Financial Engineering in Oil and Gas

Imperial College London

Bhusana Premanode

PhD (Biomedical Engineering), DIC, PhD (Financial Engineering), DIC, DBA

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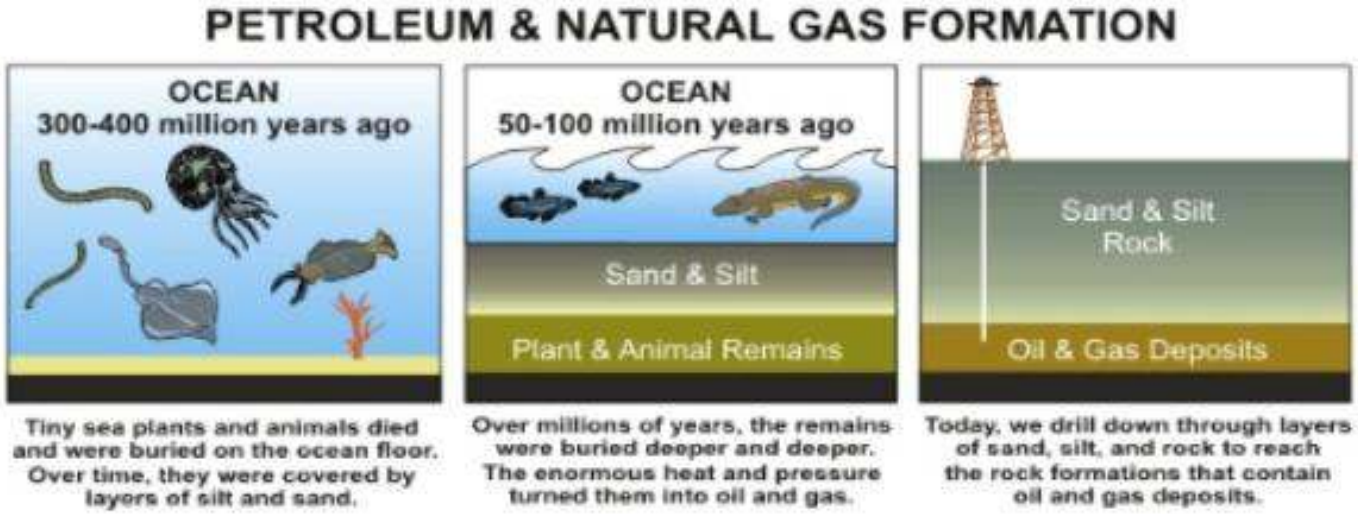
- **Introduction to oil and gas industry**
  - Oil formation
  - Upstream & Downstream
  - Life cycle of oil field
  - Petroleum value chain
- **Seven Concerns**
- **Samples of Solutions**
  - Real Options analysis
  - VAR
  - Nonlinear nonstationary forecasting in time series
- **Oil Sand (option)**

Oil Formation

Oil was formed from the remains of animals and plants that lived millions of years ago in a marine (water) environment before the dinosaurs. Over the years, the remains were covered by layers of mud. Heat and pressure from these layers helped the remains turn into what we today call crude oil . The word "petroleum" means "rock oil" or "oil from the earth."



Upstream & Downstream

The oil industry is divided into two sectors.

A. **Upstream**: exploration and Production (E&P). Involves operations in searching for underground or underwater oil and gas fields and drilling exploratory wells and at the same time operating the wells that recover to re-direct the crude oil or raw natural gas in to the surface

B. **Downstream**: includes operations that processes and stores, markets and transport crude oil, natural gas liquids like ethane, butane and propane. The downstream sector includes:
   - All oils refineries and petrochemical plant.
   - Petroleum product distribution via the affiliated retail outlets
   - Natural gas distribution companies within the operations.

