Developing an offshore gas field

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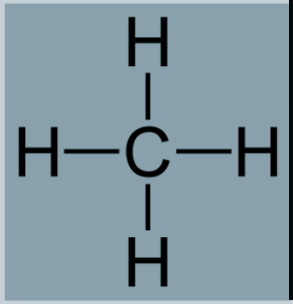
Overview

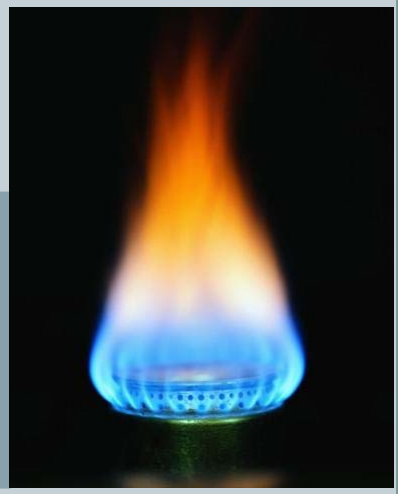
- What is natural gas?
- Sourcing gas from “Aphrodite” gas field to Vasilikos:
  - 1. Appraisal phase. 2. Production tests. 3. Unitization process.
  - 4. Developing the gas field. 5. Submarine pipelines
- Third licensing round
- Translating O&G reserves into value-added activities
- Maritime O&G centre. The case of Norway. Cy as a petrocluster
- Natural gas liquefaction: liquefaction cycles, storage facilities
- LNG seaborne exports & the future

US LNG

What is natural gas (NG)?

- NG: methane (CH_4): 70-90% w%; Ethane (C_2H_6): 5-15%
- Methane: odorless, colorless, non-toxic, non-corrosive
- Liquefies at –161°C
  - Occupies 1/600 volume in relation to its gaseous state rendering its maritime transport economically viable
- Combustible or explosive if concentration 5-15% in air
- Its smell originates from "methanethiol"
- Simplest hydrocarbon, environmentally friendly
- Long-term contracts of 15 to 20 years
- LNG is not LPG (LPG: C_3H_8, C_4H_{10})





Properties of natural gas

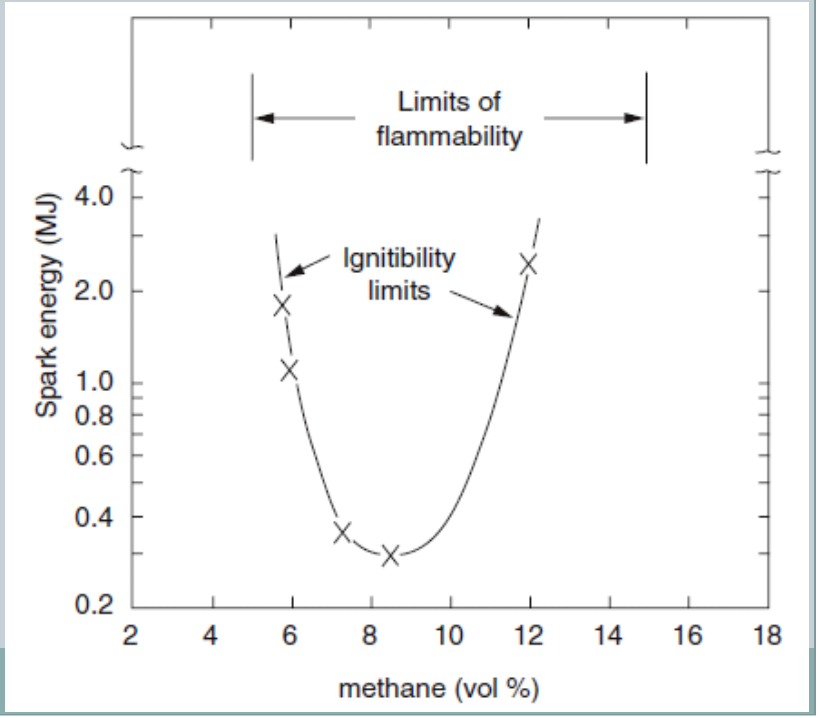
- Natural gas is: *odorless*, *colorless*, *tasteless*, '*shapeless*' & lighter than air non-corrosive, non-toxic
- Gas odorization helps detect gas leaks
- Mercaptans (or thiol) with a smell of rotten egg help smell the gas
- Smells due to *methanethiol*
- NG's flammable only in concentration 5-15% in air
- Consumers detect gas if conc ≈1% in air
- Burning of odorant does not liberate large sulphur amounts or toxicity

Properties	Value
Relative molar mass	17–20
Carbon content, weight %	73.3
Hydrogen content, weight %	23.9
Oxygen content, weight %	0.4
Hydrogen/carbon atomic ratio	3.0–4.0
Relative density, 15 °C	0.72–0.81
Boiling point, °C	−162
Autoignition temperature, °C	540–560
Octane number	120–130
Methane number	69–99
Stoichiometric air/fuel ratio, weight	17.2
Vapor flammability limits, volume %	5–15
Flammability limits	0.7–2.1
Lower heating/calorific value, MJ/kg	38–50
Stoichiometric lower heating value, MJ/kg	2.75
Methane concentration, volume %	80–99
Ethane concentration, volume %	2.7–4.6
Nitrogen concentration, volume %	0.1–15
Carbon dioxide concentration, volume %	1–5
Sulfur concentration, weight % ppm	<5
Specific CO_2 formation, g/MJ	38–50

Flammability limits

- Flammability limit: a mixture of combustible gases & air burn only if the fuel concentration (vol or moles) lies within well defined upper & lower limits
- Pure methane (CH_4) has flammability limits of 5%-15% in air
- Ignition likelihood also affected by ignition sources (y-axis)
- Ignition sources:
  - Fire heaters (stoves)
  - Open flames
  - Motor vehicles, etc

Material	Specific Gravity (Air = 1)	Lower Flammable Limit (Vol %)	Upper Flammable Limit (Vol %)
Methane	0.55	5.0	15.0
Ethane	1.04	3.0	12.4
Propane	1.52	2.1	9.5
n-Butane	2.01	1.8	8.4



LNG pricing

- Japan & S Korea: price reflects blended crude cost of Japan; min. floor of LNG price shields seller
- LNG price is usually tempered from oil fluctuations
- EU: LNG formula reflects EU produced piped gas, Brent, high & low sulfur fuel oil & coal
- US: LNG price based on Henry Hub deriving from NYMEX near-futures

Spot LNG sales

- Spot LNG emerged at end of 1990s
- Spot LNG was born because of:
  - LNG oversupply from:
    - Conservative LNG
    - Improved LNG plant productivity
    - Debottlenecking (lifting of constraints which limited LNG production)
- Asian buyers could not absorb LNG volumes due to recession
- Availability of laid-up LNG ships
- Demand for uncontracted LNG from EU & US

LNG export countries

Current exporters:

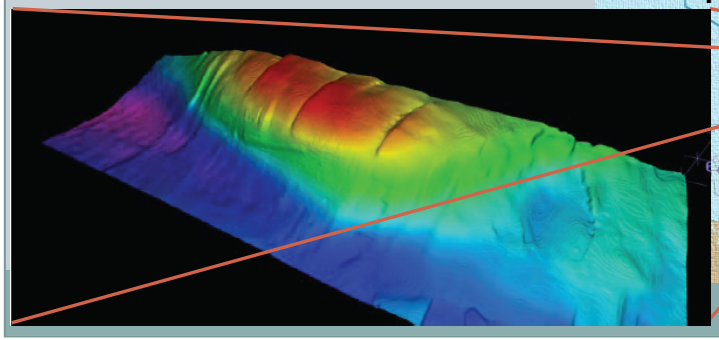
- Australia
- Qatar
- Papua New Guinea
- Oman
- Egypt (?)
- Algeria
- Nigeria
- Angola
- Equatorial Guinea
- Indonesia
- Malaysia
- Peru, Russia, Trinidad & Tobago, Yemen
- US

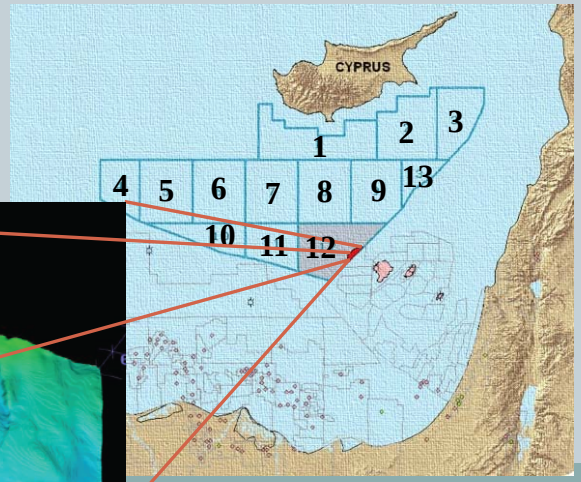
Future wannabe players:

