Synergies between Eastern Med O&G and Shipping

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Overview

• New world oil order?

• The offshore O&G prize

• East Med O&G potential, Egypt’s Zohr & Cyprus

• Developing deepwater G(&O) fields
  ○ 1. Developing gas fields 2. Subsea pipelines 3. Exploiting gas deposits

• Synergies between O&G and shipping

• Closing remarks
New world oil order?

- 27 Nov. ‘14, Saudi Arabia does not limit oil production
- 68 projects (27bn barrels) worth $400bn postponed
- **12/2015**: US lift crude oil export ban
- **01/2016**: Iran re-enters world oil markets
- Oil glut of ~1.6mbbl/d
Implications of oil price collapse

Positives
- Big savings for consumers: lower fuel cost
- Boost economic growth
- Lower fuel costs for comps eg, airlines, agriculture
- Golden opportunity to lower fuel subsidies

Negatives
- Deflationary pressures
- 65,000 jobs lost in NS alone
- Collapse in share price of energy players
- O&G comps slashed capital expenditures
- Depressed natural gas & LNG prices
- Venezuela & Nigeria at brink of collapse

Date: 23/12/14
Impact on LNG prices

- LNG spot price collapse to $6.65/MMBtu
- Asia accounts for ¾ of LNG demand
- New projects shelved
- EU & Asian LNG demand in decline
- Break even prices: $12-20/MMBtu (Austr.)
Why go after offshore O&G when:

- An ultra-deepwater well may cost $100,000,000?
- Offshore developments are prohibitively expensive?
- Frigid seabed temps can block flowlines?
- Lack of access to equipment (scuba diving limit <330m)?
- Harsh sea conditions (wave loads, wind, currents, ...)?
- Corrosive environment can expedite ferrous material degradation?
- ‘Easier’ oil exists on-land?
- Dedicated equipment & expertise are needed?
- Higher environmental stakes?
- Shortage of skilled personnel?
The offshore prize

- Fewer wells that operate at a high(er) productivity
- Large undiscovered reservoirs
- Lack of access to onshore plays (NOCs possess the rights)
- 3D seismic acquisitions hedge risks
- Technological advances (eg, synthetic lines) & past experience
- ‘Easy’ O&G and shallow fields have been discovered (almost)
- Smaller environmental footprint
- H/C demand will gradually grow
**Eastern Med H/C fields**

- **Important discoveries:**
  - **Israel:**
    1) Mari B (2000): 1.1 tcf
    2) Tamar (2009): 8.4 tcf
    3) Leviathan (2010): 22 tcf
  - **Egypt:** proven reserves = 77 tcf (2015)
    - 76% of reserves in Nile’s Delta
    - Zohr: ~30 tcf

Reserves: 37 tcf
The “supergiant” Zohr

- **30/09/15**: discovery of 30 tcf by ENI
- Estimated value: $90bn
- 6km from Cyprus EEZ
- Possibility of derailing Leviathan development
- Potential LNG exports to EU
Post-Zohr era

- Reassessment of geophysical data by Total, Noble, & ENI
- Emphasis from sand intervals to carbonate sequences
- East Med presents strong H/C potential
- Block 11 licensed to Total SA
- Total to drill in Block 11 in Sept. ‘16
Eastern Med is yet to be explored

- 4 wells in Cyprus EEZ
Cyprus exploration programme

- **Noble**: drilled 2 wells at Aphrodite
- **ENI**: drilled another 2 wells
  - 1) Onasagoras (19/12/14), 2) Praxandros, 3) Kyniras, 4) Zenon, 5) Amathousa (26/3/15), 6) Evagoras
- 03/12/15: Total renewed licence of Block 11 for 2 yrs
- 01/02/16: ENI license extension for 2 yrs; 2 wells in ‘17
**BG (Shell) Block 12 farm-in**

- **23/11/15**: Acquires 35% of Aphrodite gas filed
- BG (Shell) owns ~37% of Idku 7.2MTPA LNG plant, Egypt
- Prospect of siphoning Cyprus gas to Idku
- Considerable know-how in LNG projects
- Financial muscle to develop Aphrodite
Developing Easter Med’s G(&O) deposits

- 1. Developing deepwater gas fields
- 2. Subsea development
- 3. Submarine pipelines
- 4. Compressed natural gas
- 5. LNG exports
Developing Easter Med’s G(&O) deposits

- 1. Developing deepwater gas fields
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- 3. Submarine pipelines
- 4. Compressed natural gas
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3. Submarine pipelines

