases, oil industry and infrastructure has severely damaged due to civil uprising or war such as Libya, Iraq and etc. And in such conditions, where the asset is promising but requires finance and the owner is incapable of doing it, there might be profitable options for the countries without significant reserves.

For the onshore assets, since the accessibility to the worksite is not a major issue, the owner can partially develop the asset by drilling new wells and funding is a lot easier because whenever a well is drilled and completed, it is ready to produce and provide cash. Due to this fact, while considering onshore, international deals are mostly related with exploration of new resources rather than development of the already proven reserves.

For the development of offshore assets, the picture is quite different than onshore. In offshore projects, the durations of financing the offshore development projects can be up to several years and most of the time, there is no cash return chance during the investment period. That is why, even though the extent and the productivity of the oil and gas reservoir is known, the owner state cannot secure funds to develop the asset by itself.

The biggest natural gas field in the world, North Dome/ South Pars, which lies in between Qatar and Iran is a pretty good example for countries in such conditions. After the exploration of the field in 70's, Qatar extensively invested and developed the part of the field underlying in its territories whereas, Iran could not develop its portion that fast. South Pars, 30% of the total field reserves, has been divided into 24 different development stages and up to date, 11 of them has been completed. The reason of this, is coming from the fact that, Government of Iran cannot fund the required amount of investment.

There exists a lot offshore development opportunities worldwide for oil and gas upstream projects and within chapter 3, buyback type of contract nature will be discussed and an arbitrary field development project will be incorporated into the operational scenario and financial simulation.

2. OFFSHORE WIND ENERGY

As discussed within the introductory chapter, wind energy has become an important source for Europe, and especially offshore wind energy sector will extensively grow from 8GW to 150 GW capacity within the next 15 years period. Discussion within this chapter will be questioning what needs be done in order for Turkey to be a competitive player within offshore wind industry.

2.1 Advantages of Offshore Wind Over Onshore Wind

Access to Onshore wind is off course more feasible when compared to Offshore. That is why, onshore projects outnumbered the offshore projects. The limitations coming together with the economics of offshore substructure constructions and expensive offshore installation operations has been an important factor for wind energy invertors to go after onshore options than the offshore but the picture is about to change within the next decade.

This is due to a various reasons such as most of the wind prospective areas have already been developed, some of the prospective areas being inside the populated areas, the requirement of wind farms to be some distance away from the populated areas due to the noise created by the turbines, turbulence and shielding effects due to the topography and preservation of highly dense forest areas and environmentally preserved areas.

If the advantages of offshore wind over the onshore is considered, it is mostly related with the space required for offshore wind turbines are vast and there is no issue of fixed cost on land lease. Apart from this, there is no requirement for construction of access roads to mountainous areas or cutting trees inside forest areas. Another important advantage is that, the offshore wind regimes are more stable and not affected by the topology effects, thus turbulence and shielding affects on wind regime is negligible.

2.2 Determination of Prospective Areas

The most important factor for the determination of prospective offshore wind areas is the access to the national wind measurement database at different locations and gradient mapping of the overall territory. Increased number of measurement points and durations helps to improve more accurate models.

For mapping of the Turkish wind areas, a quite extensive model given in figure 2.1 and 2.2 has been developed under the administration of EIE under the name of Turkish Wind Energy Potential Atlas [10]. This study provides important information on potential wind zones but lacks in covering up offshore areas due to the fact that no offshore data has been included into the model yet.

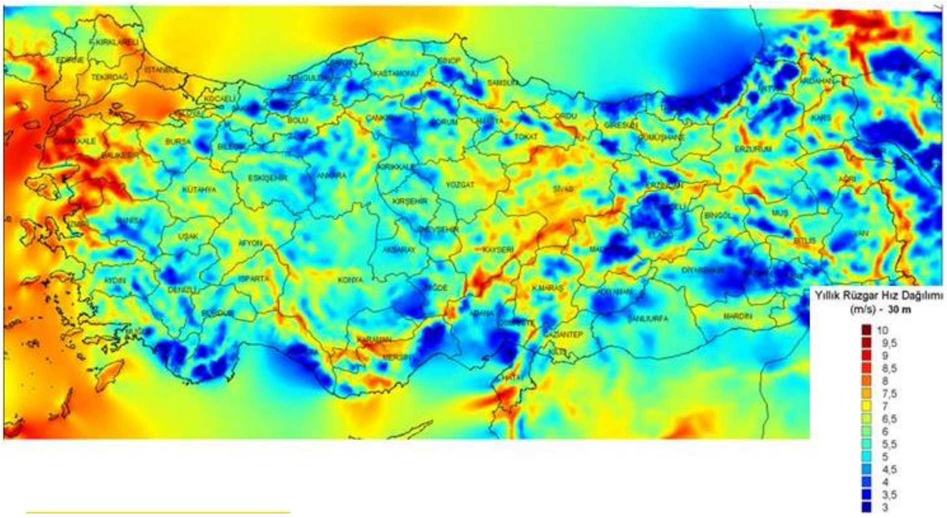

Figure 2.1: Wind energy potential atlas - average wind speed at 100m.

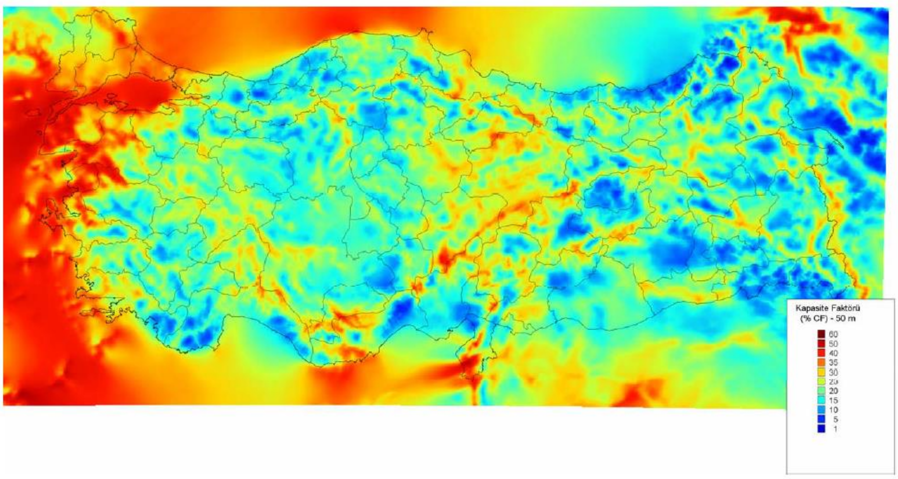

Figure 2.2: Wind energy potential atlas - average capacity factor %.

Offshore areas are modeled with extrapolation of onshore data or data exchange between neighboring countries. The base have been selected for determination of offshore prospective areas in this study will be based on the average wind speed distribution map at 100m of elevation. Data is considered to be quite limited but is relevant for preliminary selection of the areas of interest.

A second important factor for prospectivity study is the access to reliable bathymetric data, which is at key importance for the identification of the potential offshore wind areas of the Turkish seas. The bathymetric data within this study has been extracted from the Navigation, Hydrography and Oceanography Directorate's navigation maps [11].

The upper depth boundary for applicable water depths shall be determined with regards to the feasible fixed offshore substructure options. The lower depth boundary shall be limited with the applicable distance to shore, eliminating noise disturbance onshore and the minimum working depth of the selected offshore wind installation methodology and type of vessel to be used.

Upper boundary that has been selected while mapping the areas was 50m of water depth. This was due to the feasibility limitation of the jacket type structures. With regards to the recent developments in offshore turbine industry, the output power has increased from 4MW up to 7MW within the last 5 years and this helped to justify jacket structures to deeper water depths.

Lower boundary is set at 15m water depth because of the selected methodology of offshore tower installation. Within this study, A conventional Jackup rig is selected and will be converted into an offshore wind turbine installation vessel and most of the jackup rigs have minimum parking depths around 15m.

In determination of the prospective areas, Water depth window defined above has been intersected with the average wind speed distribution map at 100m of elevation within this study.

2.3 Categorization of Prospective Areas

After the intersection of wind distribution map with water depth window for Turkish Seas, promising areas are defined. During definition of these areas, a categorization has been applied in order to have a decision about the likelihood of an actual offshore wind farm project to be applied on the selected prospect.

First parameter to look at is that the average wind speed and capacity factor throughout the selected prospect. This is off course important for development of feasible wind farms. Areas below %30 percent of capacity factor and 7m/s average wind speed is set to be a cut of rate and annual averages below these values are considered to be uneconomical.

The second parameter in categorization of prospective areas is related with the proximity of the prospects to the high consumption areas. Having offshore wind farms nearby, eliminates the line losses in the energy transport and distribution systems. In addition to this, since the output of the wind farms are fluctuating over time parallel to wind regime, flexibility of electric generation portfolio and backup systems are quite important. In areas with high consumption, diversification of resources and capability of switching between these resources are definitely higher when compared to the rest of the areas.

With regards to these two factors, 3 different category has been given to the defined prospective offshore wind areas of Turkey.

Category 1 prospects are the areas with capacity factors over %50 and average wind speeds over 10m/s, basically, the best applicable in terms of feasibility. At first sight, it is quite easy to say that North Aegean territories lies in this category. Category 2 prospects are the areas with capacity factors over %40 and average wind speeds over 8 m/s. Sea of Marmara has various locations lying within this range and has proximity to highly populated and consuming areas such as Istanbul, Bursa. And the third category is the areas above %30 and 7 m/s of wind speed. Since those areas seems to be uneconomical, during definition of prospects of this type, proximity becomes more important to the market. Western Black Sea regions between Sile - Kefken and Karaburun - Limankoy are considered to be of this type.

2.4 Offshore Wind Prospects Defined

In table 2.1, result of the wind prospective study has been tabulated. In addition to this, maps of the defined prospects are provided within the Appendix-A section.

Table 2.1: Prospective offshore wind areas.

#	Name	Area	Cat.	#	Name	Area	Cat.
1	Bozcaada North	75km^2	I	18	Avsa	27km^2	II
2	Bozcaada West	55km^2	I	19	Biga	128km^2	II
3	Bozcaada East	60km^2	I	20	Erdek	230km^2	II
4	Bozcaada South	30km^2	I	21	Edremit	61km^2	II
5	Ezine	45km^2	I	22	Ayvalik-East	33km^2	II
6	Dardanel	50km^2	I	23	Ayvalik-West	21km^2	II
7	Anafarta	22km^2	I	24	Cesme-East	29km^2	II
8	Enez	180km^2	I	25	Cesme-West	18km^2	II
9	Candarli	22km^2	I	26	Limankoy	123km^2	III
10	Samandag	11km^2	I	27	Kiyikoy	95km^2	III
11	Kesan	16km^2	II	28	Karaburun	110km^2	III
12	Saroz	45km^2	II	29	Sile	118km^2	III
13	Gelibolu	110km^2	II	30	Agva	190km^2	III
14	Imrali	45km^2	II	31	Kefken	126km^2	III
15	Mudanya	61km^2	II	32	Silivri	43km^2	III
16	Kapidag	40km^2	II	33	Tekirdag	41km^2	III
17	Bandirma	43km^2	II				

2.5 Tariff for Offshore Wind Energy

Currently, there is no ongoing offshore wind energy project has been under construction in Turkey and thus, no special policy has been set for determination of offshore wind energy prices. In addition to this, there is no clue about the structure of the government support to offshore wind producers yet. In order for offshore wind producers to emerge and international players to enter into the market, government shall structure the industrial expectations, set the rules, regulations and post the tariff and duration of the tariff support for the development of this type of renewable resource.

In determination of the tariff and the duration of the government support, two main approaches are being seen from the European Union Countries. First being is a fixed tariff throughout the duration of the project and second being is the application of a higher tariff for a certain period of time and leveling back to onshore renewable prices after the recovery of extra capital expenditure related with the offshore nature of the operations.

Tariff for offshore wind energy in European Countries averages around 15 euro cents per kilowatt hour. The probabilistic economical simulation will be run with this price.

Another point here is that, government may decide to apply different tariff's for different category of wind areas in order to bring the economics of different types of prospects to same level and encourage the investors in marginal areas.

2.6 Selection of Meteorological Measuring Locations

After an initial definition of the prospective areas with the help of REPA Map and superimposing of water depth window on top of this map, a supplementary study has been made in order to understand the workflow of the wind prospecting.

In order for the further design on possible wind farms and have more information on the selected prospective areas; wind measurements are required to be done in order to verify the expectations for verification and definition of the prospective areas in more detail with a preset budget for the defined prospects above. The nature of this measurement campaign is to get the data for the locations selected and combine the gathered data with the nearby onshore wind measurements. More detailed wind mapping will able to be done and a lot more information on wind regimes of the prospective areas will be gathered. This study will provide a more realistic point of view in terms of selecting which prospects to continue working on, determination of the optimum hub height to work and selection of the optimum wind turbine.

In addition to the information gathered and creation of a more detailed and more accurate model on the wind regime, another important requirement for this kind of a preliminary project on evaluation of offshore wind potential of Turkish Offshore areas is that; proposed study will let the regulating authorities to design licensing rounds and wind farm development research on the defined prospects will able to be started.

Within this thesis, 42 initial locations have been selected as a offshore measuring point in order to cover the defined prospective areas. The selected locations are tabulated in table 2.2 below.

Table 2.2: Proposed locations for preliminary wind assessment.

#	X(m)	Y(m)	Zone	#	X(m)	Y(m)	Zone
1	284,300	4,562,759	36	22	419,620	4,416,147	35
2	268,469	4,568,612	36	23	413,467	4,404,606	35
3	744,120	4,563,523	35	24	421,419	4,401,823	35
4	707,770	4,567,369	35	25	424,301	4,407,553	35
5	638,558	4,583,367	35	26	425,177	4,391,669	35
6	620,513	4,591,116	35	27	491,022	4,375,929	35
7	609,628	4,596,402	35	28	477,229	4,359,877	35
8	596,489	4,608,957	35	29	462,255	4,350,617	35
9	591,353	4,621,969	35	30	500,305	4,305,325	35
10	588,877	4,632,377	35	31	443,783	4,245,711	35
11	591,740	4,542,246	35	32	434,193	4,242,496	35
12	554,453	4,535,535	35	33	763,561	3,996,922	36
13	414,596	4,501,629	35	34	482,209	4,479,151	35
14	427,189	4,489,812	35	35	494,958	4,484,019	35
15	452,507	4,493,652	35	36	535,017	4,471,889	35
16	475,628	4,497,225	35	37	551,963	4,471,130	35
17	483,204	4,496,747	35	38	584,419	4,486,815	35
18	481,844	4,490,572	35	39	595,114	4,476,204	35
19	436,178	4,456,424	35	40	635,355	4,484,470	35
20	406,399	4,409,496	35	41	639,176	4,472,421	35
21	425,546	4,425,541	35	42	625,056	4,476,152	35

2.7 Selection of the Meteorological Measurement System

Met-mast is the industry accepted nomenclature for naming the meteorological data gathering stations. These stations are designed in order to measure the wind speed, direction, air pressure, temperature and such. There are numerous types of these kind of offshore structures are being erected worldwide for wind resource assessments.

In general, Offshore met-masts consists of a monopile sub-structure and an access platform which also is the base of the mast being erected up to 80 -100m of elevation over mean sea level. At different heights, high accuracy anemometers are being placed in order to measure wind speed at different elevations in order to create the local curve of average wind speed vs. elevation at that particular location. With the help of this chart, the optimum elevation for the turbine hub is being decided. The statistical data obtained from this data stations are being used in order to curve fit to a Rayleigh distribution function and this data is plot as a graph of probability distribution vs. wind speed. The probability distribution is intersected with the power output curve of various types of wind turbines and thus the type of turbine to be used for the measured location can be selected. In addition to this, in some types of the met masts, power performances are also being measured with small sized wind generators. With the help of this power performance, offshore met-masts eliminates the uncertainty enormously.

Access to a very reliable information by erecting an offshore mast on a monopile to a prospective area seems to be the perfect solution for decisioning on investment, but there seems to be another cost effective and more beneficiary technology is being deployed instead of the large masts.

Lidar is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. This technology has been recently introduced into wind measurement industry and being used extensively for wind resource assessment. For onshore projects, the main measurement has been done with a conventional type of met-mast and lidar devices are being used to measure different locations within the prospect area. Lidar devices are mobile and easy to deploy. This advantage provides accurate modeling over the entire wind asset being developed.

The advantage of Lidar technology for offshore applications are even more critical than the onshore because, this technology is proven to be a replacement of the mast. Elimination of the mast, creates a huge benefit for the design of the substructure to be placed to support the access platform. A platform topside equipped with lidar instead of the 80m mast makes the topside easy to install and decommission.

A verification test has been conducted between 19th March 2013 and 11th April 2013 and results show "consistent, highly-correlated measurements with slopes near unity" said Ecofys' official report. It continued: "The calculated uncertainty in the lidar wind speed measurements is in line with high quality anemometry. The calculated uncertainty tables can be used directly in wind resource assessments, together with the classification uncertainty and site-specific uncertainty components." [12].

With regards to this highly accurate laser technology, more cost effective topsides will able to be designed equipped with Lidar device, and necessary supporting components. Within the scope of this text, for the prospectivity measurements of the previously suggested locations are being proposed to be assessed.

2.8 The Measurement Campaign

For gathering acceptable wind resource assessment information and registering the information to the government authority for a location, the minimum duration is one year. This duration is important to have the statistical distribution of the speed and direction information. If the total number of the prospective locations are considered, more than one lidar mounted platform should be manufactured. 5 is the selected number of lidar platforms for fabrication in order to conduct the preliminary assessment period within reasonable time frame.

The purpose of the measurement campaign would be to evaluate the potential of the wind area and provide more accurate data for the wind resource assessment and securing funding for further research and development on the prospects.

At this point, it might be beneficiary for the government authority to fund the preliminary resource assessment project in order to clarify the wind potential of the proposed areas all together at once. According to this clarification, further policies and strategies can be prepared, a well defined basis of operational and monetary support can be identified for achieving the optimum development environment for offshore wind industry in Turkey. Cost recovery of this project can be done through sales of the measured data.

2.9 Design of the Measurement Platform

Regarding the design of the platform for preliminary wind resource assessment lidar device is the measurement tool for the wind parameters. Apart from the measurement device itself, there needs to be couple of other systems in order to be able to operate the tool at sea conditions such as communication and remote control system, electrical supply system driven by a small sized wind turbine generator or a solar panel, a battery room for being able to run the station during for longer times when input from the wind generator or solar panel is not enough. In addition to this, a backup diesel generator might be reasonable, if the main source of energy fails.

Another important point is that, although the lidar device is capable of providing high accuracy data almost identical with the conventional measurement tool, high accuracy anemometer, a secondary tool on the platform should be mounted for double checking of the lidar device. 30m of elevation is considered to be enough for placing the high accuracy anemometer. More reliable data gathering will be achieved by this dual approach.

With the general requirements represented above, a conceptual lidar mast has been put forward in figure 2.3 shall be with the particulars such as, the deck elevation of 20m above mean sea level, 15m of mast elevated on top of the deck, 5m x 5m of deck available space for mounting the related measurement and power systems placed on top of a monopile structure foundation.

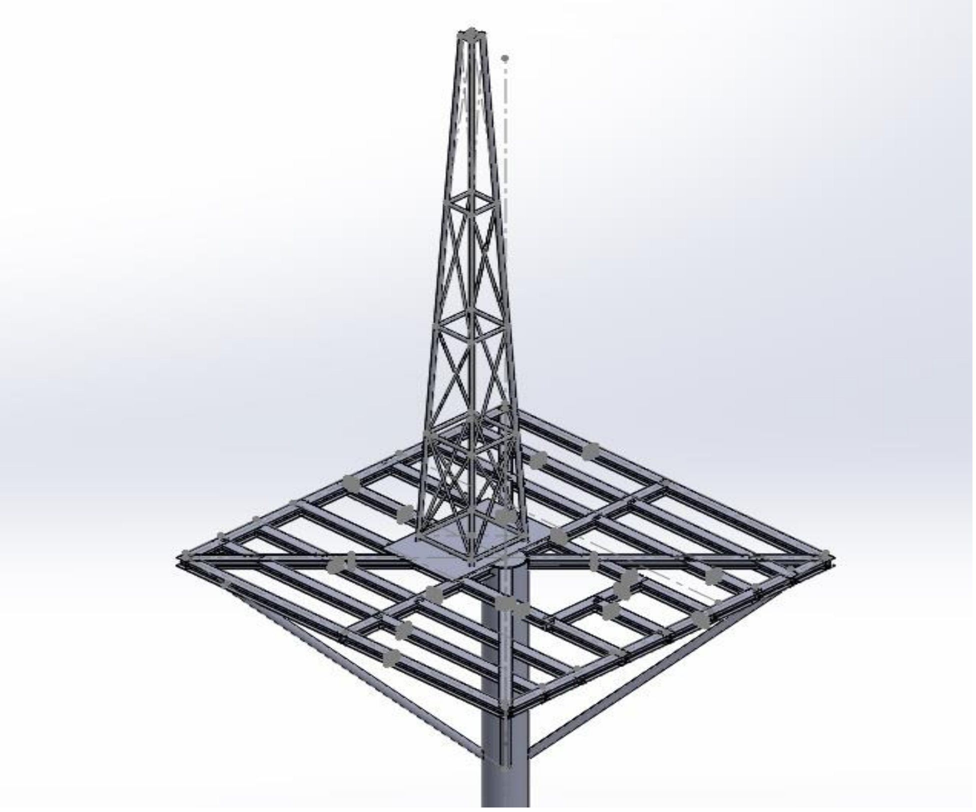

Figure 2.3: Conceptual monopile lidar equipped met-mast.

Within the 4th chapter of the thesis, a reference lidar platform at 30m water depth with the main particulars described above will be analyzed in terms of static, pile soil interaction and dynamic response of the monopile structure and natural frequency of the structure will be calculated.

2.10 Work Schedule for the Lidar Platform.

For the preliminary wind assessment of the 25 prospective areas and 45 prospective locations mentioned within the previous sections, 1 continuous year of data recovery is required for that particular location and 5 is the number of lidar platforms required for this project to be completed in a reasonable time frame of 10 years.

For the schedule of the platform installations, it is thought that, the pile will be inserted to the refusal point, caisson will be placed on top section of the pile and the clearance between the pile and caisson will be grouted. Later on, the topside will be welded on the caisson. After the one year period of data recovery, the topside will be decommissioned and will be disconnected from the caisson. The topside than will be installed on top of another monopile substructure and recommisssioned.

2.11 Determination of Capacity Factor and Turbine Selection

After recovery of definitive data from the proposed locations with the help of the measurement platforms, statistical data will be gathered and this data will provide more accurate idea on the turbine selection and determination of capacity factor at the particular area.

Table 2.3: Distribution of wind speed at 10m height in January-June period.

Range m/s	**Jan** %	**Feb** %	**Mar** %	**Apr** %	**May** %	**Jun** %
0-2	15.50	17.30	14.60	25.70	27.70	29.20
2-4	23.50	20.80	25.20	31.10	31.90	30.50
4-6	23.50	21.70	25.80	22.90	19.50	21.40
6-8	15.20	15.80	15.20	11.30	11.70	11.10
8-10	10.80	11.10	10.60	5.30	5.00	5.60
10-12	4.50	6.70	5.30	2.30	2.60	1.70
12-14	4.40	2.80	2.30	1.20	1.30	0.37
14-16	1.70	2.00	0.70	0.07	0.28	0.07
16-18	0.35	1.10	0.28	0.15	0.00	0.00
18-20	0.35	0.30	0.00	0.00	0.00	0.07
20-22	0.07	0.15	0.00	0.00	0.00	0.00
22-24	0.07	0.15	0.00	0.00	0.00	0.00
24-26	0.00	0.00	0.01	0.00	0.01	0.00
TOTAL %	100.01	99.90	99.98	100.02	99.98	100.01

A sample case will be discussed within this section of the thesis regarding the calculation of capacity factor calculation and application on a turbine. For this study, wind statistical data prepared for Akcakoca, Black Sea region will be used as an demonstrative example on annual average wind speed calculation [13]. Monthly wind distribution data averages between january and june period is given in table 2.3 and averages between july and december period is given in table 2.4. Distribution chart is given in figure 2.4. Detailed data tables are presented in Appendix-B section.

Table 2.4: Distribution of wind speed at 10m height in July-December period.

Range m/s	**Jul** %	**Aug** %	**Sep** %	**Oct** %	**Nov** %	**Dec** %	**Avg.** %
0-2	23.00	14.80	20.70	19.80	17.70	13.90	19.99
2-4	27.10	23.30	24.30	22.90	22.90	19.20	25.23
4-6	24.00	24.90	25.40	21.10	22.60	23.20	23.00
6-8	13.40	18.90	16.30	15.90	14.60	17.30	14.73
8-10	8.00	11.30	7.60	10.10	9.20	11.50	8.84
10-12	3.00	5.30	4.10	5.10	7.10	6.60	4.53
12-14	1.40	1.20	0.97	2.70	3.10	4.00	2.15
14-16	0.07	0.20	0.35	1.40	1.90	2.30	0.92
16-18	0.00	0.00	0.14	0.54	0.69	0.65	0.33
18-20	0.00	0.00	0.07	0.47	0.28	0.85	0.20
20-22	0.00	0.00	0.00	0.00	0.00	0.20	0.04
22-24	0.00	0.00	0.00	0.00	0.00	0.26	0.04
TOTAL %	99.97	99.90	99.93	100.01	100.07	99.96	99.98

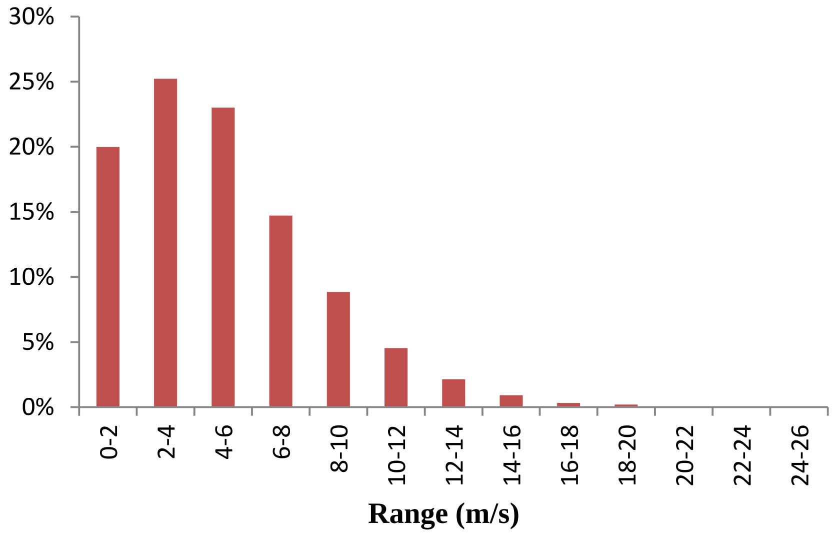

Figure 2.4: Statistical distribution of wind speed at 10m.

Wind speed changes at a particular height can be predicted with the measured data from another height. The most common equation for this prediction is the Hellmann's equation [14].

$$V_W = V_{W_{ref}} \left(\frac{H}{H_{ref}} \right)^{\mu} \tag{2.1}$$

where; V_W is the wind speed to be estimated at particular elevation, V_{Wref} is the reference wind speed at measured elevation, H_{ref} is the elevation of wind measurement, and H is the elevation of the level intended to be estimated and μ is the Hellman constant for a particular region and is assumed to be 0,2 [14]. Weighted averages are given in table 2.5 and calculated average in figure 2.5.

Table 2.5: Average wind speed at 10m height.

Range m/s	Avg m/s	Share %	Weighted %
0-2	1	19.99%	0.20
2-4	3	25.23%	0.76
4-6	5	23.00%	1.15
6-8	7	14.73%	1.03
8-10	9	8.84%	0.80
10-12	11	4.53%	0.50
12-14	13	2.15%	0.28
14-16	15	0.92%	0.14
16-18	17	0.33%	0.06
Average wind speed at 10m			4.96

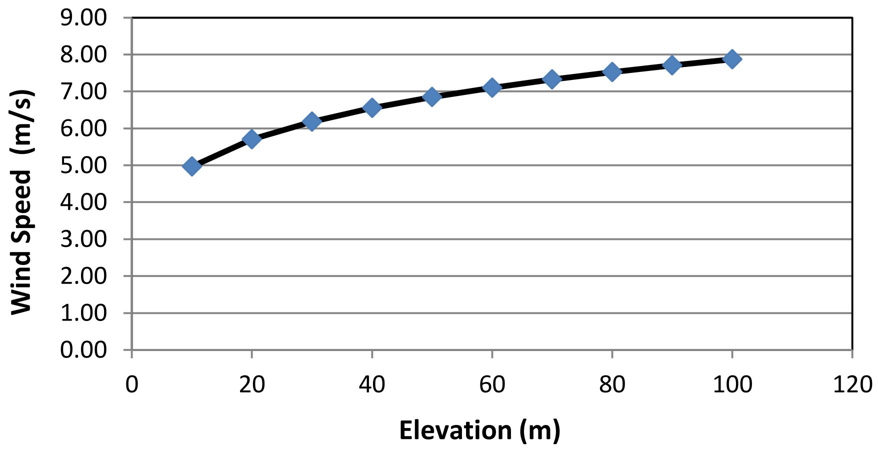

Figure 2.5: Average wind speed at different heights.

According to the Hellmann's equation the average wind speed at 100m hub height is assumed to be 7.9m/s

For obtaining an estimation of capacity from the average wind speed Siemens SWT-7.0 154 offshore wind turbine is selected. The cut-off wind speed is 3.0m/s, wind speed reaching 7.0MW power rating is 13m/s and cut-out wind speed is 25m/s for this turbine and swept area of the turbine is 18600m^2.

In order to fit a power output curve for different wind speeds, a correlation of the form

$$P(V) = \beta x \rho x A x V^3 \tag{2.2}$$

will be used.

Where $P(V)$ (W) is the power output of the turbine, $\rho = 1.225$ (kg/m^3) is the density of air , $A = 18600$(m^2) is the swept area of the selected turbine and V (m/s) is the corresponding wind speed.

Since it is known that at 13m/s wind speed, the turbine produces the rated power of 7.0MW than the dimensionless β-factor for this turbine is 0.1398

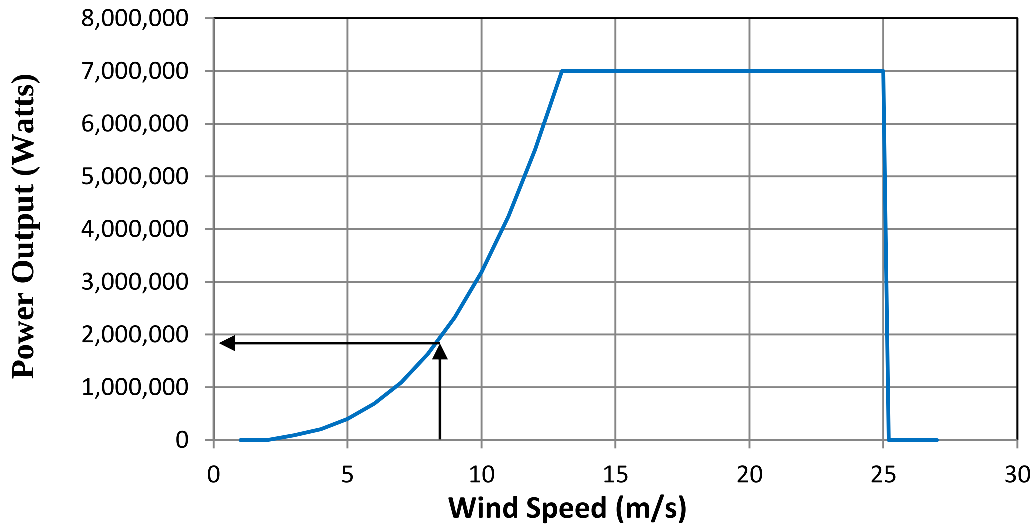

Figure 2.6: Capacity factor determination from power output vs wind speed.

According to the estimated average wind speed and estimated power output curve the capacity factor estimated for the location data given area is $1.95x100/7.0$ =27,85%.

To sum up for this section of the discussion, decision on the proper turbine depends on average wind speed and statistical distribution at the particular project area and the relation between output power curve of the turbine and average wind speed at particular hub-height of the wind turbine.

2.12 Further Assessment of the Wind Asset

After the preliminary measurement campaign described within the previous sections and gathering of 1 year data from the locations of interest, conducting preliminary assessment of turbine capacity factors, more definitive information will be available in hand will be used in order to justify and supply funding for the further assessment of the wind asset.

Further assessment should include various aspects such as the gathering of detailed bathymetric data at particular area, determination of soil and seabed characteristics for evaluation of pile soil interaction for different types of sub-structures, a pilot turbine installation for having more definitive information on power output, gathering of wave and current data in order to work on the dynamics and fatigue design of sub-structures, geological assessment of the prospect in terms of faults and earthquake considerations, evaluation of the electrical infrastructure of the closest land station and determination of applicable capacities of wind turbine installation, further wind measurements from different parts of the prospective area and combining this data with the land data in order to create a detailed wind model for the prospect, selection of the dominant wind directions and optimization of the alignment plan and distance between turbines and wake loss modeling of the determined alignment plan.

With regards to the related areas of study for each particular prospective area, well defined offshore wind farm project plans and workflows can be developed and these programs can be issued for approval from the government authorities, thus, financing of the projects can be applicable.

2.13 Wind Farm Conceptual Study

For a realistic offshore wind project concept to be put into the operational scenario various data from the 62 offshore wind farms currently being on-line has been gathered from the 5 leading countries within offshore wind industry and data tables are included in the Appendix-C section [15],[16],[17],[18],[19].

Statistical distribution of the farms in terms of various parameters are given in figure 2.7, figure 2.8, figure 2.9, figure 2.10 and figure 2.11.