- Canada
- Mozambique
- Tanzania
- Iran
- Venezuela
- Bolivia
- Israel
- Cyprus

The Aphrodite gas field

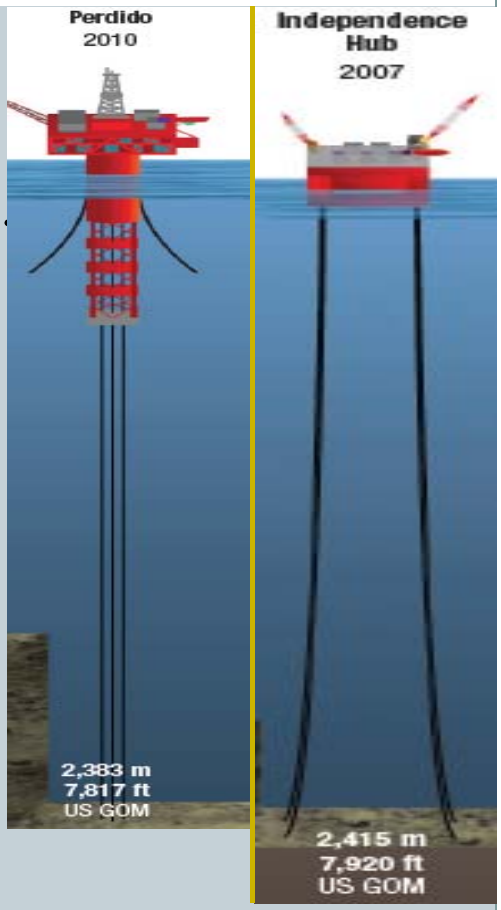
- Exploratory well: Sept. 2011; Gas discovery: Dec. 2011
- Gas volume: 140 to 225bcm (gross mean 200bcm, 5 to 8tcf, gross 7tcf)
- High quality (dry) methane gas (CH_4) ≈98% CH_4
- Reservoir: net gas pay: 94m | Area: 103km²
- Total depth: 5,861m (H_2O:1689m); ≈165km from Vasiliko
- Appraisal phase: commenced June 2013, preliminary results 3/10/2013

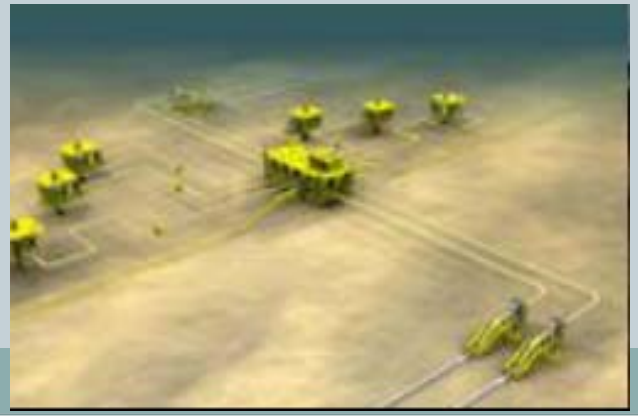




Developing the Aphrodite gas field

- Subsea architecture: dry or wet wells
- Concept: spar, FPS, semi-sub, subsea installation?
- Flowlines, manifolds, umbilicals, hydraulics, power,…
- Cost:
  - Independence Hub: $2bn – $420m
- Aphrodite development costs: $3.5 + $2bn
- Revenue for Cyprus: €9.5bn
- First gas: end 2024/beginning 2025





Drilling programme

- Eni: highly promising prospects:
  - 1) Onasagoras , 2) Praxsandros, 3) Kiniras, 4) Zenon, 5) Amathusa, 6) Evagoras
- Eni: spud "Onasagoras" on Sept., 25th, 2014 (block 9)
- Eni: second well "Zenon"
- Eni: drilling operations to span: 12-18 months
- Noble: end 2014 one (1) appraisal or wildcat well
- Total: to commence drilling beg. 2017
- Third licensing round in progress:
  - Exxon-Mobil
  - Total
  - ENI
  - Statoil
  - Cairn Energy

Sourcing the gas to Vasilikos

O&G field life-cycle

Access & Exploration [3-4 yrs] → Appraisal [1-3 yrs] → Development [2-4 yrs] → Production [20-30 yrs] → Decommis-sioning [2-3 yrs]

LNG Plant [5-7 yrs]

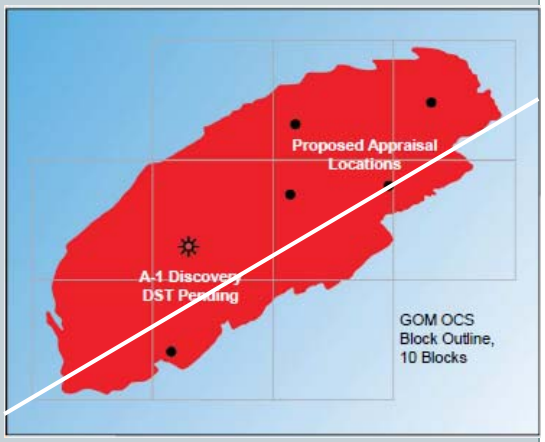
- 1. Appraisal phase
- 2. Production tests
- 3. Unitization process
- 4. Developing the gas field
- 5. Submarine pipelines

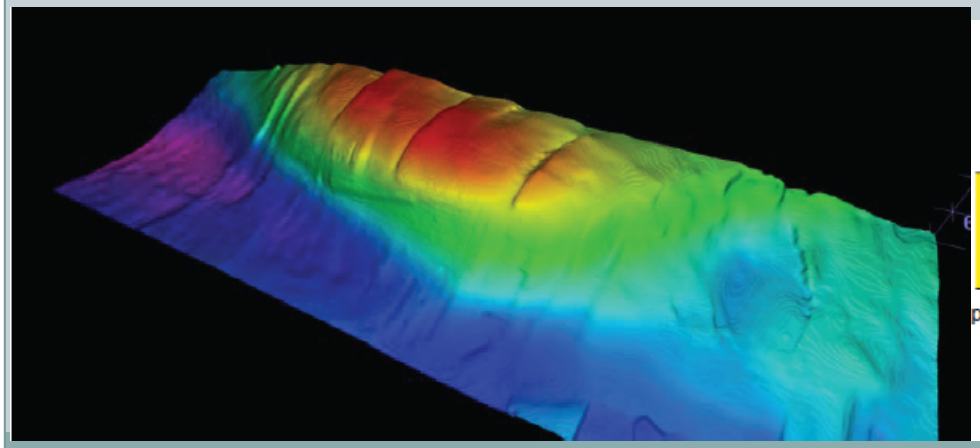
1. Appraisal phase

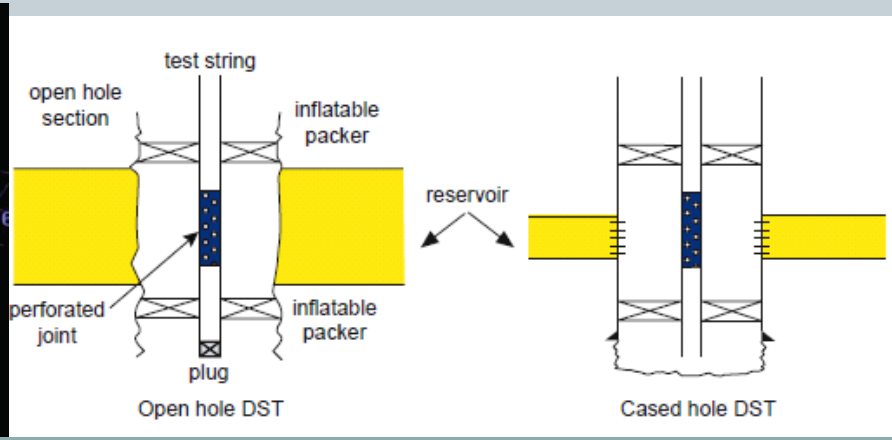
- Objective: convert a resource into a (proved) reserve (90%)
  - Define the volume of the O&G, info for next steps
- Helps optimize the development
- At least 1 appraisal well (or 2D or 3D seismic)
- Production tests
- Subsequent steps:
  - Additional appraisal well(s)
  - Independent comp. or consultant certification
  - Declaration of commerciality
  - Unitization process
  - Pre-sale of gas or gas-tied bonds
  - Exploiting the natural gas

2. Production tests (drill stem tests)

- Part of the appraisal phase
- Aim to quantify the gas volume
- Specifies the quality & composition of H/C
- Pressure, porosity, permeability data, …
- Production & flow capability of H/C
- Existence (or absence) of liquids (condensates)







