5th South East Europe Energy Dialogue
Thessaloniki 2nd & 3rd June, 2011

Session VI: “Gas Market Challenges in S.E. Europe”

Technical and Commercial Aspects of natural gas under ground storage (UGS)

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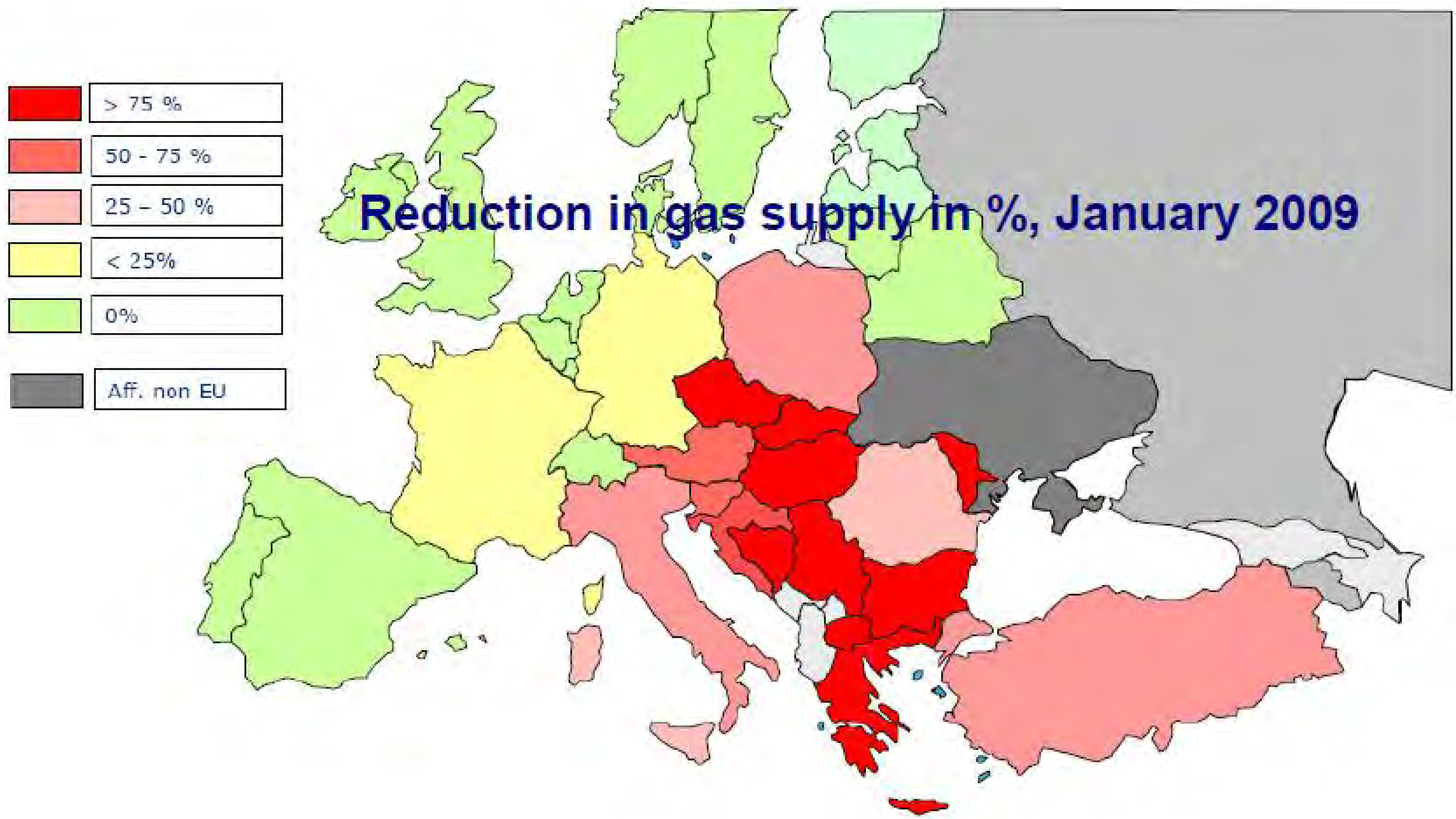
Overview

1. Introduction
2. Local Natural Gas Status
3. Basic Concepts & Advantages of UGS
4. Underground Gas Storage Facility Types
5. Main Factors Determining Suitability of a Storage facility
6. Characteristics & Main Design factors of an UGS
7. A Notional case
8. Commercial Aspects
9. Risk Analysis

Russian Ukraine crisis effect



Countries of SE Europe mostly affected and vulnerable to gas supply disruptions

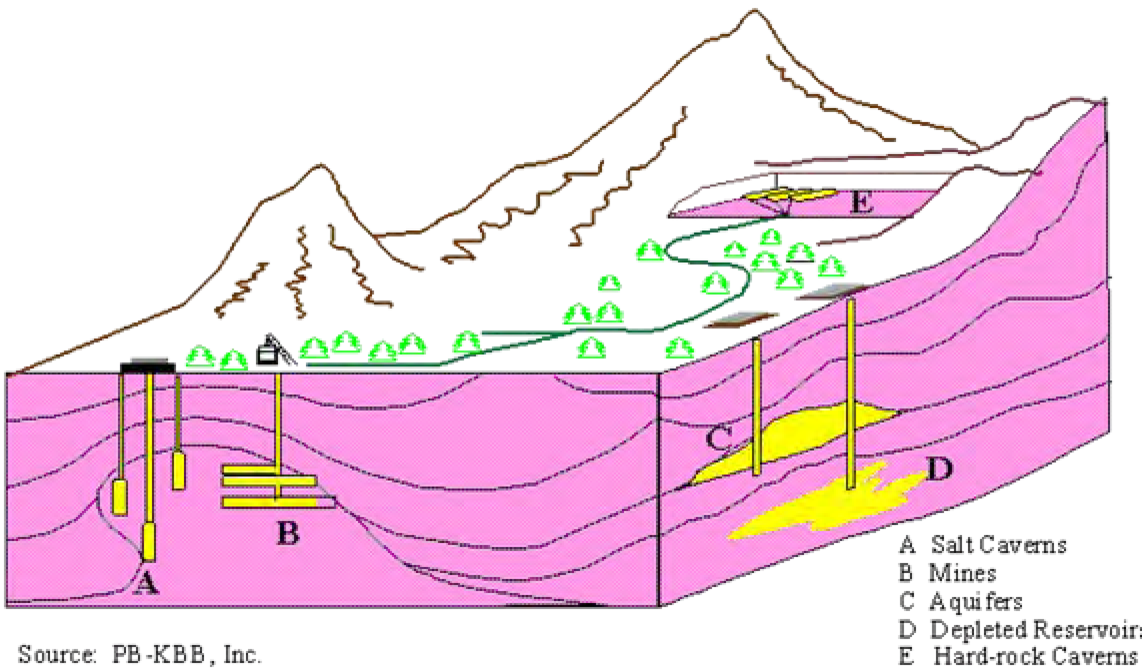
Local Natural Gas Status

- ✓ Greece has no local gas production and imports gas from Russia, Turkey and Algeria. The expected demand for 2011 is 4,0 bcm.
- ✓ Offshore South Kavala gas field seized production in 2010 having recovered since 1981, about 850 mcm of 1000 mcm of initial gas in place. Peak Production of 0,25 mcm per day was achieved during 1989-1991.
- ✓ A marginal gas field was discovered in 1988 and appraised in 1989 in Epanomi area near Thessalonica.
- ✓ The Greek State is planning to announce a new Exploration and Production license round in 2012. In addition it has been announced that it has plans to privatize offshore South Kavala reservoir to convert to UGS.
- ✓ Local gas production cannot be realized before 2020.

Basic Concept & Advantages Of UGS

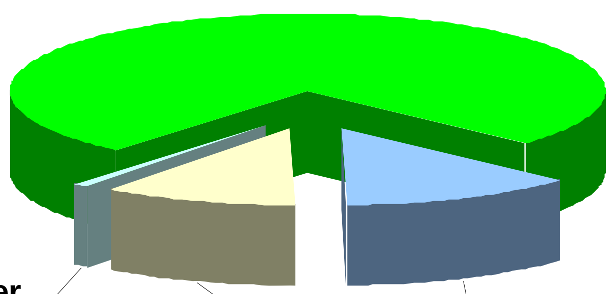
- ✓ Gas in pipelines provides part of the storage capability however, this volume is limited
- ✓ Gas typically flows through the network of distribution pipelines at a slow speed of 40 Km/h
- ✓capability to store gas more locally (withdraw and supply to industry/users more quickly
- ✓ Ensures supply reliability during periods of heavy demand by supplementing pipeline capacity
- ✓ Serving as backup supply in case of an interruption in wellhead or gas field production
- ✓ Allows load balancing of daily throughput levels on pipeline
- ✓ Allows to manage inventory levels to take advantage of expected price movements and to support futures market trading.

Underground Gas Storage Facility Types



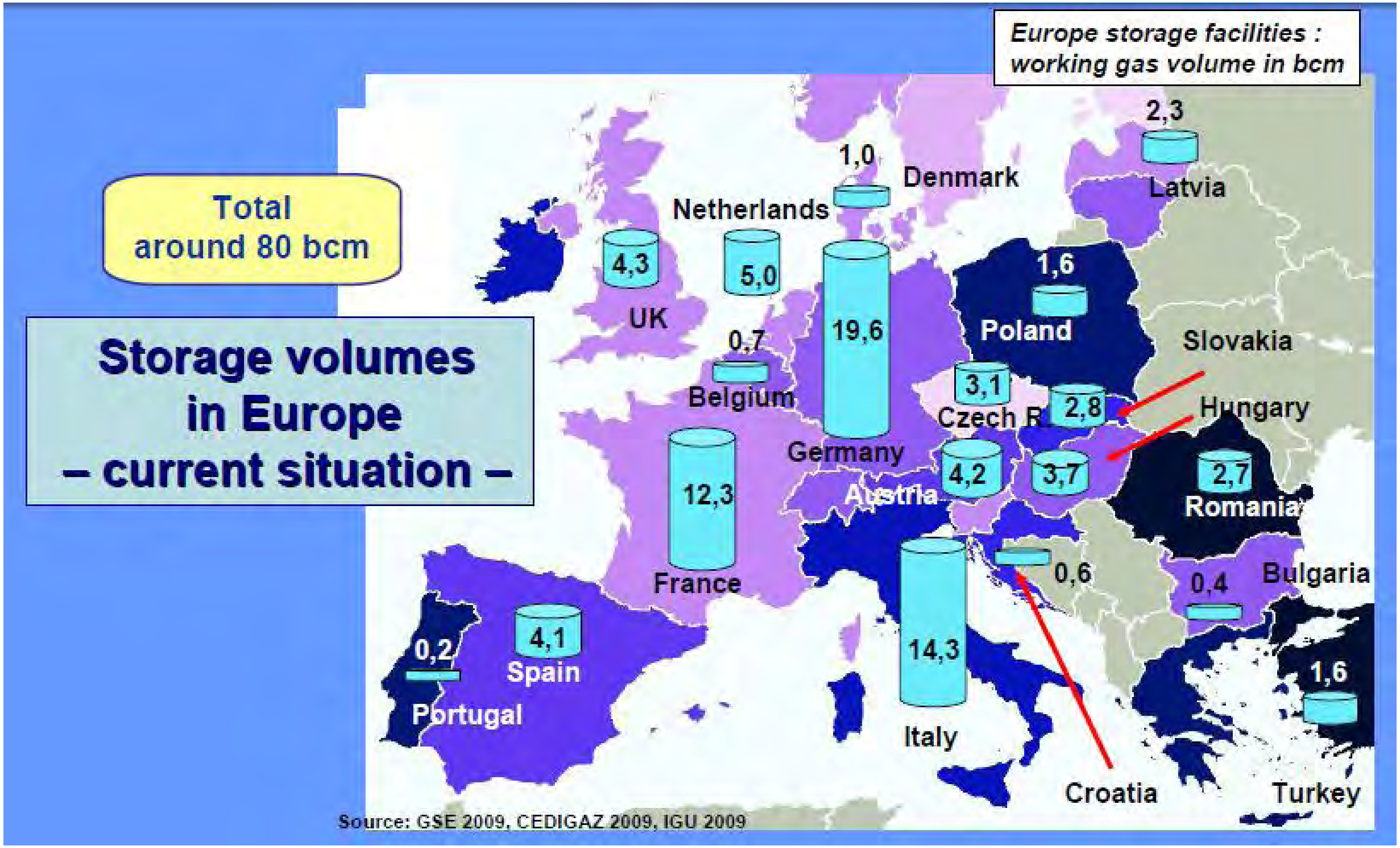
Source: PB-KBB, Inc.