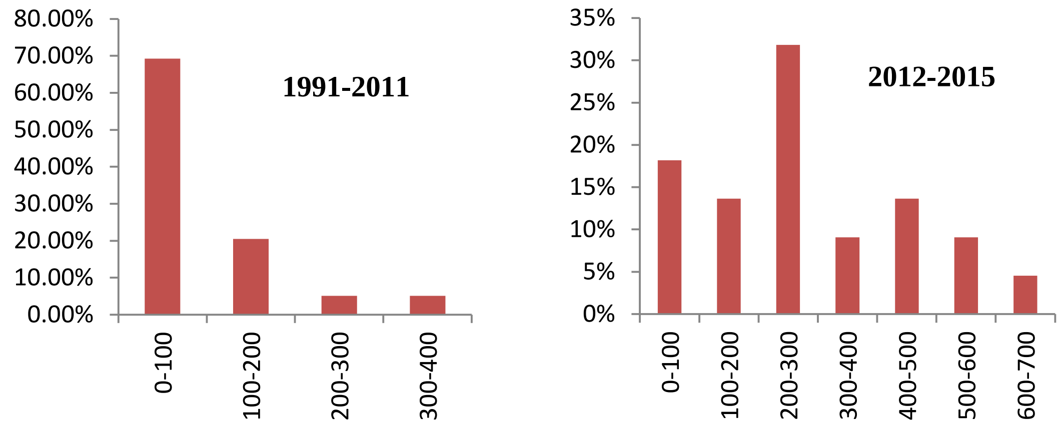

Figure 2.7: Wind Farm Capacities Distribution (MW).

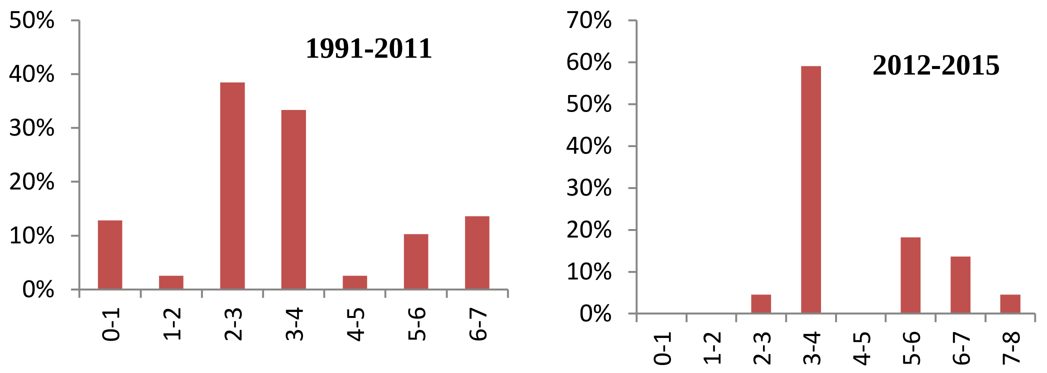

Figure 2.8: Turbine size distribution (MW).

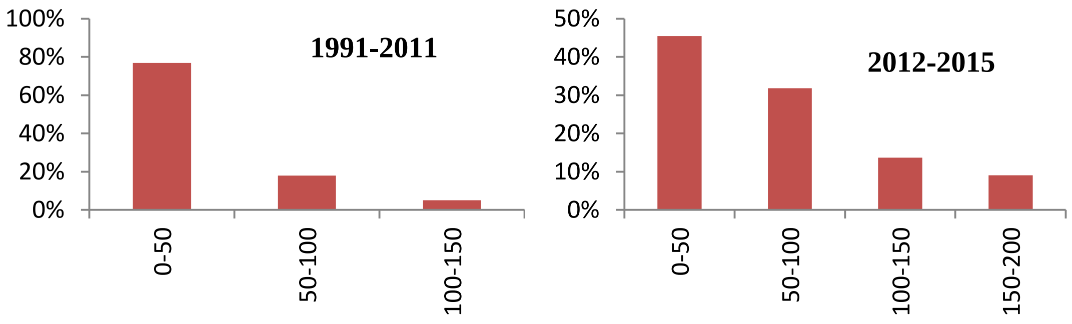

Figure 2.9: Number of turbines per farm distribution.

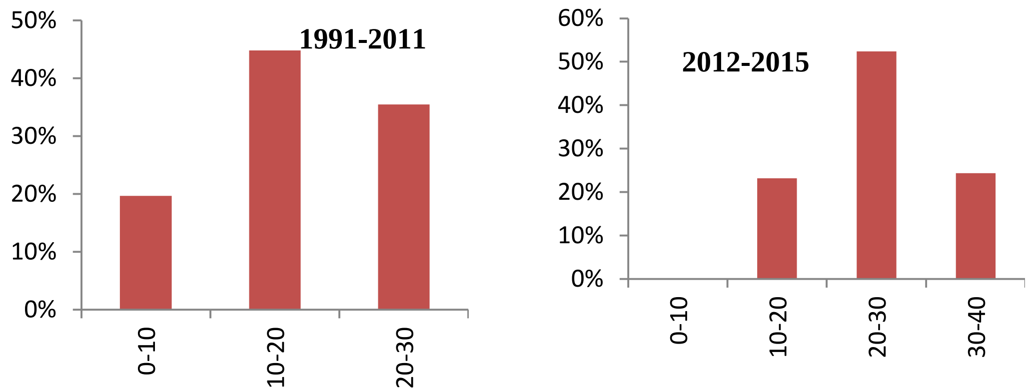

Figure 2.10: Water depth distribution of turbines (m).

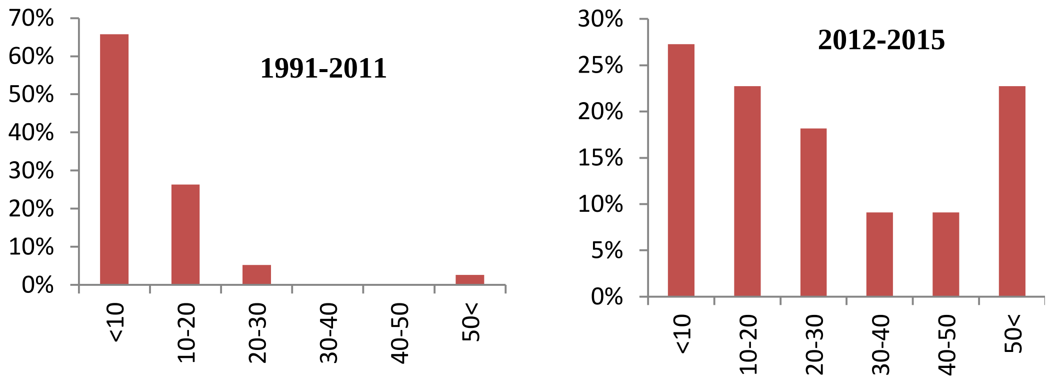

Figure 2.11: Distance of the farm to land distribution (km).

Five different characteristics such as total capacity of the offshore wind farms, individual turbine sizes, number of turbines per farm, water depths and distance of the farm to shore are compared between the time intervals of 1991-2011 and 2012-2015.

It can be said that the average size of an offshore wind farm increased to 300MW capacity from 50MW within the last 5 years and upcoming projects are in the ranges of 1000MW - 2000MW. In addition to this, individual turbine averages increased from 2 MW to 4MW and in upcoming projects sizes are 6MW and above. In terms of the number of turbines per farm, the averages increased from 30 up to 80 and in many of the new projects these numbers are over 150. For the water depth, over 50 % of the new capacity is in between the range of 20m-30m and upcoming projects are averaging around 35-45m water depth. The figure 2.12 presented below indicates the distance to shore vs water depth distribution of the upcoming offshore wind farm projects in Europe [20].

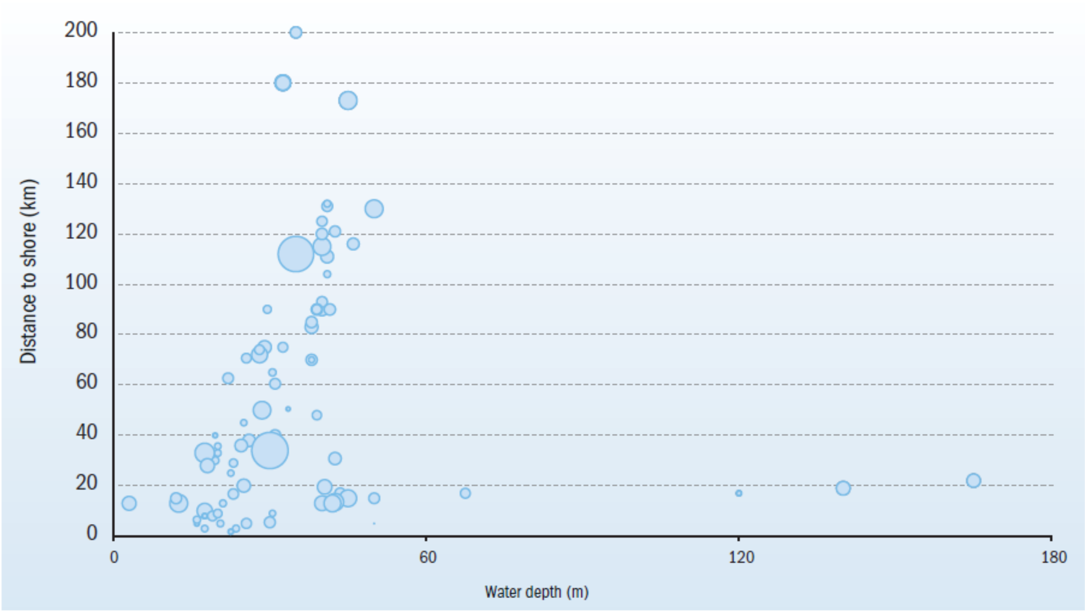

Figure 2.12: Distance shore vs. water depth for upcoming offshore wind projects.

With regards to the statistical information, the trends in European Offshore Industry shows a clear picture of the upcoming 20 years. The wind turbine power of an average wind turbine will seem to be in between 6-8MW, water depth range will be in between 35-45m, average distance to shore will be in between 50-100km and total capacity of an average wind farm will be in the range of 500MW-1000MW.

At this point, in order to represent a realistic scenario in terms of offshore wind farms, 7MW of capacity is selected, distance to shore is selected as 50km, water depth is selected as 40m and size of the farm has been selected as 150MW within the operational scenario and Monte Carlo simulation chapter.

Within chapter 4, a reference type of wind turbine jacket at 40m water depth will be discussed regarding the dynamic behavior of the jacket structure.

3. OFFSHORE UPSTREAM PROJECTS

Within the scope of this thesis, the operational scenario introduced for evaluation will cover various types of offshore upstream type of projects. The offshore upstream operations will be defined and operational requirements will be discussed in detail. The main purpose of this is to show the difference in approaches to different types of upstream operations such as; further development of a marginal field, development of an offshore natural gas field and development of a field abroad.

3.1 Offshore Gas Storage

3.1.1Requirement for natural gas storage

Natural gas storage is a strategic issue for the natural gas markets without access to local resources. The dynamic nature of natural gas consumption is quite complex and extremely difficult to model through time. The uncertainty of the consumption and supply model comes from very different factors such as uncertain nature of the on climate conditions, electricity consumption fluctuations and the reliance on natural gas for electricity, fluctuations in industrial consumption related with economical situation of the country, possibility of technical problems in the supplier side and so on.

This complex nature of the supply and demand modeling and critical requirement of uninterruptable supply of gas to customer requires the solution of reserving some amount of buffer gas for the periods of undersupply of the market.

In addition to the aforementioned requirement of gas storage coming from the dynamic structure of the supply and demand, there is also a strategic requirement for the countries without reserves. In the event of war or if force majeure conditions occur, these type of states needs gas storage facilities to sustain the economical activities and industrial production in order to prevent a catastrophic impact on overall economy.

Important parameters for setting up the natural gas storage targets of a country is that the overall daily consumption of gas and projections, the amount of gas required to sustain the economy during a cut-off in gas supply, the duration required for the country to be able to run on shortage and so on. The total required storage capacity for Turkey is set at 10% of the annual consumption and it is projected to be 70BCM in 2023 and requires 7BCM of available storage capacity and there are a numerous projects are ongoing in Turkey to reach the selected target of 7BCM capacity by 2023 [21].

Apart from setting up targets for the bulk recoverable volumes as storage for the sustainable gas market within the country during shortage periods, there is another important, maybe more, aspect to be worked on. The daily production and injection rates from/to gas storage reservoir is a lot more important than the total volume of the recoverable gas reserve figure itself if short-term shortages, fluctuations in gas supply and dynamic behavior of the climate conditions are considered. Having high production and injection daily capability rates up to the total daily consumption of the market provides the full flexibility for the operating company of the natural gas grid by easily controlling the rates and pressures within the distribution pipelines.

With the help of this powerful tool of flexibility on injections and production rates, optimizations can be made on the line pressures throughout the total gas grid and thus economical benefits on utility gas consumptions for the compressor stations can be realized.

In order to have this tool for optimization of the natural gas grid, Turkish Petroleum has announced their interest on investment for a third phase development project in order to further develop the natural gas storage field currently being operated in Silivri.

The project consists of construction, installation, commissioning of two fixed offshore jackets, 24 deviated offshore storage wells purposed both for production and injection at rates around 80,000 SCM/day and a related capacity increase on onshore gas plant in terms of gas process, purification and compression. With the help of this facility development project, TPAO will be able to supply almost all off the daily consumption of the Turkish gas market and the purpose of flexibility of the gas supply to the market during short-term shortages or in cases where gas supply is more than consumption will be achieved [21].

In figure 3.1 and figure 3.2, purpose of the project can be clearly visualized. The wells will be drilled to the same reservoir volume and aim is not to increase the storage volume. In the current set up, the offshore platform is being used for only production purposes because, these wells were drilled as natural gas production wells and casing grades are not fit for injection pressures. Gas supply to the current storage reservoir is being handled via the onshore extended reach wells.

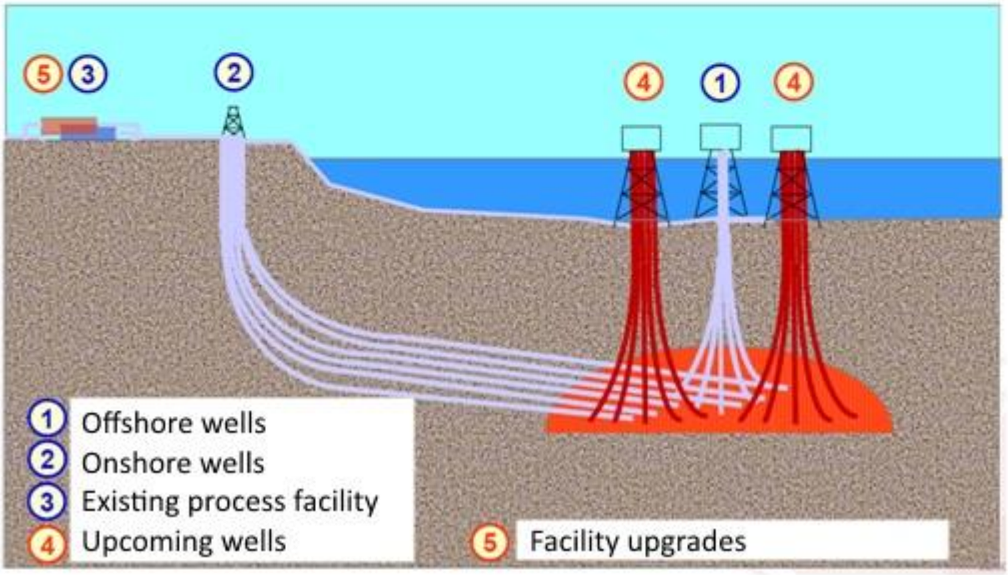

Figure 3.1: Field diagram of Silivri storage reservoir [21].

Figure 3.2: Alignment plan of Silivri storage field [21].

3.1.2 Initial considerations on project design

In order to run a successful and cost effective offshore project, some of the operating decisions shall be made under a reasonable operational approach. In this section of this text, it will be tried to cover some of these operational decisions.

First of all, since there is a lot being known about the reservoir parameters such as, permeability, porosity, physical boundaries of the reservoir, expected flow and injection rates, planned trajectories of the new wells, it can easily be said that, offshore drilling operations can be designed with high precision.

For this type of a field development operation given in figure 3.3, where there is a lot known about the subsurface parameters, the target of avoiding subsea tie-back operations can be achieved since there is no need for an appraisal well to be drilled before the installation of the offshore jacket structure.

Figure 3.3: Representative side layout for operation over a jacket [22].

In addition to this advantage, installation of the topside of the jacket platform before drilling of the wells also is operationally applicable in this case of operations. The applicability is dependent on the water depth of the field, expected leg penetration length, the topside height and air gap elevation between top of the topside and texas deck of the jackup drilling platform. At water depths around 50m, with a leg penetration of 10m into the seabed and 25 meters of topside elevation and an additional 5m above the topside top level, the required working elevation for the Jackup rig at this condition will be 90m and this required length shall be compared with the rated water depth capability of the jackup rig to be selected.

3.1.3 Important points on offshore storage well design

The selected jackup rig shall be a cantilever type of rig, this is required in order to have the flexibility of being able to drill many wells without changing the location of the Jackup barge. Cantilever system is basically designed for the rig to be able to step out of the barge. Depending on the rig and barge properties, cantilevers can extend out around 70ft out of the barge, thus operational flexibility is achieved.

Another important matter about initial considerations about the offshore rig operations is that the wells should be drilled in a batch drilling manner. The optimization can be reached by combining the drilling operations section by section and thus eliminate the logistic transfers of drilling materials back and forth from rig to shore base, rigging up and down of the drilling equipment, and breaking up and down of the bottomhole assembly for each well section. This approach is applicable, if multiple wells are being drilled at the same location.

Another advantage coming from the batch drilling approach is related with the drilling fluids. Since the same hole sections are being drilled one by one, drilling fluid consumption can be optimized and all of the corresponding sections can be drilled only by volume additions to the base mud system.

Mud line suspension system is not required since there is no need to temporarily abandon and tie back, but in any case it would be wise to hang the production casing on the intermediate casing.

3.1.4 Offshore storage jacket design

As it was previously mentioned, Turkish Petroleum Corporation is planning to install two jacket type of production and injection platforms at 24m and 46m water depth. The function of the jacket will be to provide access to wellheads and well manifolds for controlling the flow, carry measurement and processing equipment such as separators, scrubbers, flare line, well testing line, providing a working area for wireline pressure surveys, perforation operation, carrying electrical and electronic instruments such as scada system and control systems in order to conduct safe operations.

Within chapter 4, a reference jacket with 6 legs given in figure 3.4 will be discussed in further detail in terms of the dynamic behavior of the jacket and the topside.

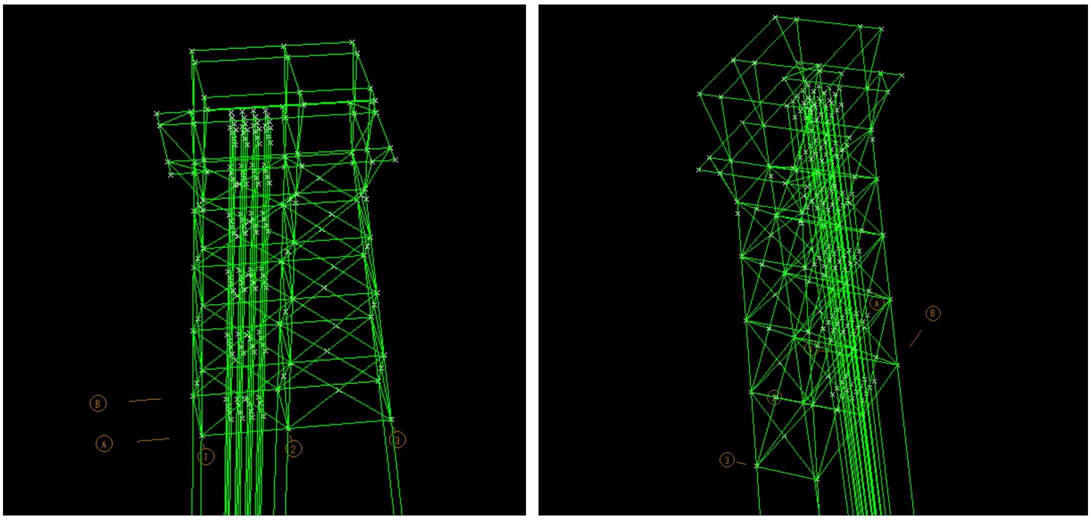

Figure 3.4: Reference type of Storage jacket at 46m water depth.

3.1.5 Incorporation of gas storage project into the financial model

It is quite complex to incorporate a natural gas storage model covering up the market into this type of a model mainly focused on offshore construction and development operations. In order to provide a reasonable basis of understanding about the economics of the offshore construction and development operations for natural gas storage operations, a series of simplification is applied in order to show the main dynamics of the cost and revenue mechanisms.

The first simplification of the model comes from the extent of the project itself. Basically, TPAO does not consider this natural gas storage facility upgrade as a reservoir volume increase and thus, addition of extra gas volume into the storage reservoir is not considered within this financial model.

A second simplification assumption is that the storage reservoir is full at the beginning and the amount of gas being produced from the storage reservoir is put back into the reservoir within the same year period.

Another simplification is coming from the idealization of the market. A developed and well functioning gas market is assumed to be fully developed in terms of consumption capacities, supply and natural gas market relies on the production of the gas storage facility during winter periods where excess consumption is observed due to household heating purposes. In other words, gas storage reservoir is considered to be a gas supply point in addition to the main function of being a strategic buffer for the economy.

3.2 Development Project on Marginal Offshore Field

A second upstream model intended to be introduced in the overall financial simulation scenario is the development considerations for the natural gas fields which are considered to be uneconomical or marginal.

As explained in the introductory chapter, the marginality considerations are dependent on so many different factors and within this section, a specific case regarding Akcakoca offshore natural gas field will be discussed and the financial simulation will be run according to this demonstrated case.

3.2.1 Background information on Akcakoca gas field

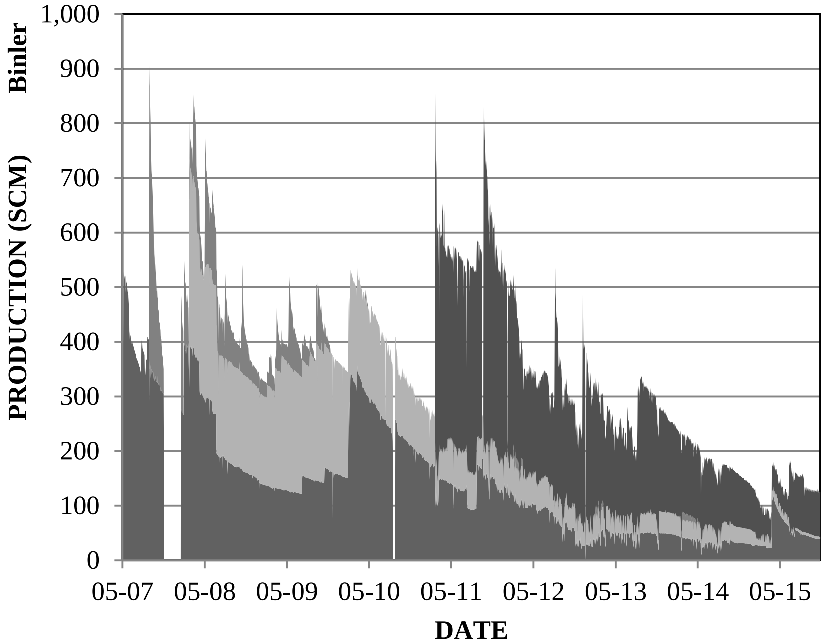

Figure 3.5: Sasb production vs. time plot.

Akcakoca gas field was discovered in 2005 and two stages of development projects are completed within 2006 - 2012 period. First gas has reached to shore in mid-2007 and so far 38BCF of gas has been produced, and field production chart is given in figure 3.5. Field is producing from 7 offshore natural gas wells from 3 tripod type production platforms installed at 62m, 71m and 79m. In addition, there are three wells producing from a four legged production platform which is installed at 94m of water depth. Field layout is given in figure 3.6.

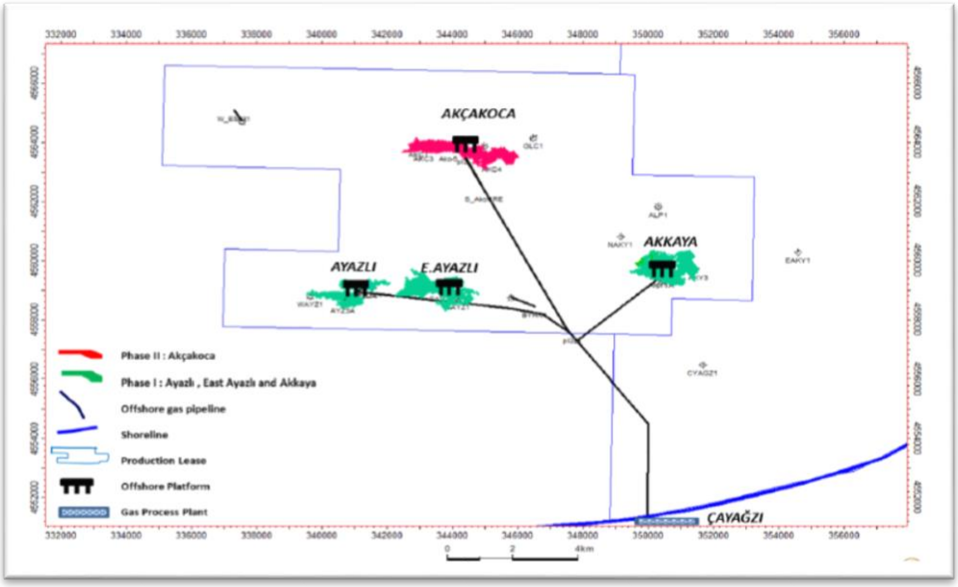

Figure 3.6: SASB field layout.

3.2.2 Marginality considerations for SASB

After 2 phases of development on Akcakoca field, so far the project has not recovered the total investment has been made for exploration, drilling, offshore and onshore construction and it is unlikely to recover if the remainder of the reserves are not developed.

Figure 3.7: SASB phase-II development site setup - tender assisted rig concept.

There are several reasons can be mentioned about the reasons such as the offshore installation failures experiences occurred in 2005, drilling of too many appraisal wells without careful consideration of development methodology, over-estimation of recoverable reserves and etc, selection of a non-compatible development concept for phase-2 development given in figure 3.7, but is not included in the scope of this thesis.

At this point, what needs to be done for this field is to re-evaluate the further potential in a realistic manner. The reservoir behavior is well known and re-assessment of the seismic data with regards to the existing production profiles shall be analyzed in order to justify a third phase development project.

Within the third phase of development proposal, in order to be on the positive side, it has been observed that, additional investment on field infrastructure development such as installation of new production jackets, offshore pipeline laying, subsea tie-back operations should be avoided and targets within the accessible range from existing infrastructure should be exploited. By this way, the investment will only be made on well operations.

3.2.3 Prospective resources

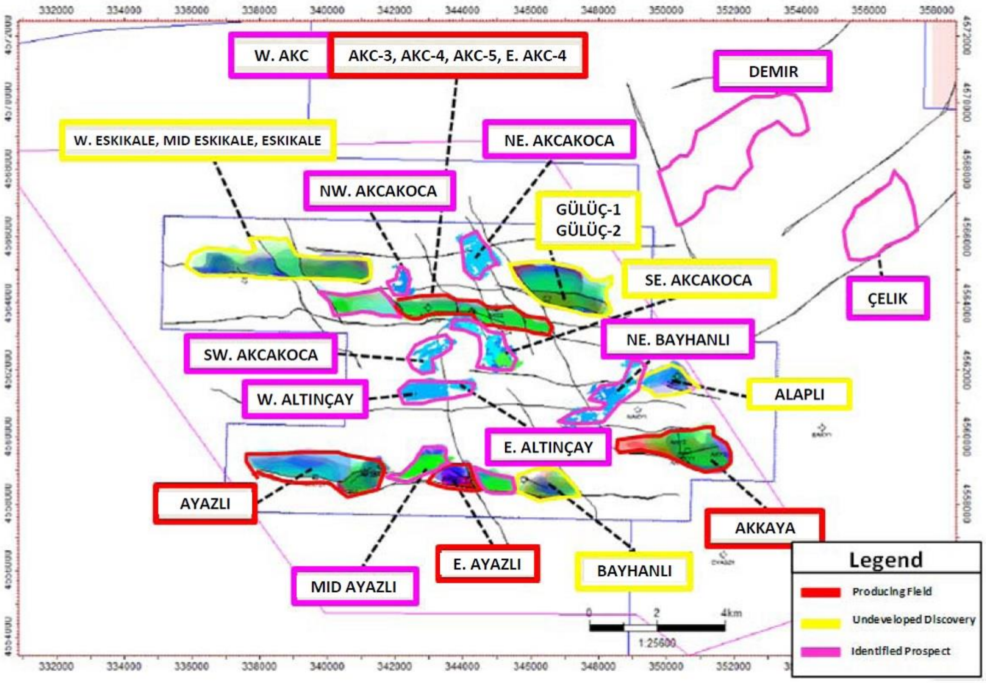

Figure 3.8: SASB prospective resources alignment.

As can be seen on the Figure 3.8 there are several prospects exist untouched. The ones depicted with yellow color represents the drilled and tested but not developed prospects, red colored areas indicates the producing reservoirs and purple colored areas are the undrilled prospects.

Within table 3.1, the prospective reserves are tabulated by Tiway's geophysicists in 2014 [23] according to this table, the defined recoverable reserve remaining in Akcakoca apart from the first two phases is 76,9 BCF. Estimates may change from one to another, quite difficult to justify due to the high uncertainty of geophysical and geological studies, but to continue further on the operational plan, these reserve figures, vertical depths and horizontal distances of the targets will be based upon.

Table 3.1: SASB remaining prospective resources [23].

PROSPECT	HOR. DISTANCE (m)	VER DEPTH (m)	REC. RES (BCF)
FROM AKCAKOCA PLATFORM			
GULUC	3000	1200	18
SOUTH AKCAKOCA	1750	1150	2,8
SW AKCAKOCA	1800	1150	7
W AKCAKOCA	2600	1200	6.9
NE AKCAKOCA	1000	1200	7
NW AKCAKOCA	1700	1200	5
W ESKIKALE / NOT ACC.	7300	1250	3.4 /NA
ESKIKALE / NOT ACCESSIBLE	6500	1200	5.0/NA
EAST ESKIALE / NOT ACC.	4600	1200	5.0/NA
FROM AKKAYA PLATFORM			
ALAPLI-1	2300	1000	3.1
NW AKKAYA	2500	950	3.7
FROM AYAZLI PLATFORM			
AYAZLI-1	600	600	2.3
ALTINCAY WEST	2900	1000	4.6
NORTH AYAZLI	1600	750	2.5
FROM EAST AYAZLI PLATFORM			
BAYHANLI-1	2400	750	2.3
ALTINCAY EAST	2200	1000	4.6
EAST AYAZLI-3	1200	900	2.5
MID AYAZLI	1200	750	4.6
TOTAL ACCESIBLE RESERVE			**76.9**

3.2.4 Operational capabilities

Operational capabilities compatible with the cost effective approach for the further development of the field will be put forward within this section of the discussion.

3.2.4.1 Over tripods

Positioning along and working over tripod platforms is applicable with a long legged cantilever type jack-up rig. The rig can be positioned along the existing tripods, with the higher elevation and cantilever standoff capability, various operations over tripods are applicable. For Akcakoca field the representative site layout of the jackup rig and the production platform is given below in figure 3.9.

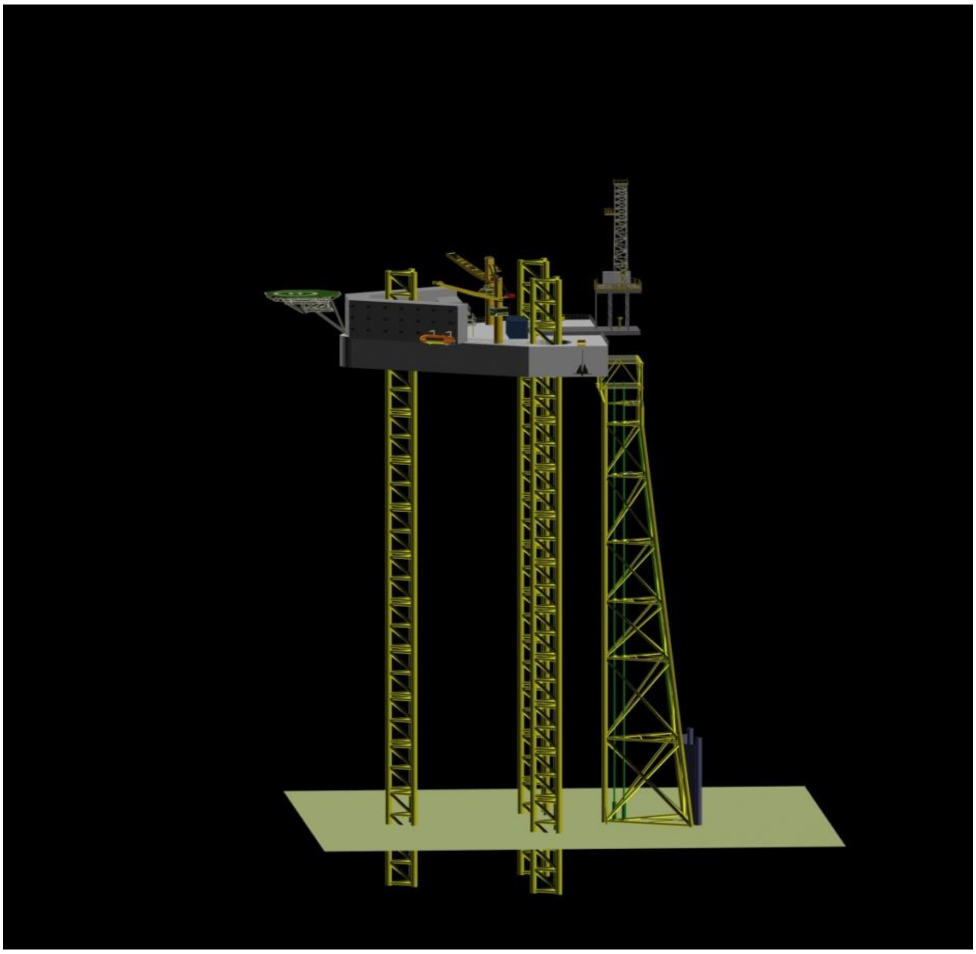

Figure 3.9: Side view of site setup of jackup rig over a tripod.