- Pipe-laying methods: J-lay or S-lay
- Near-continuous pipe-laying process
- Environmental aspects
- Cost estimate: $800m-$2.3bn
- World’s deepest offshore pipelines:
  - **Perdido**: 18”, Water depth: 2,530m; flowlines: 3,000m
  - **Blue Stream**: 24”, WD: 2,150m;
  - Forthcoming: **Stones field** (Shell, GOM): WD: 2,900m
4. Compressed natural gas (CNG)

- Transport in gas state. Pressure ~200 bar, volume drop: 200:1
- None such vessel has yet to be build
- Attractive solution for short distance NG trade
- Potential use of composite materials
- Morgan Stanley to build 1st CNG terminal in US?
5. Floating LNG (FLNG)

- Omit offshore pipelines
- Innovation: onboard liquefaction
- FLNG Prelude 1\textsuperscript{st} in the work
- Delivery: 2017
- Cost: $5-6 bn
- 600,000 t | Length: 488m
- 3.5-4 mtpa (2-3tcf)
- Working life: 30-40 yrs
FLNG Prelude
Synergies between offshore O&G and shipping

- Seismic ships acquire geophysical data
- Research vessels map sea-bed
- Ultra-deepwater wells conducted by semi-submersibles or drillships
- Offshore support vessels ferry supplies
Synergies between offshore O&G and shipping

- Pipelaying ships will lay gas/oil lines
- LNG carriers transport natural gas
- CNG move natural gas
- Tankers shuttle oil or condensates
- Maintenance vessels
Engineering feats: LNG vessels

- LNG kept at −161°C
- 3 types of ships:
  - Prismatic design
  - Spherical type
  - Membrane design
- Materials: aluminium, balsa wood, stainless steel, polyurethane
Who owns the world’s LNG fleet?

- Greek shipowners invested $1.8bn on 11 LNG newbuildings in 2014
- Average cost/vessel ≈ $165m
- Betting on LNG spot market & EU energy diversity

[Image: Energy by Sea
The world’s largest fleets of liquefied-natural-gas ships, by country]

<table>
<thead>
<tr>
<th>Country</th>
<th>Value in billions</th>
<th>Number of ships</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>$13.39</td>
<td>96</td>
</tr>
<tr>
<td>Greece</td>
<td>11.68</td>
<td>65</td>
</tr>
<tr>
<td>Qatar</td>
<td>6.95</td>
<td>35</td>
</tr>
<tr>
<td>U.K.</td>
<td>5.47</td>
<td>43</td>
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<tr>
<td>Bermuda</td>
<td>5.31</td>
<td>28</td>
</tr>
<tr>
<td>Norway</td>
<td>4.31</td>
<td>36</td>
</tr>
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</table>

[Chart: Share of LNG global fleet]
Crossing of the ‘Cyprian Arc’

- Pipeline from Aphrodite gas field to cross ‘Cyprian arc’
- Cyprian arc: N: Anatolian, S: Eurasian plates
- Assume pipe displacement of ~12.8mm/yr
- Pipeline(s) diameter = 20-24”
- Factor-in seismic displacement
- Calculate forces on pipeline
- Analyze impact of seismic activity
- Determine “optimum” pipeline orientation
- Examine ways to secure pipeline on seabed
Oil & Gas Education at University of Nicosia

- BSc in Oil & Gas Engineering
- BSc in Energy, Oil & Gas Management
- MSc in Oil, Gas & Energy Engineering
- PhD in Oil & Gas Engineering
- Academic & professional accreditation
- International & diverse body of faculty & students
- New building, experimental & computer facilities
Oil & Gas (Energy) Engineering

- Undergraduate cohort: 50 students
- Graduate cohort: 25 students
- Diverse & Intl environment from 15 countries incl. Russia, Greece, Nigeria, Ukraine, Iran, Lebanon, Libya, Angola, Egypt, etc.
Closing remarks

- Eastern Med’s carbonate rocks open up new possibilities
- Oil prices will define future projects
- Offshore O&G will assume prominence
- Zohr will provide nat. gas for LNG exports
- Cyprus O&G prospects depend on drilling activities
- Eastern Med can enhance EU energy security
- Re-analysis of drilling & geophysical data
- Marine vessels will heavily engaged
Acknowledgments

- Carbon & Energy Lab (CEL): www.carbonlab.eu
- ESI Group, France
- Schlumberger Ltd
- Fann Instrument Company
University of Nicosia Oil & Gas Engineering website:  
www.unic.ac.cy/oge