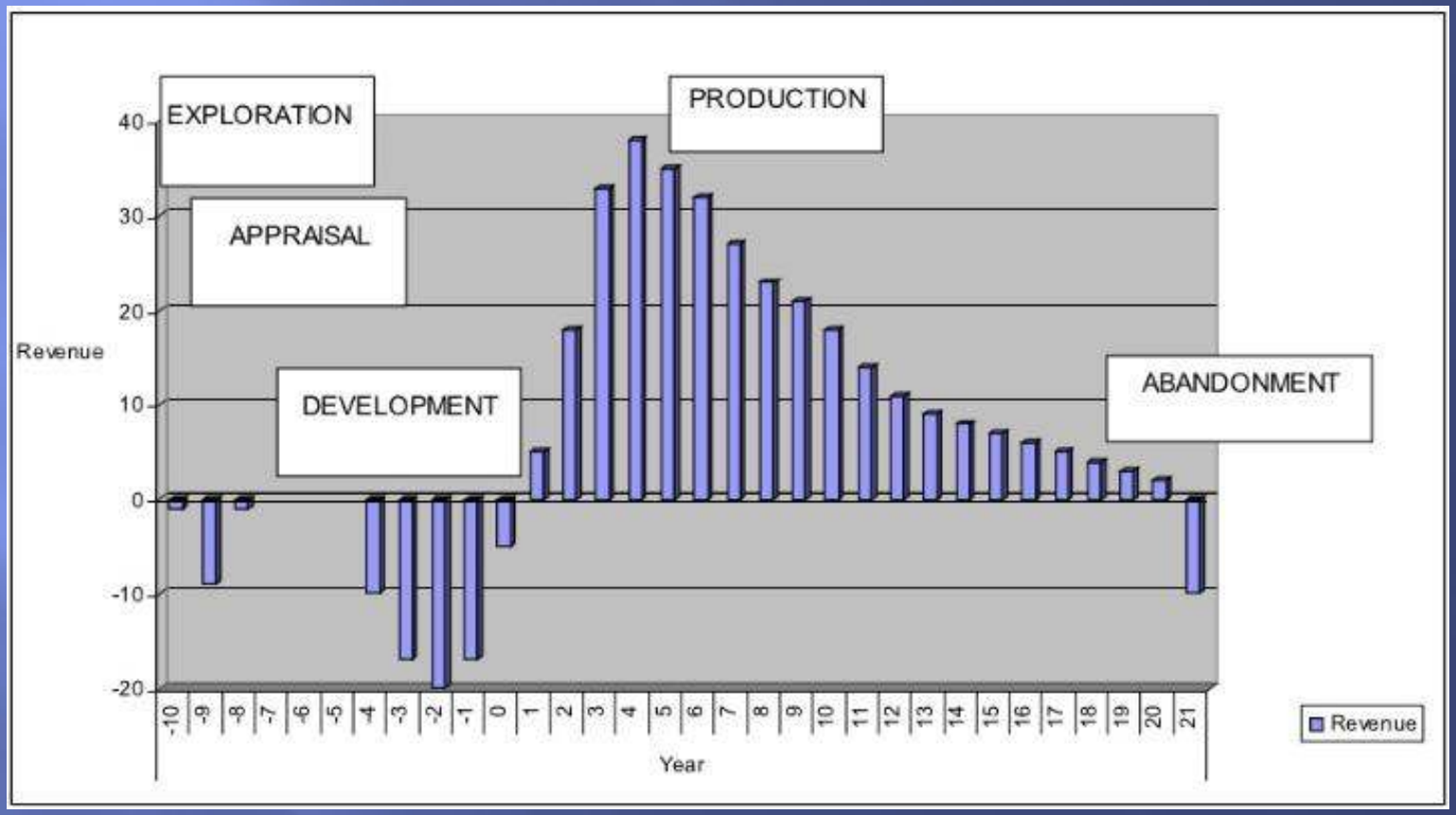
Oil Production

ONSHORE

OFFSHORE

Oil refineries are key to obtaining hydrocarbons. Oil in different parts of the world contains different proportions of the various hydrocarbons. There are refineries in many parts of the UK including Edinburgh, Liverpool and Milford Haven. North Sea oil is relatively high in naphtha, which is used for making plastics.