Jackup up rig with 375ft of usable leg length below hull is required as can be seen from the previous leg penetration data at specific site, water depth, topside elevation and meet clearance requirements and relevant information is given in table 3.2.

Table 3.2: Leg requirement for Jackup rig to park over existing tripods.

	Ayazli	East Ayazli	Akkaya
Leg Penetration (m)	11.3	19	14
Water Depth (m)	79.5	71	62.5

Topside Elevation (m)	18.3	18.3	18.3
Clearance (m)	5	5	5
Leg Requirement (m)	114.1	113.3	99.8
Leg Requirement (ft)		~375ft	

After parking the jackup rig along the tripod and positioning the cantilever on top of the topside, three different type of operations can be conducted.

a. Re-entering to the existing producers and recompletions over tripods: Workovers on existing producers over current topsides can be carried out without any modification or removal of the current topside facility.
b. Re- entering to producers, cementing and side tracking over tripods: All the phase 1 producers are equipped with 9 5/8" production casings. This provides the capability of sidetracking out of the wellbores right below 13 3/8" casing shoes, holes can be extended out with 8 1/2" directional string and recompleted with 7" strings.
c. Drilling new wells over tripods: Technically parallel to the first option, East Ayazli and Ayazli platforms do have available slots (1 each) for drilling new well without requirement of topside modification and additional wells can be engineered inside the existing tripods with minor topside modifications.

Within the scope of the operational scenario to be presented in chapter 5 and the related financial simulation presented in chapter 6; type 'a' and type 'b' is not included in the discussions for the sake of simplicity and requires more irrelevant discussion in terms of well intervention and drilling technologies.

3.2.4.2 Alongside Akcakoca structure

Water depth at Akcakoca structure is 94m and with expected seabed, and with leg penetration 10m to the seabed and 10m of clearance from mean sea level, required leg length below hull is 114m which corresponds to 375ft. But since the leg penetration at the particular location is an estimation, selection of a Jackup rig with 400ft of rated water depth capacity would be beneficiary in order to be on the safe side.
Since the rated water depth capacity is not enough for the rig to be placed on top of the structure, parking of the rig can only be done on the port or starboard side of the jacket.

A possible site setup has been demonstrated in Figure 3.10. From this location, 8 wells Guluc (3) - NW Akcakoca - NE Akcakoca - SW Akcakoca - SE Akcakoca - W Akcakoca can be drilled and put into the operational scenario and financial simulation.

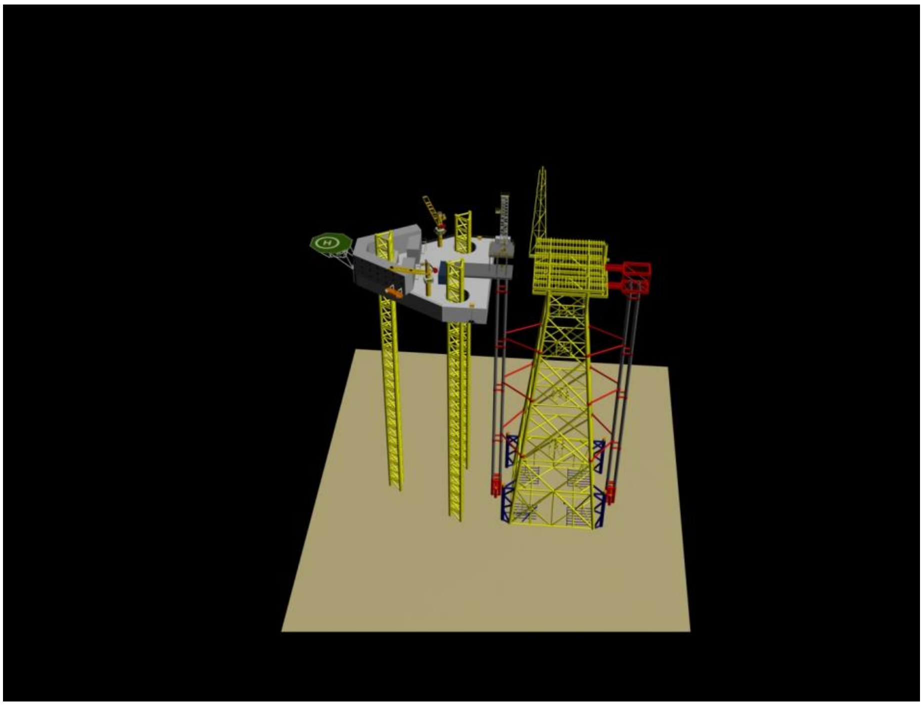

Figure 3.10: Site setup at Akcakoca location.

3.2.5 Rig specification requirement for both options

- ✓ BMC400, or KFELSB or Super 116E LT-240C, FG-JU2000 designs are all fine.
- ✓ 400ft or higher usable length below hull is required.
- ✓ The rig has to sit on cantilever. Cantilever reach shall not be less than 55ft. (17m)
- ✓ Over 1,000,000 lb lifting capacity.
- ✓ Table opening 37.5"
- ✓ 3 Mud Pumps for increased hydraulics for deviating at shallow depths with larger diameter holes.
- ✓ Rig to be equipped with a proper top drive plus capability to switch to rotary table in case of a sudden failure.

Note: Please note that the rig specs required for Akcakoca operational considerations are also capable of conducting proposed operations in the proposed storage project and the wind turbine installation operations at water depths up to 60m.

4. STRUCTURAL CONSIDERATIONS

Within the scope of this chapter, fixed structural requirements for the aforementioned type of offshore operations will be discussed, reference type of fixed structures will be put forward and dynamic response of each fixed structure will be analyzed with SACS offshore analysis software.

4.1 Analysis Methodology

In order to design an offshore fixed structure, the first two important critearias are the water depth at the installation location and amount of weight to be carried above the water level.

With regards to these two parameters, design engineer can apply different types of reference designs, compare, select the type of structure with better results and analyse further in order to cover up all the remaining related aspects of the overall design.

Before starting the analysis, first stage is to define the required parameters and some of the important parameters are listed below:

- definition of number of legs of the structure, batter of each leg, geometry at working point, other elevations of horizontal bracing, X and K brace elements.
- definition of member diameters and material thicknesses.
- definition of pile heads, pile diameters, pile batter, soil data and pile driving depths
- definition of loads to be carried such as dead, live, equipment, anodes and etc.
- definition of environmental data such as wave, wind, current and marine growth,
- definition of loading combinations and creation of different critical loading conditions.

After definition of the structure model and the critical environmental conditions, the next step is to observe the static response of the proposed model at given critical load and environmental loading conditions. Occuring stresses at each member is being calculated and divided into the allowable stress of that member. If result is over 1, that means, the element diameter or thickness should be increased because the member will most probably fail under severe loading conditions.

The static case runs should be done until the ratio of all the member stresses within the physical model over the allowable stresses are below 0.5, with 100% safety factor. If this condition has been reached, than it can be said that the model will stay as it is under severe loading conditions.

At this point, further optimisation can be done in order to make use of less material if the member stress/allowable stress ratios are significantly below 0.5 under the severe loading conditions.

Once the static case has been run and optimised, the next step is to introduce the pile elements, diameter, thickness, pile drive depths and soil information. This is required in order to see the foundation stresses occuring after the introduction of the piles and observation of the deflections related with the overall moment on the structure. At this point, the overall moment created by the frictional forces on piles against the soil is compared with the overall moment created by the extreme current, wind and wave loads. If overturning moments are higher than the resistance of the soil, additional skirt piles can be added onto the structure in order to improve the conditon or the base area of the model shall be increased by going back to the first stage of the design by changing the batter of the leg elements. Once this stage is cleared it can be said that the static in-place analysis is completed.

The next step on the design is the determination of dynamic response of the model, natural frequencies and added masses at different mode shapes. These parameters are being used in order to compare the natural periods with the wave period information and observe probability of occurance of resonance. If periods are close to each other, the designer should go back to the model and change the geometry or stiffness characteristics of the model.

After extraction of the mode shapes and determination of the natural period of vibrations, the next steps are to test the model against various dynamic conditions such as severe earthquakes or determination of fatigue on the structure due to vibrations occuring related with the wave, current and wind. Fatigue life of the structure than can be estimated with introduction of statistical wave and wind input spectrum at the particular platform location.

Within this study, determination of natural frequencies of the proposed structures will be the final step for each analysis.

4.2 Input Data

Input data is taken from the dynamic Atkin's fatigue analysis report issued for the Ayazli Platform in SASB field. All the different types of substructures will be run in dynamic analysis with the environmental loading information from Atkin's report on fatigue analysis [24].

4.2.1 Wave

Wave data has been extracted from Glenn and Associate's report [25] on Akcakoca Black Sea Area and given in table 4.1.

Table 4.1 : Wave conditions applied on structural analysis [25].

	Operating Condition	Extreme Condition
Wave Height (m)	6.0	12.0
Wave Period (s)	12.0	15.0
Wave Direction (deg)	0/45/90	0/45/90

4.2.2 Wind

Wind data has been extracted from Glenn and Associate's report [25] on Akcakoca Black Sea Area and given in table 4.2.

Table 4.2 : Wind conditions applied on static structural analysis [25].

	Operating Condition	Extreme Condition
Wind Velocity (m/s)	25	45
Direction (deg)	0,45,90	0,45,90
Height variation	AP08	AP08

4.2.3 Current

The static effect of current has been neglected on dynamic case analysis in accordance with the recommendations of API RP-2A but included in static case analysis [24] and related current parameters are given in table 4.3

Table 4.3 : Current conditions applied on static structural analysis.

	Operating Condition	Extreme Condition
Current velocity at mudline (m/s)	0.5	0.5
Current velocity at mean sea level (m/s)	1.0	1.5
Current Direction (deg)	0,45,90	0,45,90

4.2.4 Drag and inertia coefficients

The following drag and inertia coefficients on table 4.4 have been used for calculating the wave forces on members using Morrison's Equation.

Table 4.4 : Drag and inertia coefficients.

Smooth tubular members	
Cd = 0.50	Cm = 2.0
Rough tubular members	
Cd = 0.8	Cm = 2.0
Flat members	
Cd = 1.6	Cm = 2.0

4.2.5 Dead loads

Includes the weight of the deck plating, stiffeners, grating, handrails, staircases, operating equipment, piping and contingencies have been applied on top to cover uncertainty [24]. Contingencies for structural assessment are given in table 4.5.

Table 4.5: Contingencies for structural assessment.

Load	Contingency
Substructure Dead Weight	0 %
Superstructure Dead Weight	0 %
Area Live Loads	10%
Environmental Loads	10%

4.2.6 Live loads

Live loads to be used for the dynamic analysis is given as follows in table 4.6.

Table 4.6: Live loads.

#	Item	kN/m^2
1	Operating Area	2.5
2	Walkway	0.5
3	Drilling Load	2.5

4.3 Lidar Tower

Purpose of this structure is to carry the wind measurement equipment in order to conduct long term wind measurement at specific locations. The tower on the platform reaches to 30m of elevation above mean sea level and is a government criteria for the point of measurement to be registered into the national wind database. Monopile structural design parameters are tabulated in table 4.7. A representative structure is given in figure 4.1.

Table 4.7: Monopile structure properties.

Structure	Met-mast	Wall Thickness	4"
Water depth	30m	Pile Diameter	44"
Deck Area	5m x 5m	Pile w.t.	4"
Leg Diameter	48"	Total Weight	2,940kN

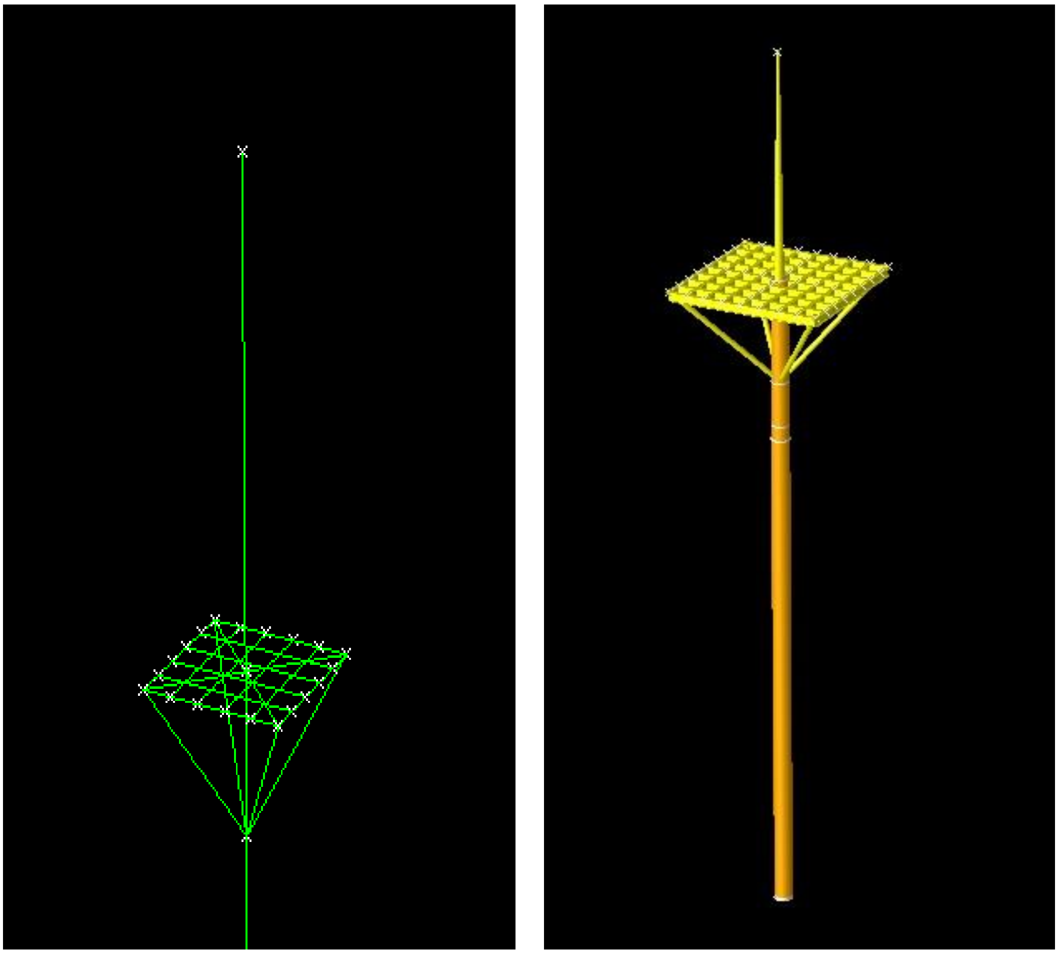

Figure 4.1 : Met-mast on monopile sub-structure.

Table 4.8: Added mass and natural periods of lidar tower.

	Added Mass (kN)	Period (sec)
X dir	5710	3.33
Y dir	5720	3.32
Rz	2997	0.038

It can be observed on table 4.8, the added mass and natural periods are similar and this is simply related with the single pile geometry. The added mass is quite high beacuse the element diameter is 48" diameter cylinder. 36" diameter would provide better results in terms of added mass and natural period of the structure if static requirements are met.

4.4 Wind Turbine 4-Legged Battered Jacket

Purpose of this structure properties given in table 4.9 is to carry the wind turbine tower, nacelle, electric generator, rotor assembly and wind blades up to the end of fatigue life of the turbine elements. In Appendix-D section, codes of model input file has been included. In Appendix-E section codes of pile and soil input file has been included. In Appendix -F section codes of modal extraction dynamic input file has been included. Rest of the model files can be found in the CD-ROM attached.

Table 4.9: Wind turbine jacket properties.

Structure	Ref Jacket-1	Ref Jacket-2
Water depth	40m	40m
Number of legs	4	4
Dimensions at W.P.	3m x 3m	5m x 5m
Batter	7	7
Legs	36" x 3"w.t.	48" x 3" w.t.
Piles	33" x 3" w.t.	45" x 3" w.t.
Elevations	-28/-12/+4	-28/-12/+4
Horizontal Bracings	16" - 1"w.t.	16" - 1"w.t.
X braces	18" - 1" w.t.	18" - 1" w.t.
Total Weight (Dead-Live)	19,500kN	22,500kN
Nacelle Weight (Included in Total)	2000kN	2000kN

Within figure 4.2 and figure 4.3 wind turbine jacket type sub-structures can be seen with different base areas and member diameters.

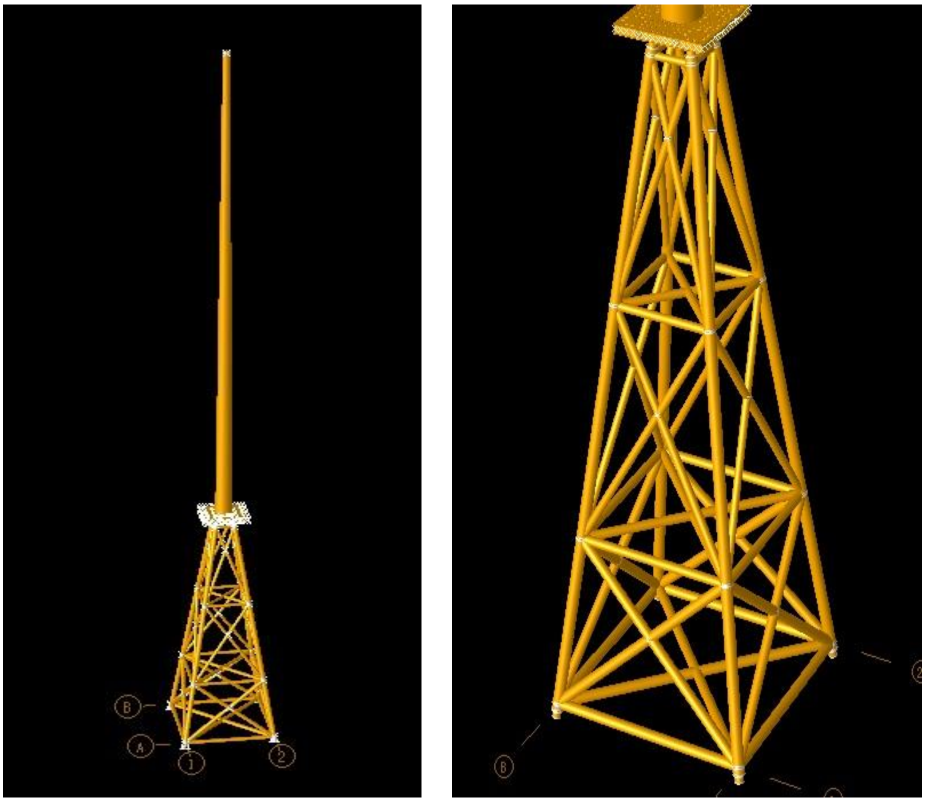

Figure 4.2: 4 legged, battered turbine jacket / ref. type-1.

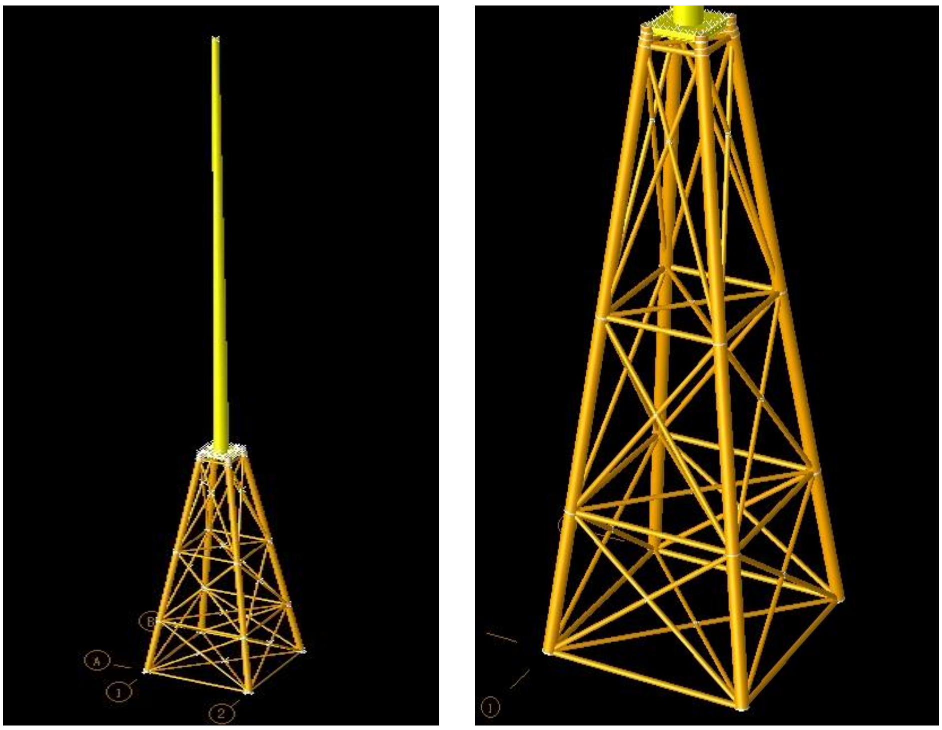

Figure 4.3: 4 legged, battered turbine Jacket / ref type-2.

Table 4.10: Added mass and natural periods of wind turbine jackets.

	Added Mass (kN)	Period (sec)	Added Mass (kN)	Period (sec)
	Ref Jacket -1		Ref Jacket -2	
X dir	265.1	14.99	1,737	0.528
Y dir	256.7	10.57	1,703	0.526
Rz	1,390	1.01	1,471	0.439

Reference jacket-1 has failed due to the high natural periods encountered. In order to overcome the problem of high natural periods, the working area, base area is increased in order to lower down the affects of overturning moment. In both of the models, weight of nacelle, generator and turbine blades is applied as 2,000kN on top of the tower. The increase in added weight also can be observed and it is mainly due to the increases in leg diameter size. The close natural periods are consistent with the almost symmetrical geometry.

4.5 Storage Jacket Structure

Purpose of the natural gas storage jacket platform is to carry the wellheads of the storage wells and provide an access platform to the wells. In addition gas processing equipment is also carried.

Table 4.11: Storage jacket properties.

Structure	Storage Jacket
Water depth	46m
Number of legs	6
Dimensions at W.P.	28m x 14m
Batter	2Legs with 5
Legs	42"x 2"w.t.
Piles	36" x 2" w.t.
Elevations	-30/-12/+4
Horizontal Bracings	24" - 1"w.t.
X braces	16" - 0.75" w.t.
Conductors	16ea - 30" - 1" w.t.
Total Weight (Dead-Live)	50,000kN

Within table 4.11 the design parameters of the storage jacket at 46m of water depth is given and structural skect has been provided in figure 4.4.

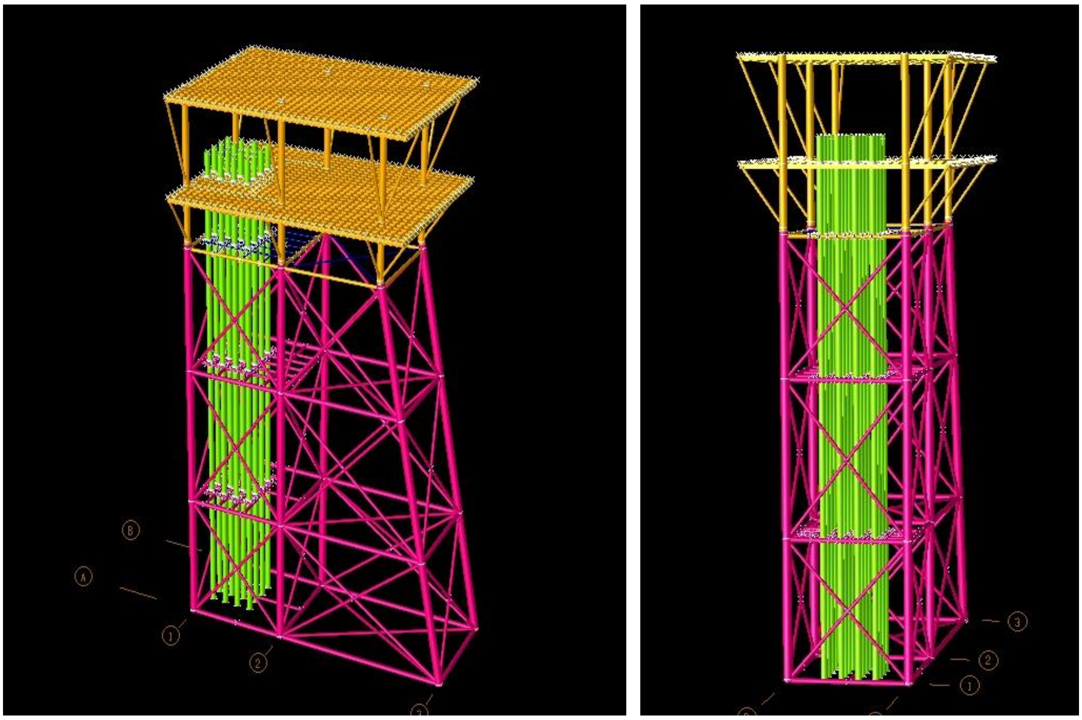

Figure 4.4: Storage jacket at 46m water depth.

Table 4.12: Added mass and natural periods of storage jacket.

	Added Mass (kN)	Period (sec)
X dir	1,107	3.213
Y dir	839	2.207
Rz	1,026	2.156

For the storage jacket, the natural frequency of the torsional vibrations are quite high seen in table 4.12, if compared with the symmetric jacket types and it is related with the difference between the length and width.

4.6 The Effect of Additional Caissons

There are 3 slots on the Akcakoca field tripod type of platforms. The purpose of additional caissons is to be able to drill new wells nearby and benefit from the current topside facilities of the production platform. Ayazli tripod platform has been selected instead of the other two platforms because Ayazli Platform is the deepest platform among the tripods in Akcakoca Field. Jacket properties are listed in table 4.13, current tripod and additional caisson model is given in figure 4.5.

Table 4.13: Ayazli jacket properties.

Structure	Ayazli
Water depth	79m
Number of legs	3
Dimensions at W.P.	7.62m Triangle
Batter	2 Legs with 7
Legs	42"x 1.5"w.t.
	36" x 1" Bat Legs.
Piles	33" x 2" w.t.
Elevations	-/-12/+4
Horizontal Bracings	24" - 0.75"w.t.
X braces	18" - 0.75" w.t.
Conductors	2ea - 30" - 1" w.t
	1 added for modified case
Total Weight (Dead-Live)	17,500kN

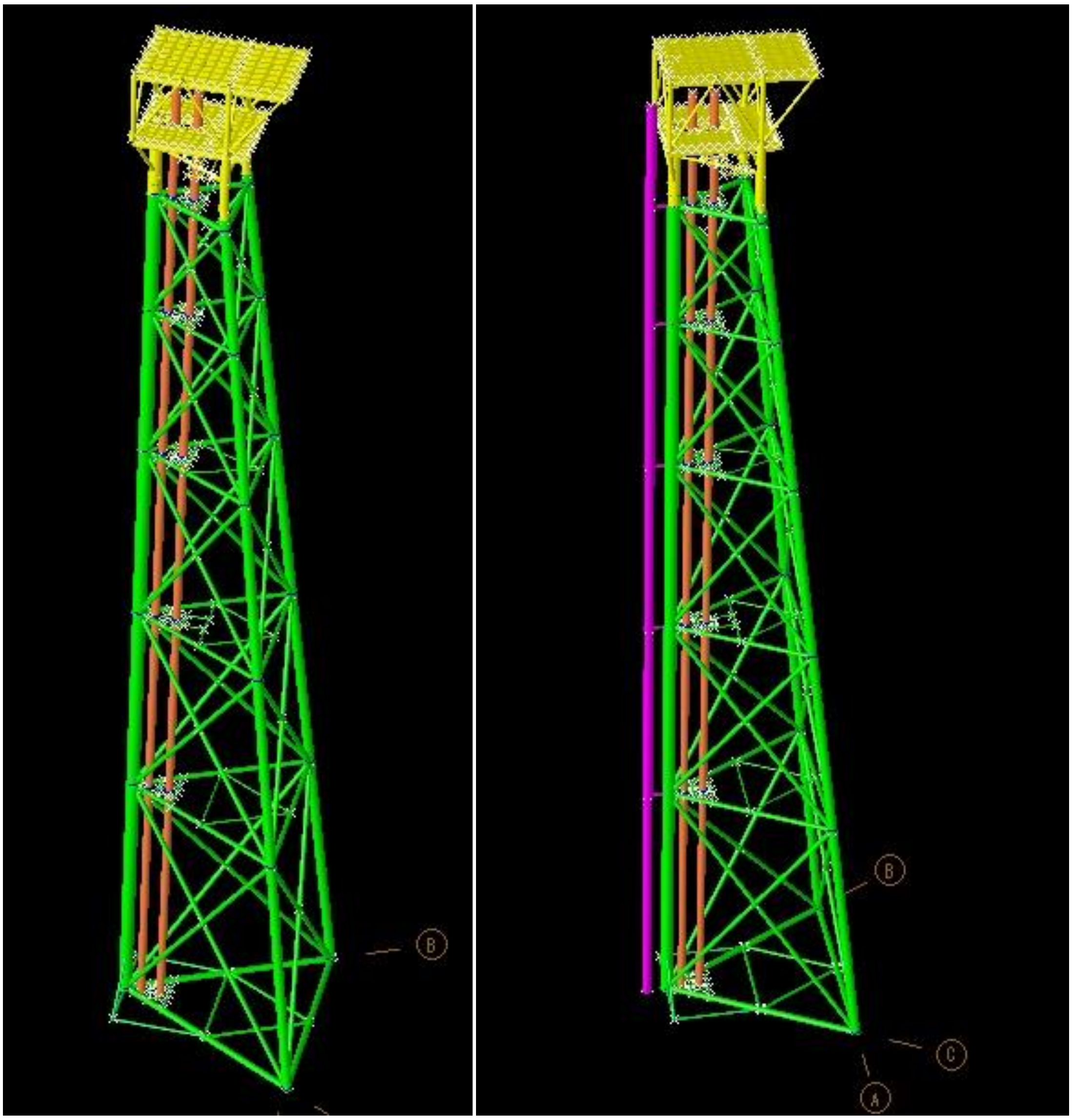

Figure 4.5: Ayazli tripod structure and additional caissons.

Table 4.14: Added mass and natural periods of Ayazli jacket.

	Added Mass (kN)	Period (sec)	Added Mass (kN)	Period (sec)	Added Mass (kN)	Period (sec)
	Atkins report		Ayazli Jacket		Modified Jacket	
X dir	330	1.87	1191	2.179	1805	1.825
Y dir	410	1.69	1660	1.573	1947	1.315
Rz	1120	1.067	1067	1.257	1315	1.067

Within table 4.14, reported values by Atkin's can be seen on the left column, calculated values with simplified model is tabulated within the middle column and the calculated values with additional caisson can be seen on the right.

The differences between Atkin's report and Ayazli Jacket is mostly related with the simplifications on modelling. In Atkin's report the member diameters and thicknesses are optimised especially for the shallower water depths but in Ayazli Jacket model member diameters and thicknesses are not optimised for the sake of simplicity.

The modified jacket added mass values are higher due to effcet of additional caisson and periods are lower an it is due to the stiffness added on the structure with additional pile.

4.7 Modification on 4-legged Akcakoca Platform

Purpose for modification on existing 4-legged Akcakoca Platform has the same purpose with the previous case of additional caisson on tripod structures, but since all the legs are battered and it is impossible to come close along the topside a more complex solution is rquired.

For this reason, multiple caissons have been decided to be driven and connected to each other in order to achieve an applicable level of stiffness. Each caisson is considered to be the carrier of a new development well and subsea template is considered to be the element for

Within this case, 6 caissons are installed on the starboard side of the current platform, 40m long template connecting caissons is modeled and 2 additional piles are driven from each side of the 6 caissons. Caissons are attached to each other at different water depths in order to increase the stiffness of the additional structure. Jacket properties are given in table 4.15 and representative models are given in figure 4.6.

Table 4.15: Akcakoca jacket properties.

Structure	Akcakoca Jacket
Water depth	94m
Number of legs	4
Dimensions at W.P.	14m Square
Batter	7
Legs	56" x 3"
Piles	48" x 3" w.t.
Elevations	-76/-61/-35/-14/+4
Horizontal Bracings	30" - 1.25"w.t.
X braces	30" - 0.75" w.t.
Conductors (Modified case)	6ea - 30" - 1" w.t.
Total Weight (Dead-Live)	83,000kN

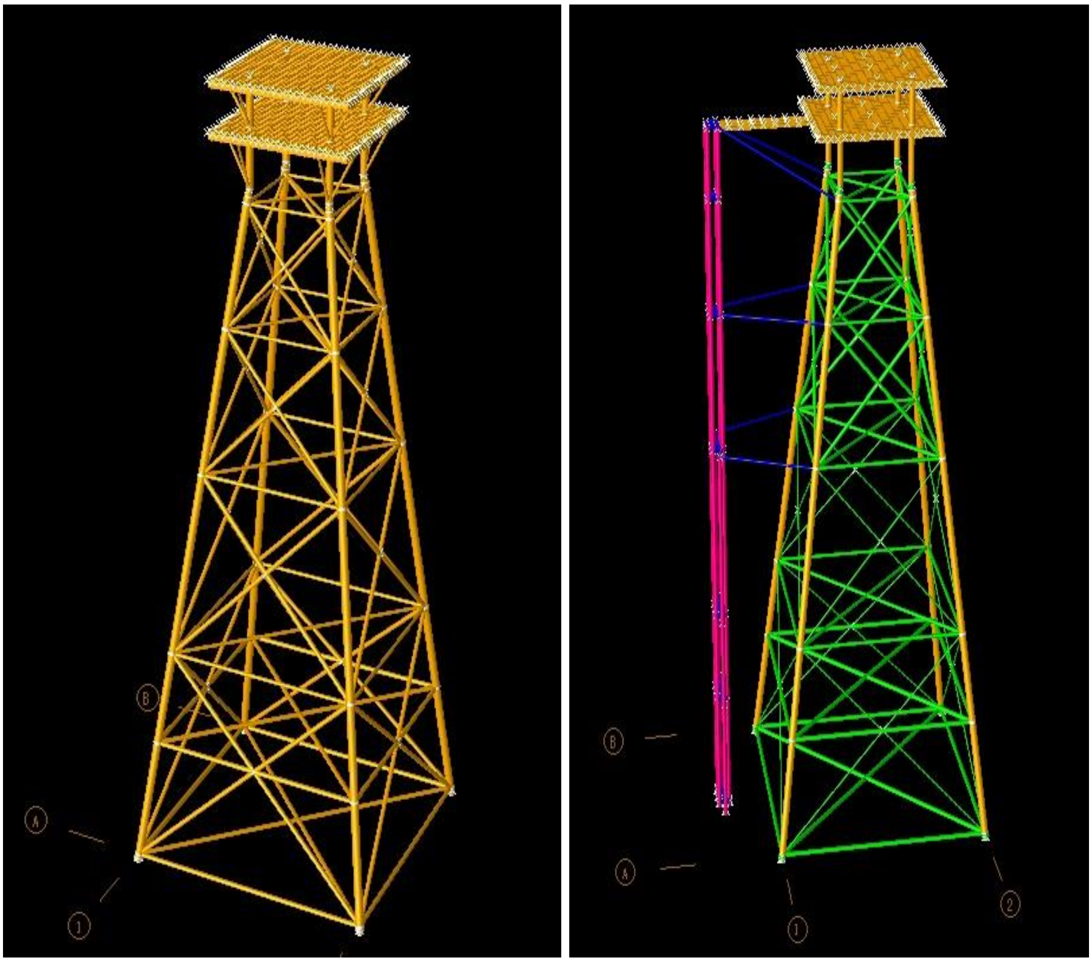

Figure 4.6: Modification on Akcakoca Jacket.