Worldwide (by type)



Aquifers and salt caverns make up 34% of Western Europe storage capacity compared to 14% in the USA were there is greater access to depleted oil/ gas fields.

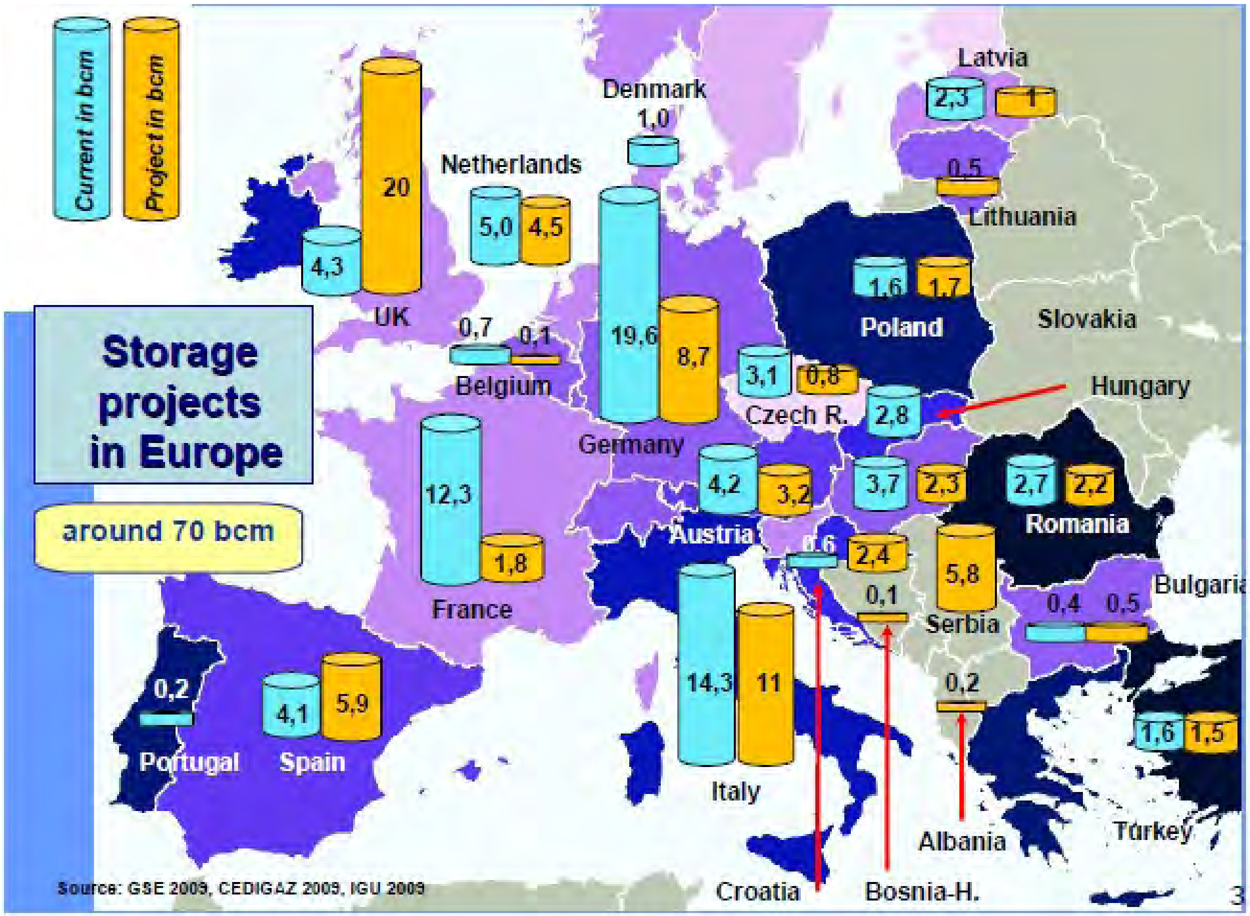
UGS facilities in Europe and storage volumes



Total number of UGS facilities 120

5,3 bcm in SE Europe

UGS facilities in Europe and storage volumes



✓UK and Italy and SE Europe leaders in new projects
✓12,7 bcm in SE Europe

HELLENIC PETROLEUM

Factors determining the suitability of a storage facility

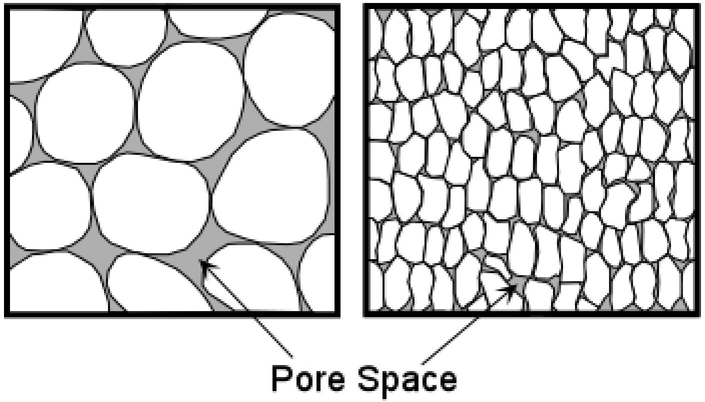
✓**Geographical**

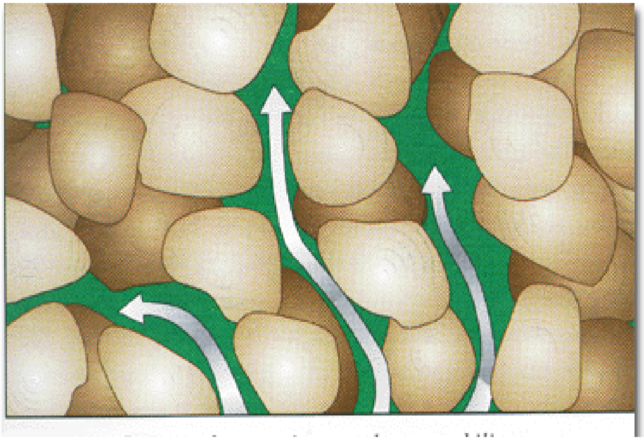
- **Proximity to the consuming regions or industry**
- **close to transport infrastructure, including main and trunk pipelines and distribution systems**

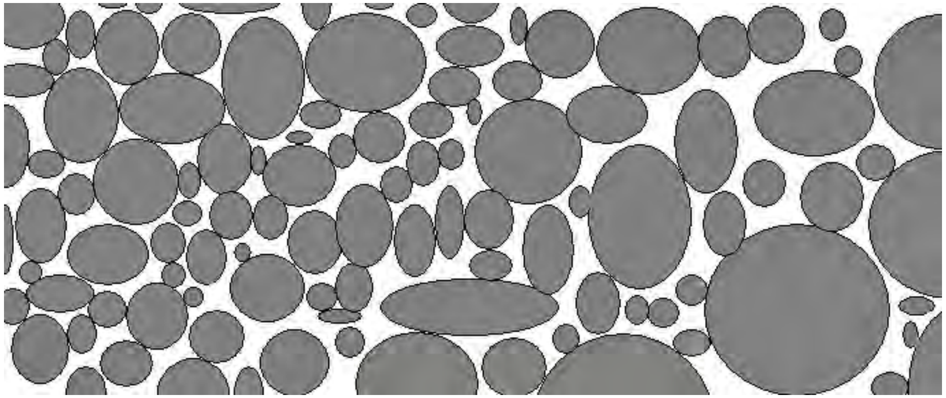
✓**Geological**

- **good porosity (determines the amount of natural gas that it may hold)**
- **permeability determines the rate at which natural gas flows through the rock formation, which in turn determines the rate of injection and withdrawal of working gas**

Reservoir Properties (Porosity – Permeability)





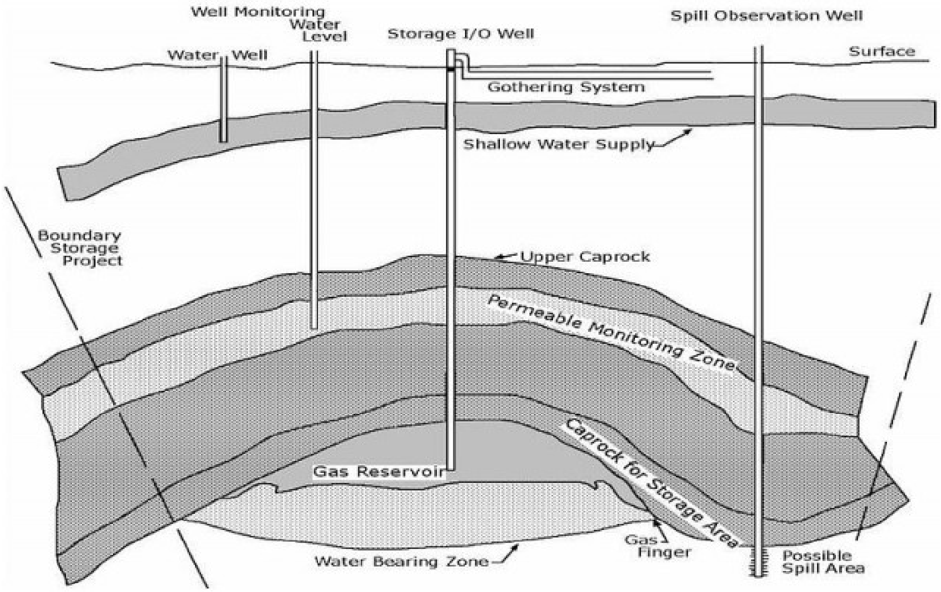


porosity is fairly good throughout, but the permeability is better on the right side.

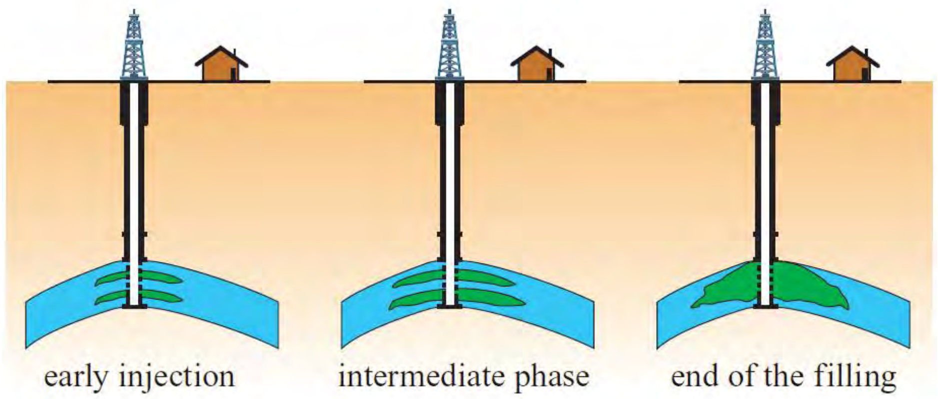
Increase in permeability

Reservoir Properties (Porosity – Permeability)

Together, the porosity and permeability of reservoirs determine the effectiveness or performance and thus economic viability of any specific site



Depleted hydrocarbon reservoirs, tend to have high permeability and porosity. They have also proved the integrity of the trap to retain hydrocarbons over geological time (millions of years).



For aquifer storage, where the porosity, permeability and cap rock all have to be proven, which is more expensive and impacts upon the viability of any proposed development.