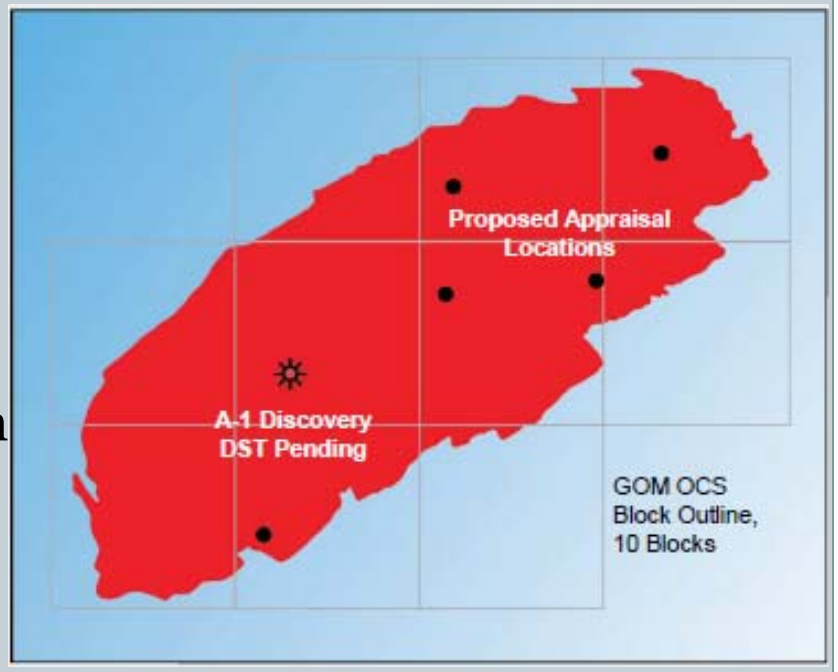
2. Production tests

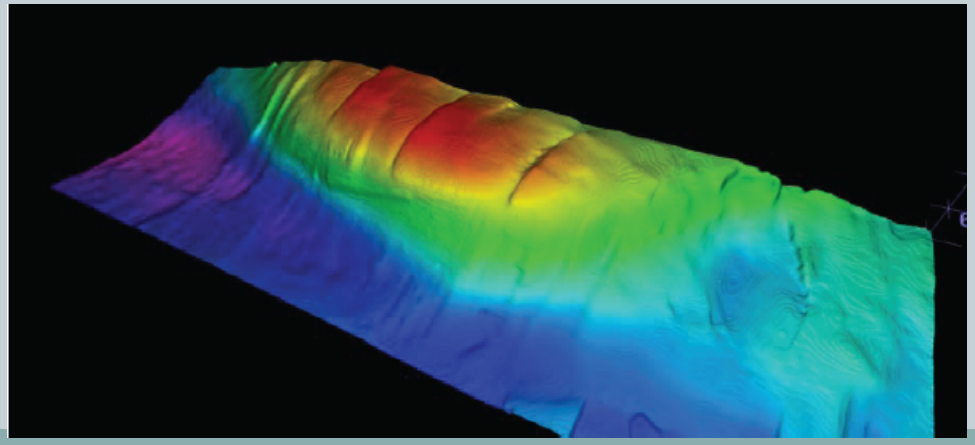
2. Production tests

- Clarify need (if any) for further appraisal well(s)
- Wells usually upgrade field gas volume (reserves growth)
- Minimize uncertainties
- May delay development phase
- Costly process but mitigates risks

Appraisal results

- Preliminary gas volume: 3.6 to 6tcf (gross mean 5tcf)
- Net pay: 40m (from 94m)
- A-2 well 6.4km from A-1
- H_2O depth: 1,700m | TD: 5,575m
- Production test: 1.586 Mcm/d
- Simulated production: 7.08 Mcm/d
- 4th largest discovery in Levantine Basin



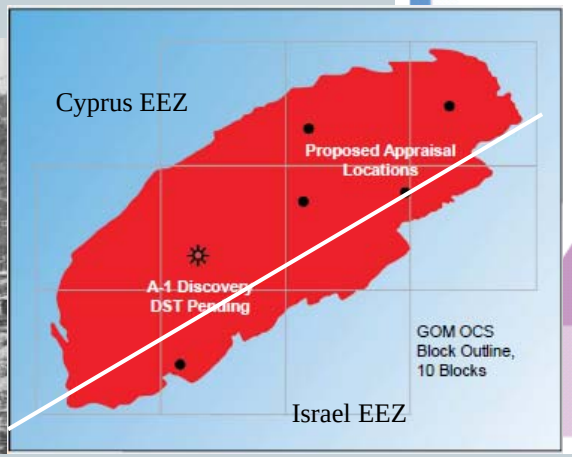


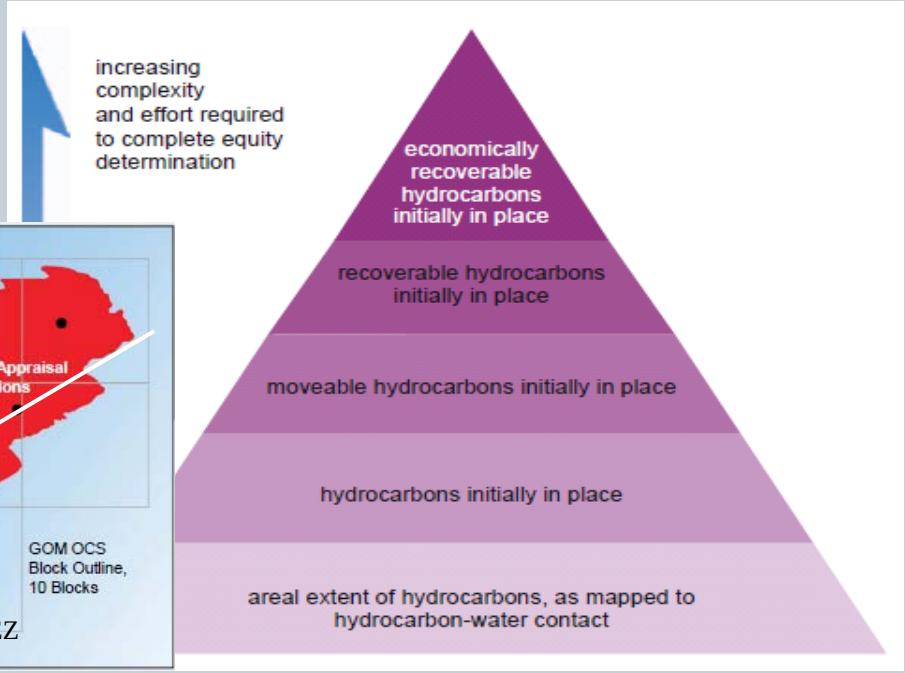
Possible reasons for lower gas quantities

- Appraisal process incomplete yet; need for another appraisal well
- Complex geological reservoir (presence of transverse faults)
- Original volume (5-8tcf) was an estimate
- Smaller net pay (reservoir thickness): 94m -> 40m
- Porosity may be lower (anisotropic reservoir)
- Lower rock permeability
- Accuracy of linewire logs diminishes with distance
- Seismic uncertainties
- Fault seal (evaporite fracture)
- 'small field behavior' vs 'reserves growth'

3. Unitization of the Aphrodite gas

- ‘Rule of capture’ reigned the O&G industry since 1859
- Flush production & rapid depletion of oil fields
- Not optimal resource management
- Doherty’s “unitization” idea implemented in late 1920s
- 80% Cyprus, 20% Israel

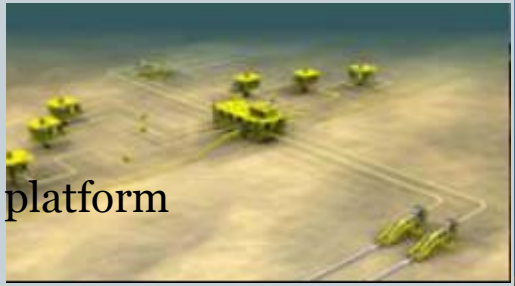


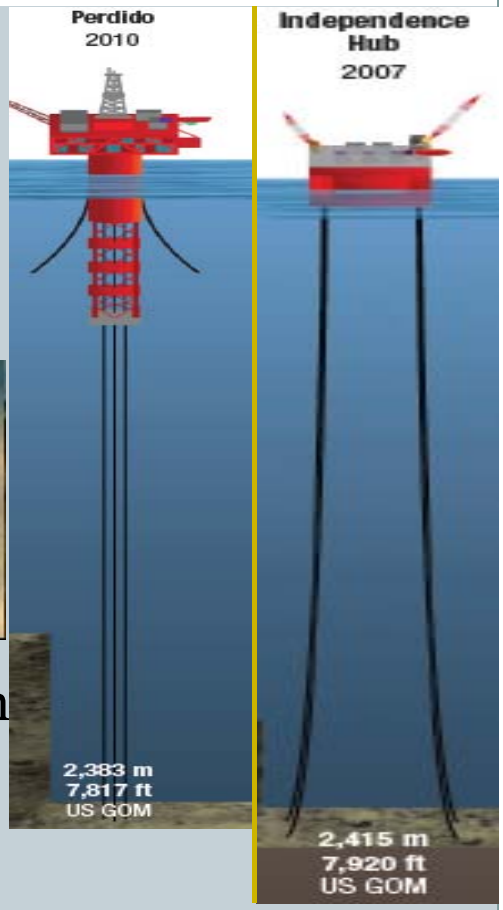


Aphrodite gas field

4. Developing the Aphrodite gas field

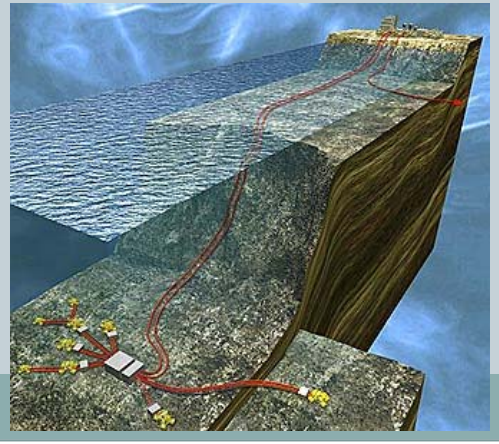
- Subsea architecture– Dry or wet wells
  - Floater: spar-based or semi-submersible; subsea development
- Flowlines – manifolds – umbilicals
- Hydraulic & electrical power & control, communications
- Flexible marine risers
- Costs:
  - Independence Hub: $2bn – $420m platform
- Development costs: $2.5-3bn
- Cyprus gas needs alone do not justify the developmen