Life Cycle of oil and gas field



Geophysics Properties
of rock in both

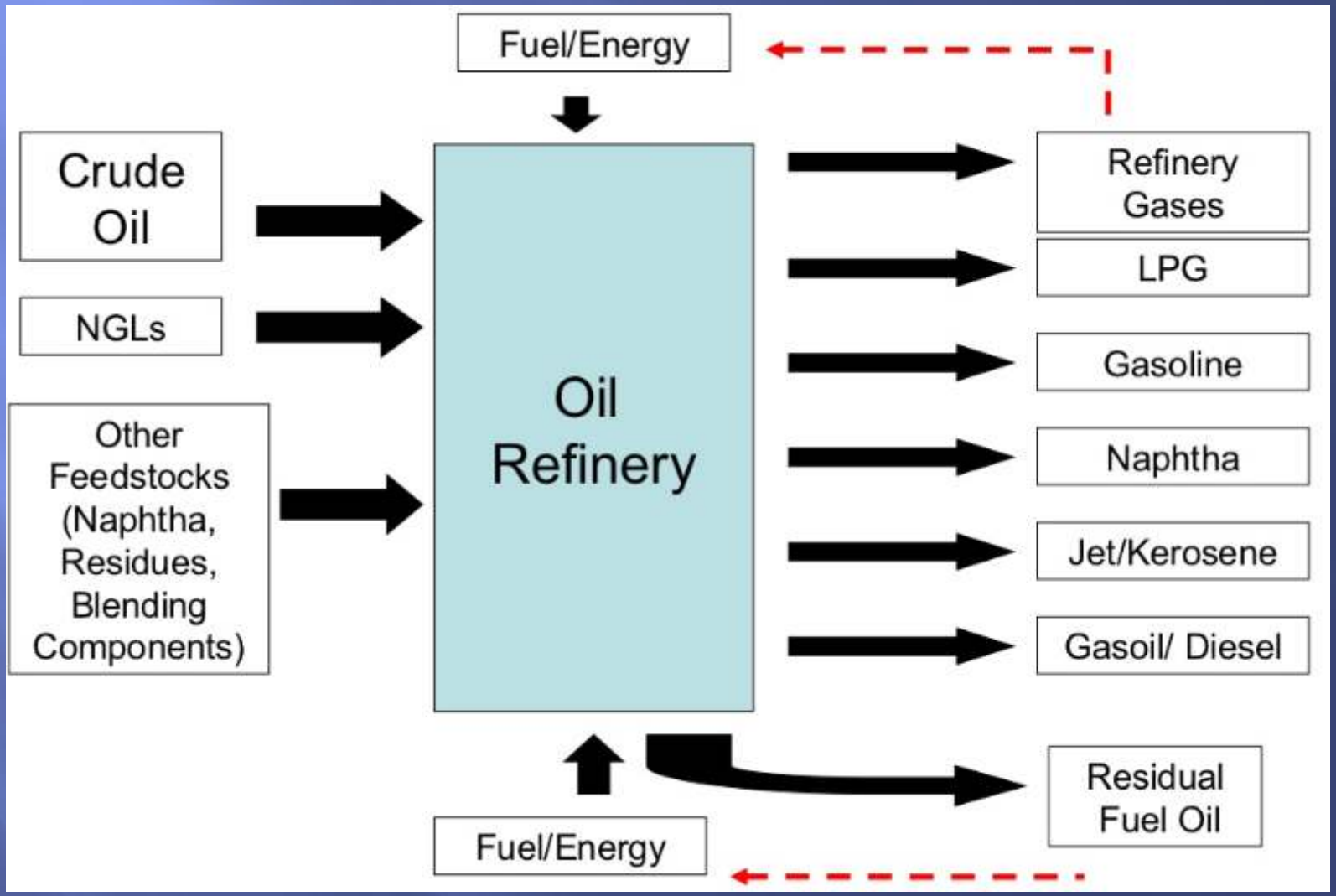
Qualitative and
Quantitative

Without the knowledge in financial engineering, it is difficult to change stages of oil and gas life cycle.

Quantify
Environmental IA, Social
Impact Assessment,
Health Ia

not economically viable

Refining Process



This slide shows some of the product that we use in our everyday life and that are the result of refining process which is one of the main stages of the Downstream phase




















Exploration
Drilling & Production
Shipping
Refining
Storage
Distribution
MARKET

An operations management and implementation firm, has identified seven mega concerns that are expected to impose significant change for the industry going forward. The issues are:

1) Remaining operationally effective while maintaining margins within an environment of fluctuating crude prices; Real options analysis & VAR

2) Leveraging sales and operations planning as an effective tool in strategic crude supply and refined product forecasting; Dynamic forecasting methods in demand and supply systems (nonlinear forecasting in time series)

3) Reinventing a more integrated strategic supply chain that can dramatically enhance cost savings (such as in the extraction of previously economically stranded and remote oil reserves) in the supply base – and reduce risk; operation research and tax planning?

- Database
- Data warehouse is a container of unorganised data. Once we use a tool e.g., data mining t organise the unorganised data in the datawarehouse, we call that container "database"

\price up and down along time series

1. Real Options analysis
2. Value at Risk (VaR/VAR)
3. Nonlinear nonstationary time series forecasitng model
4. OR methods and tax planning
5. Operation Management (OM) and Operation Behaviour (OB)

4) Responding to new levels of public scrutiny and regulatory compliance in the post-BP-Deepwater Horizon environment; EIA due diligence

5) Paying greater attention to HSE issues within broader operations concerns that are premised upon sustainability; Operation Management and Operation Behavior

6) Responding to a rapidly retiring sales force along with developing and retaining a more technologically skilled labor force – including training a new generation of energy industry employees in operational and financial efficiencies; HRM

7) Capitalizing on the new interdependencies between senior management information, operational effectiveness, and decision-making and the understanding of their impact on profitability. ICT, data mining, decision making system (real option analysis)

“The flexibility available to management – i.e. the actual "real options" – generically, will relate to project size, project timing, and the operation of the project once established. In all cases, any (non-recoverable) upfront expenditure related to this flexibility is the option premium.”