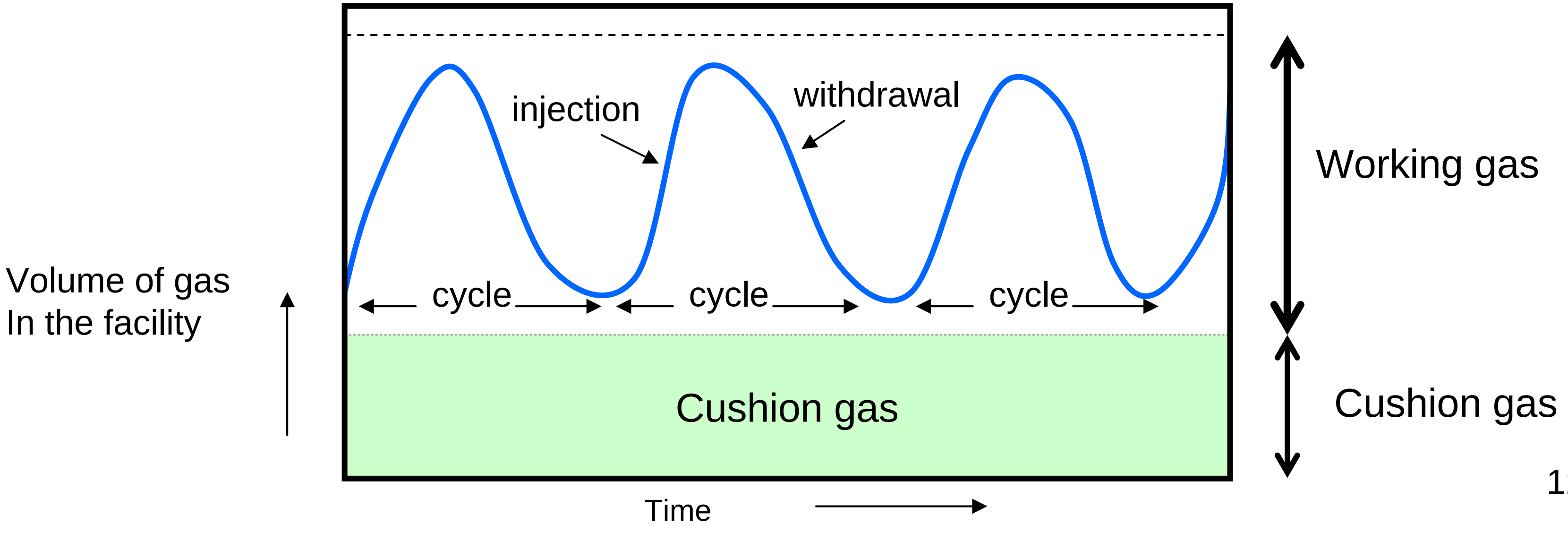
Types of gas in storage terms

Working gas

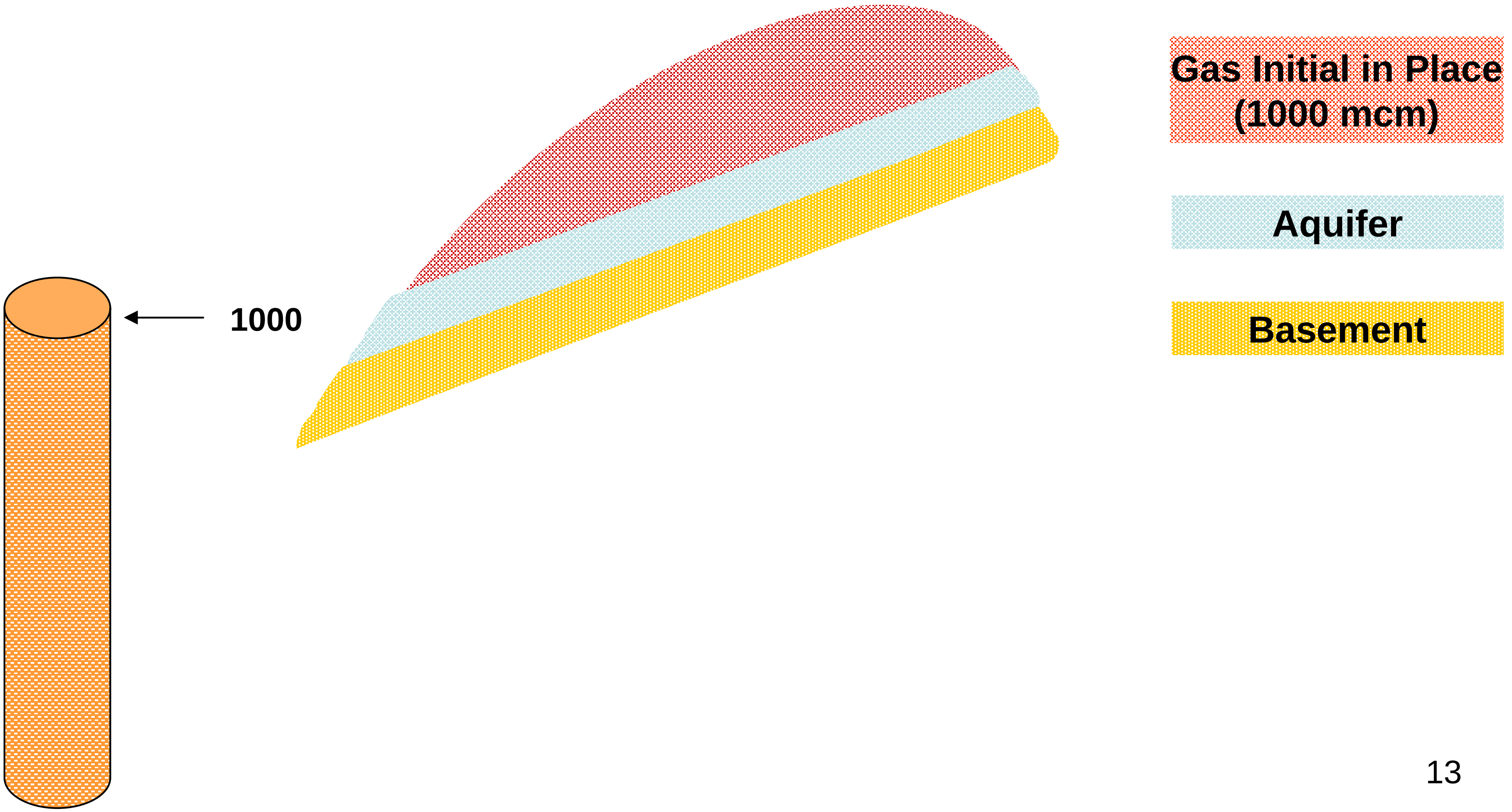
- the maximum volume of gas available for withdrawal during the normal operation of the storage facility.
- Greatest when the facility has been filled to capacity. The capacity of storage facilities normally refers to their working gas capacity.

Cushion gas

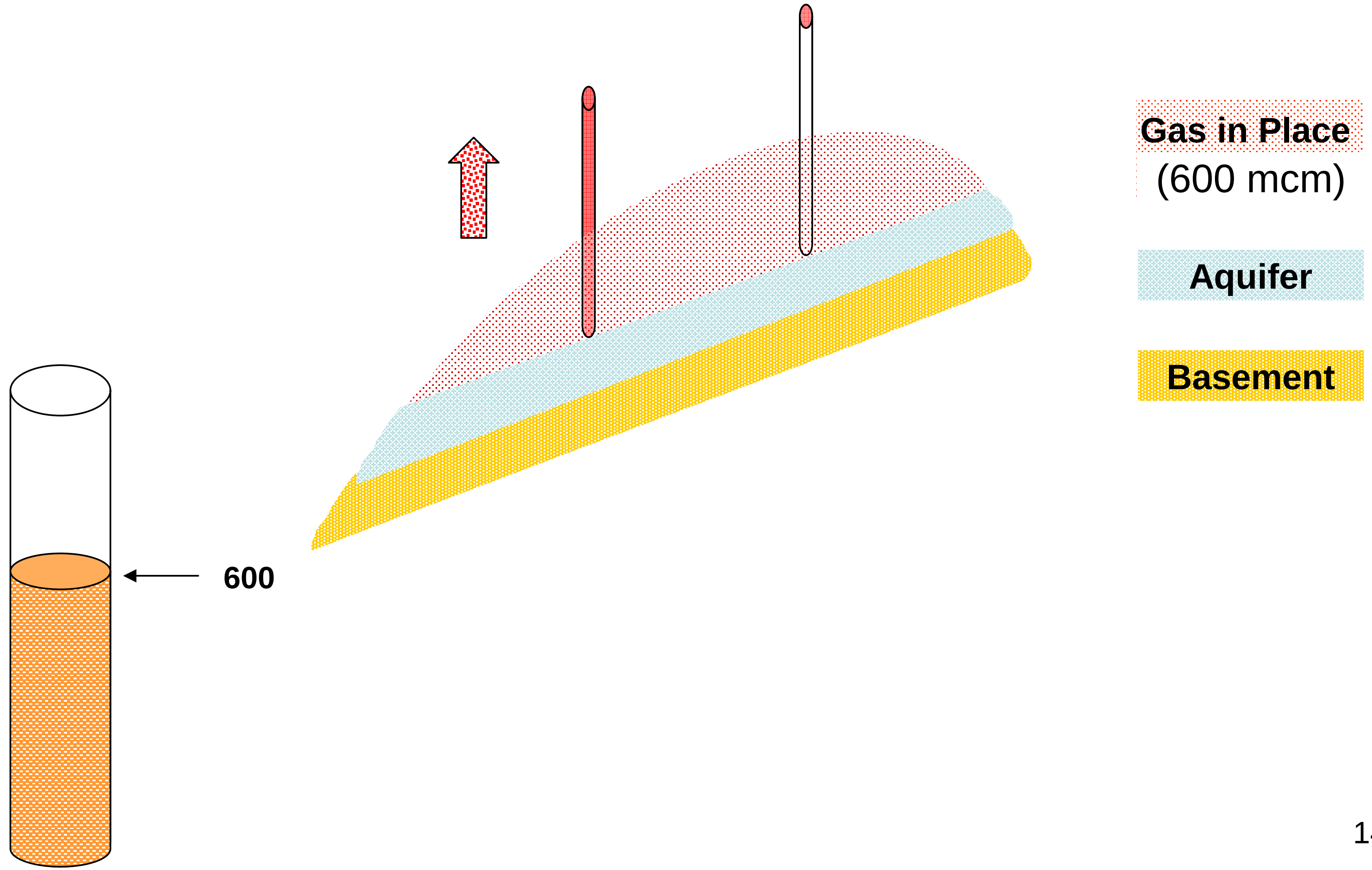
- gas permanently present in the UGS.
- not available for withdrawal
- required to maintain adequate pressure
- ensure sufficient energy is available to provide the required deliverability.