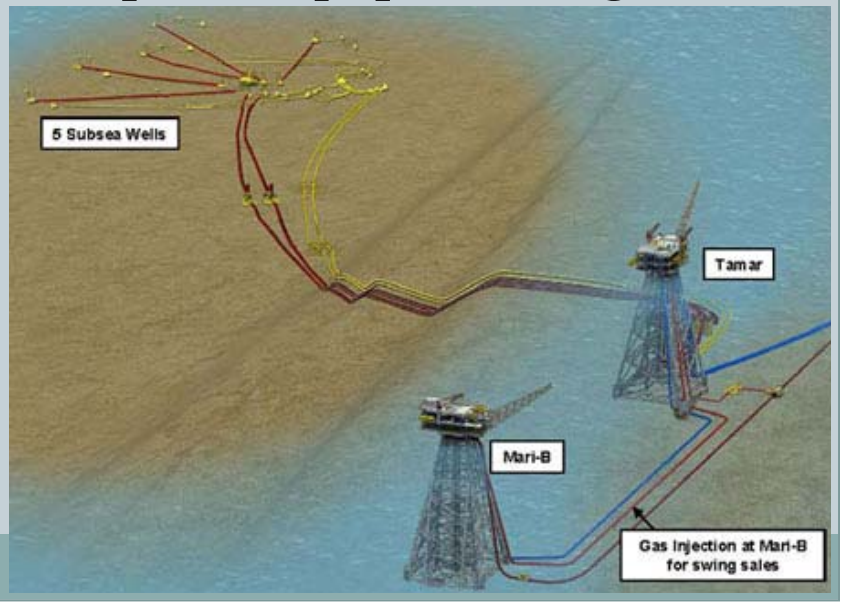




4.1 Subsea development

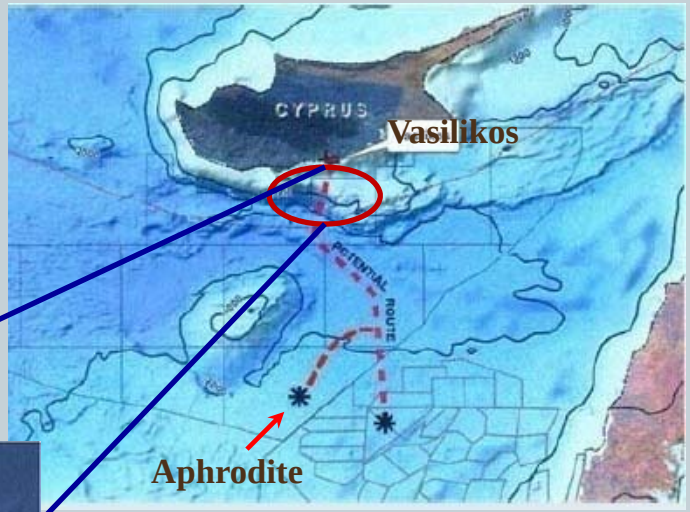
- Subsea installations connected to:
  - a) Floating platform (FPSO, TLP, Spar, ...)
  - b) The shore (e.g., Ormen Lange)
  - c) Fixed installation platforms (Compliant platform, gravity based platform)
- No water depth limit...
- Costly facilities with the time-consuming installations process
- Distances btw components measured with special equipment (e.g., lasers)
- Diverless and platformless ops

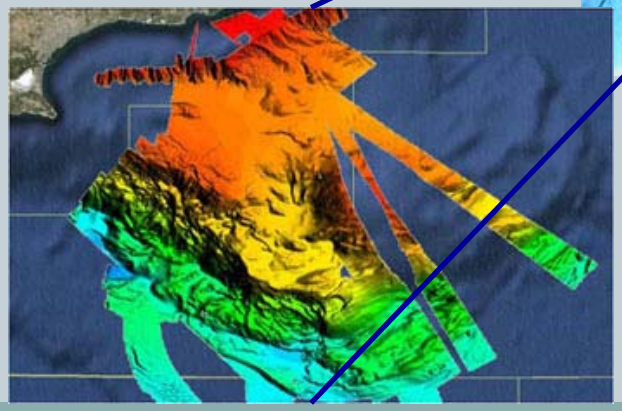




5. Submarine pipelines

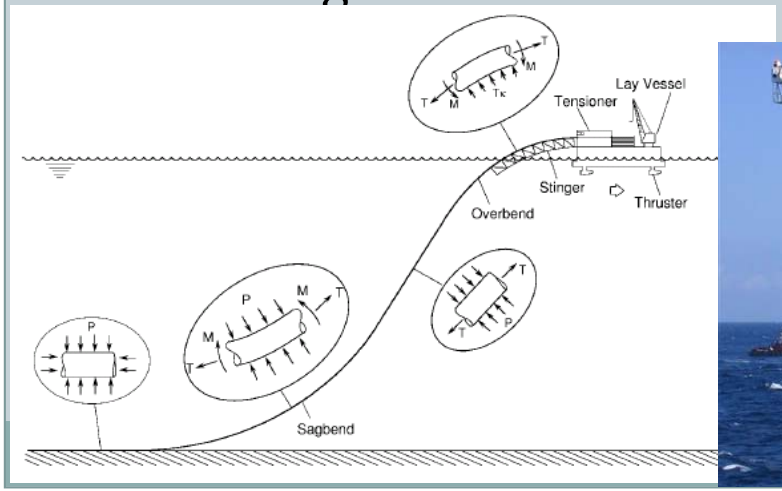
- Seabed surveying & mapping
- Water depth pressure: ≈220 bars
- Pipeline length: ≈185 km
- Technical challenges:
  - Morphology of seabed– subduction zone
  - Extreme pressures
  - Corrosive environment
  - Unstable seabed?
  - Seismogenic area
  - Geo-hazards?

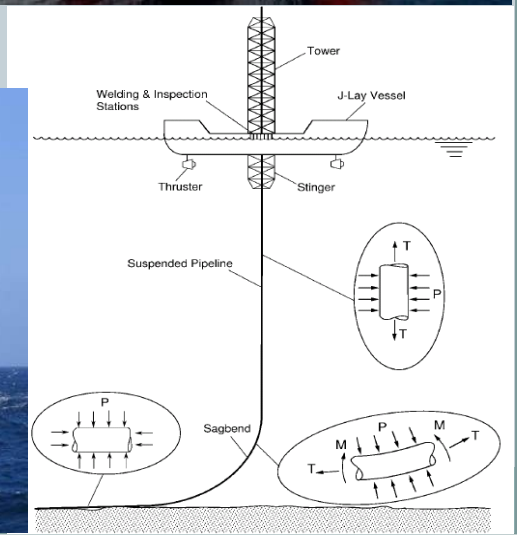




5. Submarine pipelines (2)

- Quantity of natural gas
- Route optimization through surveys
- Pipeline laying method: J-lay or S-lay
- Dig a trench
- Level seabed with pebbles
- Environmental aspects
- Estimated cost: ≈$800 m-$2.3 bn
- Financing?