The modifications on Akcakoca platform increased the added masses significantly and it is related with the dramatic change in geometry as can be seen on table 4.16. Since the symmetry is disturbed, natural periods differs in X and Y directions. The effect of additional piles can be seen as a decrease in natural periods due to the increase in stiffness.

Table 4.16: Added mass and natural periods of Akcakoca jacket.

	Added Mass (kN)	Period (sec)	Added Mass (kN)	Period (sec)
	Akcakoca Jacket		Modified Jacket	
X dir	1,870	1.401	4,598	1.03
Y dir	1,869	1.401	3,787	0.933
Rz	426	1.041	2,604	0.846

5. OPERATIONAL SCENARIO

With regards to the information provided within the previous chapters regarding the nature of offshore wind energy installation and upstream development projects to be conducted with utilization of column stabilized mobile offshore units; within this chapter of this thesis work, an arbitrary operational scenario has been put forward in order to run a probabilistic financial scenario on evaluation of feasibility.

5.1 Operational Sequence

Offshore drilling and wind turbine installation is considered to be conducted with jackup units. Offshore installation that requires heavy lift crane barges, laying vessels, wind assessment campaign, route surveys, core sampling operations, steel fabrication works on jackets and topsides, delivery of materials and required project equipment are put in a reasonable order and tabulated below in order to show the sequence of operations within the simulated scenario.

As can be seen on figure 5.1 below, the overall workflow has been categorized into 7 sub-topics such as Jackup drilling or turbine installation operations, Lift or lay barge operations such as jacket, topside installation and pipeline, cable laying operations. The third category is the fabrication of jackets, topsides, piles and delivery of materials such as turbines, electric cables, steel and such.

As the fourth category being the preliminary measurement campaign for the assessment of prospective wind areas and fifth being the onshore process or transformation facilities and connection operations to gas or electric grid depending on project.

The sixth category is the survey works such as shallow seismic, soil boring, pipeline and route surveys and final category is the administrative work such as procurement, engineering design, logistics, operational supervision and any other office duty required during the projects.

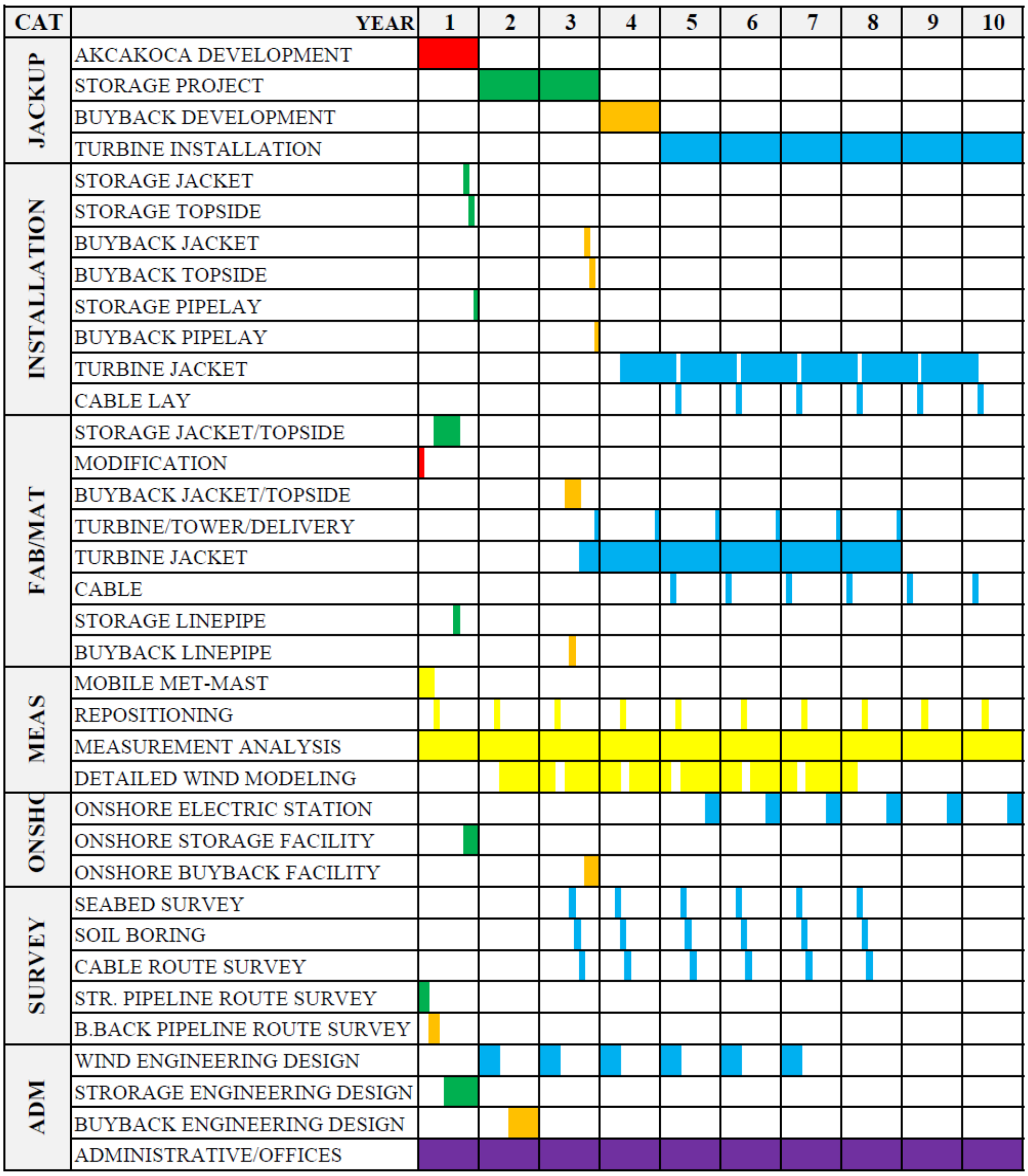

Figure 5.1: Operational workflow chart.

5.2 Operational Sequence Related with Jackup Platform

Operational scenario has been run in Monte Carlo simulation starts with mobilization of a jackup rig to Akcakoca field in Black Sea. The rig starts with the drilling of 8 wells alongside of the currently running Akcakoca 4-Legged jacket type of unmanned production platform. Since the jackup rig cannot park over on top of the current topside, the wells are considered to be drilled as close as possible on port and starboard side of the jacket in order to benefit from the process facilities of the current topside.

For consideration of the wells to be drilled, an operational workflow and estimated budget for one sample well of this type of operation has been provided within the

Appendix-G section. The time and workflow estimations are parallel to the operational averages experienced in previous Black Sea operations, and cost estimations are taken from the latest offshore and onshore upstream operations.

All these 8 wells are considered to be piled to the refusal point around 180m of vertical depth from kelly bushing elevation of the jackup platform with structural caissons and 60 meters of penetration into the seabed is expected to be observed being the conductor section of the wells. 16" diameter hole being the surface section of the wells will be drilled with directional build up to 20-60 degrees from vertical depending on the depth and distance of the target at around 550-650m measured total depth which corresponds to 450-550m of vertical depth and hole will be cased with 13 3/8" pipe in order to secure the directional section of the wellbore.

For the intermediate hole, the diameter is 12 1/4" and this section will be the hold section of the well in order to reach close to the top level of targeted sands and this section to be cased with 9 5/8". This section lengths are quite various, since the targeted sand bodies are scattered to different locations and depths but is assumed to be around 2200m of total measured depth and corresponding vertical depth of 1100m.

For the production section of the well, 8 1/2" is the diameter of the hole and the wellbore is deviated back to vertical direction in order to hit the multiple bodies of sands at different depth intervals and production hole will be logged, cased with 7" casing.

With regards to the logging results, 2 7/8" completion string will be run and corresponding sand intervals will be perforated with TCP guns and guns will be dropped into the wellbore in order to avoid probable complications with well control and prevention of skin damage to reservoir.

After drilling 8 wells, the jackup rig will be moved on top of the topsides of the tripod type of production jackets, empty slots left for future wells will be used to drill additional 2 more wells from East Ayazli and Ayazli Platforms and 2 more wells will be drilled along the vertical leg of the tripod jacket and will be connected to this leg by horizontal braces at different water depths with the help of divers.

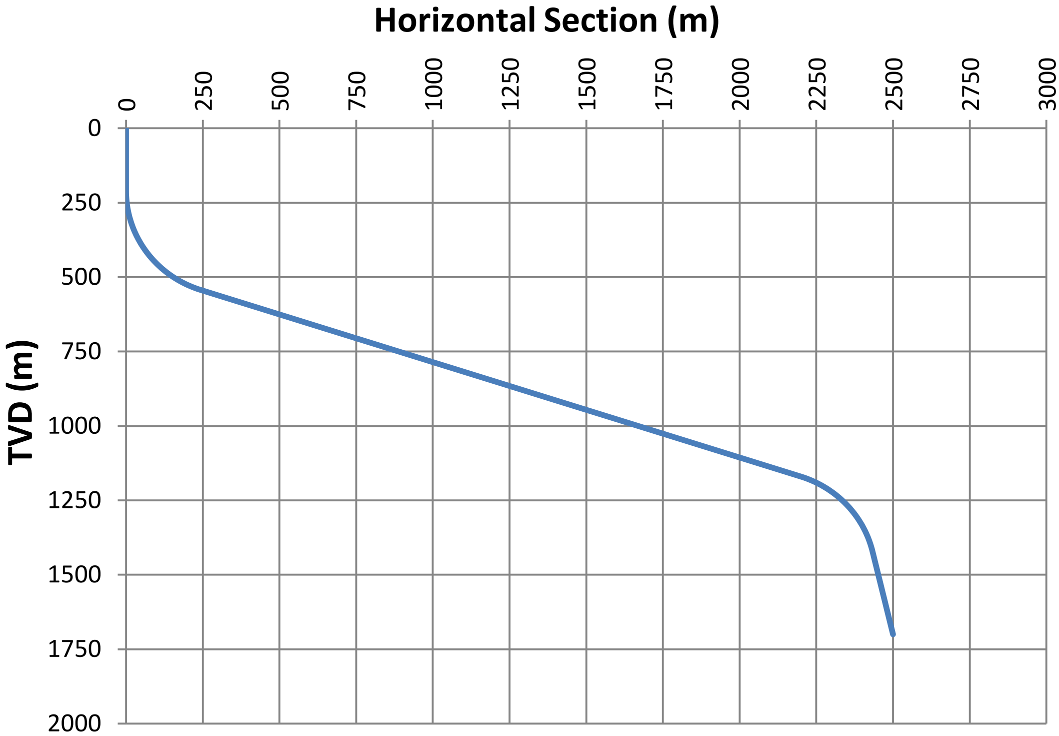

Figure 5.2: Sample well trajectory.

If the drilling operations for this type wells are considered, the formation characteristics and methodology being almost the same, the only difference comes from the distances and vertical target depths which are closer to surface around 200m than the target depths encountered nearby Akcakoca production platform. A cost saving advantage on this project comes from the already installed infrastructure of the field which is being able to test the wells with the equipment already installed on the topsides and since all the platforms are already connected to pipeline system, no flare system needs to be used during testing of the wells and test volumes also will able to be produced.

After drilling of the 12 new wells at Akcakoca field, the rig will be mobilized to Silivri in order to drill the 24 offshore directional gas storage wells, 12 each at two different locations. The nature of the drilling operations is planned to be conducted on a batch drilling manner in order to save time on operations. Within batch mannered drilling operations, instead of drilling the wells one by one to the required depth, corresponding well sections are drilled for each well and next phase is passed onto afterwards. This approach optimizes the overall operation and saves time in terms of elimination of the rigging up and down time of section related drilling tools and equipment back and forth and creates huge benefits on the logistics movements between shore base and the rig.

For running the drilling campaign with a batch drilling manner, the number of wells to be drilled from single location should be multiple and 12 is a good figure in order to achieve the significant time savings intended. This operational approach becomes applicable in conditions where the rig can easily be skidded from one well to another. Since most of the jackup type of platforms, the rig sits on top of a cantilever, skidding is easy. The proposed workflow for batch drilling approach and estimated costs which are put into the financial simulation are tabulated in the Appendix-H section.

Within the scenario, the reason for offshore storage development project to be put into the second order comes from the need to spare some time for the fabrication and installation of storage jackets and topsides. At conditions where there is plenty of information and data exists regarding the reservoir and formations, it would be wise to install and commission the production jacket beforehand in order to eliminate the unnecessary and costly, temporarily abandonment and tie-back operations. In addition to this, testing operations can be handed over to the personnel and equipment on the production deck of the jacket and jackup rig time can be saved.

Third arbitrary upstream development project put into operational scenario is selected to be quite parallel to the operational manner in storage project and production profile with Akcakoca field for the sake of simplicity and main reason the be put into the operation scenario is to incorporate a buyback type of project in the financial simulation. For this project, it is assumed that, there already exists an up and running field but the owner state of the field lacks in funding for the further development of the field and a part of the hydrocarbon field has been awarded to a third party to develop. The project is assumed to be the drilling of 12 wells from the same location, a production jacket and topside, an offshore pipeline, an onshore gas plant and connecting onshore pipeline to the grid.

Fourth and final type of project requires jackup type of platform is the offshore installation of turbine towers, nacelles and turbine blades on top of the previously installed jacket type of structures or monopiles depending on the water depth of the installation site. For the installation of wind turbines, crane barges can also be utilized but, jackup type of barges have some significant operational advantages when compared to these type of vessels such as being able to utilize smaller sized cranes on board due to the capability of elevating the hull to higher levels from mean sea level and not being affected by the environment conditions such as no wind but high swell.

With regards to the two mentioned significant advantages, it can be seen that, jackup type of wind turbine installation vessels are being designed, constructed and popularly being used nowadays and became the conventional method for these installation projects and within the operational scenario this type of a vessel is assumed to be utilized.

There are six different projects of the same size of 154MW has been considered within the scenario, with the assumption of the preliminary measurement campaign depicted more than 6 prospective areas and further measurement and seabed survey works showed average load factors above 40% and assured applicable seabed profile over the project area.

For the installation of wind turbines, 14 days is assumed to be the duration of the workflow for each turbine, including the possible delays due to the sea and weather conditions. The workflow and estimated cost is tabulated and included into the Appendix-I section.

5.3 Operational Considerations Regarding Offshore Installation Works

For conducting the offshore installation operations within this operational scenario, a heavy lift barge is required to be contracted. The expected maximum load to be lifted is around 2000 metric tons, so the heavy lift barge should be able to lift and place this amount of lift safely at once. Heavy lift barge used in Akcakoca project is given in figure 5.3.

The operational workflows for the heavy lift barge starts with the installation of the 2 storage jackets and topsides, followed by the installation of the jacket and topside of the international buyback project after these two projects. Heavy lift barge is also needed for the installation of turbine jackets, sub-station jacket and sub-station topside for each of the wind project to be conducted. The workflows and relates cost estimates are provided within the Appendix-J section of the thesis.

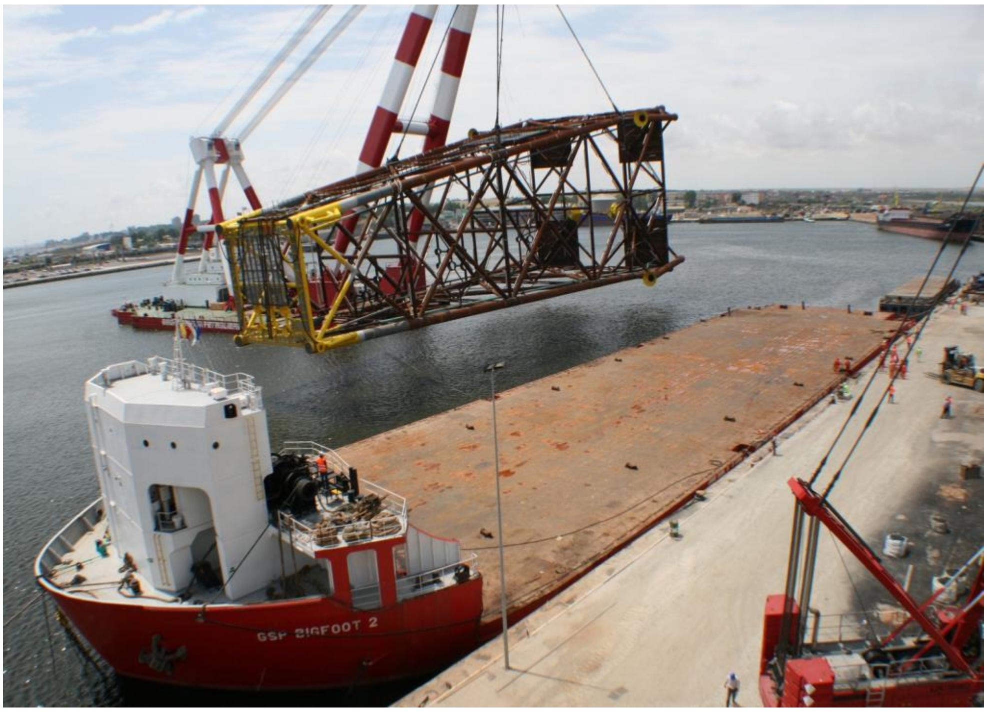

Figure 5.3: 1,800ton capacity heavy lift barge used in SASB project.

The required heavy lift barge, apart from the lifting capacity, needs to be equipped with pile driving equipment and accessories, required welding equipment and personnel should be available at construction site. In addition to this, necessary diving equipment such as pressure chambers, diving bell, diving crew should be available at site during the installation operations. Applicable diving system such as surface supplied air, surface supplied mixture or saturation should be selected as per the water depth requirements, capabilities of the diving system to be utilized.

For pipelaying operations, a lay barge is required with a clear deck area for restoring a certain amount of linepipe needed at least 2 days of laying capacity, a welding line on the port or the starboard side of the vessel with a minimum applicable length of 70m is necessary in order to align the pipe joint to be welded, 3 welding stations for root, fill and cap, an available station for NDT before the tensioner which is holding the welded pipe section over the barge deck and a final station is required for the field joint coating to be applied on the downside of the tensioner station. In addition to this, a stinger needs to be connected to the stern of the barge in order to prevent the buckling of pipe being laid.

Pipelaying operations considered within the scope of this operational scenario is relatively short pipelines of 3 and 5km for the storage project and a 30km long pipeline has been assumed for the arbitrary international development project. For the

Akcakoca project, pipelaying operation is not required since no infrastructure development other than drilling of new wells is assumed. Shore approach and trenching is also included within the scope of the pipelaying barge.

For the wind projects, cable laying is planned with an assumed amount of 50km long infield laying, connections between the turbines and the sub-station and the distance of the field location to the applicable shore connection is assumed to be 50km. Surface supplied air diving system with the required components to be available on the cable laying vessel in order to make necessary underwater connections. In addition to this, burial of the cables below the mudline and placement of the marking buoys for as a sign of warning is planned within the scope of the cable laying vessel. Operational workflow and estimated cost for a generic cable laying operation has been attached within the appendix-K section.

5.4 Locating the Estimated Costs on the Investment Table

Capital expenditure estimations has been conducted with current market prices but, since the operational scenario is for 10 years, assuming the market conditions to be constant for this long period is not realistic for input into Monte Carlo Simulation.

For this reason, cost estimations are recalculated prior to insertion to the cash flow table of the financial simulation described within section 6.7. Different weights have been applied for different type of operations and this is related with the nature of the work to be done and weighting is given in table 5.1.

Table 5.1: Capital Expenditure weighting table for various types of operations.

Type of Operation	Energy %	Commodity %	Technology %	Wage %
Jack-up rig / Turbine Ins.	60	20	10	10
Offshore installation	30	40	10	20
Fabrication/Material	10	60	0	30
Measurement	10	10	10	70
Onshore Facilities	20	40	10	30
Survey	20	20	20	40
Administrative	10	10	10	70

6. MONTE CARLO SIMULATION

The main reason of development of this kind of a financial simulation is to provide a basis of understanding on the investment breakdown of the shallow offshore operations, revenue modeling for different types of energy projects and estimation of the net present value for the proposed arbitrary operational scenario. The methodology of the financial simulation will be defined, assumptions will be explained and underlying reasons for these assumptions will be discussed.

Another reason for development of this kind of scenario is to create a general tool set for financial evaluation on very different types offshore projects with similar nature but different characteristics.

Within the scenario, apart from the probable fixed tariff on offshore renewables, all the revenues are connected to a random and volatile energy price and correlated commodity price functions in order to achieve an applicable level of randomness while running the simulation.

6.1 Selection of Offshore Projects

First of all, offshore exploration is not modeled within the scope of this financial simulation. The reason comes from the abstract and not easy to predict nature of this type of offshore projects. It is almost impossible to provide a cost estimation for an offshore exploration well unless the geological targets, sequence of expected lithology of formations and especially subsurface pressure regime estimations are given. Apart from that, in revenue modeling of this kind of a project the level of uncertainty multiplies on top of the previously mentioned reasons.

Secondly, Offshore underground storage of natural gas project is included into this financial simulation due to the fact that there already exists an offshore natural gas storage facility currently being operated by TPAO and there is an upcoming project have been announced to be initiated. In addition to this, type of offshore wells to be drilled, the average depth of the well, the characteristics of the formations and reservoir section is known and these factors helps to estimate the overall cost and duration of drilling operations.

Thirdly, a proposed development scenario regarding Akcakoca offshore gas field has been put into the operational scenario in order to represent a realistic case on offshore upstream development projects, where the targets are picked, recoverable reserves on each target are estimated, production profiles and wellhead pressure regimes for wells can be estimated from previous wells and the infrastructure of the field is known.

Offshore international development case has been put into the model in order to include the probability of participation into international offshore hydrocarbon development projects, where the owner of the asset is incapable of funding the development project. The importance of this kind of a project to be put under the operational scenario and revenue modeling is for underlining the importance of participation to foreign hydrocarbon assets to secure some quantity of hydrocarbon reserves for the price stability in internal market.

Finally, Offshore wind projects are introduced into the financial scenario as being the most promising future option for Turkish offshore industry. There is a huge potential seems to be available and this potential has been put into the simulation under the definition of a reference project, which was previously discussed in second chapter.

6.2 Assumptions Behind Revenue Modeling

The main assumption regarding this financial model is that it does not include any taxation, the cost of financial instruments such as loans and the reason behind such an assumption is to figure out the extent of the monetary value that can be achieved with application of the presented scenario within the perspective of the public interest.

6.3 Assumptions Behind Wind Projects

For the revenue modeling of offshore wind energy projects, the tariff is assumed to be fixed and projects are being supported by the government authority throughout the 20 years duration of the project, parallel to the current experience being observed in the EU. For the monetary amount of tariff to be applied in the revenue model, since Turkish government has not posted a tariff yet, a random number has been picked between 0,15 - 0,19 USD/kW-h. In each iteration within the Monte Carlo simulation, this number is picked randomly between this interval and probabilistic considerations on tariff is put into the simulation by this way. 0,15 - 0,19 USD interval might be considered a bit optimistic, by 2 cent as average on the current EU tariffs but in reality, this margin would probably be a quite important reason for foreign investors to be attracted and participate in development of Turkish offshore wind assets.

For the annual mean load capacity factor to be put into the simulation %45 is selected to be the anchor value. Since there is no statistical data has been generated offshore for a particular location yet, a likely figure has been selected between applicable range of feasibility boundary of %35- and ultimate wind capacity of %55. At this point, to provide supporting information on selection of 45% annual mean load factor of offshore wind projects for revenue modeling. Danish offshore capacity factors have been reviewed and an average of 45.4% load capacity factor has been experienced from 15 different projects. [26]. Random seasonality effects have been taken into consideration and included in the model as a volatility function with the bandwidth of %4 capacity, thus the load factor is picked randomly from the interval of 43% - 47% for each month. Monthly fluctuations are not modeled due to lack of offshore wind measurement data.

6.4 Assumptions Behind Gas Storage Field

For the natural gas storage revenue modeling, simplifications have been done due to the very complex nature of storage, consumption dynamics of the gas market and the underdeveloped condition of the storage market. In addition, strategic requirement for natural gas storage is neglected within the model due to the complications coming together with the political decision making.

At this point, market is idealized to be fully liberal in terms of supply and demand, and storage reservoir is considered to be a player in the market as a supply point for the compensation of the excess supply especially in winter periods. In addition to this, it is assumed that the volumetric amounts of gas import contracts are optimized with consideration of gas storage volumes, deliverability and injection rate figures. In other words, gas market relies on the storage facilities to some extent.

During incorporation of the Silivri offshore gas storage field development project, only the capacity increase related with the development project is considered and the currently ongoing facility is excluded for the sake of simplicity, the amount of increase on the ultimate storage capacity achieved by drilling of the 24 new wells is not included, gas storage reservoir is assumed to be full up to ultimate capacity and the produced amount in winter period is being injected back in the summer season.

The profit margin is created by the difference in between the balancing gas tariff being applied in production and discounted purchase tariff for the gas to be injected back into the reservoir. The balancing tariff is assumed as a rate over 20% over the market price and 40% discount is applied on the purchase price. While assuming the purchase price it is assumed that the reservoir is being filled with the gas from the LNG spot market. As a supporting background information if current BOTAS price and US gas price is compared, it can be seen that this ratio is 3,3 and to say that, 40% discount rate is not an optimistic value.

The production from the reservoir is picked randomly from the range of 30-60 days with the full deliverability capacity of 20,000,000 SCM/day to provide the probabilistic nature to the Monte Carlo simulation and %5 of fixed operating expense is deducted from the gas revenue for production periods and %5 of fixed operating expense is applied on top the cost during the injection periods. 5% figure is required for the utility gas to run the compressors for injection to natural gas grid at production periods and same is applied for the injection of the compressors into the reservoir. The level of fixed operating expenses is excluded due to the fact that, the additional capacity addition does not make significant increases on fixed operating expenses.

Finally, the duration of this project is set to be 40 years which is related with the expected life period of drilled wells and offshore structures.

6.5 Assumptions Behind Marginal Field Development Revenue Modeling

For the Akcakoca field, the recoverable reserves are considered to be the random variable and a total recovery between 30BCF - 50BCF is picked for different iterations. Since the field has been producing for the last 8 years, average production profile data is available, has been figured out from the existing producers and production profile of the new wells to be drilled within the development project have been correlated to the randomly picked recoverable reserve figure to create the monthly random production figures given in figure 6.1.

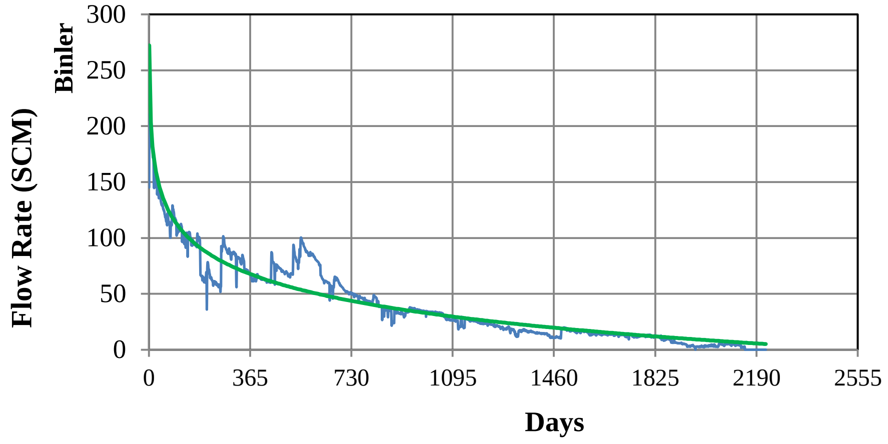

Figure 6.1: Average decline curve in Akcakoca wells.

%5 of gas has been put as operating expenditure into the simulation which has been experienced for this project throughout the life of the field and remained untouched since no modifications are considered to be done on the infrastructure of the field.

6.6 Assumptions Behind International Development Project Revenue Modeling

Since the international project being put into this financial scenario is arbitrary, some simplifications are applied for the revenue modeling. A similar production profile and operating expense percentage has been selected and the recoverable reserve is randomly picked from the same interval as Akcakoca development project. The difference in revenue comes mainly from the fixed tariff to be paid to the owner of the hydrocarbon resource as parallel to the nature of the buyback contracts.

6.7 Monte Carlo Simulation Methodology

The cost and revenue structure of the project is dependent on the future prices of the commodity and natural gas, future wages and changes in technology level. The revenue part is related to the future values of the commodity and natural gas prices whereas the cost part is a weighted average of all four variables. In that sense, a model is needed to provide a benchmark for the future values of these variables.

The most important part to evaluate the profitability of the project comes from modeling the future values of natural gas and commodity prices. One of the most commonly used methodologies to model natural gas and commodity prices is to assume that they follow Geometric Brownian motions. Although the related literature focuses on oil price and commodity price modeling, Postali (2006) and McNichols (2012), the natural gas prices can be considered to be modeled by the same way due to the similarity of its nature with oil prices. Another important issue is the co-movement between the commodity and natural gas prices. Therefore, it is assumed that the shocks for the variables are correlated with each other to incorporate the co-movement between them. In the context of Geometric Brownian modeling, these variables are assumed to follow a log-normal distribution, which means that the expected rate of return and volatility of the returns are sufficient to model them. The model can be described as follows:

$$\begin{aligned} dG_t &= \mu_G G_t dt + \sigma_G G_t dW_{t,g} \\ dC_t &= \mu_C C_t dt + \sigma_C G_t dW_{t,c} \\ corr&(dW_{t,g}, dW_{t,c}) = \rho dt \end{aligned} \tag{6.1}$$

where μ_G and μ_C represent the expected rate of return per year for natural gas and commodity prices, respectively and σ_G and σ_C stand for the volatility of the rate of returns for natural gas and commodity prices, respectively. $dW_{t,g}$ and $dW_{t,c}$ terms are normal shock with mean 0 and standard deviation $\sqrt{t}$. Based on these equations, it is possible to write the level of natural gas and commodity prices as follows:

$$\begin{aligned} G_{t+dt} &= G_t e^{(\mu G - \frac{1}{2}\sigma G^2)(dt) + \sigma_G \varepsilon_{g,t}\sqrt{dt}} \\ C_{t+dt} &= C_t e^{(\mu C - \frac{1}{2}\sigma C^2)(dt) + \sigma_C \varepsilon_{c,t}\sqrt{dt}} \\ corr&(\varepsilon_{c,t}, \varepsilon_{g,t}) = \rho \end{aligned} \tag{6.2}$$

In order to simulate the future values for the commodity and natural gas prices, we do the following steps:

- Generate three independent standard normal random variables ($u_{m,t}, u_{g,t}, u_{c,t}$) to be used in the generation of correlated standard normal shocks to the natural gas and commodity prices. $u_{m,t}$ represents the common shock for the relation between the natural gas and commodity prices whereas $u_{g,t}$ and $u_{c,t}$ stand for the specific shocks for the natural gas and commodity, respectively.

$$\varepsilon_{c,t} = \sqrt{\rho}u_{m,t} + \sqrt{1-\rho}u_{c,t}$$
$$\varepsilon_{g,t} = \sqrt{\rho}u_{m,t} + \sqrt{1-\rho}u_{g,t} \tag{6.3}$$

Where;

$E(\varepsilon_{c,t}) = 0\,, var(\varepsilon_{c,t}) = 1$

$E(\varepsilon_{g,t}) = 0 \quad var(\varepsilon_{g,t}) = 1$

$corr(\ \varepsilon_{g,t}, \varepsilon_{c,t}) = \rho$

- These random variables are used in each replication to find out the simulated commodity and natural gas prices based on the equation above. 1000 number of replications are used to simulate the natural gas and commodity price paths, where each path is for 540 months and time step used in the simulation is 1 month.
- After we find out the simulated commodity and natural gas prices, we can use them to find out the expected revenue and expected cost based on these simulations.

Another important determinant of the costs is the wages. During the analysis it is assumed that wages increase at the consumer inflation rate, where consumer price level is assumed to follow Geometric Brownian motion too. Based on the process, we can write the following equation for the price level. Based on these equations, 1000 number of replications are used to simulate the price path.

$$dP_t = \mu_P P_t dt + \sigma_P P_t dW_{t,p}$$
$$P_{t+dt} = P_t e^{(\mu P - \frac{1}{2}\sigma P^2)(dt) + \sigma_P \varepsilon_{p,t}\sqrt{dt}} \tag{6.4}$$

Lastly, another input for the cost structure of the project comes from the technology level. For the analysis it is assumed that technology level is constant so that it leads to the decline in costs.

The following table 6.1 summarizes the inputs for Monte Carlo simulations. These parameters can be adjusted depending on the choice of the modeler. It is assumed that the volatility for the rate of returns for the natural gas is higher than that of the commodity whereas the expected rate of return for the USA consumer price level is assumed to be 2% and its volatility 1%, which is believed to be reasonable assumptions given the observations. Lastly, the correlation between the natural gas and commodity shocks is assumed to be 0.75. These parameter values can be calibrated using the historical data depending on the choice of the modeler.