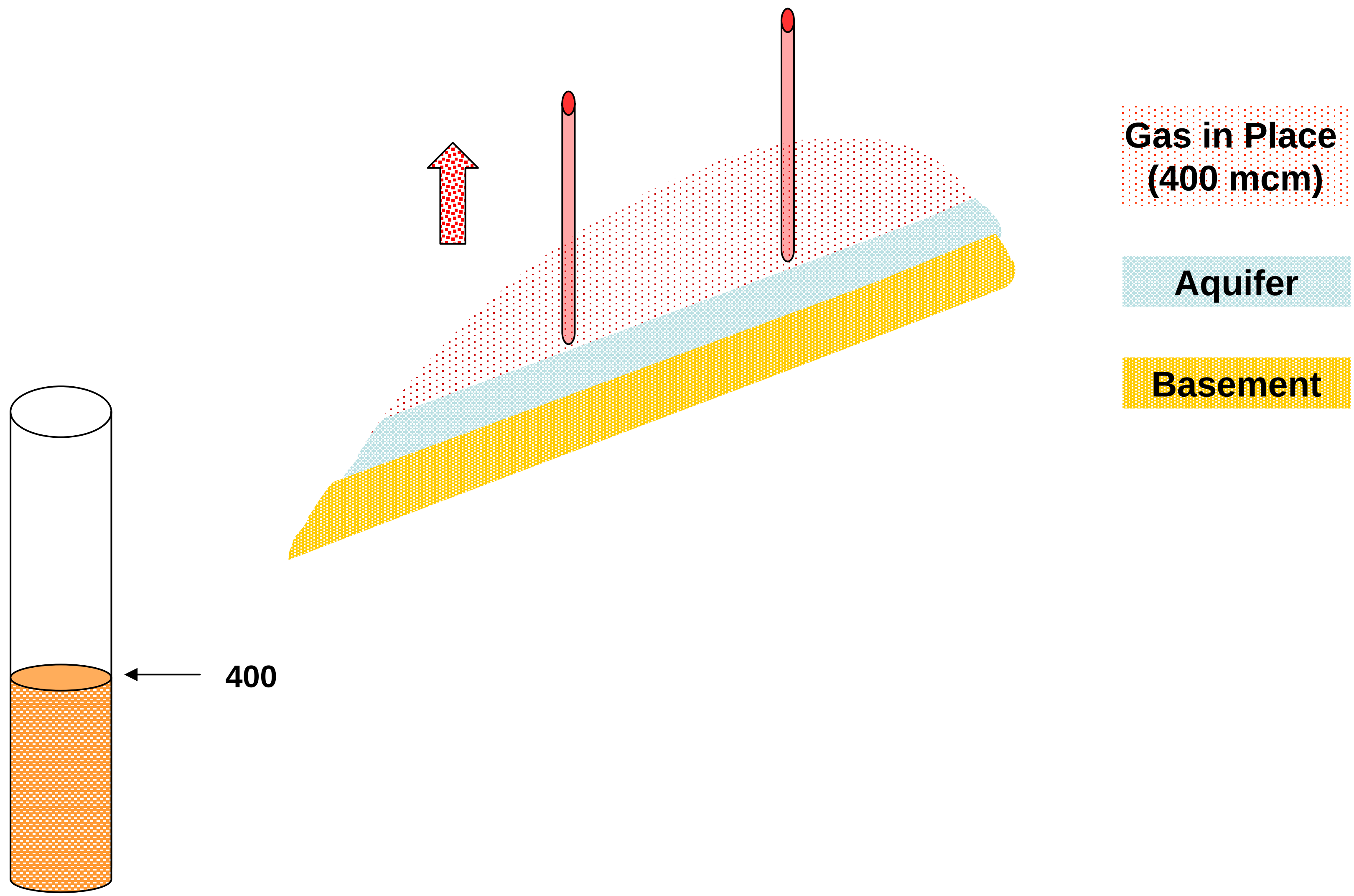
Initial status



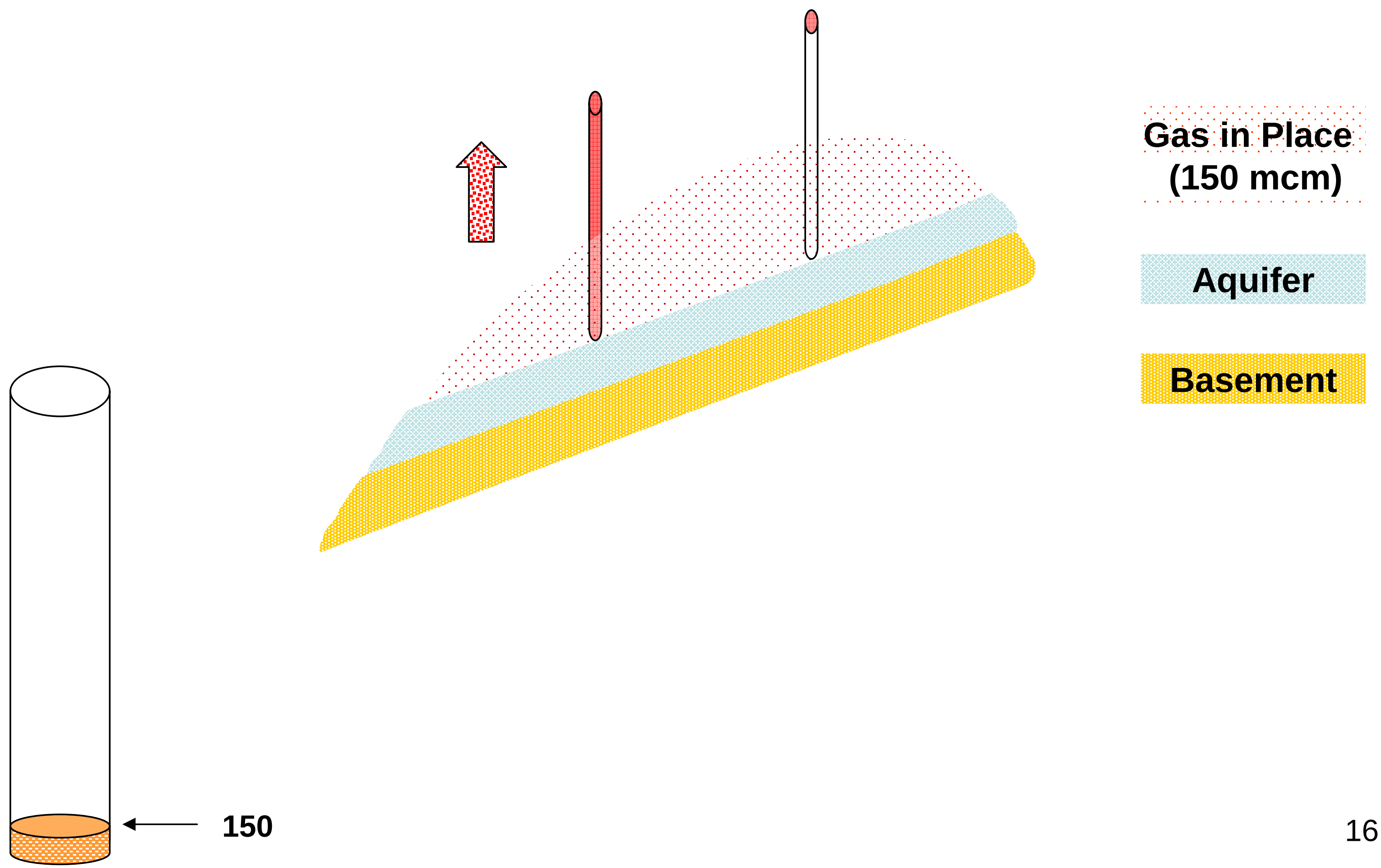
10 yrs after start of Production



15 years after start of Production

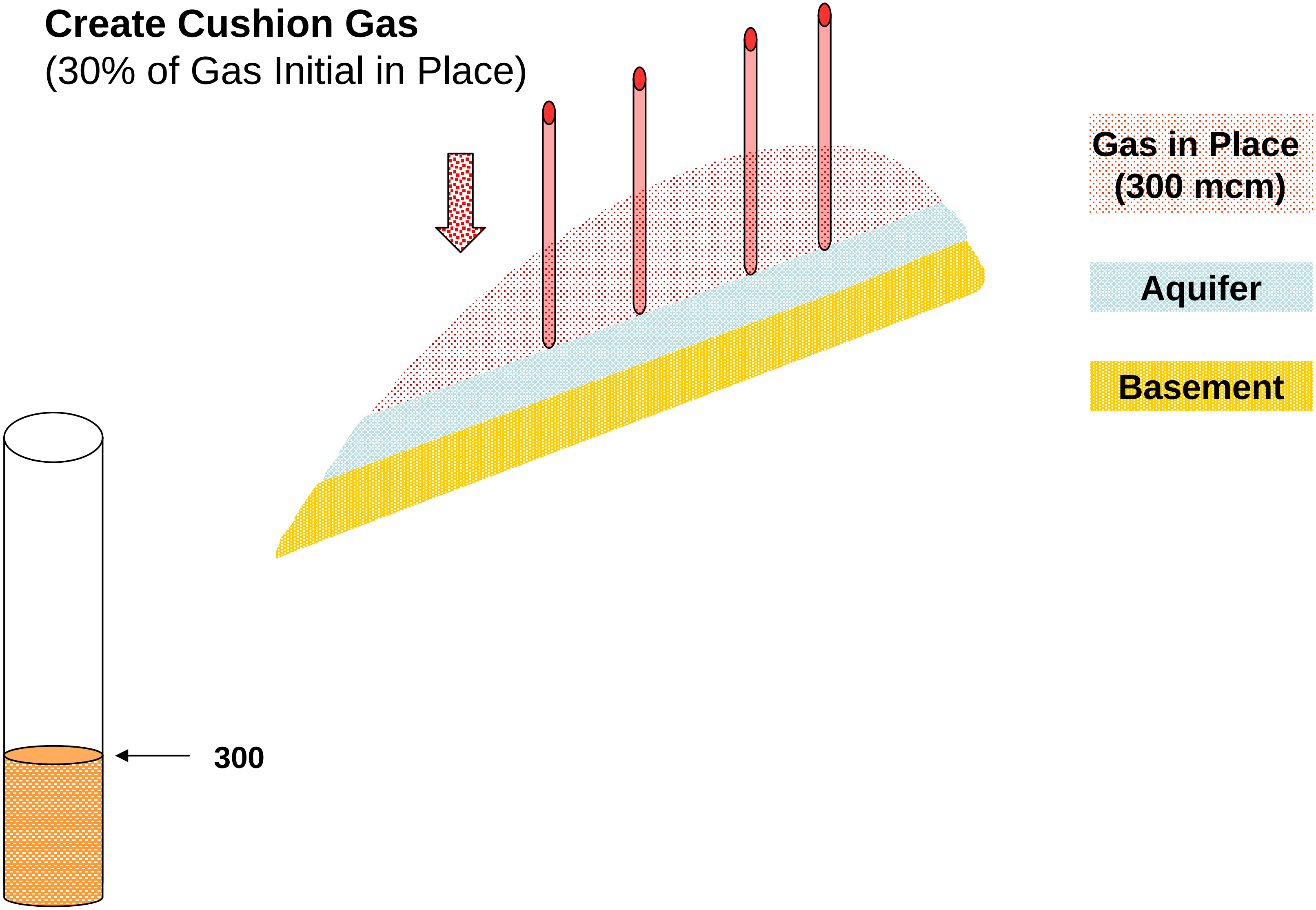


30 years after start of Production



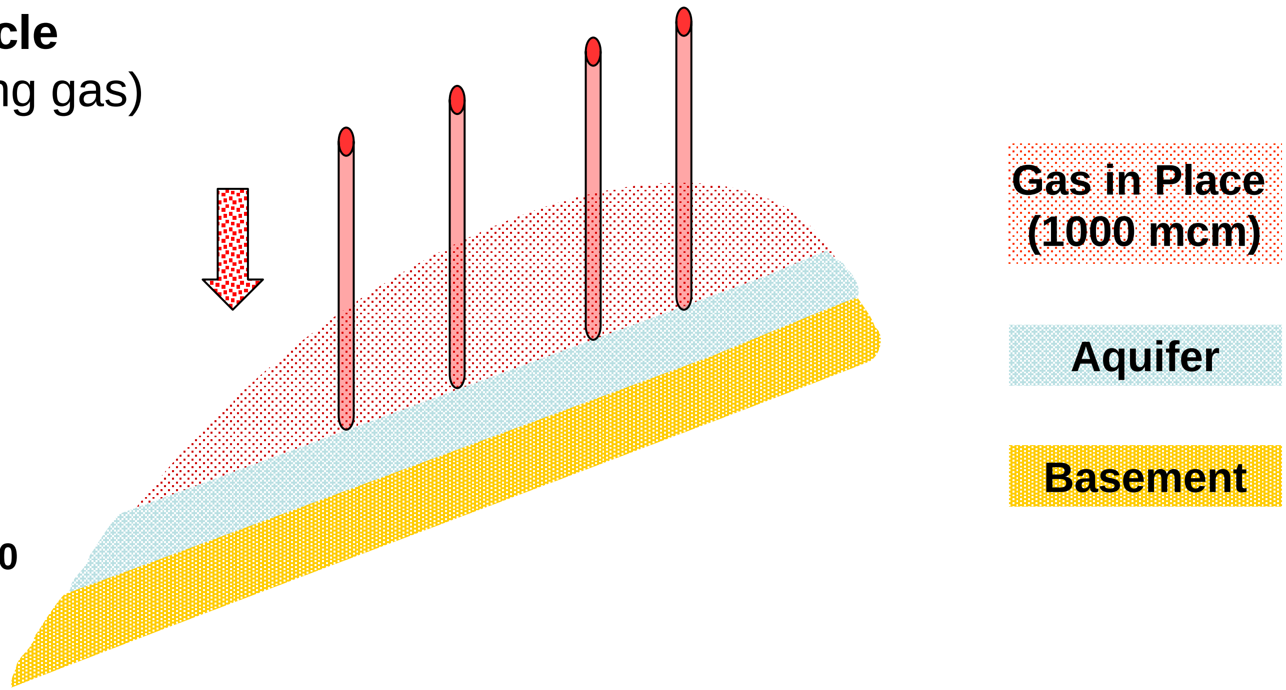
Add 150mcm to create Cushion Gas

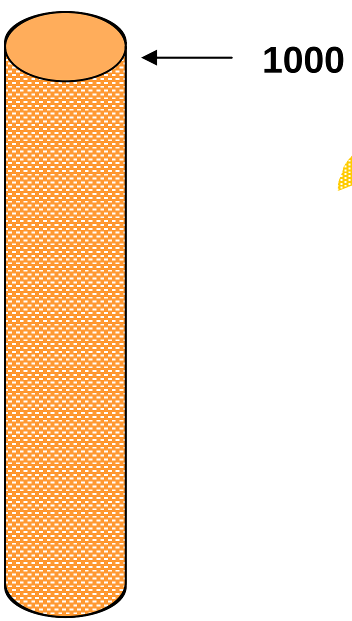
Create Cushion Gas
(30% of Gas Initial in Place)



Injection 700mcm to create working gas

Injection cycle
(Inject working gas)