Thanks for your attention!
Appendix
The offshore prize (2)

- Learning curve – repeatability & standardisation:
  - 1992: $.95/boe → 2005: $.4/boe
- Concurrent engineering from design to decommissioning
- Innovations – flexible pipes, ROVs, cranes, DP, seismic acquisition, ...
- Subsea templates help lower costs (& environ. footprint)
- Consolidation of fluids thru fewer flowlines
- Commence production & then drill additional wells
Eastern Med seismic activity 2011
Better technologies & innovations

- Testing facilities (water tanks, risers)
- Advanced materials (eg, flexible risers)
- Virtual reality modelling
- New technologies (eg, subsea compression)
- Advances in computational power
- Sophisticated computer models (simulation tools)
- Lines (synthetic polyester lines vs chains & wires)
- Communications (eg, fibre optics)
- More dexterous ROVs
- Dynamic positioning (DP3)
Tamar Gas field

- Tamar: GIP: 275 bcm (1,700 m)
  - Discovery: Jan ’09 -> Production: April. 2013
  - Development costs: $3.25bn
- 5 wet wells: clustered well layout; 1.2bcf/d
- 330 km umbilicals
- Gas hydrate stm: Monoethylene glycol
- 11,000t topside Igleside Texas
- 150km flowline; one of longest ever
- By 2014 19 new wells for a cost of $2 bn
Εξερευνητικές δραστηριότητες

- Εταιρείες: Eni/Kogas (2, 3 & 9), Total (9 & 10), Noble/Delek/Anver (12)
- Μπόνους: €150 (Eni) + €24 (Total) = €174εκ.
- Έναρξη εξερευνητικής φάσης: 24.1.2013 (Eni), 6.2.2013 (Total)
- Ερευνητικό πρόγραμμα: ως 10 γεωτρήσεις σε 3 χρόνια
  - 9-11/2013: 4,700km² 3D σεισμικά στα τεμάχια 2, 3 & 9
  - 11-12/’13: 7,000km² 2D στα 2, 3 & 9
  - 7-8/’13: 2,280km² 3D στο 11
  - 3/’14: 1,500 km² 2D στο 10
- Αναζήτηση πετρελαίου
Πρόγραμμα γεωτρήσεων

- **Eni**: υποσχόμενες γεωλογικές δομές:
  - 1) Ονασαγόρας, 2) Πράξανδρος, 3) Κινύρας,
    - 4) Ζήνων, 5) Αμαθούσα, 6) Πράξανδρος

- **Eni**: όρυξη γεώτρησης «Ονασαγόρας» στις 25 Σεπτ, 2014

- **Eni**: Δεύτερη γεώτρηση «Ζήνων»

- **Eni**: διάρκεια γεωτρητικού προγράμματος: 12-18 μήνες

- **Noble**: τέλη 2014 1 επιβεβαιωτική γεώτρηση

- **Noble**: 1 εξερευνητική γεώτρηση κοινοπραξίας

- **Total**: αρχές 2015 έναρξη γεωτρήσεων

- **Total**: τουλάχιστον 2 γεωτρήσεις

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[Image of an offshore drilling rig]
Safety considerations

- Το μεθάνιο είναι άοσμο, άχρωμο, μη-τοξικό, μη-διαβρωτικό
- Εντοπίζεται με τη χρήση “methanethiol”
- Το ΥΦΑ δεν είναι εύφλεκτο
- Καύση ΦΑ εφικτή μόνο:
  - Παρουσία σπίθας & Συγκέντρωση ΦΑ στον αέρα: 5%-15% (ΦΑ).
- Δικλείδες ασφαλείας:
  - Καύση ΦΑ (flaring), διάταξη τερματικού & εξοπλισμού
  - Διαχωρισμός σταθμού υγροποίησης σε ζωνών (blast zones) & κατάλληλων υλικών
  - Χρήση υλικών ανθεκτικών σε εκρήξεις, συστήματα πυρόσβεσης, αισθητήρες διαρροής
  - Προσομοίωση διαρροής & έκρηξης
4(α). Σταθμός ΥΦΑ (3)

- Δυνητικό κόστος

<table>
<thead>
<tr>
<th>MTPA</th>
<th>Trains</th>
<th>Tech</th>
<th>Location</th>
<th>Cost per ton minimum</th>
<th>Cost per ton maximum</th>
<th>Minimum</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>5</td>
<td>1</td>
<td>exist</td>
<td>onshore</td>
<td>$1,600</td>
<td>$2,000</td>
<td>$8</td>
<td>$10</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>exist</td>
<td>onshore</td>
<td>$1,400</td>
<td>$1,800</td>
<td>$14</td>
<td>$18</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>exist</td>
<td>onshore</td>
<td>$1,200</td>
<td>$1,600</td>
<td>$18</td>
<td>$24</td>
</tr>
</tbody>
</table>