6. Utilizing the natural gas

- Domestic utilisation– power generation & light industry
- Piping natural gas to Turkey– politics & technical issues?
- Export natural gas to Turkey via Israel?
- Export Options: Liquefied natural gas (LNG):
  - LNG land based facility
  - Floating LNG (FLNG)
- Use NG as feedstock for petro-chemical industry: fertilisers, convert it into diesel, 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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- Piping natural gas directly to Turkey– politics?
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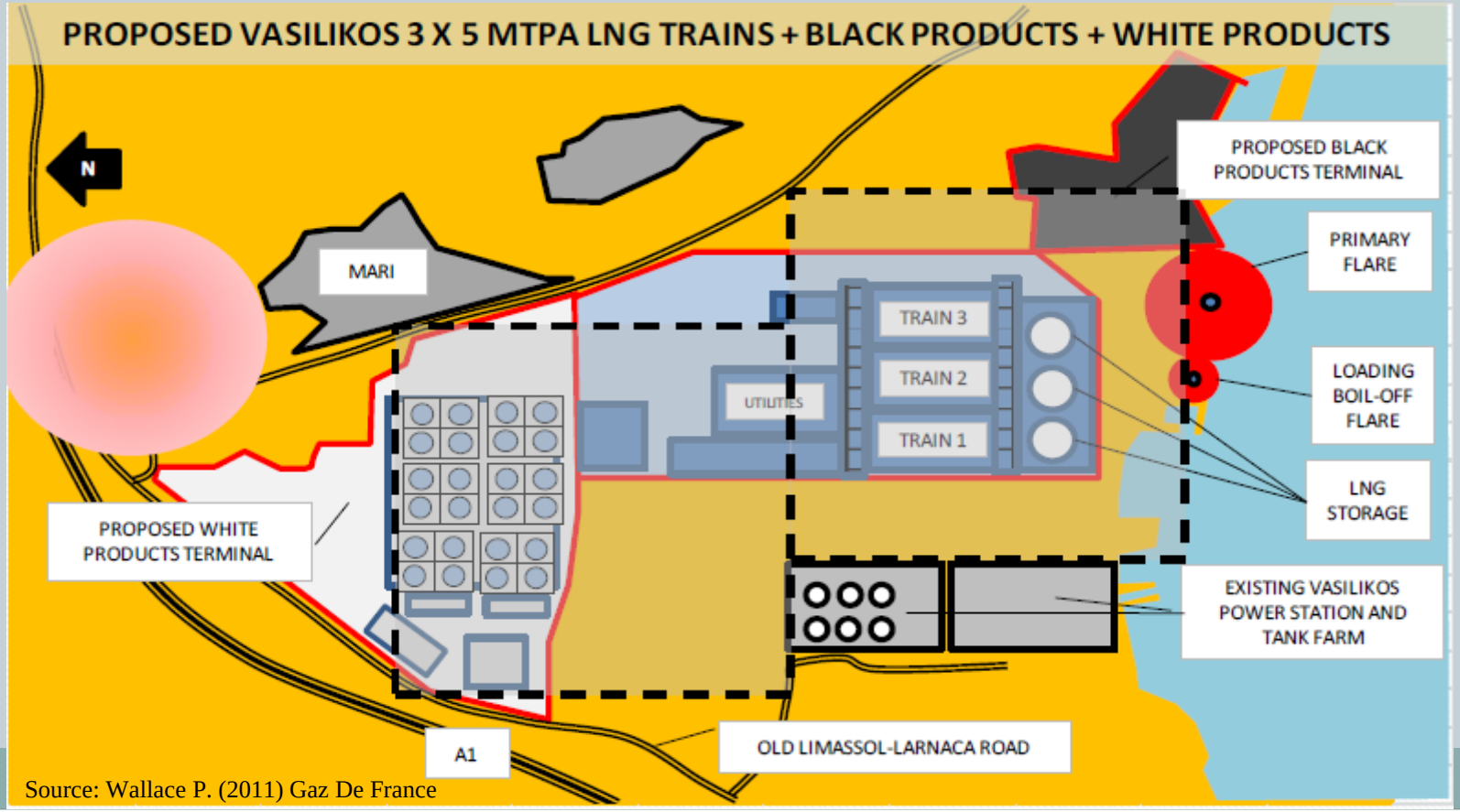
- Use NG as feedstock for petro-chemical industry: fertilisers, convert it into diesel, etc
- Sell gas in-situ; allow a farm-in; issue gas bonds; IPO
- Pipe gas to Greece via submarine pipeline: ?
- Export electricity via subsea cable to Greece &/or Israel: ?

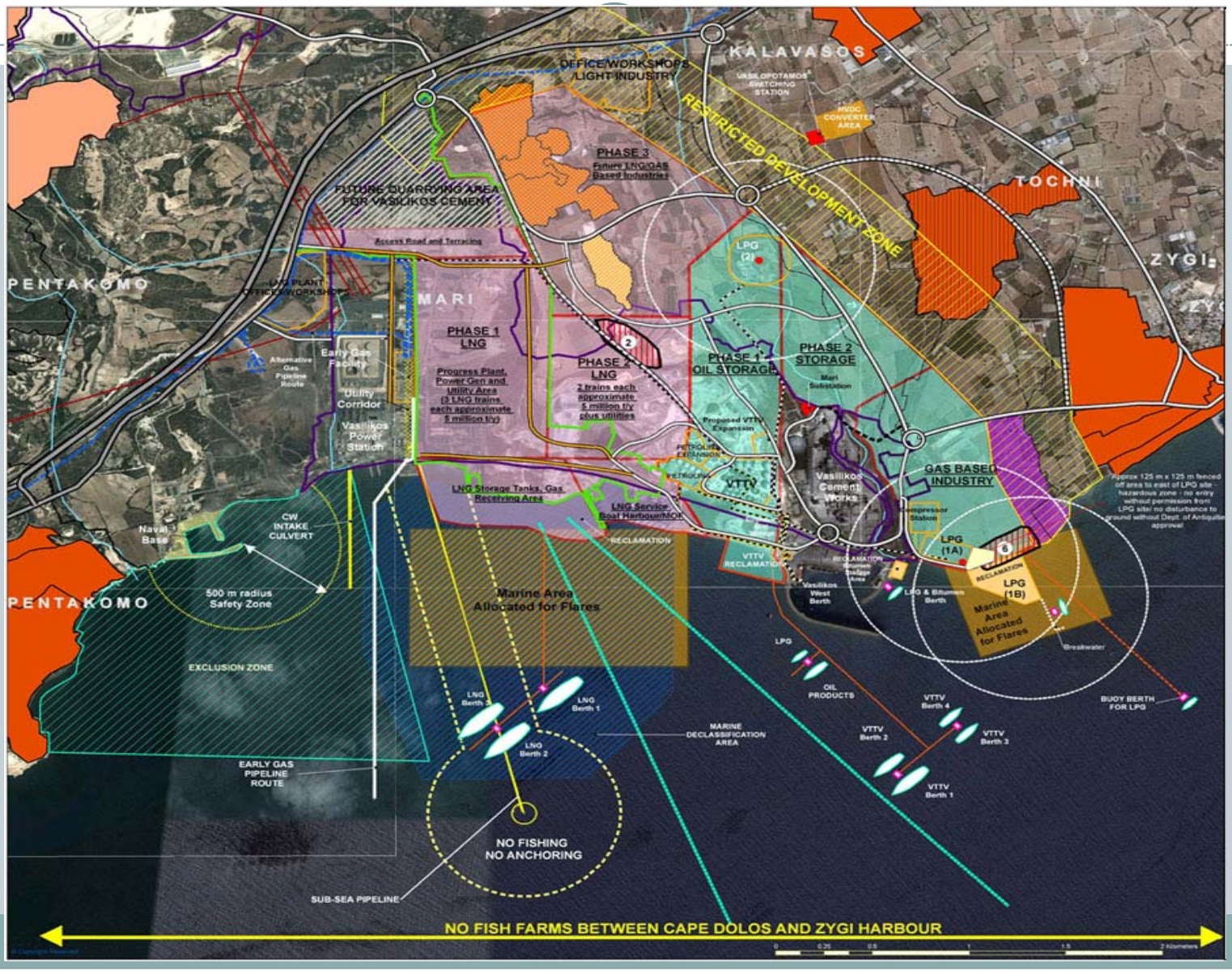
Onshore LNG plant

- Political decision
- Size of the plant depends on (LNG) output



Source: Wallace P. (2011) Gaz De France

6(a). LNG plant (2)



Onshore LNG plant

- Potential cost

Bontag A-H (Indonesia): 22.6 MTPA

MTPA	Trains	Tech	Location	Cost per ton minimum	Cost per ton maximum	Minimum Cost $bn	Maximum Cost $bn
5	1	exist	onshore	$1,600	$2,000	$8	$10
10	2	exist	onshore	$1,400	$1,800	$14	$18
15	3	exist	onshore	$1,200	$1,600	$18	$24

- Other
  - Power demand: 125 MW (5 mtpa)
  - Modularisation of plant?
  - Peak construction phase: 4,000 workers
  - Money to be raised from int'l markets
  - Completion horizon: ≈8 years

Source: Wallace P. (2011) Gaz De France

Floating LNG (FLNG)

- No need for submarine pipeline
- Innovation: onboard liquefaction
- FLNG Prelude 1st in the world?
- Keel laid: oct 12; Production: 2018
- Cost: $5-6 bn
- 600,000 t | Length: 488m
- 3.5-4 mtpa (2-3tcf)
- Working life: 30-40 yrs
- Issues: sloshing, maintenance, safety