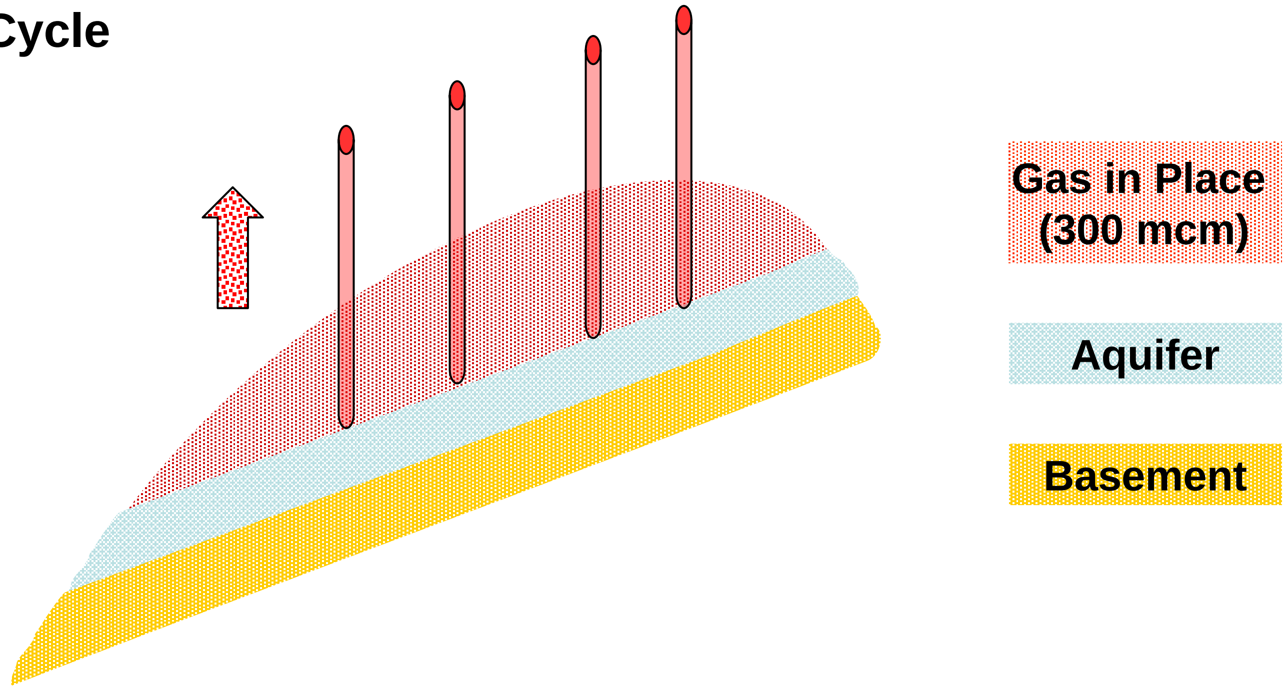


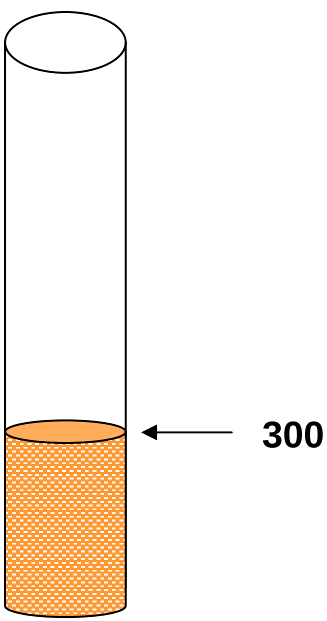


Assume 1 cycle per year

Withdraw 700mcm

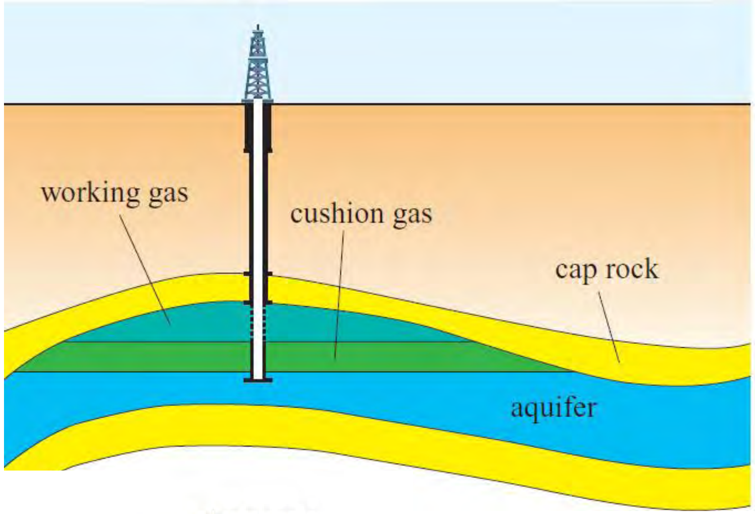
Withdrawal Cycle

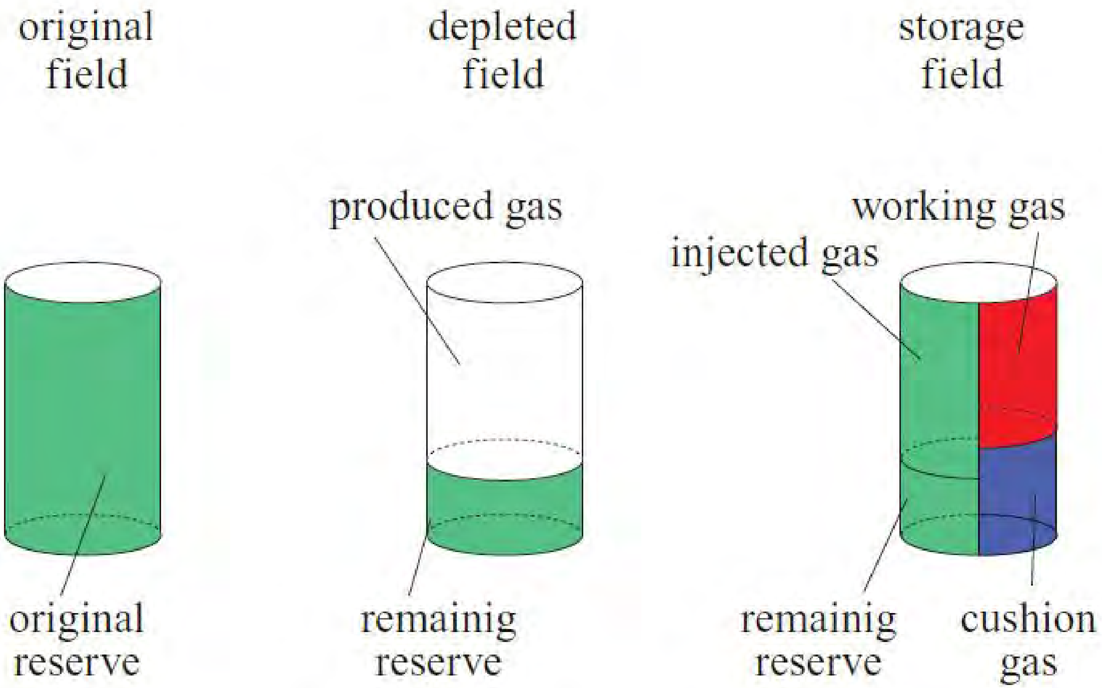




Remaining Gas

In depleted gas fields part of the cushion gas, is gas that was originally in place.

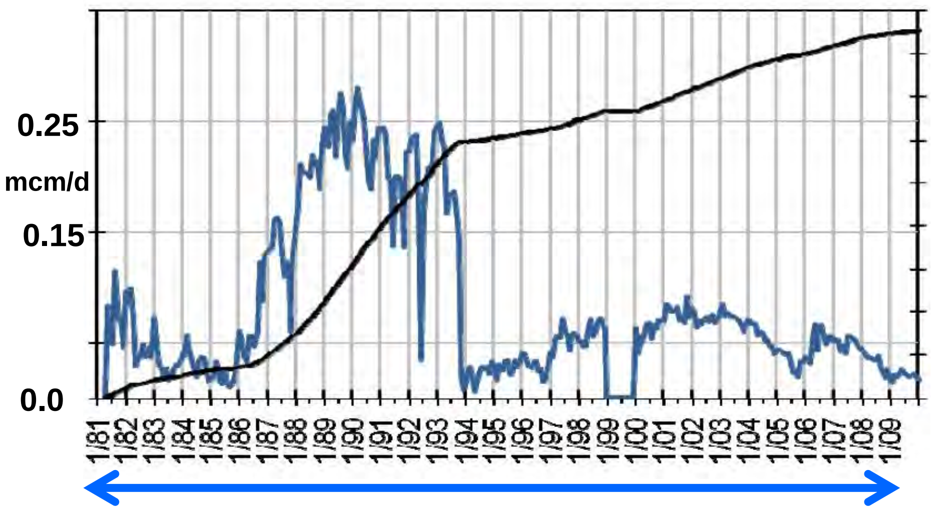




Field Production vs Withdrawal / Injection UGS Cycle

The reservoir will be subjected to elevated cycling stresses during injection and withdrawal, as a significant amount of gas that was produced during a 20-30 years production life of a gas field will be injected or produced within 3-6 months.

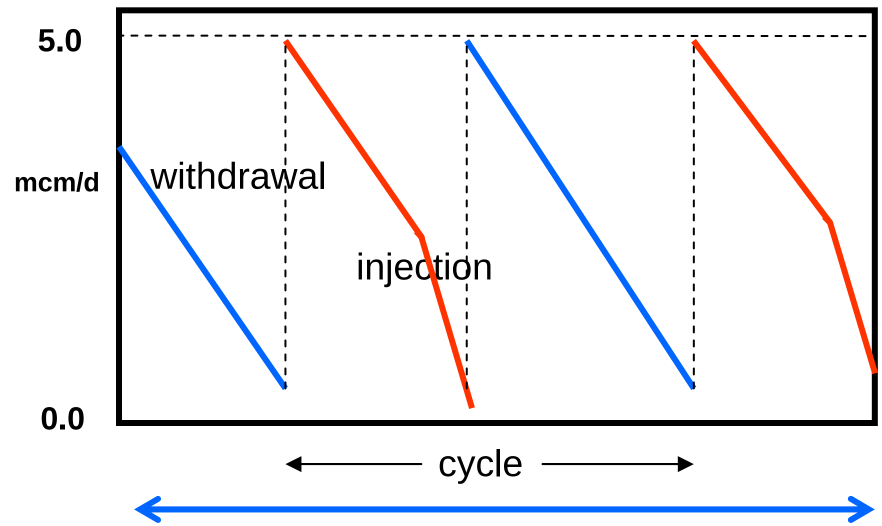
Produced 850 mcm in 28 years of production life



South Kavala gas field production profile

Peak production 0,25 mcm/d

Can inject 700 mcm in 6 months and withdraw same in 6 months.



1 year

Peak production 5,0 mcm/d

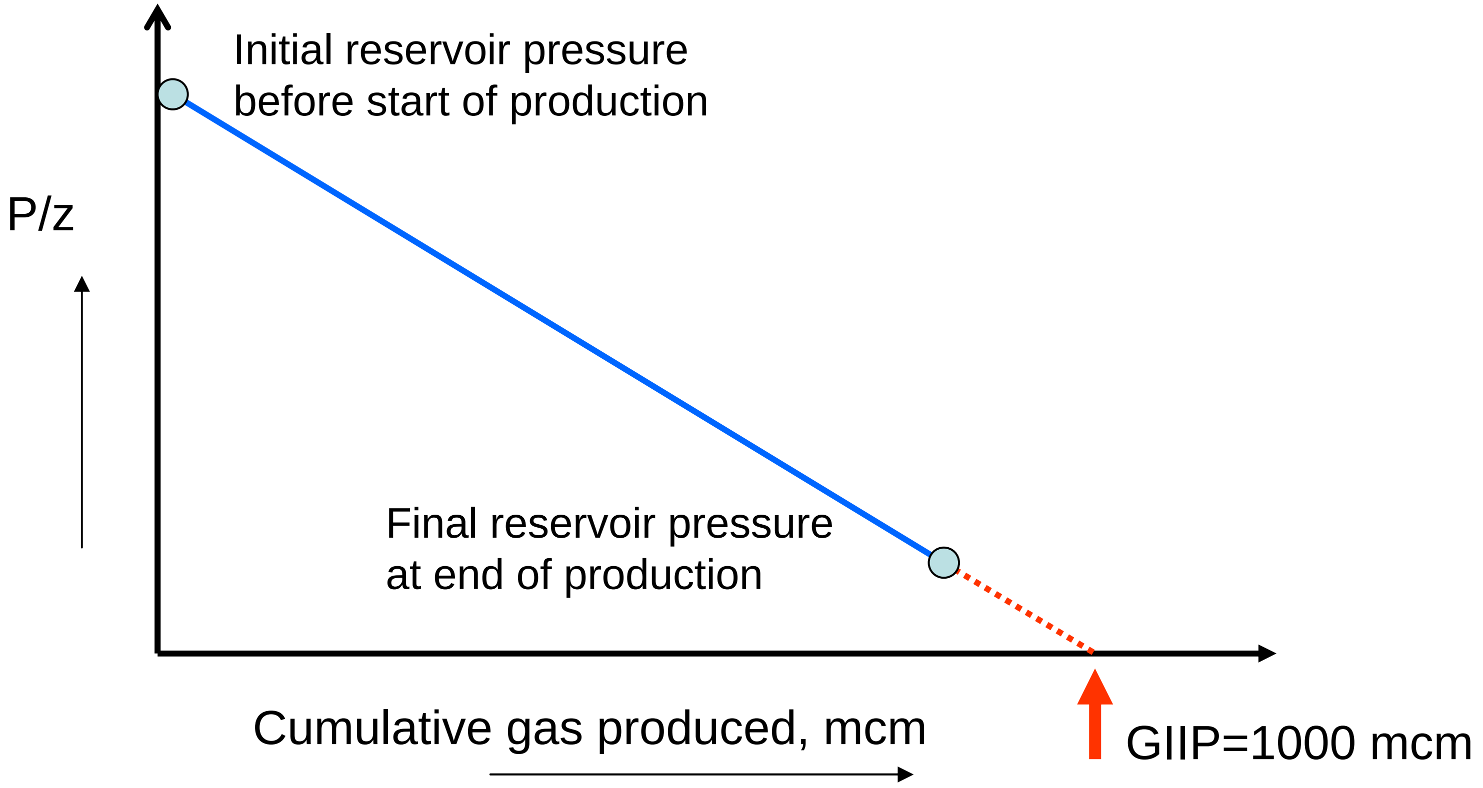
20 fold increase in peak withdrawal rate