- Άλλα ζητήματα:
  - Ηλεκτρική ενέργεια: 125 MW (5 mtpa)
  - Modularisation of plant?
  - Μέγιστη ζήτηση δυναμικού: 4,000 άτομα
  - Άντληση πόρων από διεθνείς αγορές
  - Οριζοντιας υλοποίησης: ≈7 έτη

Πηγή: Wallace P. (2011) Gaz De France

Bontag A-H (Indonesia): 22.6 MTPA
Διάταξη FLNG

• Σμίκρυνση εξοπλισμού
• Πρόσβαση στον εξοπλισμό & συντήρηση
• Θέματα: sloshing (ελεύθερες επιφάνειες) & ασφάλειας
Χαρακτηριστικά του πεδίου «Αφροδίτη»

- Μέγεθος πεδίου: 3.6-6tcf (μέσος όρος 5tcf, 140 δκμ) 100-168 δκμ
- Ψηλής ποιότητας μεθάνιο (CH₄)
- Ταμιευτήρας: net gas pay (πάχος): 94μ | 103km²
- Συνολικό βάθος: 5,861μ (Νερό: 1,689μ), ≈165km από Βασιλικό
- Συμφωνία ενοποίησης εκμετάλλευσης (unitisation agreement) με Ισραήλ;
Δοκιμές παραγωγής
Υπάρξη και αξιοποίηση πετρελαίου;

- Έχουν αναγνωριστεί 14 γεωλογικές δομές στην ΑΟΖ
- «Θερμογενές» φυσικό αέριο παραπέμπει στην ύπαρξη πετρελαίου
- Εκτενή 2D & 3D σεισμικά δεδομένα, νέα γεωλογικά στοιχεία
- Κανένα πηγάδι δεν έχει ορυκτεί στο αναμενόμενο βάθος ακόμα
- Εγνωσμένα συστήματα Y/A (working hydrocarbon stms)
- Αξιοποίηση με χρήση FPSO
Geo-hazards

- Hazards arising from *geological* or *geotechnical features*
- Geohazards endanger the *integrity* or *serviceability* of a structure
- Typical offshore geohazards include:
  - Submarine (land)slides (eg, Storegga slide)
  - Gas seeps;
  - Mud volcanoes;
  - Debris flow;
  - Gas hydrates;
  - Shelf edge erosion;
  - Subduction zone;
  - Gas chimney;
  - Seismogenic area;
  - High velocity flow;
  - Turbidity current.
- Remove, monitor or avoid threats
System design challenges

- Lack of human access complicates things
- Need for in-built redundancy (e.g., data retrieval)
- Ease of installation, retrieval & replacement
- Corrosion protection
- Thermal shock management
- Provisions for ROV intervention & ROV friendly design
- Safety standards
- Stringent environmental regulations
- Economic considerations
- Reliability issues
- Rigorous testing
- Electronics & materials’ challenges
- Immersed in water
- Dropped objects (e.g., shipwrecks, etc)
1. Developing Easter Med’s G(&O) fields

- Subsea architecture: Dry or wet wells
  - Spar, FPS or subsea installation
- Flowlines – manifolds – umbilicals
- Hydraulic, electrical energy and control, communication
- Marine risers
- Cost:
  - Independence Hub: $2bn — $420 FPS
- Aphrodite development costs: $2.5-3bn
2. Subsea development

- Subsea systems connected to:
  - a) Floating installations (FPSO, TLP, Spar, ...)
  - b) Sea to beach (e.g., Ormen Lange)
  - c) Fixed leg platforms (Compliant platform, gravity based platform)
- No water depth limitations
- Costly assets with time consuming procedures
- Distances between subsea components measured via laser
- Unmanned assets (Platformless)
- Subsea boosting
4. Exploiting gas deposits