Table 6.1 : Monte Carlo inputs used in the simulation.

Expected Rate of Return for Natural Gas	2%
Volatility of Rate of Returns for Natural Gas	10%
Expected Rate of Return for Commodity	2%
Volatility of Rate of Returns for Natural Gas	5%
Correlation Between Natural Gas and Commodity	0.75
Expected Rate of Return for Price Level	2%
Volatility of Rate of Returns for Price Level	1%

For the calculation of net present value, it is required to assume a measure for the sensitivity of the projects to the general economic conditions. By using the Capital Asset Pricing Model, given the market risk premium is around 7% in USA and 10 year USA Treasury bond yield is close to 3%, the internal rate of asset return is assumed to be 10%. The distribution of net present value calculations can be shown as follows in figure 6.2. It should be kept in mind that the numbers are only operational cash flows, which means that any financing decisions of the project are not included. The results indicate that the projects seem to be quite profitable since each outcome in 1000 simulations is greater than 1 billion USD and in some scenarios it is observed that NPV might be higher than 2 billion USD.

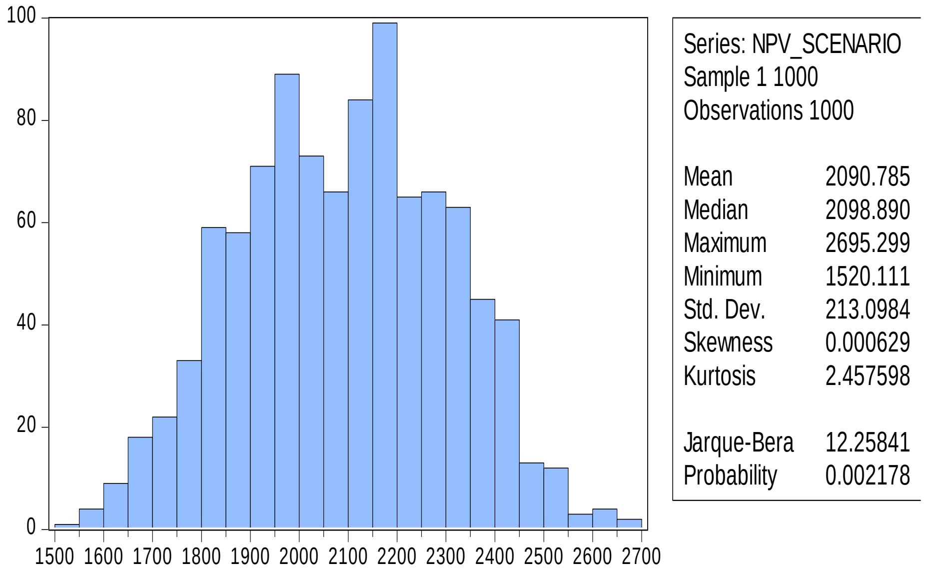

Figure 6.2: Histogram of net present value (NPV) using 1000 simulations.

7. CONCLUSION AND RECOMMENDATIONS

As the technical capabilities of the floating drilling platforms, vessels and floating offshore structures increased rapidly in 1990s and 2000s, the popularity of jackup type of drilling operations and jacket type of structures decreased. In other words, for oil and gas industry, deep water technology is the main consideration nowadays. But with the emergence of offshore wind industry, column stabilized barges and steel frame jacket type of fixed substructures seems to become popular again. This can be seen from the trends in European Wind Industry. More attention on fixed structural design or column stabilized offshore barges should be given by the naval architecture and offshore engineering departments in Turkey.

Wind turbine technology has developed extensively within the last 5 years. The average turbine sizes increased from 3MW up to 8MW. This fact has changed the economical considerations regarding the offshore wind farms. Due to this fact, the written reports related with the economics of offshore wind before 2011 should be neglected due to the rapid advancements in offshore wind turbine technology.

4 Legged - Battered Jackets up to 60m of water depth seems to be the solution for the wind industry within the next 20 years. If the total projection of 150GW installed capacity is reached in EU, this corresponds to the construction and installation of an additional 20,000 offshore wind structure within the next 15 years.

Conducting a preliminary wind assessment campaign would be very beneficiary to structure the offshore wind market in Turkey. By this way, the possible problems previously encountered in investment and licensing side of the onshore wind projects can be overcome.

Lidar technology has brought an important advantage on offshore wind resource assessment. This is related with the sub-structure requirements of the lidar equipped platforms. There is no need to install a met-tower up to 100m of elevation from mean sea level any more.

A further research and development subject on offshore wind resource assessment is related with the application of lidar devices on buoys. The accuracy of the measurements needs to be assured by successfully taking out the effects of wave and current on the buoy.

Akcakoca natural gas field, seems to be marginal and not profitable for most of the engineers and companies previously related with the project. But with regards to the discussions and information provided within the previous chapters, it might be worthwhile to invest and recover additional reserves between 30BCF - 50BCF.

Natural Gas storage is important for the establishment of gas grid flexibility. Silivri offshore project with 2 jackets and 24 wells will be a very important instrument for establishment of the flexibility of the market. The model inserted within the Monte Carlo simulation should be improved further with detailed daily consumptions, imports, seasonality data.

Financial simulation should be considered as a primary tool for evaluating the feasibility of the aforementioned types of offshore projects, in terms of detailing in the model, it might be worthwhile to develop the model together with professionals from different backgrounds, taxation and financial instruments also can be inserted into the overall scenario. The validity and sharpness of the Monte Carlo model can be increased with access to more detailed and reliable data.

Financial simulation yielded around 2 billion USD of net present value with %10 interest rate. This figure shows that offshore wind industry and upstream sector has a significant potential for creating new jobs, supplying significant amount of renewable energy to market, providing flexibility on natural gas market, development of reserves. It is recommended that, a national strategy should be prepared for supporting the development of offshore construction sector and utilization of unproductive shipbuilding facilities.

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APPENDICES

APPENDIX A : PRELIMINARY WIND PROSPECT MAPS
APPENDIX B : STATISTICAL WIND DATA FOR AKCAKOCA
APPENDIX C : EUROPEAN OFFSHORE WIND FARMS
APPENDIX D : SAMPLE MODEL INPUT FILE WIND TURBINE JACKET
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APPENDIX J : JACKET INSTALLATION WORKFLOW AND COST ESTIMATION
APPENDIX K : CABLE INSTALLATION WORKFLOW AND COST ESTIMATION

APPENDIX A

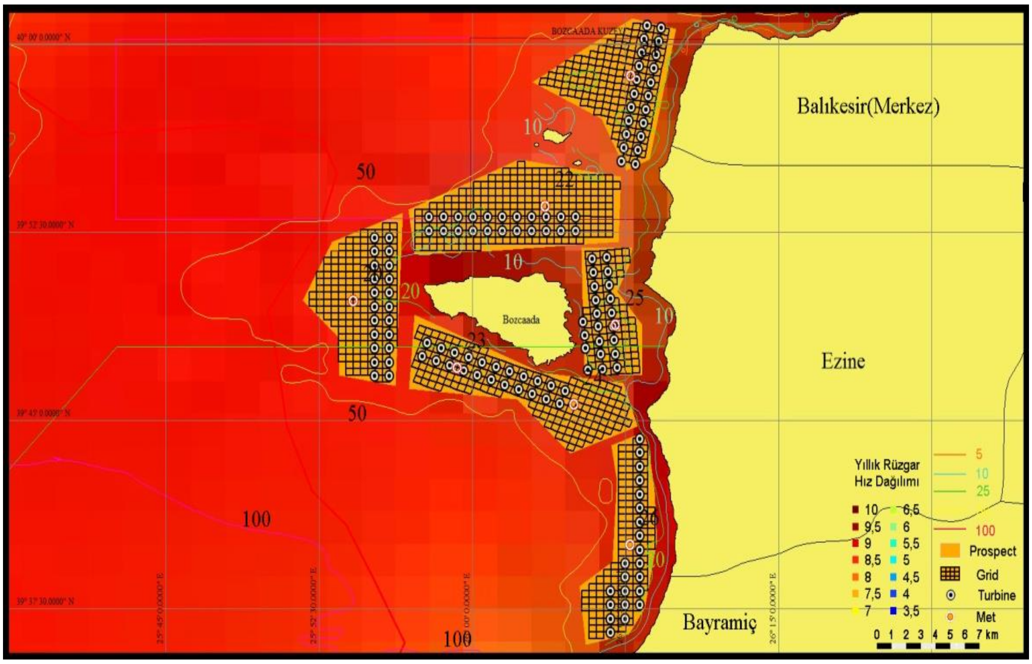

Figure A.1: Bozcaada - Ezine - Dardanel Prospects.

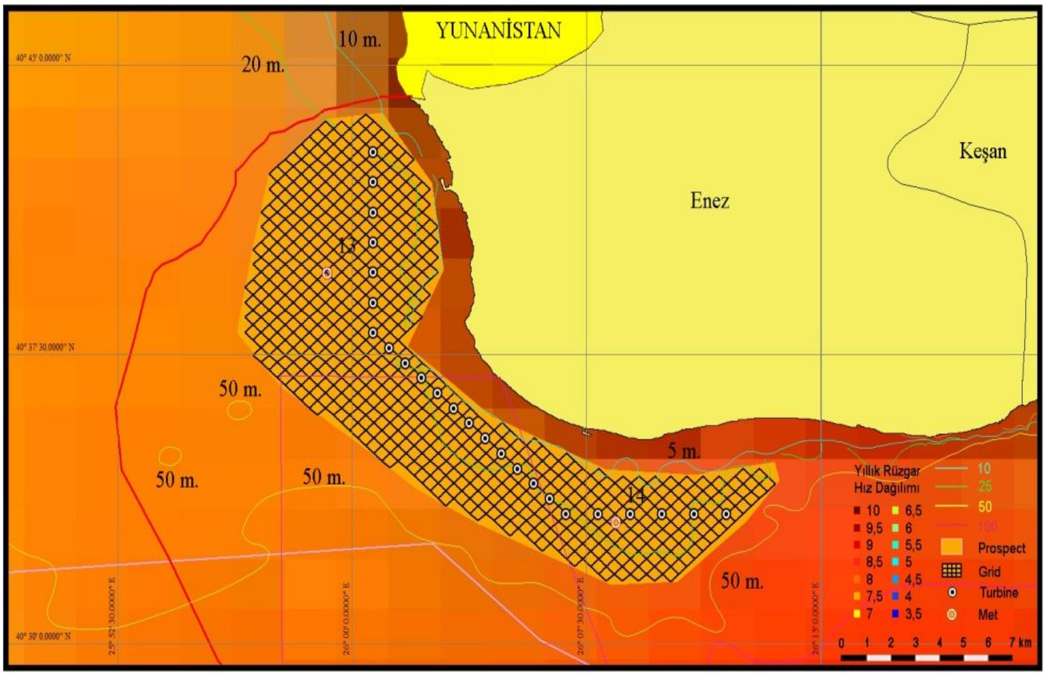

Figure A.2: Enez Prospect.

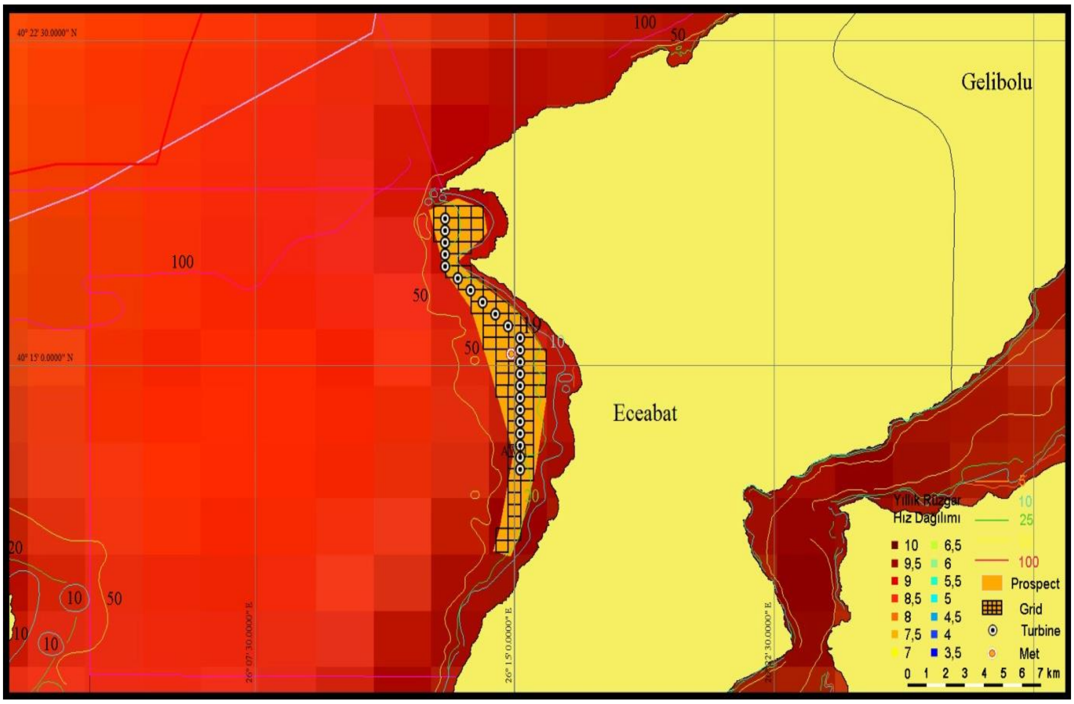

Figure A.3: Anafarta Prospect.

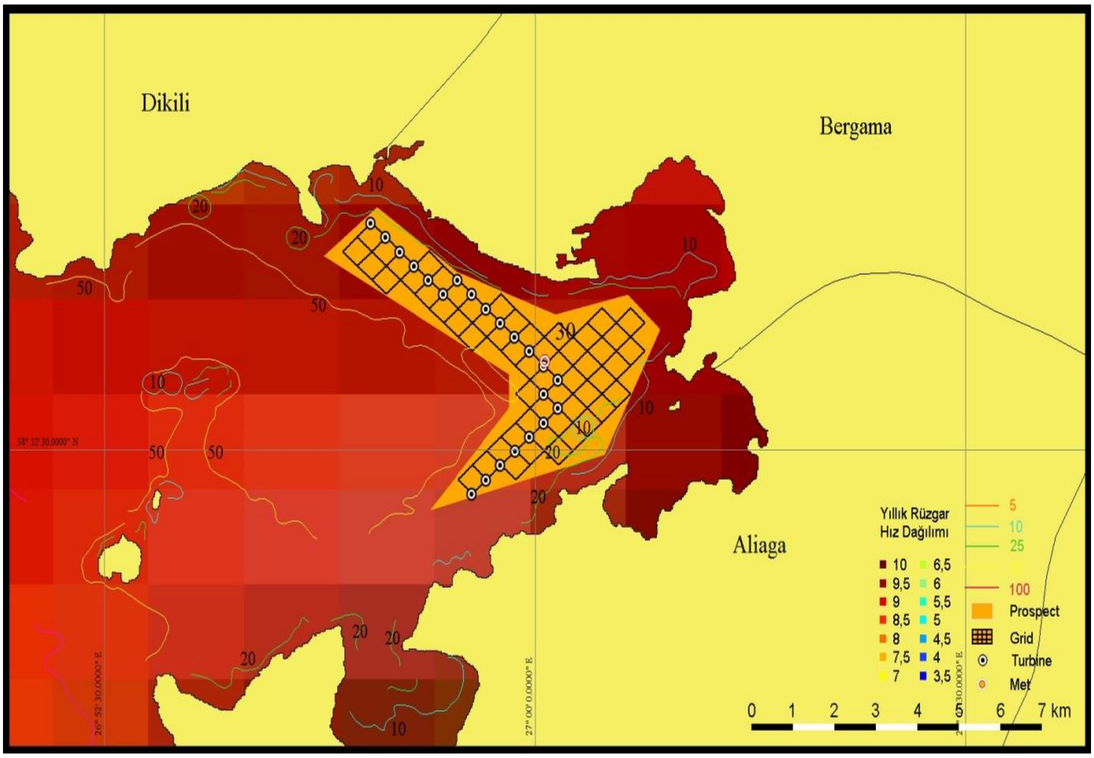

Figure A.4: Candarli Prospect.

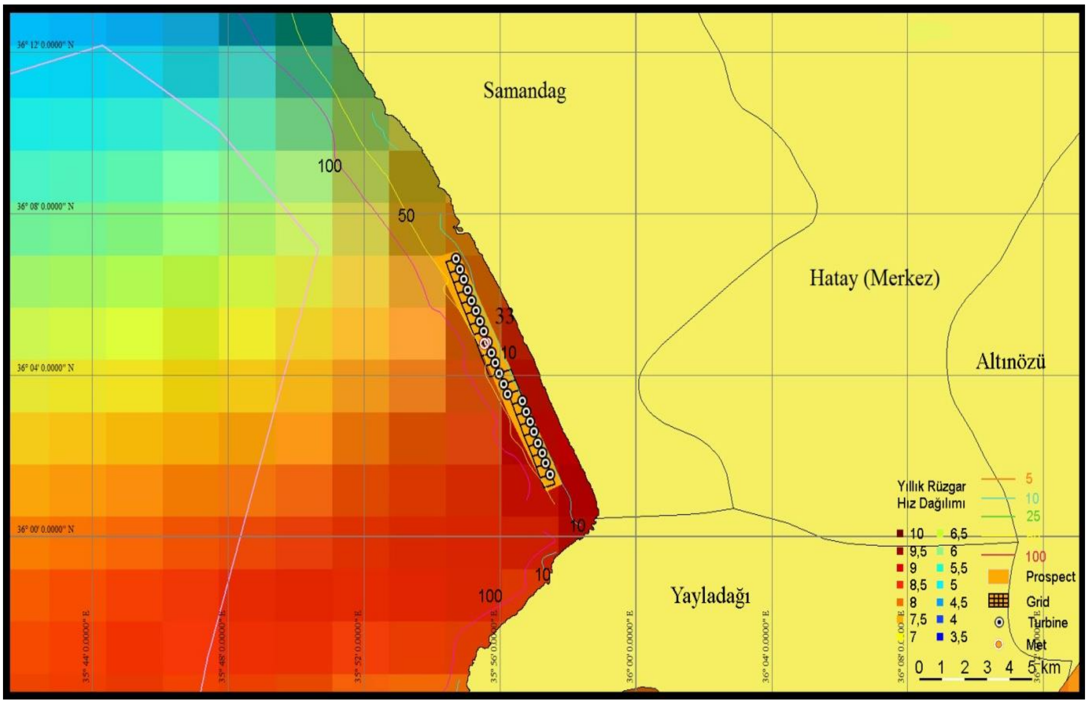

Figure A.5: Samandag Prospect.

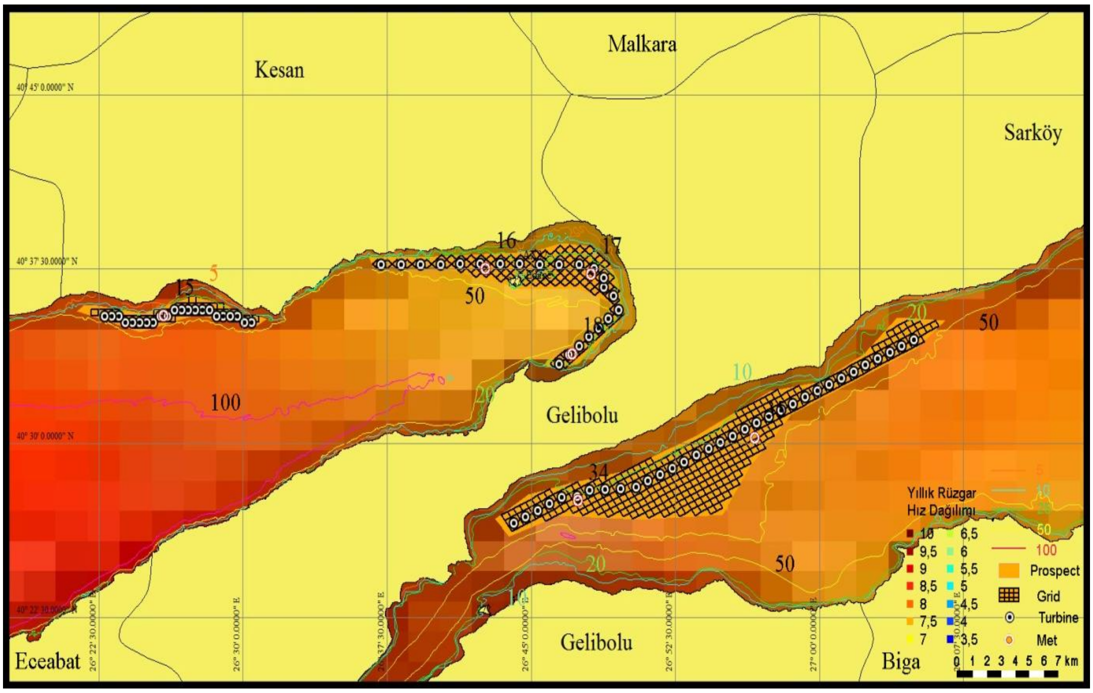

Figure A.6: Kesan - Saroz - Gelibolu Prospects.

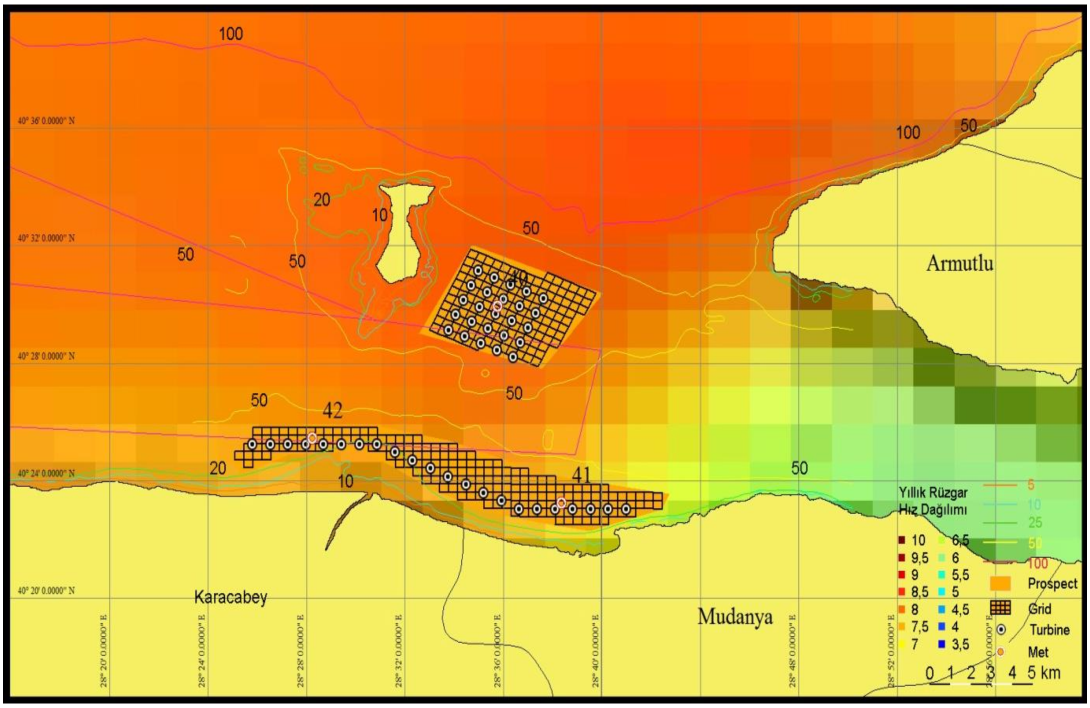

Figure A.7: Imrali - Mudanya Prospects.

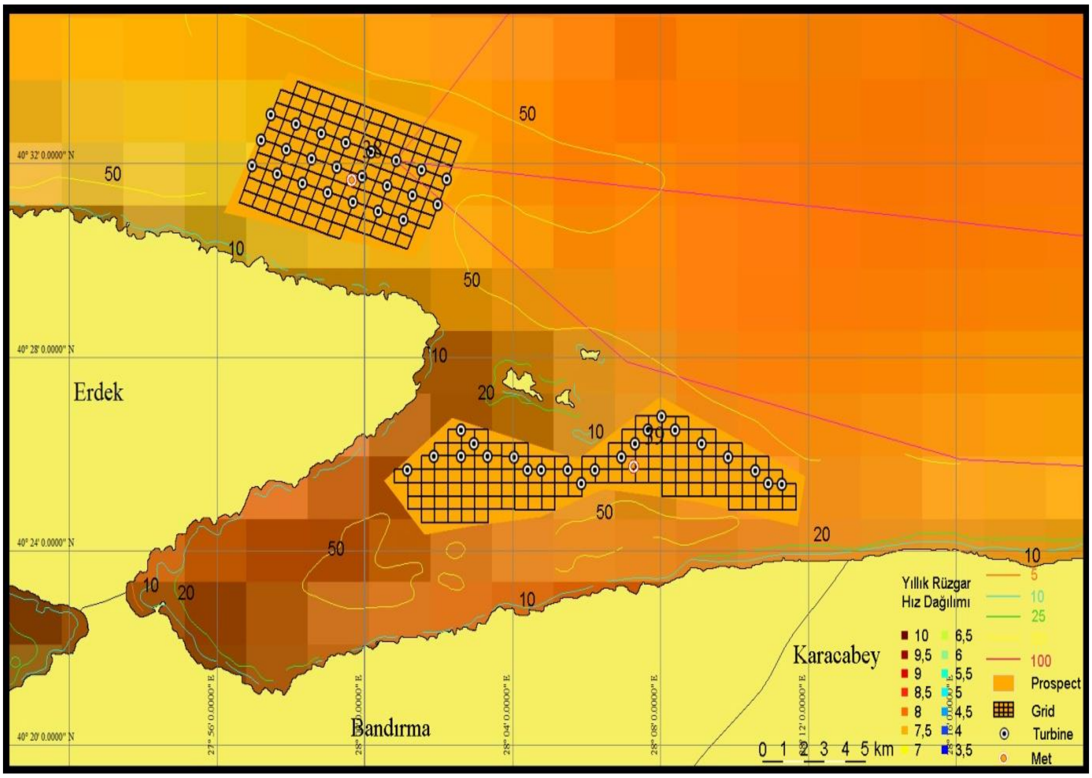

Figure A.8: Kapidag - Bandirma Prospects.

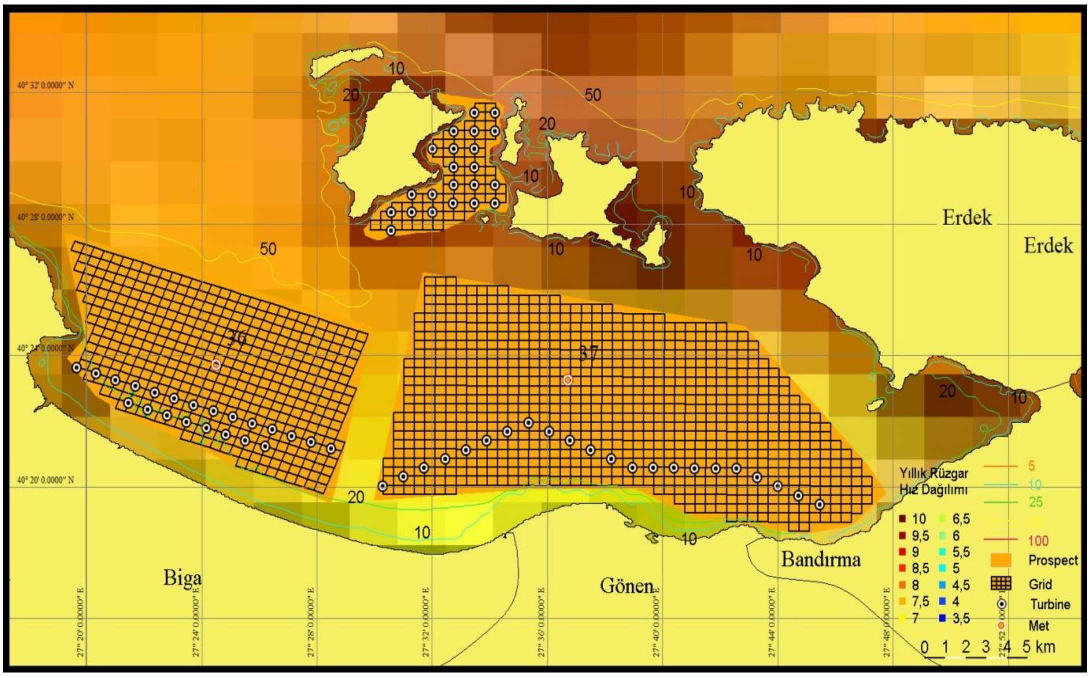

Figure A.9: Avsa - Biga - Erdek Prospects.

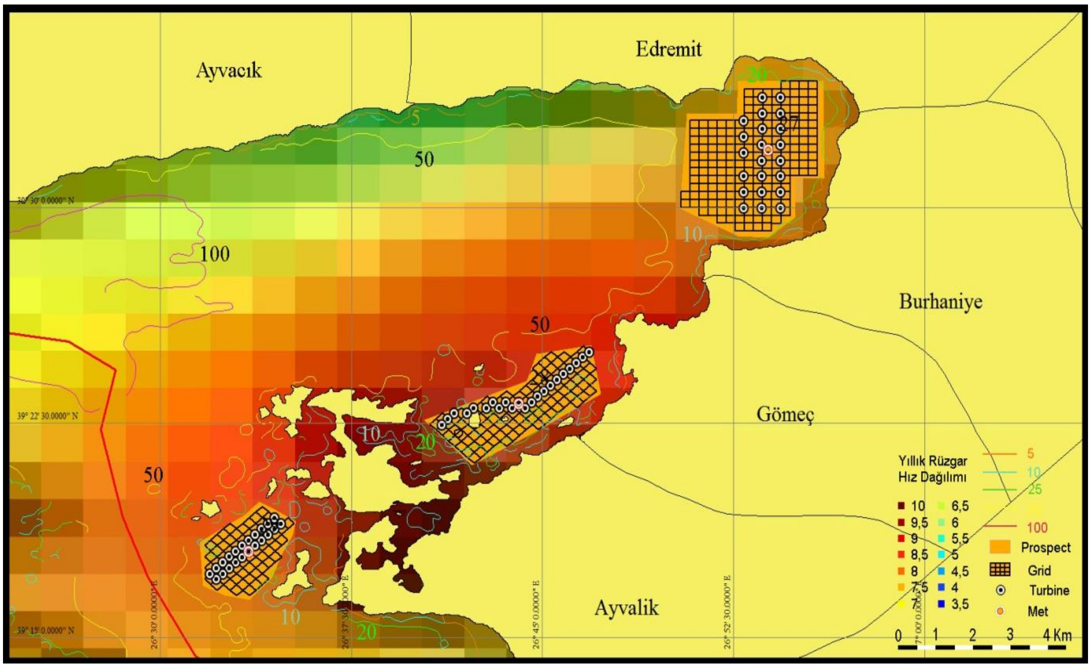

Figure A.10: Ayvalik - Edremit Prospects.

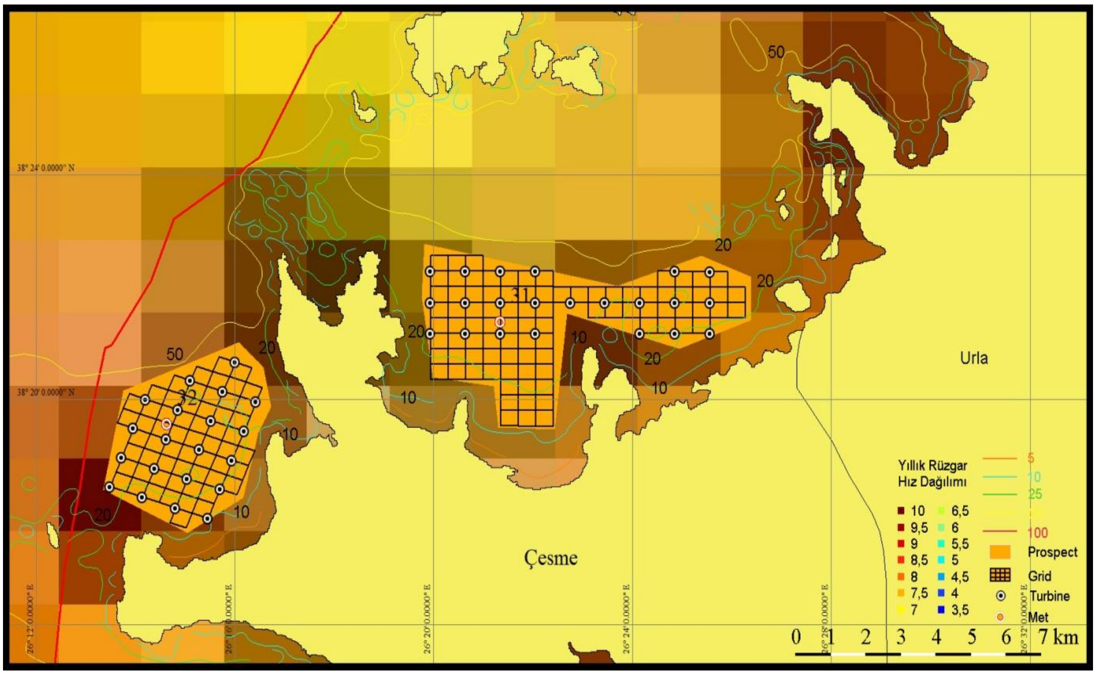

Figure A.11: Cesme Prospects.