Main technical design factors of an UGS depleted Gas Field

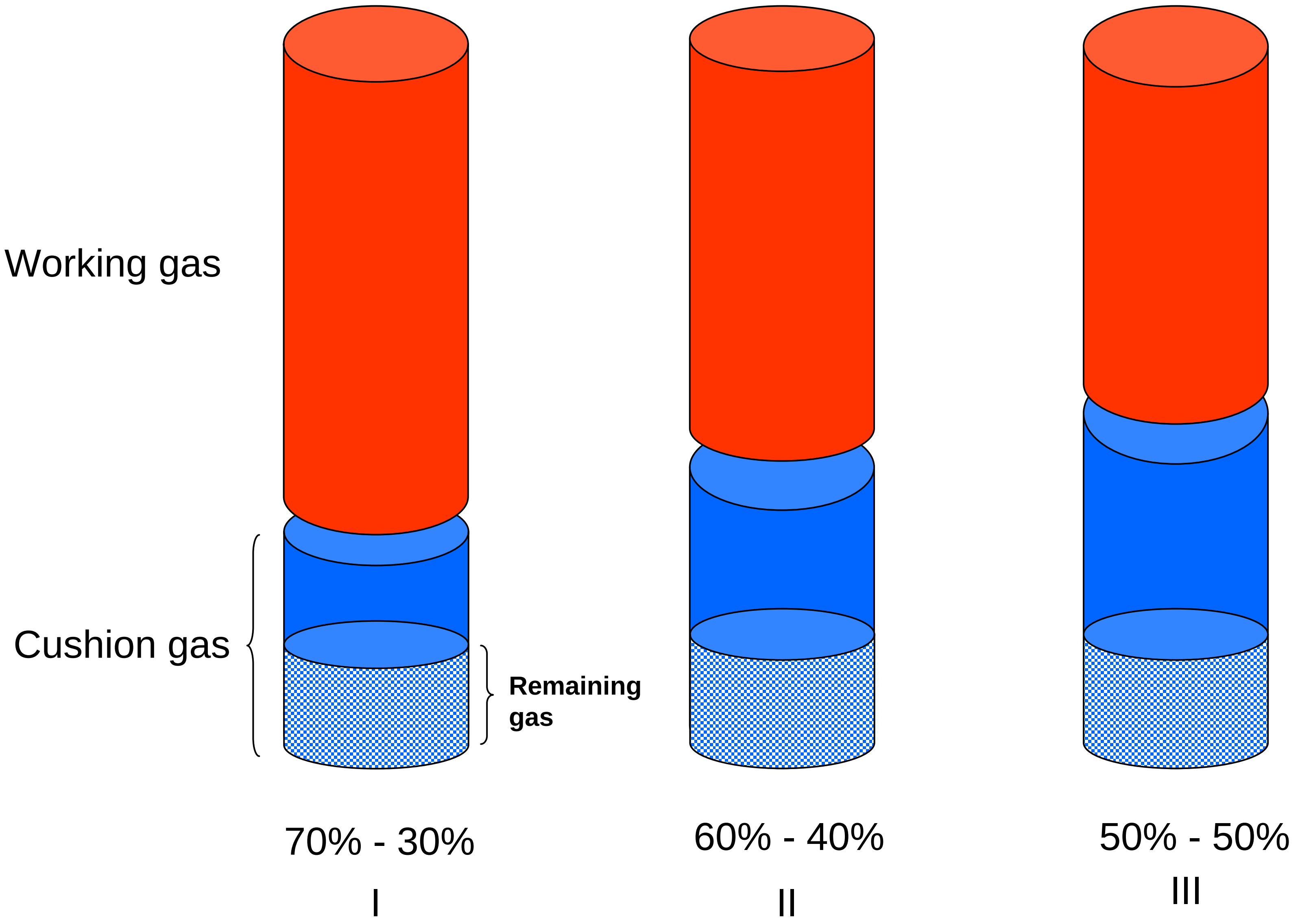
- ✓Capacity
- ✓Reservoir deliverability
- ✓Reservoir pressure and depth
- ✓Depletion drive mechanism
- ✓Well depth and configuration
- ✓Distance from main trunk line

Capacity

Assume that pressure and production data are available in addition to a gas PVT analysis to provide compressibility (z) values.

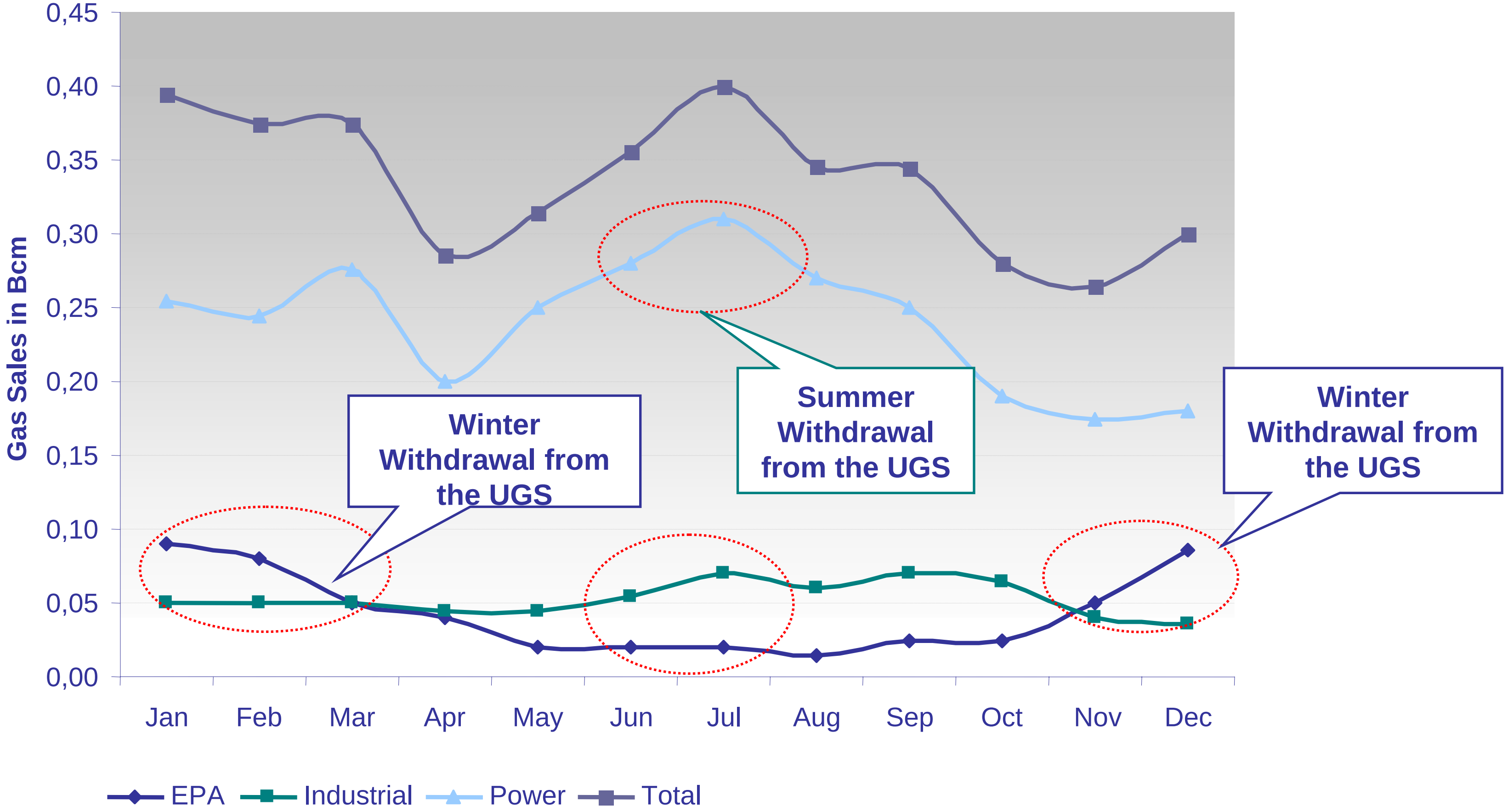


Storage volumes scenarios



Seasonal demand in Greek gas market

2008 Total Gas Sales approx 4 Bcm

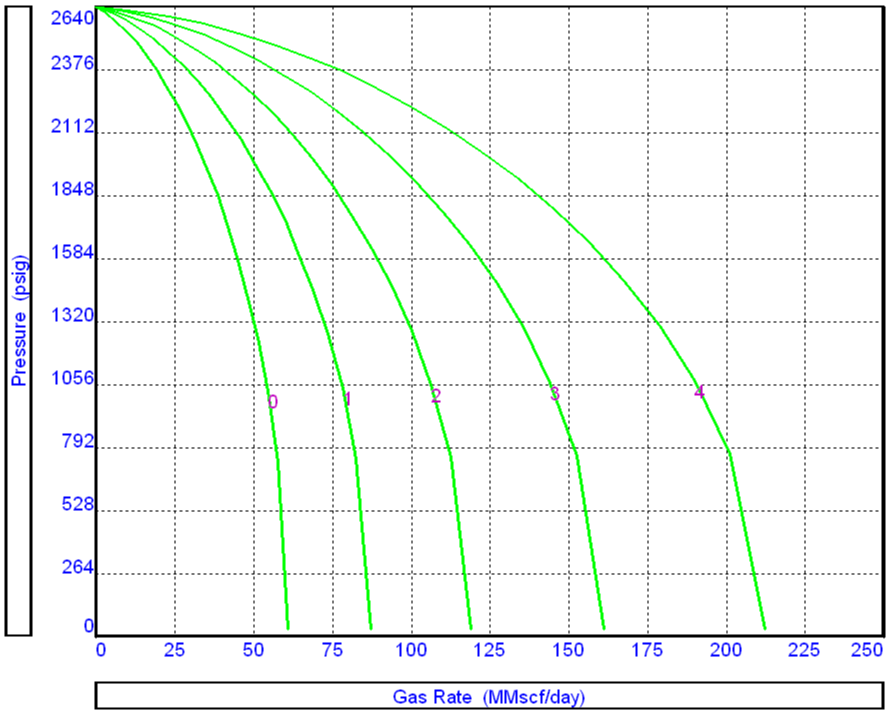


It appears that gas will be cycled twice per year. Short cycle during summer (60 days) and longer cycle during winter (120 days)

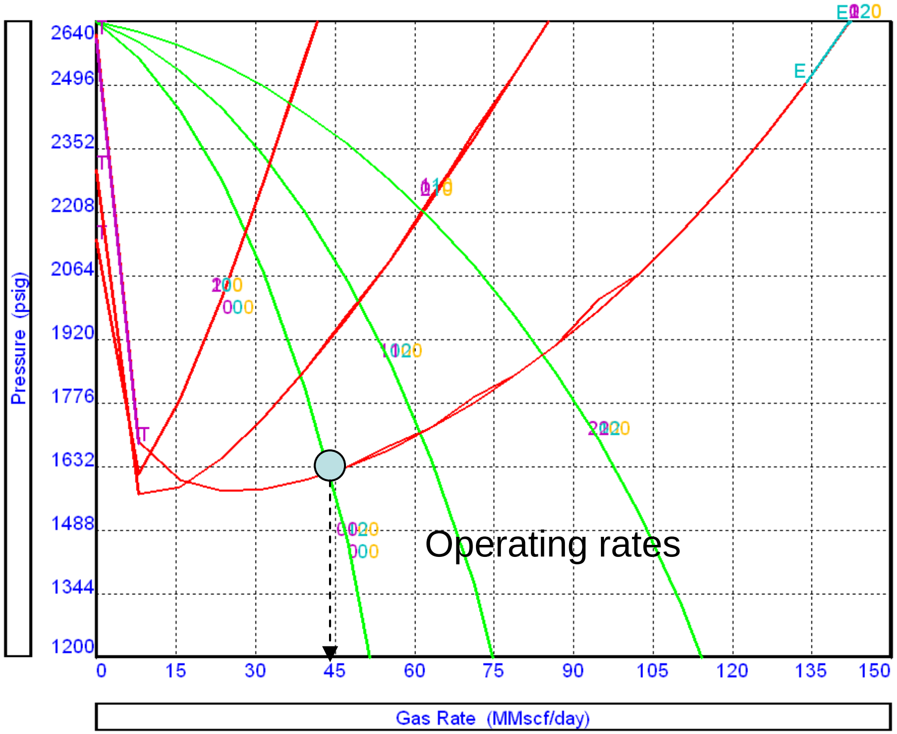
Note: Source DEPA

Deliverability

Estimate peak rates and investigate whether the 60 and 120 days withdrawal Periods can deliver stored working gas volume.