Prelude FLNG

Petronas FLNG

- Anchored offshore Malaysia
- L_{pp} = 365m
- 132,000 tonnes
- 1.2 mtpa

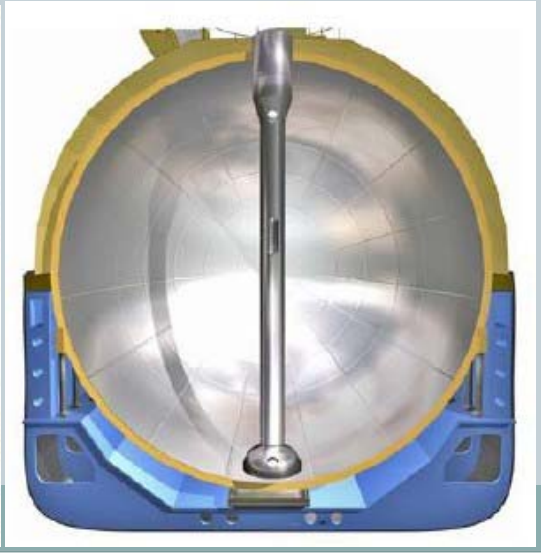
PFLNG SATU

LNG seaborne exports

- Ships committed to 15-20 year contracts
- On-board liquefaction (boil off gas)
- LNG stored at atmospheric pressure at –161°C
- Need for regasification terminal
- Q-max: 266,000 m³ (Qatar)

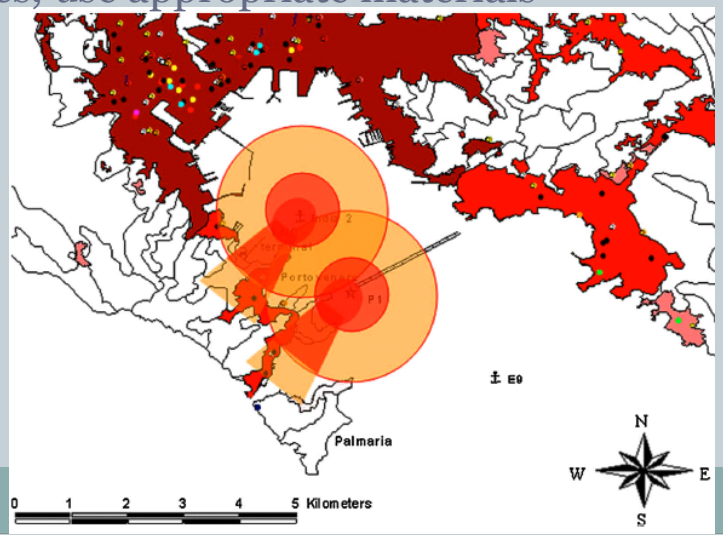
LNG carriers

- Three containment systems (self-supporting & integral):
  - Prismatic design
  - Spherical type
  - Membrane design
- Materials: aluminum, balsa wood, stain. steel, polyurethane
- Advanced leakage protection systems



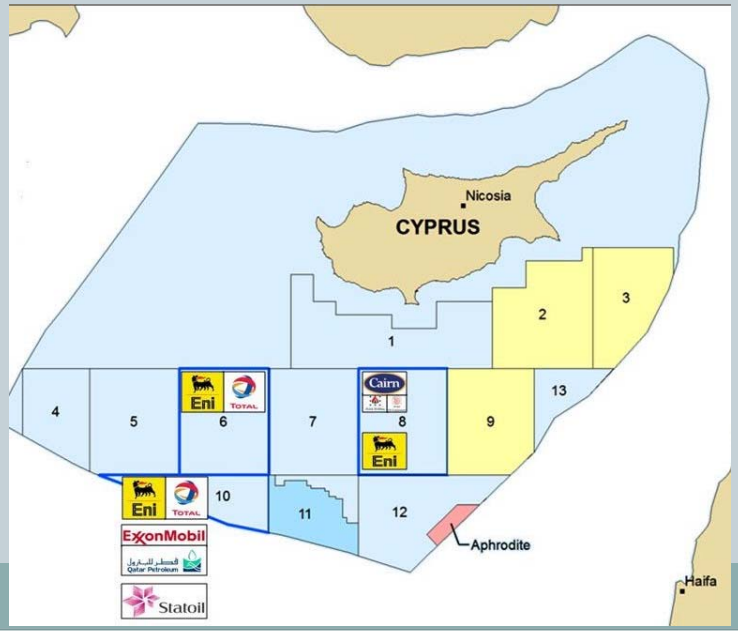
Nat gas safety issues

- Methane is odorless, colorless, non-toxic, non-corrosive
- Detected with the use of “methanethiol”
- LNG is not flammable
- Burning of nat. gas under certain conditions only:
  - Presence of spark, concentration of nat. gas: 5%-15% (NG).
- Safety barriers:
  - Flare nat. gas, LNG & equipment positioning
  - Divide LNG plant into blast zones, keep distances, use appropriate materials
  - Use of explosion proof materials, fire fighting systems, nat. gas leakage sensors
  - Simulation of NG leakage & explosion

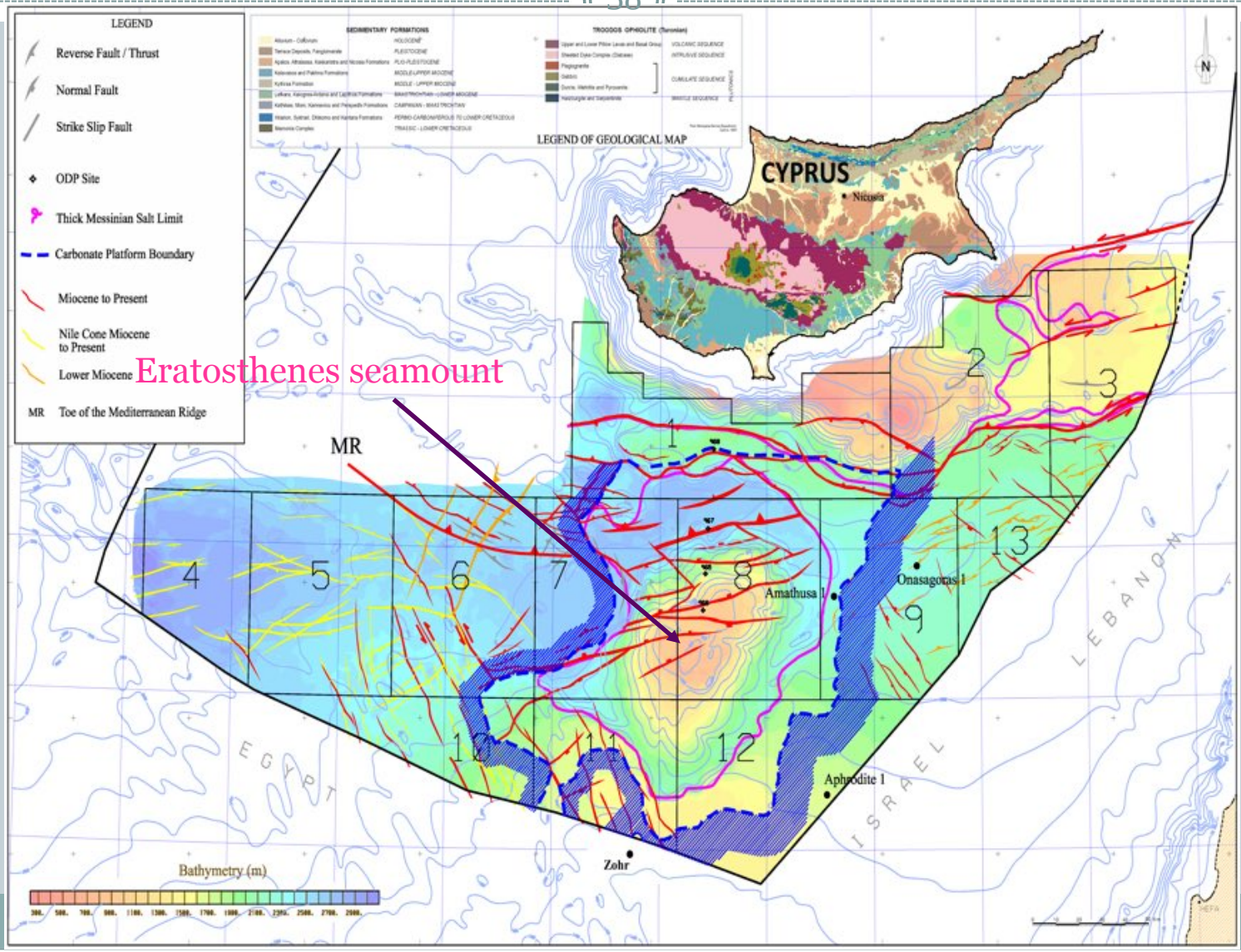


Third licensing round

- 24/03/16: call for 3rd licensing round
- Blocks: 6, 8 & 10
- Companies: Exxon-Mobil, QP, ENI, Total, Statoil, Cairn, Delek, Anver
- Block 10 attracted the most attention
- 20/11/16: Announcement of results
- Selection criteria: signature bonus, exploration programme, …



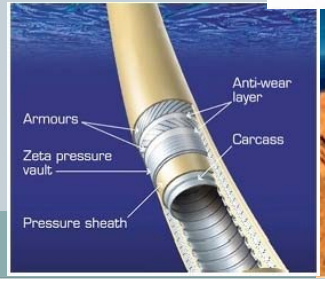
Carbonate platform

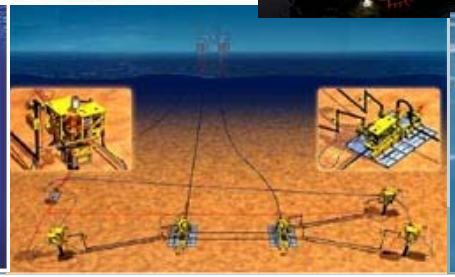


Translating O&G reserves into value-added activities

What is an O&G maritime centre?