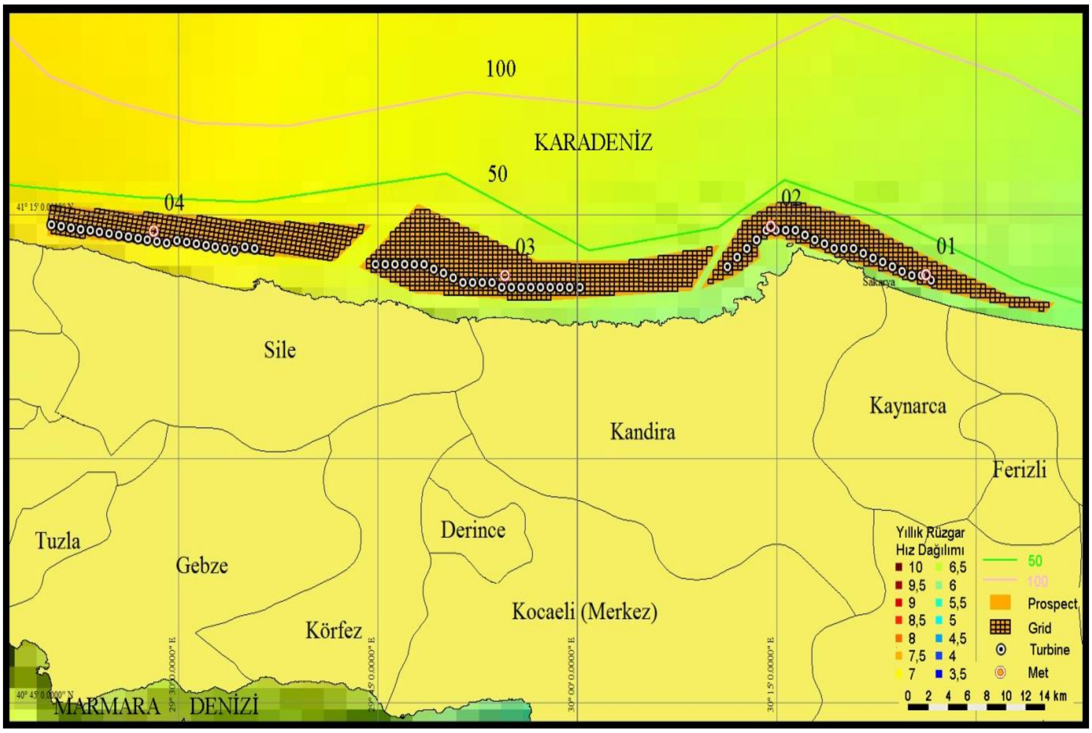

Figure A.12: Kefken - Agva - Sile Prospects.

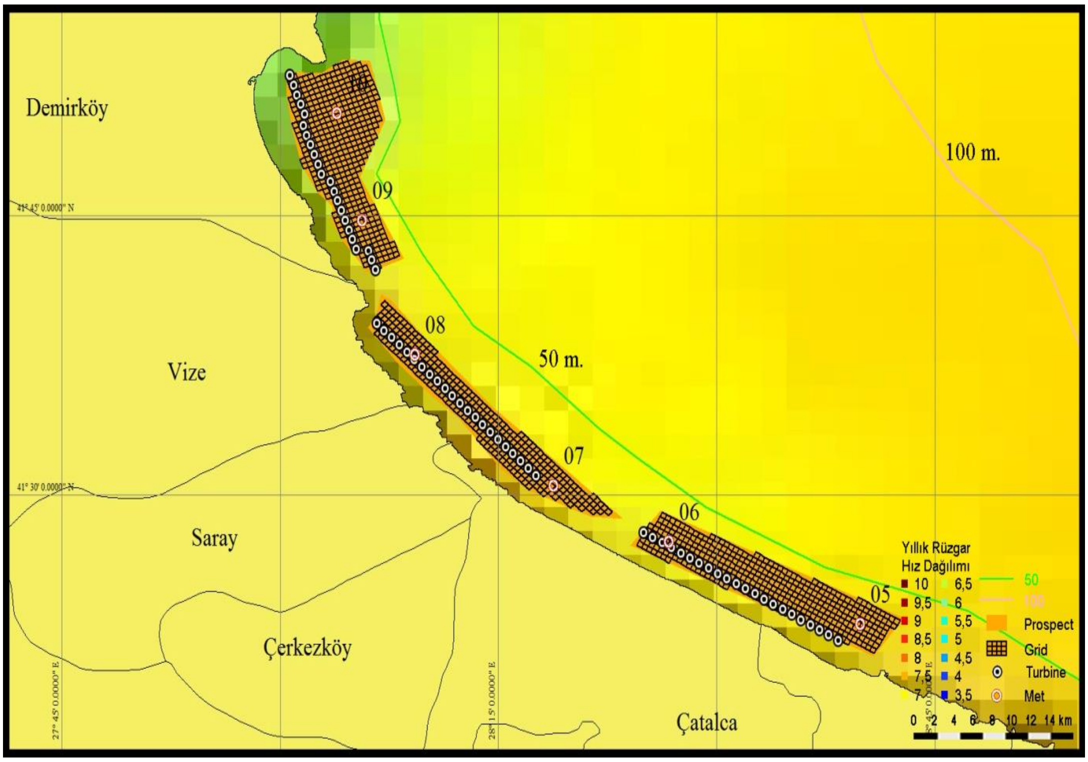

Figure A.13: Limankoy - Kiyikoy - Karaburun Prospects.

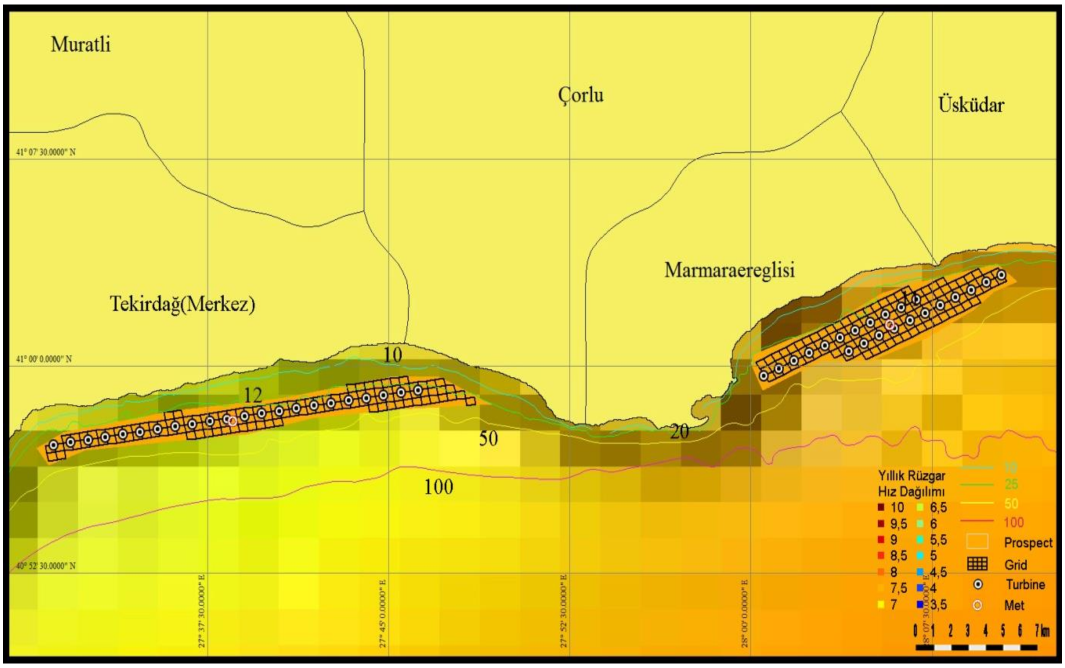

Figure A.14: Tekirdag and Eregli Prospects.

APPENDIX B

Table B.1: January - 10min Mean Wind Speed at 10m msl (m/s).

Wind Speed	N	NE	E	SE	S	SW	W	NW	Total	CFD
0-2	1.9	2.1	1.7	2.2	2.1	1.7	1.9	2.1	15.5	100
2-4	2.8	3.5	2.8	2.4	3.1	4.8	2.0	2.2	23.5	84.5
4-6	3.2	5.3	2.6	0.49	3.8	4.6	1.9	1.7	23.5	60.9
6-8	2.4	4.0	0.76	0.28	1.7	3.4	1.7	1.1	15.2	37.4
8-10	1.9	3.0	0.35		0.76	2.6	1.4	0.83	10.8	22.2
10-12	0.42	1.8			0.14	1.6	0.35	0.21	4.5	11.5
12-14	0.42	2.4			0.14	0.97	0.42	0.07	4.4	6.9
14-16	0.14	0.56				0.62		0.35	1.7	2.6
16-18		0.14				0.14		0.07	0.35	0.90
18-20	0.14					0.21			0.35	0.56
20-22	0.07								0.07	0.21
22-24	0.07								0.07	0.14
24-26	0.07								0.07	0.07
Total	13.4	22.7	8.2	5.3	11.7	20.5	9.6	8.6	100	

Table B.2: February- 10min Mean Wind Speed at 10m msl (m/s).

Wind Speed	N	NE	E	SE	S	SW	W	NW	Total	CFD
0-2	2.5	2.0	1.9	2.3	2.8	1.7	1.9	2.3	17.3	100
2-4	2.2	3.4	2.7	2.2	3.5	2.8	2.3	1.7	20.8	82.7
4-6	3.3	4.2	1.5	2.0	3.1	4.9	1.5	1.2	21.7	61.8
6-8	2.9	4.9	0.45	0.61	0.83	3.6	1.3	1.2	15.8	40.1
8-10	1.4	3.2		0.08	0.61	3.9	1.2	0.68	11.1	24.2
10-12	1.1	1.8			0.23	1.9	1.2	0.45	6.7	13.2
12-14	0.23	0.91		0.08	0.38	0.68	0.23	0.30	2.8	6.5
14-16	0.38	0.98			0.15	0.15	0.23	0.08	2.0	3.7
16-18	0.23	0.38				0.45		0.08	1.1	1.7
18-20	0.23	0.08							0.30	0.61
20-22	0.08							0.08	0.15	0.30
22-24	0.15								0.15	0.15
24-26										
Total	14.6	21.8	6.6	7.2	11.6	20.2	9.9	8.1	100	

Table B.3: March- 10min Mean Wind Speed at 10m msl (m/s).

Wind Speed	N	NE	E	SE	S	SW	W	NW	Total	CFD
0-2	2.0	1.8	2.2	1.4	2.2	1.5	1.8	1.8	14.6	100
2-4	3.6	3.9	3.1	2.5	3.6	3.1	2.8	2.6	25.2	85.4
4-6	5.0	6.0	2.2	0.91	2.9	4.2	2.5	2.2	25.8	60.2
6-8	2.0	5.9	0.70		0.77	3.2	1.5	1.2	15.2	34.4
8-10	1.5	4.0	0.07	0.07	0.14	2.5	1.5	0.77	10.6	19.2
10-12	0.56	2.9	0.14	0.07	0.14	0.70	0.70	0.14	5.3	8.6
12-14	0.28	1.2			0.07	0.63	0.14		2.3	3.3
14-16	0.07	0.35				0.21		0.07	0.70	0.98
16-18		0.14				0.14			0.28	0.28
18-20										
20-22										
22-24										
24-26										
Total	15.0	26.2	8.4	5.0	9.8	16.2	10.9	8.5	100	

Table B.4: April- 10min Mean Wind Speed at 10m msl (m/s).

Wind Speed	N	NE	E	SE	S	SW	W	NW	Total	CFD
0-2	4.1	3.6	3.1	3.2	2.7	3.3	3.2	2.6	25.7	100
2-4	3.2	4.7	4.8	2.6	3.5	4.9	4.7	2.8	31.1	74.3
4-6	1.3	6.0	3.1	1.3	1.4	5.7	2.5	1.5	22.9	43.2
6-8	0.88	4.1	1.1	0.15	0.88	2.5	1.1	0.52	11.3	20.3
8-10	0.44	1.8	0.22		0.22	1.3	0.81	0.59	5.3	9.0
10-12	0.22	0.81	0.07		0.07	0.59	0.29	0.22	2.3	3.7
12-14	0.07	0.44				0.37	0.15	0.15	1.2	1.4
14-16		0.07							0.07	0.22
16-18		0.07					0.07		0.15	0.15
18-20										
20-22										
22-24										
24-26										
Total	10.3	21.6	12.4	7.2	8.7	18.6	12.8	8.4	100	

Table B.5: May - 10min Mean Wind Speed at 10m msl (m/s).

Wind Speed	N	NE	E	SE	S	SW	W	NW	Total	CFD
0-2	3.8	5.2	3.3	3.0	2.7	3.4	3.1	3.2	27.7	100
2-4	5.4	7.9	5.5	1.8	3.1	3.3	2.5	2.4	31.9	72.3
4-6	1.8	8.6	2.1	0.71	1.6	2.6	1.7	0.36	19.5	40.3
6-8	0.92	6.5	0.50	0.21	0.21	1.8	0.71	0.78	11.7	20.8
8-10	0.21	3.6	0.21			0.36	0.57	0.07	5.0	9.2
10-12	0.07	2.2				0.14	0.14	0.07	2.6	4.2
12-14	0.14	1.1					0.07		1.3	1.6
14-16		0.28							0.28	0.28
16-18										
18-20										
20-22										
22-24										
24-26										
Total	12.4	35.3	11.6	5.7	7.6	11.7	8.8	6.9	100	

Table B.6: June - 10min Mean Wind Speed at 10m msl (m/s).

Wind Speed	N	NE	E	SE	S	SW	W	NW	Total	CFD
0-2	5.6	4.9	3.8	2.5	2.9	3.1	2.6	3.8	29.2	100
2-4	5.1	9.3	4.5	1.5	1.8	2.3	2.6	3.1	30.5	70.8
4-6	3.8	9.7	2.3	0.66	0.51	1.5	2.0	1.0	21.4	40.3
6-8	1.2	6.8	0.95			0.51	0.81	0.73	11.1	18.9
8-10	0.81	3.7	0.29			0.07	0.73	0.07	5.6	7.8
10-12	0.15	1.1	0.07	0.07		0.07	0.22		1.7	2.2
12-14							0.37		0.37	0.51
14-16							0.07		0.07	0.15
16-18										0.07
18-20							0.07		0.07	0.07
20-22										
22-24										
24-26										
Total	16.8	35.4	12.0	4.8	5.3	7.5	9.4	8.8	100	

Table B.7: July- 10min Mean Wind Speed at 10m msl (m/s).

Wind Speed	N	NE	E	SE	S	SW	W	NW	Total	CFD
0-2	4.0	4.9	3.2	2.1	1.2	2.0	2.2	3.2	23	100
2-4	5.7	9.7	3.6	1.4	0.88	0.81	2.0	2.9	27.1	77
4-6	4.7	13.2	1.8	0.2	0.07	0.95	1.4	1.8	24	49.9
6-8	1.8	9.8	0.68			0.20	0.54	0.41	13.4	25.9
8-10	0.81	6.4	0.34			0.20	0.20	0.07	8.0	12.5
10-12	0.14	2.8					0.14		3.0	4.5
12-14	0.14	1.1						0.07	1.4	1.4
14-16		0.07							0.07	0.07
16-18										
18-20										
20-22										
22-24										
24-26										
Total	17.3	48.1	9.7	3.6	2.2	4.2	6.5	8.4	100	

Table B.8: August- 10min Mean Wind Speed at 10m msl (m/s).

Wind Speed	N	NE	E	SE	S	SW	W	NW	Total	CFD
0-2	3.5	2.8	2.0	0.80	1.6	0.60	1.2	2.3	14.8	100
2-4	5.5	8.8	2.8	0.40	0.40	1.5	1.8	2.1	23.3	85.2
4-6	4.1	13.8	1.8	0.13	0.47	0.80	2.3	1.5	24.9	61.9
6-8	2.0	13.9	1.1	0.07		0.20	0.73	0.93	18.9	37.0
8-10	0.67	9.1	0.67			0.27	0.27	0.40	11.3	18.1
10-12	0.13	4.6	0.27				0.20	0.13	5.3	6.7
12-14		1.0	0.07					0.13	1.2	1.4
14-16	0.07	0.13							0.20	0.20
16-18										
18-20										
20-22										
22-24										
24-26										
Total	15.9	54.1	8.7	1.4	2.5	3.3	6.5	7.5	100	

Table B.9: September- 10min Mean Wind Speed at 10m msl (m/s).

Wind Speed	N	NE	E	SE	S	SW	W	NW	Total	CFD
0-2	3.5	4.0	3.1	2.1	2.2	1.8	1.8	2.3	20.7	100
2-4	4.2	6.9	3.5	1.5	1.9	2.0	1.7	2.5	24.3	79.3
4-6	2.6	12.2	3.7	0.69	0.69	1.2	2.4	2.0	25.4	55
6-8	1.3	10.5	0.69		0.21	0.69	1.9	1.0	16.3	29.6
8-10	0.21	5.8	0.28			0.28	0.69	0.42	7.6	13.3
10-12	0.28	2.5	0.14			0.07	0.76	0.35	4.1	5.6
12-14	0.07	0.63				0.07	0.21		0.97	1.5
14-16		0.28					0.07		0.35	0.56
16-18		0.07						0.07	0.14	0.21
18-20	0.07								0.07	0.07
20-22										
22-24										
24-26										
Total	12.2	42.8	11.4	4.3	5.0	6.1	9.4	8.7	100	

Table B.10: October - 10min Mean Wind Speed at 10m msl (m/s).

Wind Speed	N	NE	E	SE	S	SW	W	NW	Total	CFD
0-2	3.0	3.1	2.6	2.9	1.9	1.8	2.8	1.6	19.8	100
2-4	3.1	6.4	3.4	1.6	2.4	1.6	2.3	2.1	22.9	80.2
4-6	2.6	8.1	2.1	0.81	1.6	2.8	1.8	1.2	21.1	57.3
6-8	2.2	8.1	0.81	0.07	0.61	2.3	1.3	0.47	15.9	36.2
8-10	1.6	4.8	0.34		0.34	1.6	1.1	0.34	10.1	20.3
10-12	0.41	3.1	0.14		0.07	0.81	0.54	0.07	5.1	10.2
12-14	0.27	1.8	0.20			0.27	0.14	0.07	2.7	5.1
14-16	0.27	0.88	0.07			0.07	0.07		1.4	2.4
16-18	0.07	0.41					0.07		0.54	1.0
18-20		0.41					0.07		0.47	0.47
20-22										
22-24										
24-26										
Total	13.6	37.1	9.7	5.4	7.0	11.2	10.1	5.9	100	

Table B.11: November - 10min Mean Wind Speed at 10m msl (m/s).

Wind Speed	N	NE	E	SE	S	SW	W	NW	Total	CFD
0-2	1.7	2.1	2.6	3.0	3.9	1.4	1.5	1.5	17.7	100
2-4	1.7	2.9	3.1	3.0	5.4	4.1	1.6	1.0	22.9	82.3
4-6	2.0	5.3	2.8	1.2	4.5	3.7	2.0	1.2	22.6	59.4
6-8	2.0	4.0	0.83	0.48	1.2	2.8	1.9	1.3	14.6	36.9
8-10	1.2	2.6	0.34	0.07	0.55	2.3	1.4	0.76	9.2	22.3
10-12	1.6	2.3	0.07		0.41	0.97	1.1	0.69	7.1	13.1
12-14	1.0	1.0	0.07			0.55	0.28	0.14	3.1	6.0
14-16	0.62	0.83			0.28	0.21			1.9	2.9
16-18	0.14	0.28				0.14	0.14		0.69	0.97
18-20		0.07				0.14	0.07		0.28	0.28
20-22										
22-24										
24-26										
Total	12.1	21.3	9.7	7.7	16.3	16.3	10	6.6	100	

Table B.12: December - 10min Mean Wind Speed at 10m msl (m/s).

Wind Speed	N	NE	E	SE	S	SW	W	NW	Total	CFD
0-2	1.2	2.1	2.2	1.9	1.9	1.4	1.4	1.8	13.9	100
2-4	3.3	3.4	1.3	2.9	3.5	2.1	1.4	1.2	19.2	86.1
4-6	3.0	4.7	2.1	0.98	4.6	4.9	1.9	1.0	23.2	66.9
6-8	2.3	4.0	1.1	0.59	2.3	4.9	1.3	0.72	17.3	43.7
8-10	1.6	3.6	0.20		1.4	2.7	0.91	1.1	11.5	26.4
10-12	1.2	2.3			0.46	1.8	0.46	0.33	6.6	15.0
12-14	0.52	2.0			0.13	0.98	0.13	0.26	4.0	8.3
14-16	0.65	1.5				0.13		0.07	2.3	4.3
16-18	0.20	0.39				0.07			0.65	2.0
18-20	0.20	0.59				0.07			0.85	1.3
20-22		0.20							0.20	0.46
22-24	0.07	0.20							0.26	0.26
24-26										
Total	14.2	25.0	6.9	6.4	14.2	19.1	7.5	6.6	100	

APPENDIX C

Table C.1: European offshore wind farm capacities and turbines.

NAME OF THE FARM	CAPACITY (MW)	TURBINES No	# TURBINE CAP (MW)	MANUF.
Lillgrund	110	48	2.3	Siemens
Karehamn	48	16	3	Vestas
Vanern	30	10	3	Dynawind
Utgrunden	11	7	1.5	Enron
Yttre Stengrund	10	5	2	NEG
Bockstigen	2.75	5	0.55	WinWorld
Anholt	400	111	3.6	Siemens
Horns II	209	91	2.3	Siemens
Rodsand	207	90	2.3	Siemens
Nysted	166	72	2.3	Siemens
Horns I	160	80	2	Vestas
Middelgrunden	40	20	2	Siemens
Samso	23	10	2.3	Siemens
Sprogo	21	7	3	Vestas
Ronland 1	17.2	8	2.3	Vestas
Avedore Holme	10.8	3	3.6	Siemens
Frederikshavn	7.6	3	2.3	Nordex
Tuno Knob	5	10	0.5	Vestas
Vindeby	4.95	11	0.45	Nordex
Alpha Ventus	60	12	5	Multibrid
BARD-1	400	80	5	BARD
Breitling	2.5	1	5	Nordex
DanTysk	288	80	3.6	Siemens
Ems Emden	4.5	1	4.5	Enercon
EnBM Baltic-I	48.3	21	2.3	Siemens
Global Tech-I	400	80	5	Multibrid
Hooksiel	5	1	5	BARD
Meerwind	288	80	3.6	Siemens
Nordsee Ost	295	48	6.2	Senvion
Riffgat	113	30	3.6	Siemens
Trianel Borkum -I	200	40	5	Areva
arrow	90	30	3	Vestas
Beatrice	10	2	5	Repower
Blyth Offshore	4	2	2	Vestas
Burbo Bank	90	25	3.6	Siemens
Greater Gabbard	504	140	3.6	Siemens
Gunfleet Sands 1 & 2	172	48	3.6	Siemens

Table C.1 (cont.) : European offshore wind farm capacities and turbines.

NAME OF THE FARM	CAPACITY (MW)	TURBINES No	# TURBINE CAP (MW)	MANUF.
Gunfleet Sands 3	12	2	6	Siemens
Gwynt y Môr	576	160	3.6	Siemens
Humber Gateway	219	73	3	Vestas
Kentish Flats	90	30	3	Vestas
Lincs	270	75	3.6	Siemens
London Array	630	175	3.6	Siemens
Lynn and Inner Dowsing	194	54	3.6	Siemens
Methil	7	1	7	Samsung
North Hoyle	60	30	2	Vestas
Ormonde	150	30	5	Repower
Rhyl Flats	90	25	3.6	Siemens
Robin Rigg	180	60	3	Vestas
Scroby Sands	60	30	2	Vestas
Sheringham Shoal	317	88	3.6	Siemens
Teesside	62	27	2.3	Siemens
Thanet	300	100	3	Vestas
Walney	367	102	3.6	Siemens
Westermost Rough	210	35	6	Siemens
West of Duddon Sands	389	108	3.6	Siemens
Egmond aan Zee	108	36	3	Vestas
Eneco Luchterduinen	129	43	3	Vestas
Gemini	600	150	4	Siemens
Irene Vorrink	17	28	0.6	Nordtank
Lely	2	4	0.5	Nedwind
Princess Amalia	120	60	2	Vestas

Table C.2: Various technical information on European offshore wind farms.

NAME OF THE FARM	YEAR	COST (Mil. €)	WATER DEPTH (M)	CAP. (%)	DIST. (KM)	COUNTRY
Lillgrund	2008	197	13		9	SWEDEN
Karehamn	2013	120	21		5	
Vanern	2010		22		10	
Utgrunden	2006	17	15		7	
Yttre Stengrund	2001	13	7		4	
Bockstigen	1997	4	5		6	
Anholt	2013	1350	19	46.7	23	DENMARK
Horns II	2009	470	17	48.4		
Rodsand	2010	400	12	42.1	9	
Nysted	2003	248	9	36.1	11	
Horns I	2002	272	20	39.9	18	
Middelgrunden	2000	47	6	25.7	4.7	
Samso	2003	30	13	38.9	4	
Sprogo	2009		16	36.5	10	
Ronland 1	2003		2	44.1	0.1	
Avedore Holme	2009	25	2	29.2	0.1	
Frederikshavn	2003		4	29.3	0.3	
Tuno Knob	1995	10	7	29.7	6	
Vindeby	1991	10	4	23.8	1.8	
Alpha Ventus	2010	250	28		56	GERMANY
BARD-1	2013	2900	40		100	
Breitling	2006		0.5		0.3	
DanTysk	2015	850	31		70	
Ems Emden	2004		3		0.6	
EnBM Baltic-I	2011	300	19		16	
Global Tech-I	2015				110	
Hooksiel	2008		5		0.4	
Meerwind	2014	1300	26		53	
Nordsee Ost	2015				55	
Riffgat	2014	480	24		42	
Trianel Borkum -I	2015	900	33		45	
Arrow	2006	241.08	20		7	ENGLAND
Beatrice	2007	68.6	45	20	23	
Blyth Offshore	2000	7.84	11		1.6	
Burbo Bank	2007	176.4	6	35	7	
Greater Gabbard	2012	2940	32		23	
Gunfleet Sands 1 & 2	2010	588	15		7	
Gunfleet Sands 3	2013	99.96	12		8	
Gwynt y Môr	2015	3920	20		17	

Table C.2 (cont.) : Various technical information on European offshore wind farms.

NAME OF THE FARM	YEAR	COST (Mil. €)	WATER DEPTH (M)	CAP. (%)	DIST. (KM)	COUNTRY
Lincs	2013	1960	15		8	ENGLAND
Humber Gateway	2015	736.96	15		10	
Kentish Flats	2005	238.14	5	30	10	
London Array	2013	3528	25		20	
Lynn and Inner Dowsing	2009	588	11	37	5	
Methil	2013		5		0.05	
North Hoyle	2003	156.8	12	36	7	
Ormonde	2012	1081.92	22		9.5	
Rhyl Flats	2009	388.08	15		8	
Robin Rigg	2010	776.16	12		11	
Scroby Sands	2004	147.98	8	32	2.5	
Sheringham Shoal	2012	2156	24		17	
Teesside	2013	392	15		1.5	
Thanet	2010	1764	25		11	
Walney	2010	2352	30		14	
Westermost Rough	2015	725.2	15		10	
West of Duddon Sands	2014	3136	24		15	
Egmond aan Zee	2008	200	18		13	NETHERLANDS
Eneco Luchterduinen	2015	450	24		24	
Gemini	2017	2800	36		55	
Irene Vorrink	1996	26	3		1	
Lely	1994	6	4		0	
Princess Amalia	2008	350	24		26	

APPENDIX D

```
LDOPT       NF+Z1.0280007.849000 -40.000  40.000GLOBMN
  Jacket Definition
OPTIONS      MN       SD     1 1
LCSEL ST        OPR1 OPR2 OPR3 STM1 STM2 STM3
UCPART        0.5000.5001.0001.000300.0
AMOD
AMOD   STM1 1.330STM2 1.330STM3 1.330
SECT
SECT DDE       PLG                          45.0006.00060.0004.0004.100
SECT SDE       CON                          254.007.620106.687.6207.620
GRUP
GRUP CVD SDE                20.007.72224.80 1    1.001.00     0.500 7.8490
GRUP DL6        106.68 7.620 20.007.72224.80      1.001.00          7.8490
GRUP DL7        106.68 7.620 20.007.72224.80      1.001.00          7.8490
GRUP GIR DDE               20.007.72224.80 1    1.001.00          7.8490
GRUP HOR         50.800 2.540 20.007.72224.80      1.001.00          7.8490
GRUP LG1        121.92 7.620 20.007.72224.80      1.001.00         F7.8490
GRUP LG2        121.92 7.620 20.007.72224.80      1.001.00         F7.8490
GRUP LG3        121.92 7.620 20.007.72224.80      1.001.00         F7.8490
GRUP LG4        121.92 7.620 20.007.72224.80      1.001.00         F7.8490
GRUP PL1        106.68 7.620 20.007.72224.80      1.001.00         F7.8490
GRUP PL2        106.68 7.620 20.007.72224.80      1.001.00         F7.8490
GRUP PL3        106.68 7.620 20.007.72224.80      1.001.00         F7.8490
GRUP PL4        106.68 7.620 20.007.72224.80      1.001.00         F7.8490
GRUP PL5        106.68 7.620 20.007.72224.80      1.001.00         F7.8490
GRUP W.B        76.200 2.540 20.007.72224.80 9    1.001.00         F1.00-3
GRUP XBR         45.720 2.540 20.007.72224.80      1.001.00          7.8490
GRUP XBS        45.720 2.540 20.007.72224.80      1.001.00          7.8490
GRUP XPL        40.640 2.540 20.007.72224.80      1.001.00          7.8490
GRUP XPS        40.640 2.540 20.007.72224.80      1.001.00          7.8490
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MEMBER 603L703L DL6
MEMBER 604L704L DL6
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MEMBER100000031 GIR
MEMBER OFFSETS                         -30.00           -30.00
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MEMBER OFFSETS                         -30.00           -30.00
MEMBER100010034 GIR
MEMBER OFFSETS                         -30.00           -30.00
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MEMBER OFFSETS                         -30.00           -30.00
MEMBER100030027 GIR
MEMBER OFFSETS                         -30.00           -30.00
MEMBER100040018 GIR
MEMBER OFFSETS                         -30.00           -30.00
MEMBER100040039 GIR
MEMBER OFFSETS                         -30.00           -30.00
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MEMBER100050008 GIR
MEMBER OFFSETS                         -30.00           -30.00
MEMBER100060001 GIR
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MEMBER OFFSETS	-30.00	-30.00
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MEMBER OFFSETS	-30.00	-30.00
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MEMBER OFFSETS	-30.00	-30.00
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MEMBER 404P504L PL4
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MEMBER 504L604L PL5
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MEMBER 202L2A1X XBS
MEMBER 203L1B1X XBS
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MEMBER 204L2C2X XBS
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MEMBER 301L2C1X XBS
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MEMBER 403L3B1X XBS
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MEMBER 302L3D1X XPS
MEMBER 303L3D1X XPS
MEMBER 402L4D1X XPS
MEMBER 403L4D1X XPS
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JOINT 0003    2.   0.   10. 50.000        50.000
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JOINT 0006    0.   2.   10.-62.500 50.000 50.000
JOINT 0007   -1.   2.   10.-87.500 50.000 50.000
JOINT 0008   -1.   0.   10.-25.000        50.000
JOINT 0009    0.   0.   10.-62.500        50.000
JOINT 0010   -1.   0.   10.-87.500        50.000
JOINT 0011   -1.  -2.   10.-25.000-50.000 50.000
JOINT 0012    0.  -2.   10.-62.500-50.000 50.000
JOINT 0013   -1.  -2.   10.-87.500-50.000 50.000
JOINT 0014    1.  -2.   10. 25.000-50.000 50.000
JOINT 0015    1.  -2.   10. 87.500-50.000 50.000
JOINT 0016    0.  -2.   10. 62.500-50.000 50.000
JOINT 0017    1.   0.   10. 25.000        50.000
JOINT 0018    0.   0.   10. 62.500        50.000
JOINT 0019    1.   0.   10. 87.500        50.000
JOINT 0020    1.   2.   10. 25.000 50.000 50.000
JOINT 0021    0.   2.   10. 62.500 50.000 50.000
JOINT 0022    1.   2.   10. 87.500 50.000 50.000
JOINT 0023    2.   1.   10. 50.000 25.000 50.000
JOINT 0024    2.   1.   10. 50.000 87.500 50.000
JOINT 0025    2.   0.   10. 50.000 62.500 50.000
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JOINT 0038      0.    -1.    10.       -25.000 50.000
JOINT 0039      0.     0.    10.       -62.500 50.000
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JOINT 101P     -9.    -9.   -40.-64.286-64.286        PILEHD
JOINT 102L      9.    -9.   -40. 64.286-64.286
JOINT 102P      9.    -9.   -40. 64.286-64.286        PILEHD
JOINT 103L     -9.     9.   -40.-64.286 64.286
JOINT 103P     -9.     9.   -40.-64.286 64.286        PILEHD
JOINT 104L      9.     9.   -40. 64.286 64.286
JOINT 104P      9.     9.   -40. 64.286 64.286        PILEHD
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JOINT 1B1X      0.     8.   -33.4.500-4 70.209-41.463
JOINT 1C1X     -8.     0.   -33.-70.209       -41.463
JOINT 1C2X      8.     0.   -33. 70.209       -41.463
JOINT 1D1X      0.     0.   -40.
JOINT 201L     -7.    -7.   -28.-92.858-92.857
JOINT 201P     -7.    -7.   -28.-92.858-92.857
JOINT 202L      7.    -7.   -28. 92.858-92.857
JOINT 202P      7.    -7.   -28. 92.858-92.857
JOINT 203L     -7.     7.   -28.-92.858 92.857
JOINT 203P     -7.     7.   -28.-92.858 92.857
JOINT 204L      7.     7.   -28. 92.858 92.857
JOINT 204P      7.     7.   -28. 92.858 92.857
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JOINT 2B1X      0.     6.   -18.-4.50-4 59.323-65.263
JOINT 2C1X     -6.     0.   -18.-59.324       -65.263
JOINT 2C2X      6.     0.   -18. 59.324       -65.263
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JOINT 301P     -5.    -5.   -12.-64.286-64.286
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JOINT 302P      5.    -5.   -12. 64.286-64.286
JOINT 303L     -5.     5.   -12.-64.286 64.286
JOINT 303P     -5.     5.   -12.-64.286 64.286
JOINT 304L      5.     5.   -12. 64.286 64.286
JOINT 304P      5.     5.   -12. 64.286 64.286
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JOINT 3C1X     -3.     0.     2.-59.976        30.172
JOINT 3C2X      3.     0.     2. 59.976        30.172
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JOINT 401P     -2.    -2.     9.-64.286-64.286
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JOINT 402P      2.    -2.     9. 64.286-64.286
JOINT 403L     -2.     2.     9.-64.286 64.286
JOINT 403P     -2.     2.     9.-64.286 64.286
JOINT 404L      2.     2.     9. 64.286 64.286
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JOINT 603L     -2.     2.    10.-50.000 50.000
JOINT 604L      2.     2.    10. 50.000 50.000
JOINT 701L     -2.    -2.    10.-50.000-50.000 50.000
JOINT 702L      2.    -2.    10. 50.000-50.000 50.000
JOINT 703L     -2.     2.    10.-50.000 50.000 50.000
JOINT 704L      2.     2.    10. 50.000 50.000 50.000
CENTER  CEN1
CDM
CDM     2.50 0.600       1.200       0.600       1.200
CDM   250.00 0.600       1.200       0.600       1.200
MGROV
MGROV   0.000     20.000   2.500                 1.400
MGROV   24.000    40.000   5.000                 1.400
GRPOV
GRPOVAL       PL1NN             0.001 0.001 0.001                       N
GRPOVAL       PL2NN             0.001 0.001 0.001                       N
GRPOVAL       PL3NN             0.001 0.001 0.001                       N
GRPOVAL       PL4NN             0.001 0.001 0.001                       N
GRPOV         W.BNF 0.001  0.001  0.001 0.001 0.001                        N
SURFID MAINWT1 LY 703L 704L 702L   0.500
SURFDR 701L 703L 704L 702L
WGTMEMANOD101L201L  4.081  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD101L201L  8.162  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD201L301L  5.441  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD201L301L 10.882  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD301L401L  7.141  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD301L401L 14.283  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD401L501L  0.170  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD401L501L  0.340  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD102L202L  4.081  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD102L202L  8.162  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD202L302L  5.441  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD202L302L 10.882  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD302L402L  7.141  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD302L402L 14.283  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD402L502L  0.170  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD402L502L  0.340  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD103L203L  4.081  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD103L203L  8.162  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD203L303L  5.441  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD203L303L 10.882  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD303L403L  7.141  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD303L403L 14.283  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD403L503L  0.170  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD403L503L  0.340  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD104L204L  4.081  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD104L204L  8.162  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD204L304L  5.441  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD204L304L 10.882  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD304L404L  7.141  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD304L404L 14.283  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD404L504L  0.170  2.500            1.001.001.00GLOBCONC 2.700ANODE
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WGTMEMANOD404L504L  0.340  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD101L1A1X  3.905  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD101L1A1X  7.810  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD202L1A1X  3.211  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD202L1A1X  6.421  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD201L1A1X  3.211  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD201L1A1X  6.421  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD102L1A1X  3.905  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD102L1A1X  7.810  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD201L2A1X  4.110  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD201L2A1X  8.220  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD302L2A1X  2.925  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD302L2A1X  5.850  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD301L2A1X  2.925  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD301L2A1X  5.850  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD202L2A1X  4.110  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD202L2A1X  8.220  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD301L3A1X  5.170  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD301L3A1X 10.340  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD402L3A1X  2.421  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD402L3A1X  4.843  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD401L3A1X  2.421  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD401L3A1X  4.843  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD302L3A1X  5.170  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD302L3A1X 10.340  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD103L1B1X  3.905  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD103L1B1X  7.810  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD204L1B1X  3.211  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD204L1B1X  6.421  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD203L1B1X  3.211  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD203L1B1X  6.421  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD104L1B1X  3.905  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD104L1B1X  7.810  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD203L2B1X  4.110  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD203L2B1X  8.220  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD304L2B1X  2.925  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD304L2B1X  5.850  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD303L2B1X  2.925  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD303L2B1X  5.850  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD204L2B1X  4.110  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD204L2B1X  8.220  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD303L3B1X  5.170  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD303L3B1X 10.340  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD404L3B1X  2.421  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD404L3B1X  4.843  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD403L3B1X  2.421  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD403L3B1X  4.843  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD304L3B1X  5.170  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD304L3B1X 10.340  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD101L1C1X  3.905  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD101L1C1X  7.810  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD203L1C1X  3.211  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD203L1C1X  6.421  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD201L1C1X  3.211  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD201L1C1X  6.421  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD103L1C1X  3.905  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD103L1C1X  7.810  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD201L2C1X  4.110  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD201L2C1X  8.220  2.500            1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD303L2C1X  2.925  2.500            1.001.001.00GLOBCONC 2.700ANODE
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WGTMEMANOD303L2C1X  5.850  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD301L2C1X  2.925  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD301L2C1X  5.850  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD203L2C1X  4.110  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD203L2C1X  8.220  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD301L3C1X  5.170  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD301L3C1X 10.340  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD403L3C1X  2.421  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD403L3C1X  4.843  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD401L3C1X  2.421  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD401L3C1X  4.843  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD303L3C1X  5.170  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD303L3C1X 10.340  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD102L1C2X  3.905  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD102L1C2X  7.810  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD204L1C2X  3.211  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD204L1C2X  6.421  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD202L1C2X  3.211  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD202L1C2X  6.421  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD104L1C2X  3.905  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD104L1C2X  7.810  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD202L2C2X  4.110  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD202L2C2X  8.220  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD304L2C2X  2.925  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD304L2C2X  5.850  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD302L2C2X  2.925  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD302L2C2X  5.850  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD204L2C2X  4.110  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD204L2C2X  8.220  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD302L3C2X  5.170  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD302L3C2X 10.340  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD404L3C2X  2.421  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD404L3C2X  4.843  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD402L3C2X  2.421  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD402L3C2X  4.843  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD304L3C2X  5.170  2.500             1.001.001.00GLOBCONC 2.700ANODE
WGTMEMANOD304L3C2X 10.340  2.500             1.001.001.00GLOBCONC 2.700ANODE
SURFWTAREA  0.500AREAWT         1.001.001.00MAINWT1
SURFWTLIVE  1.000CELLLIVE       1.001.001.00MAINWT1
WGTJT MISC2000.00NACE    0041                    1.0001.0001.000
LOAD
LOADCNAREA
INCWGT  AREA
ACCEL              1.00000                               N CEN1
LOADCNLIVE
INCWGT  LIVE
ACCEL              1.00000                               N CEN1
LOADCNMISC
INCWGT  MISC
ACCEL              1.00000                               N CEN1
LOADCNP000
INCWGT  ANOD
WAVE
WAVE1.00STRE  6.00      12.00        0.00      D       20.00  18MS10 1
WIND
WIND D    25.000          0.00        AP08
CURR
CURR       0.000   0.500   0.000                 -5.000BC LN
CURR      40.000   1.000
DEAD
```