- Domestic utilisation – power generation & light industry
- Piping natural gas to Turkey – politics & technical issues?
- Export natural gas to Turkey via Israel?
- Liquefied natural gas (LNG) exports:
  - LNG land based facility
  - Floating LNG (FLNG)
- Use NG as feedstock for petro-chemical industry: fertilisers, convert it into diesel, ethylene, etc
- Sell gas in-situ; permit farm-in; issue gas bonds; IPO
- Pipe gas to Greece via submarine pipeline?
- Sell electricity via subsea cable to Greece & Israel?
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- Innovations – flexible pipes, ROVs, cranes, DP, seismic acquisition, ...
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Challenges to offshore E&P
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- Abnormal (reservoir) geo-pressures & temps
- Eddies (Loop Current, GOM) exposes risers to undue stress & vibration
- Excessive geological faulting btw 330m-750m below seabed
- Gas pockets can jeopardise drilling
- DW reservoirs are more compartmentalized, more faults, less homogeneous sediments & less continuous
- Subsistence of sea floor (eg, Ekofisk)
- Flow assurance (gas hydrate formation)
- High hydrostatic pressure ($H_2O > 2000m$)
- Freezing temps (-1 to 2°C)
Challenges to offshore E&P (2)

- Geohazards; sour fluids
- Equipment installation, maintenance & repair done remotely
- Often longer E&P timeframes
  - Morphology of seabed – subduction zones
  - Unstable/soft seabed?
  - Seismogenic area
- Soft deepwater sediments
- Metocean: wind, waves, currents, tides, ice loads, etc.
  - North Sea: wind speed: 200km/hr, waves: 30m
  - GOM: Hurricane season: 240km/hr, waves: 25m
  - West Africa: 120km/hr, waves: 8m

“Though we walked on the moon three decades ago, we'll probably never walk on the deep seafloor.” Kuznig R. (2001)
Worldwide Progression of Water Depth Capabilities for Offshore Drilling & Production (As of March 2014)

Legend:
- Platform/Floater
- Exploration
- Subsea

Denotes Current World Record

- World Record DP Drilling
  - 10,411' (3,174m)
  - Offshore India
  - Rig: Tirupati Deepwater KG1
  - Operator: ONGC

- World Record Deepest Subsea Tree
  - 9,627' (2,934m)
  - US 60M, Toldeo
  - Operator: Shell

- World Record Deepest Floating Facility
  - 8,200 (2,500m) USCGM
  - BW Pioneer FPSO
  - Operator: Petrobras

Year:
- 1940
- 1950
- 1960
- 1970
- 1980
- 1990
- 2000
- 2010
- 2014
- 2020

Water Depth Feet (m):
- 0
- 1,000
- 2,000
- 3,000
- 4,000
- 5,000
- 6,000
- 7,000
- 8,000
- 9,000
- 10,000
- 11,000
- 12,000

Notes:
1. Assistance from Quest Offshore Resources, Inc. (www.QUESTDF.com)
How deep can we drill offshore?

- Drilling rigs designed for ≈3,700m (12,000ft) water depth
- Operations *limited* by:
  - Variable Deck Load (drill string, drilling & completion fluids)
  - Rig hoisting capacity \( f = (\text{total well depth}, \text{drilling risers}, \ldots) \)
- Increased water depth risks include:
  - Longer drilling and production risers prone to fatigue & failure
  - Higher hydrostatic pressure
  - Increased overall drill length, drill string span, well casing, ...
  - Extended operational durations
- Formation evaluation tools are a concern:
  - Fluid sampling & pressure measurements done in a single trip
  - Longer logging cables needed
  - Logging-while-drilling (LWD) tools subject to shocks & vibrations
How deep can we drill offshore? (2)

- Rotary steerable systems op. envelope = 175°C
- Flow assurance (wax & gas hydrates)
- Corrosion issues (longer risers, other equipment)
- Longer intervention times
- Downhole pressure gauges temp. limit = 15 days @ 210°C
- Sealing systems to withstand higher pressures (& temps)
- Other issues: sand management, cementing & perforation
Vasilikos Energy Centre Master plan
4(a). Shore-based LNG plant
Refrigeration cycle C3-MR
2. Flow assurance in gas lines

- Gas hydrates can block submarine gas pipelines
- Hydrate strike fear because:
  - Hard to predict; occur within min; hydrate inhibition stm failure.
- Pipeline length: 185km (Aphrodite-Vasilikos)
- Project objectives:
  - Quantify pressure drop in long tie-backs;
  - Trace heat loss from pipeline to seabed/water;
  - Assess impact of hydrate solids on flow characteristics;
  - How will pipeline occlusions affect gas flow?
  - Examine the impact of subsea boosting
Research projects at Carbon & Energy Lab

- 1. Pipeline crossing of the ‘Cyprian arc’
- 2. Flow assurance in gas lines
Research projects at Carbon & Energy Lab

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