Inflow performance sensitivities



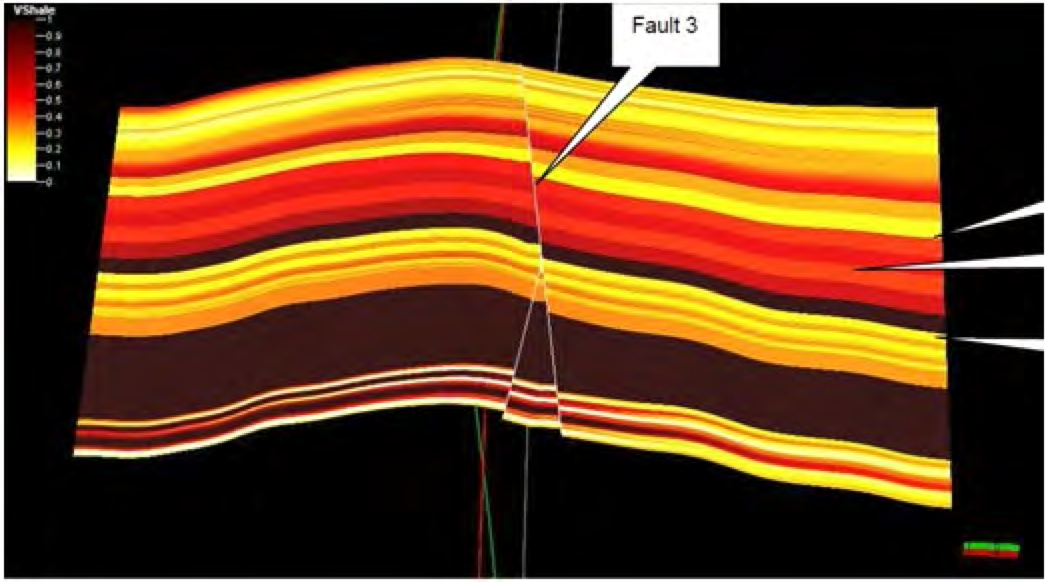
Vertical lift performance sensitivities

Reservoir pressure and depth

- ✓ **Since gas is compressible, the higher the pressure the more gas can be stored, however,**
- ✓ **The bottomhole injection pressure should not be greater than the initial reservoir pressure to avoid leakage**

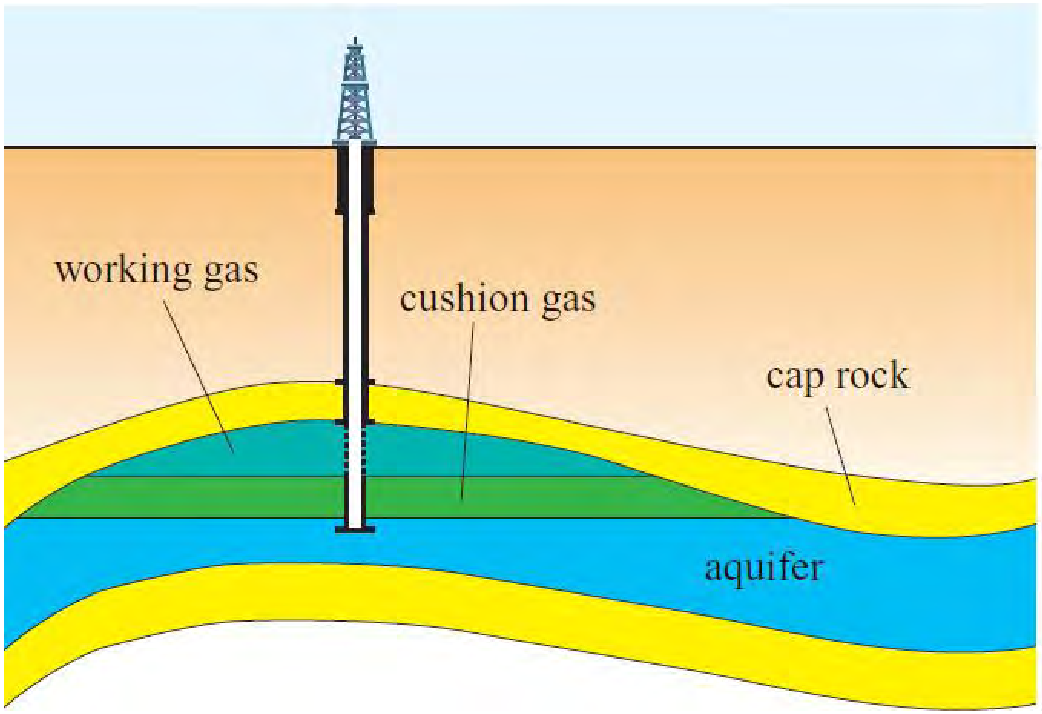
- ✓ **The integrity of the cap rock should be appropriate to sustain a higher than original pressure**

- ✓ **The reactivation of faults should be addressed**



Drive mechanism

Depletion drive vs water drive



Underground gas storage favors little or no waterdrive

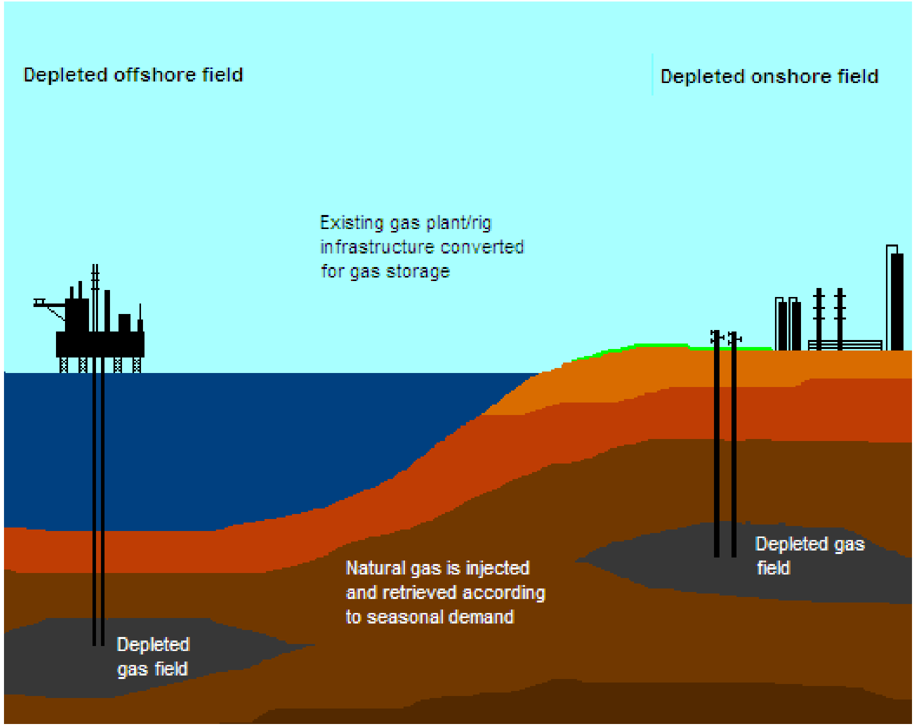
- Depletion drive in gasfields would leave the pore spaces largely filled with gas
- Water drive would result in water invasion into the reservoir.

Storage in water drive would require greater injection pressures in order to drive the water out of the pore spaces.

This could increase the risk of overpressuring the area surrounding the borehole and cause fracturing of the reservoir rock.

Onshore - offshore

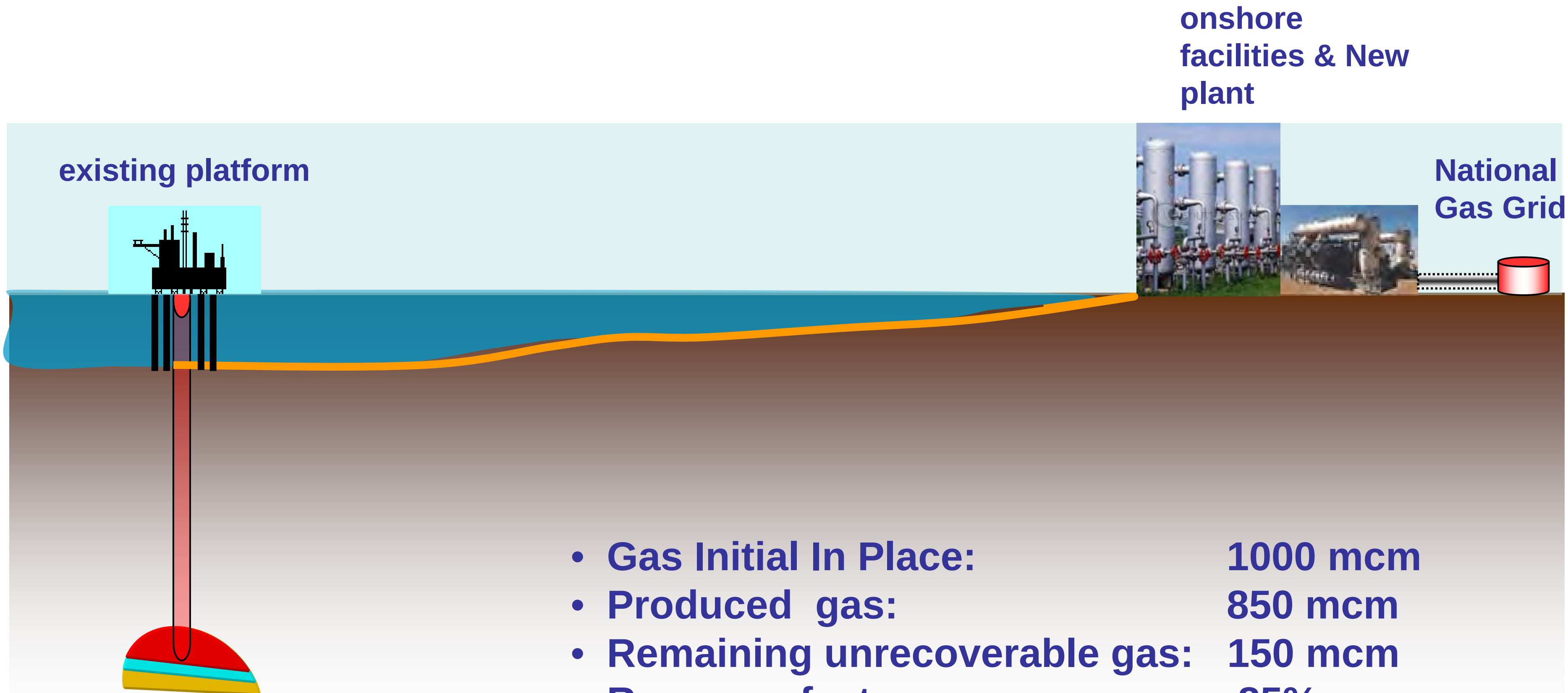
- Offshore UGS cause less public concern
- small gas fields are developed with light unmanned platforms not suitable to sustain load of heavy compressors and UGS surface facilities.
- A high pressure pipeline connects the platform with onshore facilities.
- Distance to shore is critical
- Safety issues



- Onshore UGS cause public concern
- heavy compressors and UGS surface facilities are installed just above the gas field.
- High pressure pipeline length is very limited.