- Cluster of oil field service companies & maritime suppliers
- Supermajors, independent & nat'l oil comps (IOCs & NOCs) outsource non-core oil activities like:
  - Construction & contracting e.g. drilling, offshore rigs (Aker slns)
  - Services e.g. seismic surveys (PGS), logging, riser design (2H)
  - Vendors e.g. electrical & mechanical equipment (NATCO Group)
- Maritime suppliers:
  - Offshore support vessels, FPSOs
  - Drilling equipment e.g. drill bits
  - Subsea installations, maintenance
  - O&G well equipment





The case of Norway (I)

- O&G industry started in 1969 with Ekofisk oil field
- 1970s: "Norwegianization" of oil: more state control, participation & revenues; operational & fiscal ownership
- Statoil, Petroleum Directorate, Petoro were founded
- Economy benefits more from cluster than from O&G sales
- 2nd highest per capita income $97K
- Gov't pension fund $600bn
- How did Norway make it?

Norway's subsea pipeline network

The case of Norway (II)

- ‘Grand-scale clubbing’ of Norwegian & biggest oil firms
- Success factors:
  - Abundant O&G resources; stable macroeconomic policies
  - Strong public institutions; high productivity; maritime industry
- Took control of its own O&G operations
- Statoil given ≥50%; IOC borne exploration costs
- Protectionism: preference to Norwegian suppliers & services
- Oil prices crushed in 1986: recession, unemployment→4.5%
- Gov’t recognized need for IOCs abilities to hedge risk & lower cost

Future activities in the Cypriot EEZ

- Blocks 2, 3 & 9 granted to ENI-KOGAS (24.1.13)
- Concessions for 10 & 11 awarded to Total (6.2.13)
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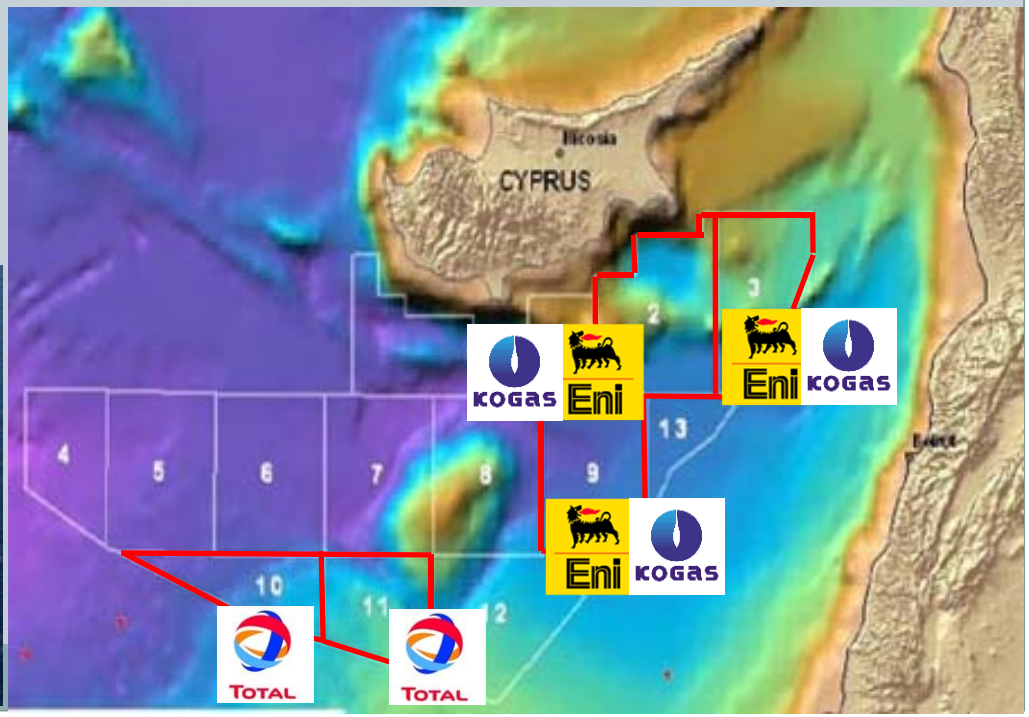
- First oil well?



Can Cyprus take control over its O&G destiny?

- No Cypriot comp. currently participates in E&P in EEZ
- Opportunity for the National Oil Company (KRETYK)
  - Legitimise the NOC
  - Raise capital for operations
  - Staff it accordingly
  - Clarify its duties: take part in permits or oversee companies?
- Role of the MECI&T– Energy Service?
- PSC: 'local content' participation & knowledge transfer?
- No funds for education, training or R&D yet
- Can Cyprus become an O&G service/supplier cluster?

Cyprus's competitive advantages

- 49.1% btw 30-34 yrs old hold university degree
  - 2nd highest % in the EU after Ireland (51.1%)
- Good relations with MENA countries & Israel
- Low corporate tax– 12.5% on profits
- Geostrategic location; EU member
- Double tax treaties with 45 countries
- Modern legal & accounting stms based on English practices
- Advanced transportation & communications infrastructure
- Qualified & multilingual workforce
- World-class ship management centre
- Signatory to UN Law of the Sea (UNCLOS)

Government's role

- Involve Cypriot companies in O&G activities
- Facilitate knowledge transfer from IOCs
- Control the pace of extraction so that local sector develops:
  - Reduce the size of offshore blocks
  - Spread exports over time
- Promote oil exploration
- Engage local expertise: Universities, shipping and local OFS
- Cultivate entrepreneurial culture for O&G industry
- Need for a vision (& road map)

Larnaka Port as a Logistics/Service Center?

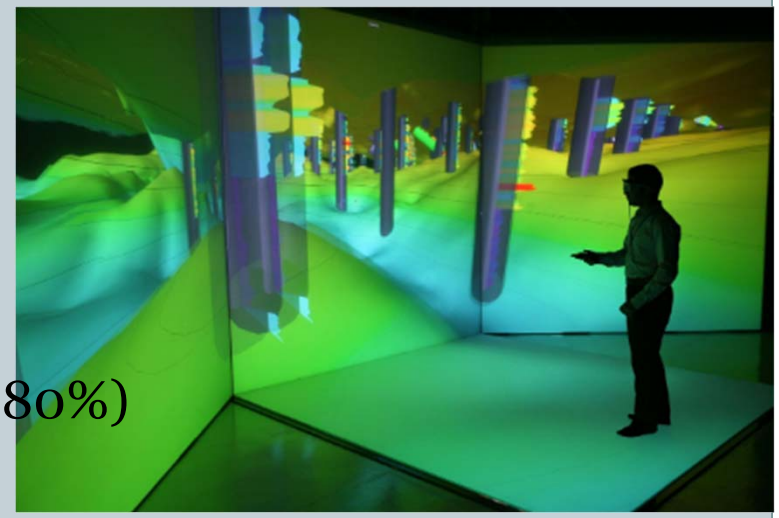
- Sea area: 250,000 m²
- Land area: 445,000 m²
- Port (water) depth: 12 m; probably no need to deepen it
- 8 km from Larnaka airport

Cyprus Petroleum Storage Company

Larnaka Port

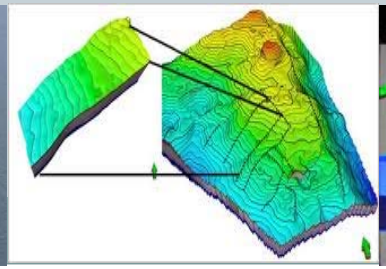
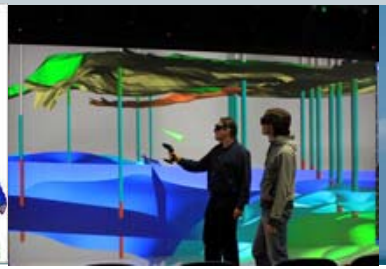
Other O&G areas for Cyprus

- Research & development
- Environmental studies & monitoring
- Education & training– 3 universities already
- Maintenance of oil rigs & installations
- Diving & inspection
- Transhipment centre
- Oil & gas law & accounting services
- Energy hub for entire Eastern Med
- Offshore O&G discoveries will dominate (80%)



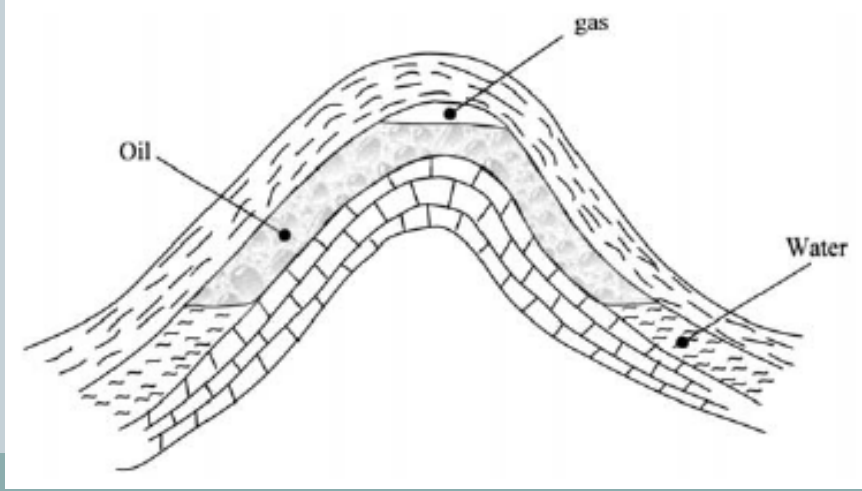
Cyprus as a petro-cluster?