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DEAD      -Z                          M BML
LOADCNP045
INCWGT  ANOD
WAVE
WAVE1.00STRE  6.00       12.00        45.00      D  45.00 20.00  18MS10 1
WIND
WIND D    25.000          45.00       AP08
CURR
CURR       0.000   0.500  45.000                -5.000BC LN
CURR      40.000   1.000  45.000
DEAD
DEAD      -Z                          M BML
LOADCNP090
INCWGT  ANOD
WAVE
WAVE1.00STRE  6.00       12.00        90.00      D  90.00 20.00  18MS10 1
WIND
WIND D    25.000          90.00       AP08
CURR
CURR       0.000   0.500  90.000                -5.000BC LN
CURR      40.000   1.000  90.000
DEAD
DEAD      -Z                          M BML
LOADCNS000
INCWGT  ANOD
WAVE
WAVE1.00STRE 12.00 41.00 15.00         0.00      D        20.00  18MS10 1
WIND
WIND D    45.000           0.00       AP08
CURR
CURR       0.000   0.500   0.000                -5.000BC LN
CURR      40.000   1.500
DEAD
DEAD      -Z        41.000            M BML
LOADCNS045
INCWGT  ANOD
WAVE
WAVE1.00STRE 12.00 41.00 15.00        45.00      D  45.00 20.00  18MS10 1
WIND
WIND D    45.000          45.00       AP08
CURR
CURR       0.000   0.500  45.000                -5.000BC LN
CURR      40.000   1.500  45.000
DEAD
DEAD      -Z        41.000            M BML
LOADCNS090
INCWGT  ANOD
WAVE
WAVE1.00STRE 12.00 41.00 15.00        90.00      D  90.00 20.00  18MS10 1
WIND
WIND D    45.000          90.00       AP08
CURR
CURR       0.000   0.500  90.000                -5.000BC LN
CURR      40.000   1.500  90.000
DEAD
DEAD      -Z        41.000            M BML
LCOMB
LCOMB OPR1 AREA1.0000LIVE1.0000MISC1.0000P0001.1000
LCOMB OPR2 AREA1.0000LIVE1.0000MISC1.0000P0451.1000
LCOMB OPR3 AREA1.0000LIVE1.0000MISC1.0000P0901.1000
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LCOMB STM1 AREA1.0000LIVE0.7500MISC1.0000S0001.1000
LCOMB STM2 AREA1.0000LIVE0.7500MISC1.0000S0451.1000
LCOMB STM3 AREA1.0000LIVE0.7500MISC1.0000S0901.1000
END
 **LEG1**    1    -2.500    -2.500    10.000    -9.643    -9.643   -40.000
 **LEG2**    1   100.000   -40.000     9.500   1   0   1
 **LEG1**    2     2.500    -2.500    10.000     9.643    -9.643   -40.000
 **LEG2**    2   100.000   -40.000     9.500   1   0   1
 **LEG1**    3    -2.500     2.500    10.000    -9.643     9.643   -40.000
 **LEG2**    3   100.000   -40.000     9.500   1   0   1
 **LEG1**    4     2.500     2.500    10.000     9.643     9.643   -40.000
 **LEG2**    4   100.000   -40.000     9.500   1   0   1
 **ELEV**    -40.0001000    10.0001000   -40.0001000     9.5001000
 **ELEV**    -28.0001000   -12.0001000     9.0001000    10.5001000   100.0001000
 **LGLB**  10LG2LG2LG2LG2LG2LG2LG2LG2LG2LG2W.B
 **PLLB**  10PL1PL1PL1PL1PL1PL1PL1PL1PL1PL1
 **ROWS** ROW A   ROW B   ROW 1   ROW 2                  1
 **CONN**    9   0   0   9   0   0   9   9   0   0   0   0   1   1
 **PHY1**PILE01     PILE101P-201P  MEM201P-301P  MEM301P-401P  MEM401P-501L  MEM
 **PHY1**PILE02     PILE102P-202P  MEM202P-302P  MEM302P-402P  MEM402P-502L  MEM
 **PHY1**PILE03     PILE103P-203P  MEM203P-303P  MEM303P-403P  MEM403P-503L  MEM
 **PHY1**PILE04     PILE104P-204P  MEM204P-304P  MEM304P-404P  MEM404P-504L  MEM
 **PHY1**S-103L-102LSTRX103L-1D1X  MEM102L-1D1X  MEM
 **PHY1**S-201L-102LSTRX201L-1A1X  MEM102L-1A1X  MEM
 **PHY1**S-201L-103LSTRX201L-1C1X  MEM103L-1C1X  MEM
 **PHY1**S-202L-104LSTRX202L-1C2X  MEM104L-1C2X  MEM
 **PHY1**S-203L-104LSTRX203L-1B1X  MEM104L-1B1X  MEM
 **PHY1**S-203L-202LSTRX203L-2D1X  MEM202L-2D1X  MEM
 **PHY1**S-301L-202LSTRX301L-2A1X  MEM202L-2A1X  MEM
 **PHY1**S-301L-203LSTRX301L-2C1X  MEM203L-2C1X  MEM
 **PHY1**S-302L-204LSTRX302L-2C2X  MEM204L-2C2X  MEM
 **PHY1**S-303L-204LSTRX303L-2B1X  MEM204L-2B1X  MEM
 **PHY1**S-303L-302LSTRX303L-3D1X  MEM302L-3D1X  MEM
 **PHY1**S-401L-302LSTRX401L-3A1X  MEM302L-3A1X  MEM
 **PHY1**S-401L-303LSTRX401L-3C1X  MEM303L-3C1X  MEM
 **PHY1**S-402L-304LSTRX402L-3C2X  MEM304L-3C2X  MEM
 **PHY1**S-403L-304LSTRX403L-3B1X  MEM304L-3B1X  MEM
 **PHY1**S-403L-402LSTRX403L-4D1X  MEM402L-4D1X  MEM
 **PHY1**T-101L-104LTHRX101L-1D1X  MEM104L-1D1X  MEM
 **PHY1**T-101L-202LTHRX101L-1A1X  MEM202L-1A1X  MEM
 **PHY1**T-101L-203LTHRX101L-1C1X  MEM203L-1C1X  MEM
 **PHY1**T-102L-204LTHRX102L-1C2X  MEM204L-1C2X  MEM
 **PHY1**T-103L-204LTHRX103L-1B1X  MEM204L-1B1X  MEM
 **PHY1**T-201L-204LTHRX201L-2D1X  MEM204L-2D1X  MEM
 **PHY1**T-201L-302LTHRX201L-2A1X  MEM302L-2A1X  MEM
 **PHY1**T-201L-303LTHRX201L-2C1X  MEM303L-2C1X  MEM
 **PHY1**T-202L-304LTHRX202L-2C2X  MEM304L-2C2X  MEM
 **PHY1**T-203L-304LTHRX203L-2B1X  MEM304L-2B1X  MEM
 **PHY1**T-301L-304LTHRX301L-3D1X  MEM304L-3D1X  MEM
 **PHY1**T-301L-402LTHRX301L-3A1X  MEM402L-3A1X  MEM
 **PHY1**T-301L-403LTHRX301L-3C1X  MEM403L-3C1X  MEM
 **PHY1**T-302L-404LTHRX302L-3C2X  MEM404L-3C2X  MEM
 **PHY1**T-303L-404LTHRX303L-3B1X  MEM404L-3B1X  MEM
 **PHY1**T-401L-404LTHRX401L-4D1X  MEM404L-4D1X  MEM
 **PHY1**T0000-0003 THRO0000-0010  MEM0010-0008  MEM0008-0009  MEM0009-0004
MEM
 **PHY1**T0000-0003 THRO0004-0018  MEM0018-0017  MEM0017-0019  MEM0019-0003
MEM
 **PHY1**T0001-0004 THRO0001-0034  MEM0034-0032  MEM0032-0033  MEM0033-0004
MEM
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 **PHY1**T0004-0002 THRO0004-0039  MEM0039-0038  MEM0038-0040  MEM0040-0002
MEM
 **PHY1**T701L-703L THRO701L-0037  MEM0037-0035  MEM0035-0036  MEM0036-0000
MEM
 **PHY1**T701L-703L THRO0000-0031  MEM0031-0029  MEM0029-0030  MEM0030-703L
MEM
 **PHY1**T702L-701L THRO702L-0015  MEM0015-0014  MEM0014-0016  MEM0016-0002
MEM
 **PHY1**T702L-701L THRO0002-0012  MEM0012-0011  MEM0011-0013  MEM0013-701L
MEM
 **PHY1**T703L-704L THRO703L-0007  MEM0007-0005  MEM0005-0006  MEM0006-0001
MEM
 **PHY1**T703L-704L THRO0001-0021  MEM0021-0020  MEM0020-0022  MEM0022-704L
MEM
 **PHY1**T704L-702L THRO704L-0024  MEM0024-0023  MEM0023-0025  MEM0025-0003
MEM
 **PHY1**T704L-702L THRO0003-0027  MEM0027-0026  MEM0026-0028  MEM0028-702L
MEM
 **PHY1**X-1A1X     XBRCT-101L-202LPHYS-201L-102LPHY
 **PHY1**X-1B1X     XBRCT-103L-204LPHYS-203L-104LPHY
 **PHY1**X-1C1X     XBRCT-101L-203LPHYS-201L-103LPHY
 **PHY1**X-1C2X     XBRCT-102L-204LPHYS-202L-104LPHY
 **PHY1**X-1D1X     XBRCT-101L-104LPHYS-103L-102LPHY
 **PHY1**X-2A1X     XBRCT-201L-302LPHYS-301L-202LPHY
 **PHY1**X-2B1X     XBRCT-203L-304LPHYS-303L-204LPHY
 **PHY1**X-2C1X     XBRCT-201L-303LPHYS-301L-203LPHY
 **PHY1**X-2C2X     XBRCT-202L-304LPHYS-302L-204LPHY
 **PHY1**X-2D1X     XBRCT-201L-204LPHYS-203L-202LPHY
 **PHY1**X-3A1X     XBRCT-301L-402LPHYS-401L-302LPHY
 **PHY1**X-3B1X     XBRCT-303L-404LPHYS-403L-304LPHY
 **PHY1**X-3C1X     XBRCT-301L-403LPHYS-401L-303LPHY
 **PHY1**X-3C2X     XBRCT-302L-404LPHYS-402L-304LPHY
 **PHY1**X-3D1X     XBRCT-301L-304LPHYS-303L-302LPHY
 **PHY1**X-4D1X     XBRCT-401L-404LPHYS-403L-402LPHY
 **JNCV** 0 0 0 0 0 0 1
 **GCOL** CVDM255 255 0   GIRM255 255 0
END
```

APPENDIX E

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PSIOPT +ZMN   Y      SM             900        PP                7.849
PILSUP MAX
PLTRQ  SD
PLTPL 101P 102P 103P 104P
PLGRUP
PLGRUP PA1        106.68   12.   20.   8.0  35.5   90.00            1.0
PLGRUP PA2        106.68   12.   20.   8.0  35.5   90.00            1.0
PLGRUP PA3        106.68   12.   20.   8.0  35.5   90.00            1.0
PLGRUP PA4        106.68   12.   20.   8.0  35.5   90.00            1.00.9338
PILE
PILE  101P201P PA1                                    SOL1
PILE  102P202P PA2                                    SOL1
PILE  103P203P PA3                                    SOL1
PILE  104P204P PA4                                    SOL1
SOIL
SOIL TZAXIAL HEAD 13  8             1.0SOL1
SOIL T-Z     SLOCSM   8      0       5.2E-4
SOIL         T-Z      0     0    0.0.1702     00.3302     00.6071     00.8534
SOIL         T-Z      01.067      0 2.134     021.336
SOIL T-Z     SLOCSM   8  1.219        5.2E-4
SOIL         T-Z      0     0   21. 0.170   36.0.3302   54.0.6071   64.0.8534
SOIL         T-Z    71. 1.067   64. 2.134   64.21.336
SOIL T-Z     SLOCSM   8 3.3528        5.2E-4
SOIL         T-Z      0     0   37.0.1702   62.0.3302   93.0.6071  112.0.8534
SOIL         T-Z   125. 1.067  112. 2.134  112.21.336
SOIL T-Z     SLOCSM   8   4.88        5.2E-4
SOIL         T-Z      0     0   46.0.1702   76.0.3302  114.0.6071  137.0.8534
SOIL         T-Z   152. 1.067  137. 2.134  137.21.336
SOIL T-Z     SLOCSM   8   6.44        5.2E-4
SOIL         T-Z      0     0   53.0.1072   88.0.3302  131.0.6071  158.0.8534
SOIL         T-Z   175. 1.067  158. 2.134  158.21.336
SOIL T-Z     SLOCSM   8  10.67        5.2E-4
SOIL         T-Z      0     0   55.0.1702   92.0.3302  137.0.6071  165.0.8534
SOIL         T-Z   183. 1.067  165. 2.134  165.21.336
SOIL T-Z     SLOCSM   8  10.68        5.2E-4
SOIL         T-Z      0     0  371.0.1702  618.0.3302  926.0.6071 1112.0.8534
SOIL         T-Z  1235. 1.067 1112. 2.134 1112.21.336
SOIL T-Z     SLOCSM   8  18.59        5.2E-4
SOIL         T-Z      0     0  476.0.1702  793.0.3302 1189.0.6071 1427.0.8534
SOIL         T-Z  1585. 1.067 1427. 2.134 1427.21.336
SOIL T-Z     SLOCSM   8  24.69        5.2E-4
SOIL         T-Z      0     0  528.0.1702  879.0.3302 1319.0.6071 1583.0.8534
SOIL         T-Z  1758. 1.067 1583. 2.134 1583.21.336
SOIL T-Z     SLOCSM   8  36.27        5.2E-4
SOIL         T-Z      0     0  672.0.1702 1120.0.3302 1680.0.6701 2015.0.8534
SOIL         T-Z  2239. 1.067 2015. 2.134 2015.21.336
SOIL T-Z     SLOCSM   8  40.84        5.2E-4
SOIL         T-Z      0     0  742.0.1702 1237.0.3302 1856.0.6071 2227.0.8534
SOIL         T-Z  2475. 1.067 2227. 2.134 2227.21.336
SOIL T-Z     SLOCSM   8  49.68        5.2E-4
SOIL         T-Z      0     0  873.0.1702 1455.0.3302 2182.0.6071 2618.0.8534
SOIL         T-Z  2909. 1.067 2618. 2.134 2618.21.336
SOIL T-Z     SLOCSM   8  72.24        5.2E-4
SOIL         T-Z      0     0 1197.0.1702 1995.0.3302 2992.0.6071 3591.0.8534
SOIL         T-Z  3990. 1.067 3591. 2.134 3591.21.336
SOIL TORSION HEAD               50000.SOL1
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SOIL BEARING HEAD  3  7             2.54SOL1
SOIL BEAR    SLOC     7  18.59       4.9E-4
SOIL         T-Z      0     0   82. 0.084  165. 0.546  247. 1.764  296. 3.066
SOIL         T-Z   329.    4.2  329.   4.7
SOIL BEAR    SLOC     7  36.27       4.9E-4
SOIL         T-Z      0     0   87. 0.084  173. 0.546  260. 1.764  312. 3.066
SOIL         T-Z   346.    4.2  346.   4.7
SOIL BEAR    SLOC     7  72.24       4.9E-4
SOIL         T-Z      0     0  130. 0.084  260. 0.546  390. 1.764  468. 3.066
SOIL         T-Z   520.    4.2  520.    5.
SOIL LATERAL HEAD 12  8      106.7    2.54SOL1 MARINE-GEO 42IN
SOIL         SLOCSM   8           .175
SOIL         P-Y      0     0  0.19 0.054  0.26 0.134  0.36 0.336  0.48  0.84
SOIL         P-Y   0.66   2.1  0.95   6.3     0  31.5
SOIL         SLOCSM   8  0.914      .175
SOIL         P-Y      0     0  0.28 0.054  0.38 0.134  0.52 0.336  0.70  0.84
SOIL         P-Y   0.96   2.1  1.38   6.3  0.22  31.5
SOIL         SLOCSM   8 2.1336      .175
SOIL         P-Y      0     0  0.41 0.054  0.56 0.134  0.76 0.336  1.03  0.84
SOIL         P-Y   1.39   2.1  2.01   6.3  0.74  31.5
SOIL         SLOCSM   8  3.353      .175
SOIL         P-Y      0     0  0.55 0.054  0.75 0.134  1.02 0.336  1.38  0.84
SOIL         P-Y   1.87   2.1  2.69   6.3  1.56  31.5
SOIL         SLOCSM   8  4.572      .175
SOIL         P-Y      0     0  0.66 0.054  0.90 0.134  1.22 0.336  1.66  0.84
SOIL         P-Y   2.25   2.1  3.24   6.3  2.55  31.5
SOIL         SLOCSM   8  5.791      .175
SOIL         P-Y      0     0  0.77 0.054  1.05 0.134  1.42 0.336  1.93  0.84
SOIL         P-Y   2.62   2.1  3.78   6.3  3.78   60.
SOIL         SLOCSM   8   7.62      .175
SOIL         P-Y      0     0  0.77 0.054  1.05 0.134  1.42 0.336  1.93  0.84
SOIL         P-Y   2.63   2.1  3.78   6.3  3.78   60.
SOIL         SLOCSM   8  9.144      .175
SOIL         P-Y      0     0  0.77 0.054  1.05 0.134  1.42 0.336  1.93  0.84
SOIL         P-Y   2.63   2.1  3.78   6.3  3.78   60.
SOIL         SLOCSM   8 10.668      .175
SOIL         P-Y      0     0  0.77 0.054  1.05 0.134  1.42 0.336  1.93  0.84
SOIL         P-Y   2.63   2.1  3.78   6.3  3.78   60.
SOIL         SLOCSM   8 10.669      .175
SOIL         P-Y      0     0 12.56 0.027 17.05 0.067 23.14 0.168 31.41  0.42
SOIL         P-Y  42.63  1.05 61.39  3.15 61.39   60.
SOIL         SLOCSM   8 18.593      .175
SOIL         P-Y      0     0 14.70 0.027 19.95 0.067 27.08 0.168 36.75  0.42
SOIL         P-Y  49.88  1.05 71.82  3.15 71.82   60.
SOIL         SLOCSM   8 36.271      .175
SOIL         P-Y      0     0 15.47 0.027   21. 0.067 28.50 0.168 38.68  0.42
SOIL         P-Y  52.50  1.05 75.60  3.15 75.60   60.
END
```