Cost to develop an offshore UGS is higher

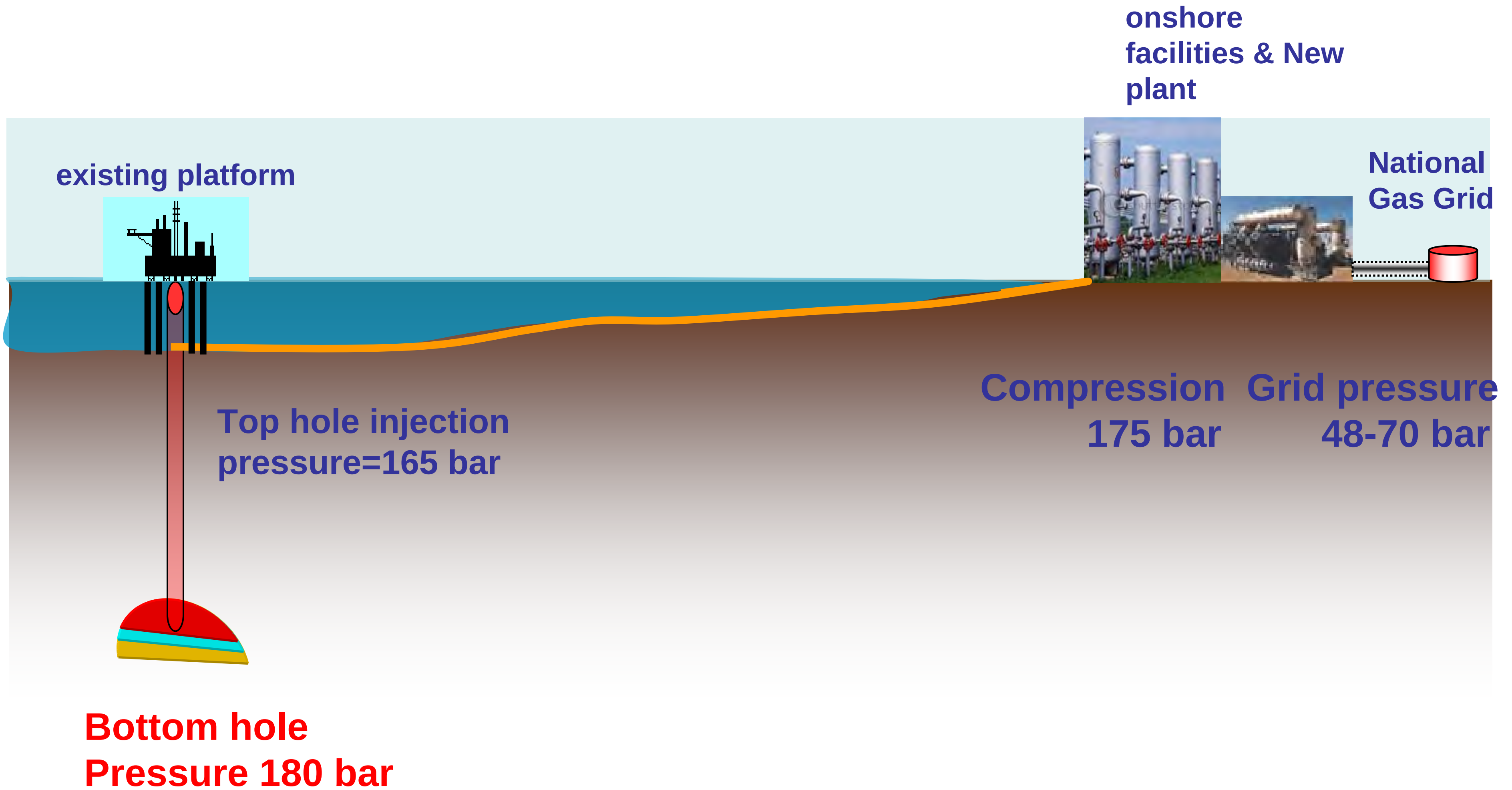
Notional case



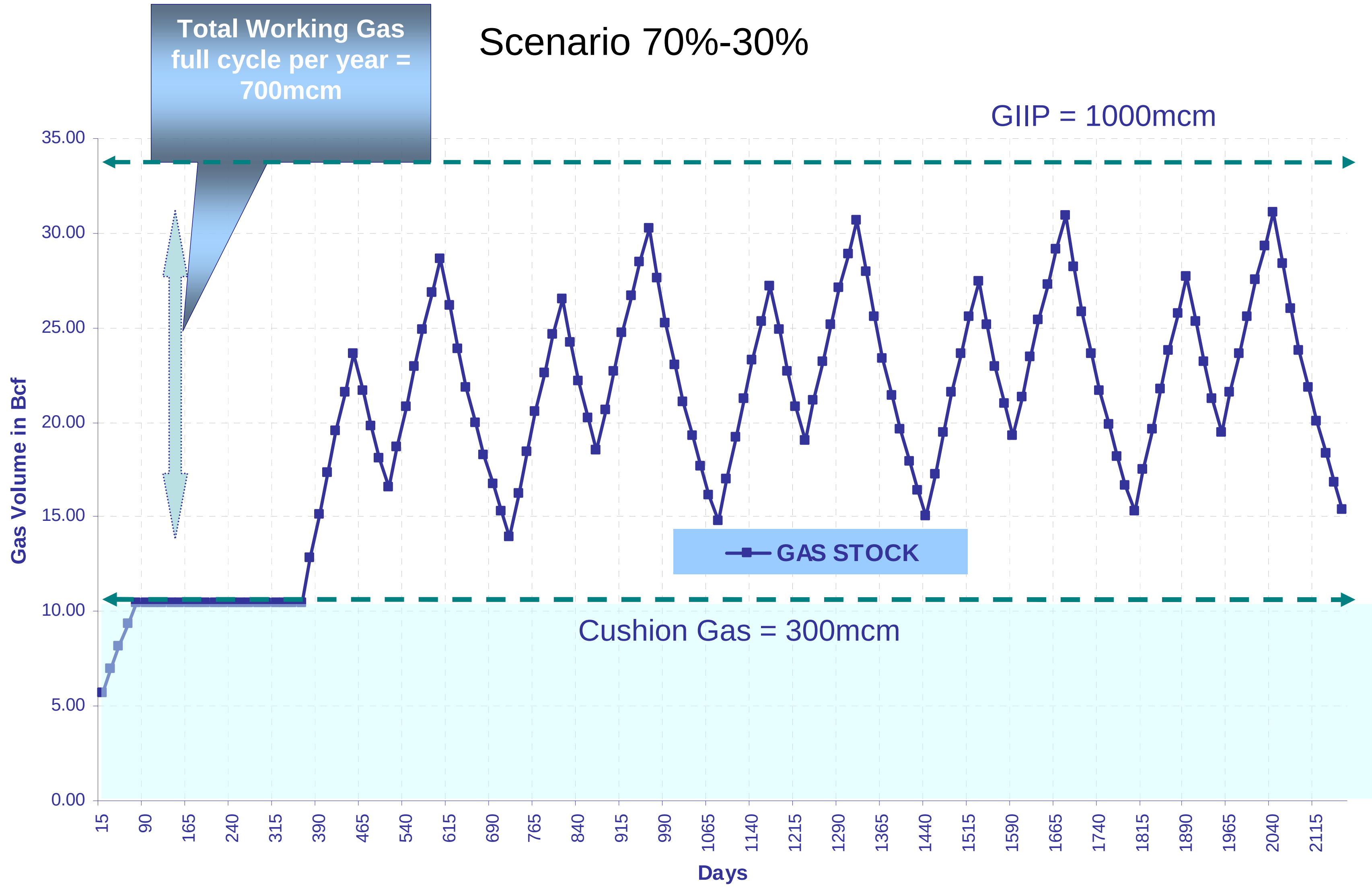
- Gas Initial In Place: 1000 mcm
- Produced gas: 850 mcm
- Remaining unrecoverable gas: 150 mcm
- Recovery factor 85%
- Short distance to shore
- Close to the national gas grid

Reservoir
Pressure 180 bar
-no water drive-
-good porosity-
-good permeability-

Design requirements

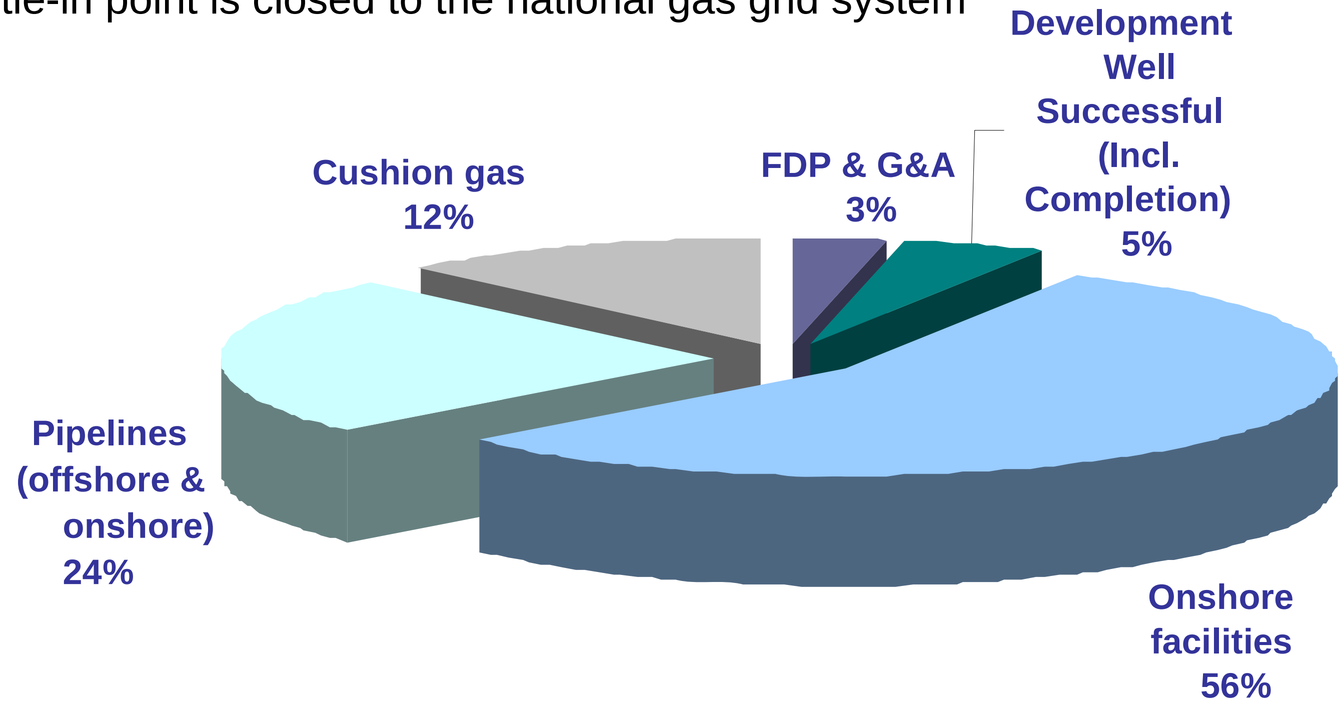


UGS Working Gas Profile



UGS – main development concept
Capital Expenditure

- ✓ The gas reservoir and the wells are located offshore.
- ✓ The existing platform will be used as a wellhead platform
- ✓ A new pipeline will connect the offshore and onshore locations.
- ✓ Main processing facilities will be located onshore (gas compression for injection, gas dehydration).
- ✓ The tie-in point is closed to the national gas grid system



Commercial Aspects
UGS facilities use by traders

Cost of Gas

Gasification and Transportation Fees:
- Gas transportation fees
- LNG gasification fees

A trader may use the
UGS Facilities
IF
Cost of Gas - Sales Gas Price
is greater than
Storage + Transportation Fees

Gas Sales Price

Storage Tariff

Risk Analysis

Sensitivities

- **Market related sensitivities**
  - ✓ Market Demand for Natural Gas
  - ✓ Market Supply in the Greek Market
  - ✓ Estimated Sales Gas Price
  - ✓ Injection Costs
  - ✓ Opportunity Cost as a sole storage Usage of the UGS
- **Operations related sensitivities**
  - ✓ Capital Costs
  - ✓ Operating Expenses
  - ✓ Transportation Costs
  - ✓ Inflation Rate

Scenarios

- **Optimistic Scenario**
  - ✓ Favourable market conditions
  - ✓ Difference between Withdrawal and Injection Prices higher due to higher demand for natural gas
  - ✓ Competitive sales price to EPA's
  - ✓ Lower Transportation Costs
  - ✓ New Gas Discoveries in Eastern Mediterranean
  - ✓ UGS used as a transitional point/ hub towards Europe
  - ✓ Third Parties Access to UGS (especially for Large Gas companies that supply the European market)
  - ✓ Relative few LNG storage facilities in Eastern Mediterranean Area
  - ✓ Planned Pipeline infrastructure for natural gas
- **Pessimistic Scenario**
  - ✓ Unfavourable market conditions
  - ✓ Higher Operational and Maintenance Costs

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Thank you for your attention