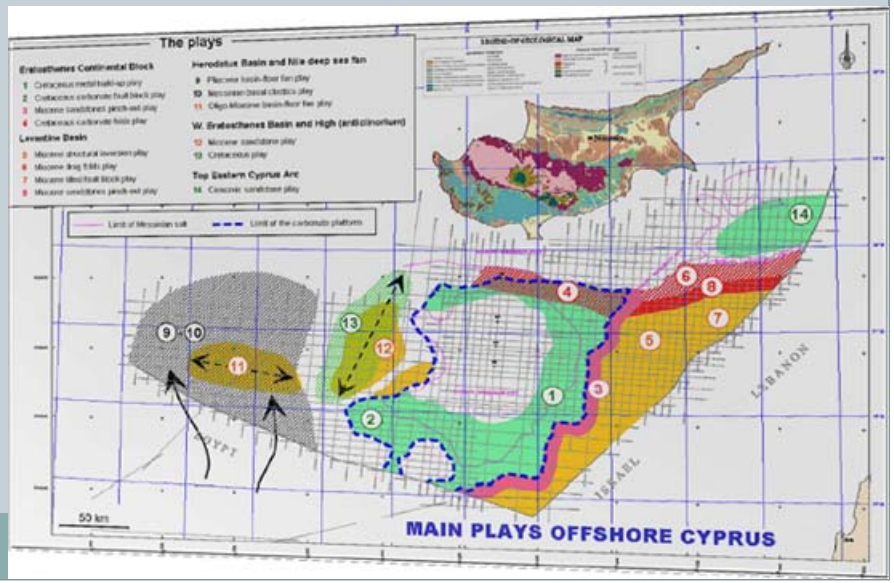
- NOC should participate in O&G field life cycle
- Cyprus strengths in services not manufacturing
- Encourage local private sector engagement in O&G projects
- Incentives for OFS and IOCs to set-up local offices
- Training & education of Cypriots
- Institute legal framework & transparent decision-making
- Establish a body for regulation of O&G industry
- Funding for R&D in O&G

Is there oil to be found?

- 14 hydrocarbon plays identified in the EEZ
- “Thermogenic” gas offers evidence for oil
- Extensive 2D seismic data, new geological data
- No well yet has reached the desired depth in Cyprus EEZ
- Proven working hydrocarbons stms
- Discovery of oil by Shemen oil in Israel





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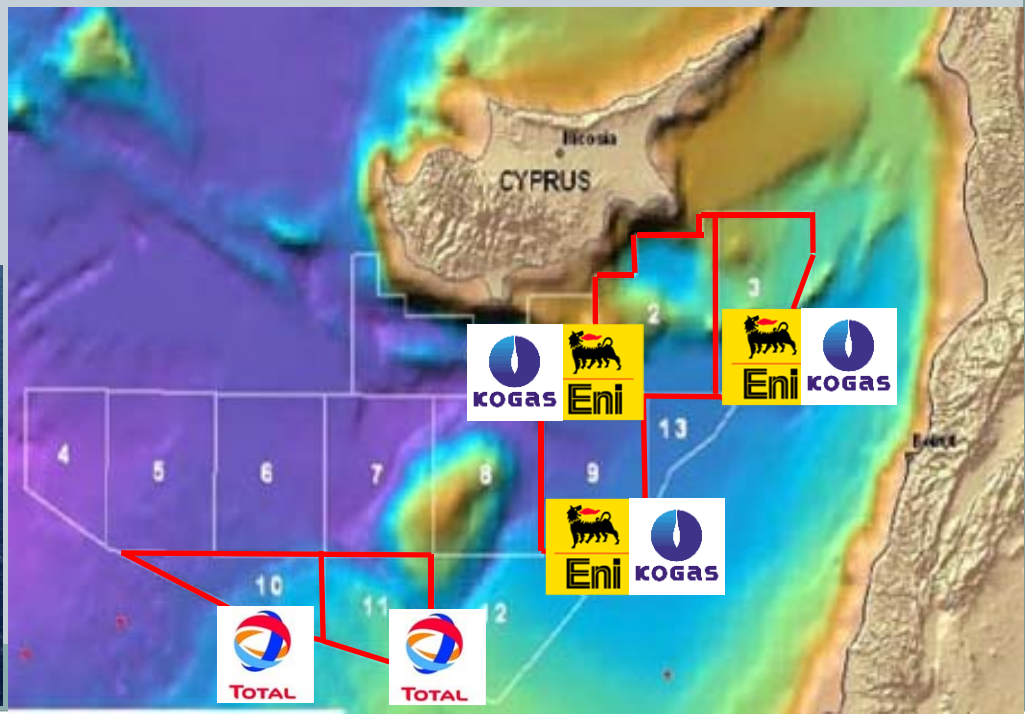
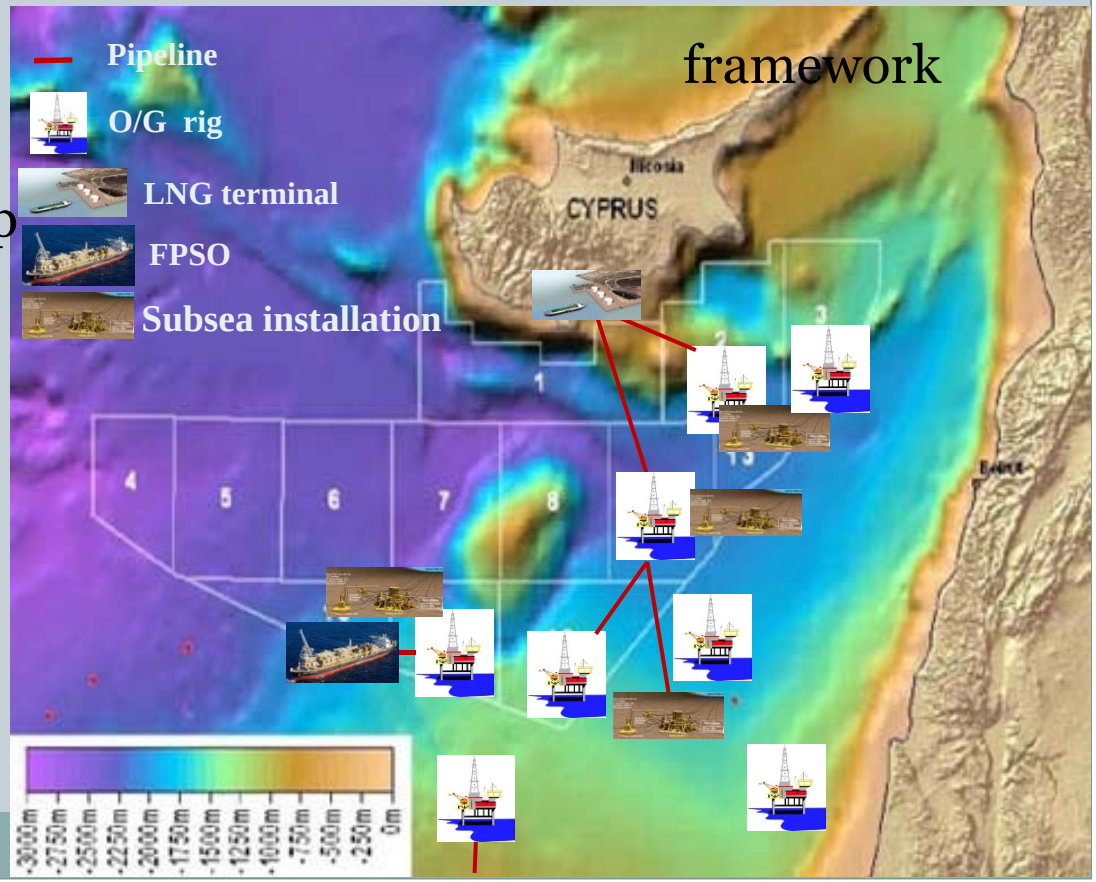


The future ahead

- World-class companies active in EEZ
- Potential for Cyprus to become O&G supply & service cluster
- Priority: oil exploration
- Legal & transparent
- NOC participate in E&P
- Need for a vision & roadmap
- O&G are Cyprus' hope!



Thanks for your attention!