APPENDIX F

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DYNOPT +ZMN 10CONS7.84905                1.0
DYNOP2  1.0  1.0   1.0
END
```

APPENDIX G

Table G.1: Operational workflow of a gas well in SASB.

NAME OF OPERATION	PLAN HRS	CUM. DAYS
RIG ARRIVE ON LOCATION	0.0	0.00
Position the rig and pin down the legs	3.00	0.13
Penetrate legs (Pre-load, take water, final load)	13.00	0.67
Jack-up the rig	3.00	0.79
Secure and lock hydraulic jack system	2.50	0.90
Position the cantilever	1.50	0.96
Clear main deck area	2.00	1.04
Install Texas Deck	2.00	1.13
Install hexagon, all stairs, water and mud lines	4.00	1.29
R/U, Assemble & Function test the Hammer	3.00	1.42
R/U 20" Casing Handling Tools	1.50	1.48
Run 20" Conductor to Seabed (Free Run)	2.00	1.56
Place Chaser on top of Cond. & Drive 20" /w hammer Conductor to 180.00 m	7.00	1.85
Cut and L/D 20" Casing and Grind, Cut Surface	2.00	1.94
L/D Hammer	2.00	2.02
N/U Diverter Spool, BOP, Diverter and 10" Pneumatic Valve	10.00	2.44
Make Hydraulic and Pneumatic Connections	2.00	2.52
Function Test BOP and Pneumatic Valve	1.00	2.56
N/U Bell Nipple and Flow Line	4.00	2.73
M/U and rack back 270 jts of DP (3.5min/jnt) Prepare MUD for 16" Hole	16.00	3.40
M/U BHA #1, RIH	6.00	3.65
Drill inside conductor to 20" Shoe	3.00	3.77
Displace sea water w/mud	1.00	3.81
Drill hole to 350 m, Controlled drilling, 10-15 m/hr	18.00	4.56
Circulate	1.00	4.60
Wiper trip	2.50	4.71
Drill hole to 600 m, Controlled drilling, 10-15 m/hr	25.00	5.75
Circulate	1.00	5.79
Wiper trip to shoe	3.00	5.92
Circulate and POOH	4.00	6.08
RIH, Circulate, Spot Hi-vis pill and POOH	5.00	6.29
R/U 13 3/8" Casing Handling Tools	1.00	6.33
Pick-up one joint and M/U MLS Casing hanger, L/D	1.50	6.40
M/U Shoe and Collar	1.50	6.46
RIH 13 3/8" Casing to TD	7.00	6.75
M/U cementing head and lines	0.50	6.77
Pressure test cement lines and circulate	1.50	6.83
Mix & pump cement slurry	1.00	6.88
Displace cement	1.00	6.92
Open MLS ports	0.50	6.94
Circulate, spud retarded water mixture	1.00	6.98
Close MLS ports and pressure test	0.50	7.00
R/D casing handling equipment	0.50	7.02
N/D bell nipple and diverter, cut casing, L/D diverter spool	5.00	7.23

Table G.1 (cont.) : Operational workflow of a gas well in SASB.

NAME OF OPERATION	PLAN HRS	CUM. DAYS
Weld 13 5/8" housing	4.00	7.40
Pressure test between two welds	0.50	7.42
N/U wellhead and BOPs, surface lines	10.00	7.83
Connect hydraulic hoses, function test BOPs	1.00	7.88
Pressure test surface lines	1.50	7.94
RIH w/ cup type tester	0.50	7.96
Pressure test BOPs	1.50	8.02
N/U bell nipple	1.50	8.08
L/D 16" stabilizers, 9 1/2" DC's M/U bit and BHA 2	4.00	8.25
RIH to 100 m	1.50	8.31
Displace seawater with mud	0.50	8.33
RIH and tug cementing plug @ 600m.	1.00	8.38
Drill plugs, cement and shoe and 2 m formation	6.00	8.63
Conduct leak-off test	1.50	8.69
Pull into shoe	1.00	8.73
Displace mud with new KCl mud	1.00	8.77
Drill new hole to900 m, 10 mph	30.00	10.02
Circulate	1.00	10.06
Wiper trip	5.00	10.27
Drill new hole to 1200 m, 9 mph	33.50	11.67
Circulate	1.00	11.71
POOH to change bit, RIH	7.00	12.00
Circulate	0.50	12.02
Drill new hole to 1500 m, 8 mph	37.50	13.58
Circulate	1.00	13.63
Wiper trip	5.00	13.83
Circulate	1.00	13.88
POOH	7.50	14.19
Drill new hole to 1800 m, 8 mph	37.50	15.75
Circulate	1.00	15.79
Wiper trip	5.00	16.00
Circulate	1.00	16.04
POOH	7.50	16.35
Drill new hole to 2100 m, 8 mph	37.50	17.92
Circulate	1.00	17.96
Wiper trip	5.00	18.17
Circulate	1.00	18.21
POOH	7.50	18.52
R/U Slb., Run OH logs PEX, R/D Slb. Interval 600m-2100m	10.00	14.60
P/U One Jnt. 9 5/8" Casing and M/U 9 5/8" MLS hanger, L/D Casing	1.50	14.67
RIH (Ream if necessary) circulate and POOH	6.00	14.92
R/U Power Tong and Casing Handling Tools	3.00	15.04
RIH 9 5/8" Casing	14.00	15.63
M/U Circulating Head, Lines and Circulate	2.50	15.73
L/D Circulating Head, Install Cementing Head, Pressure Test	0.50	15.75
Mix, Pump and Displace Cement	2.50	15.85
L/D Cementing Head. M/U Circulating Head	0.50	15.88
Open MLS Ports	0.50	15.90
Circulate	2.00	15.98

Table G.1 (cont.) : Operational workflow of a gas well in SASB.

NAME OF OPERATION	PLAN HRS	CUM. DAYS
Close Ports, Pressure Test	0.50	16.00
R/D Casing Tools and Power Tong	1.00	16.04
N/D BOP's, Cut and L/D Casing	7.00	16.33
Drop Slips, N/U Wellhead and BOP's, Function test BOP's	9.00	16.71
Pressure Test Surface Lines	1.00	16.75
Pressure Test BOP's	1.00	16.79
N/U Bell Nipple, Secure BOP's	2.00	16.88
L/D BHA 2 and M/U BHA 3	6.00	17.13
RIH to 100 m. Displace Seawater with Mud	1.00	17.17
RIH to Top of Cementing Plugs	3.00	17.29
Pressure Test Casing	0.50	17.31
Drill Plugs, Float collar, Cement FS	6.00	17.56
Drill 4m new hole, Integrity test	3.00	17.69
Drill new hole to 2300 m, 7 mph	43.00	19.48
Circulate	0.50	19.50
Wiper trip to 1500 m, dump shaker box	6.00	19.75
Circulate	0.50	19.77
Drill new hole to 2500 m, 6 mph	50.00	21.85
Circulate	1.00	21.90
POOH for logging	8.00	22.23
R/U Slb., Run OH logs PEX, R/D Slb.	8.00	22.56
P/U one 7" Casing and M/U 7" MLS Hanger, L/D cas.	1.50	22.63
RIH w/ Bit and Ream If Necessary	3.50	22.77
Circulate	1.00	22.81
POOH	4.00	22.98
R/U Power Tong and Casing Handling Tools	2.00	23.06
RIH 7" Casing to 2500m	16.00	23.73
M/U Cementing Head, Lines and Circulate	2.50	23.83
Mix, Pump and Displace Cement	3.00	23.96
R/D Casing Tools and Power Tong	1.00	24.13
N/D BOP's, Cut and L/D Casing, N/U Wellhead and BOP's	5.00	24.33
Pressure test BOP's	1.00	24.38
L/D BHA3 & 5" DP's load Vega	20.00	25.21
P/U and M/U 6" bit, 7" Scraper, 4 3/4" DCs and 3 1/2" DPs. RIH	26.00	26.29
complete Preparation of completion fluid,displace,filtrate.	8.00	26.63
Pressure test casings.POOH	8.00	26.96
R/U Slb., Run CBL, R/D Slb.	6.00	27.21
Setup surface testing equipment, pressure test, load and prepare TCP guns	12.00	27.71
Install test booms	6.00	27.96
P/T Surface testing equipment and lines.	2.00	28.04
P/U and M/U TCP guns and test string on a retrievable packer	6.00	28.29
RIH test string. Correlate CCL/GR with wire line	12.00	28.79
Pull with wire line, Lay down CCL/GR tools	3.00	28.92
P/U and M/U flow tree, pressure test	4.00	29.08
Inject Nitrogen	6.00	29.33
Fire TCP guns, perforate	3.00	29.46
Move out all tools and equipment from platform	36.00	30.96
RELEASE THE RIG		30.96

Table G.2 : Cost estimation table for a sample well in SASB.

COST ITEM	UNIT	COST	QTY	TOTAL COST
TANGIBLES				
CONDUCTOR CASING / STRUCTURAL CAISSON	1,200	$/M	160	$192,000
MUDLINE SUSPENSION SYSTEM	40,000	$/SET	1	$40,000
CASING AND ACCESSORIES				
13 3/8"	130	$/M	900	$117,000
9 5/8"	85	$/M	1700	$144,500
7" GASTIGHT	105	$/M	800	$84,000
13 3/8" FS/FC/PLUGS	2,250	$/SET	1	$2,250
9 5/8" FS/FC/PLUGS	2,600	$/SET	1	$2,600
7" FS/FC/PLUGS	3,300	$/SET	1	$3,300
13 3/8" CENTRALIZER/STOP COLLAR/SCRATCHER	250	$/SET	10	$2,500
9 5/8" CENTRALIZER/STOP COLLAR/SCRATCHER	225	$/SET	30	$6,750
7" CENTRALIZER/STOP COLLAR/SCRATCHER	275	$/SET	10	$2,750
TUBING AND ACCESSORIES				
2 7/8" PRODUCTION TUBING	19	$/M	2750	$0
SCSSV	25,000	$/SET	1	$0
PRODUCTION PACKER	7,500	$/SET	1	$0
VARIOUS STRING MEMBERS	4,500	$/SET	1	$0
WELLHEAD AND X-MAS TREE EQUIPMENT				
13 5/8" CASING HEAD HOUSING	4,250	$/PCS	1	$4,250
13 5/8" X 11" SPOOL	5,250	$/PCS	1	$5,250
TUBING HANGER SPOOL	6,500	$/PCS	1	$6,500
X-MASS TREE	17,500	$/PCS	1	$17,500
DOWNHOLE EQUIPMENT				
9 5/8" ACP	22,000	$/PCS	1	$22,000
9 5/8" STAGE COLLAR	15,000	$/PCS	1	$15,000
7" ACP	22,000	$/PCS	1	$22,000
7" STAGE COLLAR/PLUGS	15,000	$/PCS	1	$15,000
7" LINER HANGER	35,000	$/PCS	1	$35,000
INTANGIBLES				
RIG MOB/DEMOB/INTERMOVE				
MOB/DEMOB	3,000,000	$/JOB	0	$0
INTERMOVE	200,000	$/JOB	0	$0
RIG POSITIONING SERVICE	25,000	$/JOB	1	$25,000
CONDUCTOR HAMMERING / PILE DRIVING	50,000	$/JOB	1	$50,000
RIG RATES	100,000	$/DAY	30	$3,000,000
DIESEL/LUBES/WATER	5,000	$/DAY	30	$150,000

Table G.2 (cont.) : Cost estimation table for a sample well in SASB.

COST ITEM	UNIT	COST	QTY	TOTAL COST
INTANGIBLES				
DELAYS ON OPERATION / WAITING ON WEATHER	100,000	$/DAY	0	$0
TIEBACK SERVICES	1,500	$/DAY	0	$0
DRILLING BITS				
17 1/2"	22,500	$/PCS	1	$22,500
12 1/4"	12,500	$/PCS	3	$37,500
8 1/2"	6,000	$/PCS	3	$18,000
6"	3,750	$/PCS	0	$0
DRILLING FLUID/COMPLETION FLUID				
KCL/PHPA MUD SYSTEM	70	$/BBL	2600	$182,000
COMPLETION SERVICE	20	$/BBL	1500	$30,000
ENGINEERING	1,250	$/DAY	27	$33,750
FILTRATION	3,500	$/DAY	0	$0
CASING AND TUBING RUNNING SERVICES				
POWER TONG OPERATING	1,500	$/DAY	8	$12,000
POWER TONG FOOTAGE CHARGE	6	$/M	7500	$45,000
RUNNING CREW	2,500	$/DAY	6	$15,000
JAM UNIT	2,000	$/DAY	2	$4,000
JAM UNIT CREW	2,000	$/DAY	2	$4,000
CEMENT AND ADDITIVES				$0
CEMENT	150	$/TON	140	$21,000
ADDITIVES	20,000	$/JOB	3	$60,000
CEMENTING SERVICES				
PUMP	2,250	$/DAY	33	$74,250
CREW	2,000	$/DAY	9	$18,000
CEMENTING HEAD AND RELATED EQP	2,450	$/DAY	9	$22,050
WIRELINE - OPEN HOLE				
RIG UP CHARGE	4,300	$/JOB	3	$12,900
CREW	3,500	$/DAY	9	$31,500
OFFSHORE WIRELINE UNIT MONTHLY	22,500	$/MON	1	$22,500
17 1/2" HOLE	25,000	$/JOB	1	$25,000
12 1/4" HOLE	115,000	$/JOB	1	$115,000
8 1/2" HOLE	135,000	$/JOB	1	$135,000
WIRELINE - CASED HOLE				
RIG UP CHARGE	4,300	$/JOB	2	$8,600
CREW	3,500	$/DAY	6	$21,000
FOOTAGE CHARGES	17	$/M	2500	$42,500

Table G.2 (cont.) : Cost estimation table for a sample well in SASB.

COST ITEM	UNIT	COST	QTY	COST
INTANGIBLES				
DIRECTIONAL DRILLING SERVICES				$0
CREW	7,500	$/DAY	21	$157,500
EQUIPMENT RATES	12,500	$/DAY	21	$262,500
MUD LOGGING SERVICES				
UNIT	750	$/DAY	27	$20,250
DATA ENGINEERS	1,000	$/DAY	27	$27,000
MUD LOGGERS	750	$/DAY	27	$20,250
CONSUMABLES	100	$/DAY	27	$2,700
EOWR	2,000	$/REP	27	$54,000
WELL TESTING SERVICES				
CREW	7,500	$/DAY	5	$37,500
SWT EQUIPMENT	17,500	$/DAY	5	$87,500
SAMPLING PACKAGE	3,500	$/DAY	5	$17,500
COMPLETION SERVICES				
CREW CHARGES	5,500	$/DAY	6	$33,000
VARIOUS COMPLETION EQP.	17,500	$/JOB	1	$17,500
PERFORATION SERVICES				
CREW CHARGES	5,500	$/DAY	5	$27,500
PREPARATION FEES	35,000	$/JOB	1	$35,000
TCP EQP.	15,000	$/JOB	1	$15,000
TCP GUNS	1,750	$/JOB	20	$35,000
FISHING SERVICES / RENTAL TOOLS	750	$/DAY	33	$24,750
DOCK, STORAGE, CRANE SERVICES	1,250	$/DAY	33	$41,250
SUPPLY VESSEL	5,000	$/DAY	33	$165,000
SHIPPING AGENT	500	$/DAY	33	$16,500
PERSONNEL TRANSPORT BOAT	1,150	$/DAY	33	$37,950
ADMINISTRATIVE				
WELL PLANNING	15,000	$/WELL	1	$15,000
PROJECT PERSONNEL	1,750	$/DAY	33	$57,750
TRAVEL AND ACCOMODATIONS	250	$/DAY	33	$8,250
COMMUNICATIONS	100	$/DAY	33	$3,300
TAXES/ASSOCIATED COST	750	$/DAY	33	$24,750
CUSTOM AGENT	250	$/DAY	33	$8,250
WELL INSURANCE	90,000	$/WELL	1	$90,000
GRAND-TOTAL				$6,320,650

APPENDIX H

Table H.1: Batch drilling operational workflow for storage wells.

#	NAME OF OPERATION	PLAN HRS	CUM. DAYS
1	Rig arrive on location	3	0.13
2	Position the rig and pin down the legs	13	0.67
3	Jack the rig up	3	0.79
4	Secure and lock hydraulic jack system	2.5	0.9
5	Install cement, water and diesel hoses	1.5	0.96
6	Clear main deck	2	1.04
7	Install texas deck	2	1.13
8	Install hexagon stairs,water and mud lines	4	1.29
9	Position the cantilever on well #1	1.5	1.35
10	R/U, Assemble, Function test the hammer	3	1.48
11	R/U 20" casing handling tools	1.5	1.54
12	Run 20" Conductor to seabed (Free run)	2	1.63
13	Place chaser on top of Cond. And Drive 20" /w hammer	7	1.92
14	Cut and L/D 20" Casing, cut and grind surface	2	2
15	Skid cantilever on the other 11 wells and Repeat steps-(10-14)	187	9.79
16	L/D Hammer	2	9.88
17	N/U Diverter Spool, BOP, Diverter and 10" Pneumatic Valve	10	10.29
18	Make Hydraulic and Pneumatic Connections	2	10.38
19	Function Test BOP and Pneumatic Valve	1	10.42
20	N/U Bell Nipple and Flow Line	4	10.58
21	M/U and rack back 270 joints of DP (3.5min/jnt)	16	11.25
22	M/U BHA #1, RIH	6	11.5
23	Drill inside conductor to 20" Shoe	3	11.63
24	Displace sea water w/mud	1	11.67
25	Drill hole to 300 m, Controlled drilling, 10-15 m/hr	15	12.29
26	Circulate	1	12.33
27	Wiper trip	2.5	12.44
28	Circulate and POOH	4	12.6
29	RIH, Circulate, Spot Hi-vis pill and POOH	5	12.81
30	R/U 13 3/8" Casing Handling Tools	1	12.85
31	Pick-up one joint and M/U MLS Casing hanger, L/D	1.5	12.92
32	M/U Shoe and Collar	1.5	12.98
33	RIH 13 3/8" Casing to TD	7	13.27
34	M/U cementing head and lines	0.5	13.29
35	Pressure test cement lines and circulate	1.5	13.35
36	Mix & pump cement slurry	1	13.4
37	Displace cement	1	13.44
38	Bump the plug wait for 15 mins. Release the pressure. WOC	8	13.77
39	R/D casing handling equipment	0.5	13.79

Table H.1 (cont.) : Batch drilling operational workflow for storage wells.

#	NAME OF OPERATION	PLAN HRS	CUM. DAYS
40	N/D bell nipple and diverter, cut casing, L/D diverter spool	5	14
41	Weld 13 5/8" housing	4	14.17
42	Pressure test between two welds	0.5	14.19
43	Skid cantilever on the other 11 wells and repeat steps (17-42) except (21-22)	896.5	51.54
44	N/U wellhead and BOPs, surface lines	10	51.96
45	Connect hydraulic hoses, function test BOPs	1	52
46	Pressure test surface lines	1.5	52.06
47	RIH w/ cup type tester	0.5	52.08
48	Pressure test BOPs	1.5	52.15
49	N/U bell nipple	1.5	52.21
50	L/D 17 1/2" stabilizers, 9 1/2" DC's M/U bit and BHA 2	4	52.38
51	RIH and tug cementing plug @ 280m.	2	52.46
52	Drill plugs, cement and shoe and 2 m formation	6	52.71
53	Conduct leak-off test	1.5	52.77
54	Pull into shoe	1	52.81
55	Displace mud with new KCl mud	1	52.85
56	Drill new hole to 600 m, 10 mph	30	54.1
57	Circulate	1	54.15
58	Wiper trip	5	54.35
59	Drill new hole to 900 m, 9 mph	33.5	55.75
60	Circulate	1	55.79
61	Wiper trip	5	56
62	Drill new hole to 1200 m, 8 mph	37	57.54
63	Circulate	1	57.58
64	Wiper trip	5	57.79
65	Circulate	1	57.83
66	POOH	7.5	58.15
67	Run 12 1/4" section correlation logs	10	58.56
68	RIH	4	58.73
69	Circulate and POOH	6	58.98
70	R/U Power Tong and Casing Handling Tools	3	59.1
71	RIH 9 5/8" Casing	14	59.69
72	M/U Circulating Head, Lines and Circulate	2.5	59.79
73	L/D Circulating Head, Install Cementing Head, Pressure Test	0.5	59.81
74	Mix, Pump and Displace Cement	2.5	59.92
75	L/D Cementing Head. M/U Circulating Head	0.5	59.94
76	R/D Casing Tools and Power Tong	1	59.98
77	N/D BOP's, Cut and L/D Casing	7	60.27
78	Skid cantilever on the other 11 wells and repeat steps (44-77) except (50)	2260.5	154.46
79	Drop Slips, N/U Wellhead and BOP's, Function test BOP's	9	154.83

Table H.1 (cont.) : Batch drilling operational workflow for storage wells.

#	NAME OF OPERATION	PLAN HRS	CUM. DAYS
80	Pressure Test Surface Lines	1	154.88
81	Pressure Test BOP's	1	154.92
82	N/U Bell Nipple, Secure BOP's	2	155
83	L/D 12 1/4" BHA and M/U BHA 8 1/2" BHA	6	155.25
84	RIH to Top of Cementing Plugs	3	155.38
85	Pressure Test Casing	0.5	155.4
86	Drill Plugs, Float collar, Cement FS	6	155.65
87	Drill 4m new hole, Integrity test	3	155.77
88	Drill new hole to 1500 m, 7 mph	43	157.56
89	Circulate	0.5	157.58
90	Wiper trip to 1200 m, dump shaker box	6	157.83
91	Circulate	0.5	157.85
92	Drill new hole to 1800 m, 6 mph	50	159.94
93	Circulate	1	159.98
94	POOH to change bit, RIH	8	160.31
95	Circulate	0.5	160.33
96	Drill new hole to 2100 m, 6 mph	50	162.42
97	Circulate	4	162.58
98	Wiper trip to 1200 m, dump shaker box,RIH	10	163
99	Circulate	0.5	163.02
100	POOH for logging	8	163.35
101	R/U wireline / run formation evaluation logs / reservoir testers	24	164.35
102	RIH w/ Bit and Ream	3.5	164.5
103	Circulate	1	164.54
104	POOH	4	164.71
105	R/U Power Tong and Casing Handling Tools	2	164.79
106	RIH 7" Casing to 2100m	16	165.46
107	M/U Cementing Head, Lines and Circulate	2.5	165.56
108	Mix, Pump and Displace Cement	3	165.69
109	R/D Casing Tools and Power Tong	1	165.73
110	N/D BOP's, Cut and L/D Casing	5	165.94
111	Skid cantilever on the other 11 wells and repeat steps (79-110) except (83)	2959	289.23
112	L/D 8 1/2" BHA & 5" DP's	20	290.06
113	P/U and M/U 6" bit, 7" Scraper, 4 3/4" DCs and 3 1/2" DPs	26	291.15
114	RIH,Pressure test casings, Conduct scraper run	10	291.56
115	Complete Preparation of completion fluid,displace,filtrate.	8	291.9
116	Circulate till clean.	4	292.06
117	POOH and rack back 6" clean-up string	10	292.48
118	P/U and M/U TCP - completion string - RIH	12	292.98
119	N/D BOPs - N/U tubing hanger	6	293.23

Table H.1 (cont.) : Batch drilling operational workflow for storage wells.

#	NAME OF OPERATION	PLAN HRS	CUM. DAYS
120	Set packer - Pressure test annulus	6	293.48
121	N/U x-mas tree and flow lines	8	293.81
122	Inject nitrogen to create underbalance	2	293.9
123	Drop the bar - perforate - hand the well over to testing dept.	2	293.98
124	Skid cantilever on the other 11 wells and repeat steps (114-123)	748	325.15
125	Move out all tools and equipment from platform	72	328.15

Table H.3 : Cost estimation for batch drilling.

COST ITEM	UNIT	COST	QTY	TOTAL COST
TANGIBLES				
CONDUCTOR CASING / STRUCTURAL CAISSON	1,200	USD/M	160	$192,000
MUDLINE SUSPENSION SYSTEM	40,000	USD/SET	12	$480,000
CASING AND ACCESSORIES				
13 3/8"	130	$/M	4000	$520,000
9 5/8"	85	$/M	15000	$1,275,000
7" GASTIGHT	105	$/M	25000	$2,625,000
13 3/8" FS/FC/PLUGS	2,250	$/SET	12	$27,000
9 5/8" FS/FC/PLUGS	2,600	$/SET	12	$31,200
7" FS/FC/PLUGS	3,300	$/SET	12	$39,600
13 3/8" CENTRALIZER/STOP COLLAR/SCRATCHER	250	$/SET	120	$30,000
9 5/8" CENTRALIZER/STOP COLLAR/SCRATCHER	225	$/SET	240	$54,000
7" CENTRALIZER/STOP COLLAR/SCRATCHER	275	$/SET	240	$66,000
TUBING AND ACCESSORIES				
2 7/8" PRODUCTION TUBING	19	$/M	19500	$370,500
SCSSV	25,000	$/SET	12	$0
PRODUCTION PACKER	7,500	$/SET	12	$0
VARIOUS STRING MEMBERS	4,500	$/SET	12	$0
WELLHEAD AND X-MAS TREE EQUIPMENT				
13 5/8" CASING HEAD HOUSING	4,250	$/PCS	12	$51,000
13 5/8" X 11" SPOOL	5,250	$/PCS	12	$63,000
TUBING HANGER SPOOL	6,500	$/PCS	12	$78,000
X-MASS TREE	17,500	$/PCS	12	$210,000
DOWNHOLE EQUIPMENT				
9 5/8" ACP	22,000	$/PCS	12	$264,000
9 5/8" STAGE COLLAR	15,000	$/PCS	12	$180,000
7" ACP	22,000	$/PCS	12	$264,000
7" STAGE COLLAR/PLUGS	15,000	$/PCS	12	$180,000
INTANGIBLES				
RIG MOB/DEMOB/INTERMOVE				
MOB/DEMOB	1,500,000	$/JOB	1	$1,500,000
INTERMOVE	200,000	$/JOB	0	$0
RIG POSITIONING SERVICE	25,000	$/JOB	1	$25,000
CONDUCTOR HAMMERING / PILE DRIVING	25,000	$/JOB	12	$300,000
RIG RATES	70,000	$/DAY	360	$25,200,000
DIESEL/LUBES/WATER	5,000	$/DAY	360	$1,800,000
DELAYS ON OPERATION / WAITING ON WEATHER	70,000	$/DAY	30	$2,100,000

Table H.3 (cont.) : Cost estimation for batch drilling.

COST ITEM	UNIT	COST	QTY	TOTAL COST
INTANGIBLES				
TIEBACK SERVICES	1,500	$/DAY	0	$0
DRILLING BITS				
17 1/2"	22,500	$/PCS	10	$225,000
12 1/4"	12,500	$/PCS	20	$250,000
8 1/2"	6,000	$/PCS	30	$180,000
6"	3,750	$/PCS	6	$22,500
DRILLING FLUID/COMPLETION FLUID				
KCL/PHPA MUD SYSTEM	70	$/BBL	18000	$1,260,000
COMPLETION SERVICE	20	$/BBL	12000	$240,000
ENGINEERING	1,250	$/DAY	300	$375,000
FILTRATION	3,500	$/DAY	30	$105,000
CASING AND TUBING RUNNING SERVICES				
POWER TONG OPERATING	1,500	$/DAY	96	$144,000
POWER TONG FOOTAGE CHARGE	6	$/M	47000	$282,000
RUNNING CREW	2,500	$/DAY	96	$240,000
JAM UNIT	2,000	$/DAY	48	$96,000
JAM UNIT CREW	2,000	$/DAY	48	$96,000
CEMENT AND ADDITIVES				$0
CEMENT	150	$/TON	4000	$600,000
ADDITIVES	20,000	$/JOB	36	$720,000
CEMENTING SERVICES				
PUMP	2,250	$/DAY	300	$675,000
CREW	2,000	$/DAY	100	$200,000
CEMENTING HEAD AND RELATED EQP	2,450	$/DAY	100	$245,000
WIRELINE - OPEN HOLE				
RIG UP CHARGE	4,300	$/JOB	30	$129,000
CREW	3,500	$/DAY	72	$252,000
OFFSHORE WIRELINE UNIT MONTHLY	22,500	$/MON	12	$270,000
17 1/2" HOLE	25,000	$/JOB	0	$0
12 1/4" HOLE	55,000	$/JOB	12	$660,000
8 1/2" HOLE	215,000	$/JOB	12	$2,580,000
WIRELINE - CASED HOLE				
RIG UP CHARGE	4,300	$/JOB	2	$8,600
CREW	3,500	$/DAY	30	$105,000
FOOTAGE CHARGES	17	$/M	25000	$425,000

Table H.3 (cont.) : Cost estimation for batch drilling.

COST ITEM	UNIT	COST	QTY	TOTAL COST
INTANGIBLES				
DIRECTIONAL DRILLING SERVICES				$0
CREW	7,500	$/DAY	120	$900,000
EQUIPMENT RATES	12,500	$/DAY	120	$1,500,000
MUD LOGGING SERVICES				
UNIT	750	$/DAY	300	$225,000
DATA ENGINEERS	1,000	$/DAY	300	$300,000
MUD LOGGERS	750	$/DAY	300	$225,000
CONSUMABLES	100	$/DAY	300	$30,000
EOWR	2,000	$/REP	300	$600,000
WELL TESTING SERVICES				
CREW	7,500	$/DAY	60	$450,000
SWT EQUIPMENT	17,500	$/DAY	60	$1,050,000
SAMPLING PACKAGE	3,500	$/DAY	60	$210,000
COMPLETION SERVICES				
CREW CHARGES	5,500	$/DAY	60	$330,000
VARIOUS COMPLETION EQP.	17,500	$/JOB	12	$210,000
PERFORATION SERVICES				
CREW CHARGES	5,500	$/DAY	60	$330,000
PREPARATION FEES	35,000	$/JOB	12	$420,000
TCP EQP.	15,000	$/JOB	12	$180,000
TCP GUNS	1,750	$/M	240	$420,000
FISHING SERVICES / RENTAL TOOLS	750	$/DAY	300	$225,000
DOCK, STORAGE, CRANE SERVICES	1,250	$/DAY	300	$375,000
SUPPLY VESSEL	5,000	$/DAY	300	$1,500,000
SHIPPING AGENT	500	$/DAY	300	$150,000
PERSONNEL TRANSPORT BOAT	1,150	$/DAY	300	$345,000
ADMINISTRATIVE				
WELL PLANNING	7,500	$/WELL	12	$90,000
PROJECT PERSONNEL	1,750	$/DAY	360	$630,000
TRAVEL AND ACCOMODATIONS	250	$/DAY	360	$90,000
COMMUNICATIONS	100	$/DAY	360	$36,000
TAXES/ASSOCIATED COST	750	$/DAY	360	$270,000
CUSTOM AGENT	250	$/DAY	360	$90,000
WELL INSURANCE	80,000	$/WELL	12	$960,000
TOTAL ESTIMATED COST				$60,451,400

APPENDIX I

Table I.1: Workflow for turbine tower and turbine installation.

NAME OF OPERATION	HRS	TOTAL DAYS
Jackup barge arrive on location	3.0	0.13
Position the rig and pin down the legs	15.0	0.75
Jack the rig up	3.0	0.88
Secure and lock hydraulic jack system	2.5	0.98
Arrange main deck for installation	2.0	1.06
Rig up the crane	6.0	1.31
Transport of turbine and tower elements from transport barge	24.0	2.31
P/U tower piece #1 and place over transition piece	12.0	2.81
P/U tower section #2 and place over	12.0	3.31
P/U tower section #3 and place over	12.0	3.81
P/U tower section #4 and place over	12.0	4.31
P/U tower section #5 and place over	12.0	4.81
P/U Nacelle and place over tower swivel	6.0	5.06
P/U and attach blade #1	12.0	5.56
P/U and attach blade #2	12.0	6.06
P/U and attach blade #3	12.0	6.56
Cabling and connections	18.0	7.31
Function test of the unit	24.0	8.31
Arrange main deck for rigmove	6.0	8.56
Unlock hydraulic jack system	2.5	8.67
Jack the rig down	5.0	8.77
Pull the legs	8.0	9.00
Daylight required operations-contingency %30	66.3	11.53
Wind and sea-contingency %20 on top	57.5	13.93

Table I.2: Cost estimation on wind turbine installation.

TOTAL COST ESTIMATE OPERATION: 22 TURBINE INSTALLATION	UNIT COST	UNIT	INSTALLATION	
INTANGIBLES				
TURBINE/NACELLE/BLADES - 7MW	7,000,000	$	22	$154,000,000
TRANSPORT FROM ORIGIN	200,000	$/MW	154	$30,800,000
RIG MOB/DEMOB/INTERMOVE				$0
MOB/DEMOB	1,000,000	$/JOB	1	$1,000,000
INTERMOVE	100,000	$/JOB	22	$2,200,000
RIG POSITIONING SERVICE	7,500	$/JOB	22	$165,000
RIG RATES	70,000	$/DAY	220	$15,400,000
DIESEL/LUBES/WATER	2,000	$/DAY	330	$660,000
WAITING ON WEATHER/DAYLIGHT	70,000	$/DAY	110	$7,700,000
TRANSPORT BARGE / TUG BOAT	3,500	$/DAY	330	$1,155,000
DOCK, STORAGE, CRANE SERVICES	750	$/DAY	330	$247,500
SUPPLY VESSEL	3,500	$/DAY	330	$1,155,000
SHIPPING AGENT	350	$/DAY	330	$115,500
PERSONNEL TRANSPORT BOAT	1,100	$/DAY	330	$363,000
ADMINISTRATIVE				
PLANNING	7,500	$/TOWER	22	$165,000
PROJECT PERSONNEL	1,750	$/DAY	330	$577,500
TRAVEL AND ACCOMODATIONS	250	$/DAY	330	$82,500
COMMUNICATIONS	100	$/DAY	330	$33,000
TAXES/ASSOCIATED COST	750	$/DAY	330	$247,500
CUSTOM AGENT	250	$/DAY	330	$82,500
OPERATIONAL INSURANCE	20,000	$/TOWER	22	$440,000
TOTAL TOWER AND TURBINE INSTALLATION COST				$216,589,000

APPENDIX J

Table J.1: Workflow for jacket installation.

JACKET INSTALLATION	HRS	TOTAL DAYS
Mobilisation from shorebase to location	12	0.50
Spread and drop the anchors, arrange position on winch	12	1.00
Alignment of the transport barge for jacket launch	3	1.13
R/U crane and connect lifting slings.	3	1.25
P/U and launch the jacket	2	1.33
Align the position of the jacket	4	1.50
Position the pile barge along the jacket	2	1.58
P/U pile #1 and run in leg #1	4	1.75
P/U hammer and drive the pile #1	6	2.00
P/U pile #2 and run in leg #2	6	2.25
P/U hammer and drive the pile #2	6	2.50
P/U pile #3 and run in leg #3	6	2.75
P/U hammer and drive the pile #3	6	3.00
P/U pile #4 and run in leg #4	6	3.25
P/U hammer and drive the pile #4	6	3.50
Grouting	12	4.00
Daylight contingency (%25)	24	5.00
Wind and sea-contingency %50 on top	60.0	7.50

Table J.2: Cost estimation for turbine jacket installation project.

TOTAL COST ESTIMATE OPERATION: 23 TURBINE JACKET INSTALLATION	UNIT COST	UNIT	TOTAL COST	
INTANGIBLES				
JACKET FABRICATION INCLUDING MATERIAL	2,500,000	$/EACH	23	$57,500,000
PILE	1,000,000		23	$23,000,000
TRANSITION PIECE	500,000		22	$11,000,000
TOPSIDE FOR ELECTRIC SUB STATION	10,000,000		1	$10,000,000
LOAD-OUT ON TRANSPORT BARGE	200,000	$/EACH	23	$4,600,000
TRANSPORT BARGE AND TUG BOAT	4,500		180	$810,000
PILE BARGE AND TUG BOAT	4,500		180	$810,000
CRANE BARGE - OPERATING RATE	250,000	$/JOB	120	$30,000,000
CRANE BARGE - STAND BY - WEATHER	150,000	$/JOB	60	$9,000,000
CRANE BARGE SUPPLY-ANCHOR BOATS x 2	6,000	$/DAY	180	$1,080,000
DIVING SYSTEM (SURFACE SUPPLIED AIR)	3,500	$/DAY	180	$630,000
DIVING CREW (SURFACE SUPPLIED AIR)	2,500	$/DAY	180	$450,000
GROUTING	50,000	$/JACKET	23	$1,150,000
FUEL AND CONSUMABLES	2,000	$/DAY	340	$680,000
SHOREBASE SUPPORT	750	$/DAY	330	$247,500
SHIPPING AGENT	500	$/DAY	330	$165,000
PERSONNEL TRANSPORT BOAT	1,150	$/DAY	330	$379,500
ADMINISTRATIVE				
JOB PLANNING	12,500	$/jacket	22	$275,000
PROJECT PERSONNEL	1,750	$/DAY	330	$577,500
TRAVEL AND ACCOMODATIONS	250	$/DAY	330	$82,500
COMMUNICATIONS	100	$/DAY	330	$33,000
TAXES/ASSOCIATED COST	750	$/DAY	330	$247,500
CUSTOM AGENT	250	$/DAY	330	$82,500
OPERATIONAL INSURANCE	10,000	$/JACKET	22	$220,000
TOTAL ESTIMATED COST				$153,020,000

APPENDIX K

Table K.1: Workflow for cable laying operation for a wind farm.

CABLE LAYING OPERATIONS	HRS	TOTAL DAYS
Cable Laying vessel arrives to minimum draft for shore approach	24	1.00
Application of shore approach procedure and pushing of cable	24	2.00
Laying of the cable / application of cable connections / burial of cables	240	12.00
Connection to offshore main station.	12	12.50
Cable laying between turbines and offshore station	132	18.00
Pulling up of cables thru j-tubes and connections to turbines	264	29.00
Marking of important locations with buoys	240	39.00
Wind and sea-contingency %100 on top	468.0	58.50

Table K.2: Cost estimation for cable laying operation for a wind farm.

TOTAL COST ESTIMATE OPERATION : NORTH MARMARA 12 STORAGE WELLS	UNIT COST	UNIT	QTY	TOTAL COST
INTANGIBLES				
CABLE COST INCLUDING DELIVERY	150	$/METER	100,000	$15,000,000
CABLE LAY VESSEL	35,000	$/DAY	60	$2,100,000
FUEL AND CONSUMABLES	2,500		60	$150,000
TRENCHING AND BURIAL EQUIPMENT	500,000		22	$11,000,000
CONNECTORS	1,000,000		1	$1,000,000
DIVING EQUIPMENT	2,500		60	$150,000
DIVERS	3,500		60	$210,000
MARKING BUOYS	7,500		100	$750,000
CAISSON INSTALLATION AT BEACH	500,000		1	$500,000
BURIAL OF CABLE AT BEACH	500,000		1	$500,000
SHOREBASE SUPPORT	750	$/DAY	60	$45,000
SHIPPING AGENT	500	$/DAY	60	$30,000
PERSONNEL TRANSPORT BOAT	1,150	$/DAY	60	$69,000
ADMINISTRATIVE				
JOB PLANNING	50,000	$/jacket	1	$50,000
PROJECT PERSONNEL	1,750	$/DAY	60	$105,000
TRAVEL AND ACCOMODATIONS	250	$/DAY	60	$15,000
COMMUNICATIONS	100	$/DAY	60	$6,000
TAXES/ASSOCIATED COST	750	$/DAY	60	$45,000
CUSTOM AGENT	250	$/DAY	60	$15,000
OPERATIONAL INSURANCE	2,000	$/JACKET	60	$120,000
TOTAL CABLE LAYING COST ESTIMATED				$31,860,000

CURRICULUM VITAE

Name - Surname **: Mahmut Erbil SOYLU**

Place of birth / Date **: Istanbul / 03.09.1983**

E-mail **: soyluma@itu.edu.tr**

Educational Background **:**

- ✓ **Sep 2001 - Jun 2006:** Middle East Technical University petroleum and natural gas engineering bachelor of science degree

Professional Experience **:**

July 2006 – Present Tiway Turkey Limited / (Toreador Turkey Limited)
Company Info: Independent oil & gas exploration and production company.
Position : Lead Engineer

Drilling - Testing and Completions:

- ✓ **Aug 2014 - Oct 2014:** Elise-1 exploration well on behalf of another Operator. - Project Manager.
- ✓ **Feb 2014 -Jun 2014 -** Kısmetli-01 Exploratory well in Southeast Anatolia - Application of foam/dust drilling. - Project manager
- ✓ **Aug 2013 - Sep 2014 -** Cendere oilfield development drilling campaign - 4 wells. Follow up of activities on behalf of company.
- ✓ **May 2013 - July 2013:** Herekli - 1 exploration well in Adana basin. - Project Manager
- ✓ **Jun-Jul 2012**: East Sıraseki-1 exploration well in Adana basin. - Project Manager - Company man.
- ✓ **Nov 2009 -Feb 2010:** Tatiana field in Crimea. Wellsite supervisor in Tat-101 deep well - 5000m. HPHT environment
- ✓ **Apr-Jun 2010:** Project manager for Bakuk-101 exploration well. Application of underbalance with air/nitrogen while drilling thru reservoir.
- ✓ **Apr-Aug 2009:** Durusu-1 West Black Sea exploration project. Drilling programming, purchases, contracts and wellsite supervision. Jack up well

- ✓ **Jun-Jul 2007:** Karaburun-1 Western Black Sea exploration project. Drilling programming, purchases, contracts and site supervision. Jack up well
- ✓ **Jul 2006 - Dec 2007:** Offshore Drilling campaing team member, drilling and completions engineer, company man.
  Akkaya 1-A,2,3 East Ayazlı 1,2 Bayhanlı-1, North Akkaya-1, Ayalı 2-A,3A, Akcakoca-3 and 4, Guluc-1, Alaplı-1. (Jack up, Semi submirsible wells)
- ✓ **Jul 2006 - Dec 2007:** Tie-back to several wells on Akkaya, East Ayazlı and Ayazlı platforms.

Workovers and Production:

- ✓ Apr 2011- Ongoing : Follow up of production activities of Bakuk Gas Field and prepare necessary remedial programs.
- ✓ May 2007 - Ongoing : Follow up of workover and production activities in SASB offshore gas field.
- ✓ June-Aug 2011: Cendere 14,15,18,20 workovers . Plugging watered out levels, perforating missed intervals, acidizing and swab testing.
- ✓ Oct 2010: Bakuk-2 workover, Re-entry, run cased hole formation evaluation logs, completion, perforatrion and swt.

Pipelines:

- ✓ Dec 2010 - Mar 2011: Project manager and designer of Bakuk-Camurlu NG pipeline. 1000psi operating pressure,6", 23.5km line with 700m of elevation difference
- ✓ Jan -Mar 2008: Field supervisor of Subsea tie-in to Ayazlı production platform. (81m water depth) Completed the project without sat diving.
- ✓ Apr 2008: Project manager of Offshore waste water pipeline installation. 2.5km, HDPE, 8"
- ✓ Sept 2007: Field supervisor of offshore pipeline repairs at East Ayazlı. (72m water depth) Project completed without Saturation diving system.
- ✓ Dec 2006: Trenching (burial of pipe), client representative.
- ✓ Nov 2006 - Dec 2006: Offshore pipeline construction company representative and field engineer. 18km pipeline with 3 branches, S-laying method, utilised sat diving.

Offshore Installation :

- ✓ Nov 2009 - Sept 2011: Follow up of South Akcakoca Sub Basin Development phase 2 on behalf of Tiway. Phase 2 development consists of 1 jacket and platform rig installation, pipeline tie-in, tie-back to 2 previously drilled wells and 2 further development wells.
- ✓ Oct 2007: Client Representative on Ayazlı Jacket, Topside installation.