Where the project's scope is uncertain, flexibility as to the size of the relevant facilities is valuable, and constitutes optionality

- **Option to expand**
- **Option to contract**
- **Option to expand or contract**

Where there is uncertainty as to when, and how, business or other conditions will eventuate, flexibility as to the timing of the relevant project(s) is valuable, and constitutes optionality. **Growth options** are perhaps the most generic in this category – these entail the option to exercise only those projects that appear to be profitable at the time of initiation.

- **Initiation or deferment options**
- **Option to abandon**
- **Sequencing options**

Management may have flexibility relating to the product produced and /or the process used in manufacture. This flexibility constitutes optionality.

- **Output mix options**
- **Input mix options**
- **Operating scale options**

- Uncertainty – lack of certainty with understanding that there exists other possibilities of outcomes
  - There is 90% chance that the market goes up tomorrow → there is 10% uncertainty

- Risk – State of uncertainty with understanding that at least one outcome involves a loss
  - There is 10% chance that my investment will lose money today

- Increasing need for risk management after the 1987 market crash
- J.P. Morgan employees credited for developing VaR
- Known as the 4:15pm report
- RiskMetrics spinoff in 1994
- CreditMetrics and CorporateMetrics

- "We are *X* percent certain that we will not lose more than *V* dollars in time *T*."
- Function of confidence level *X* and time *T*

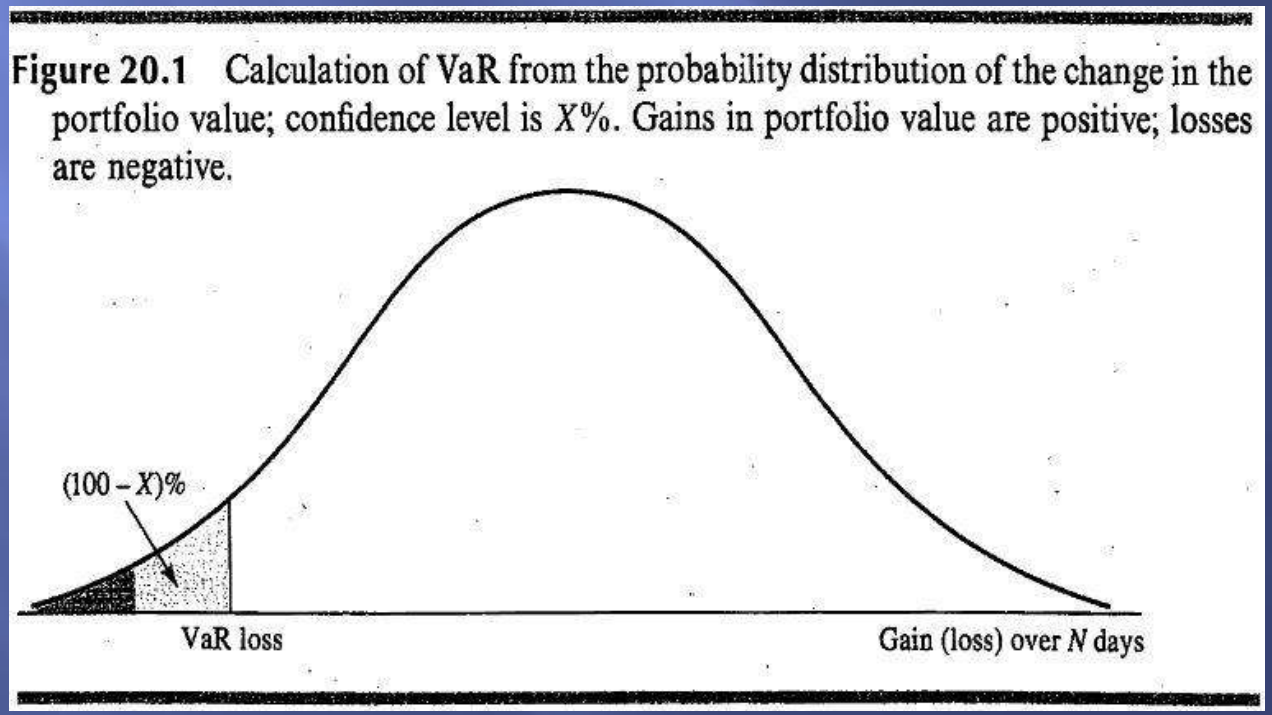


Figure 20.1 Calculation of VaR from the probability distribution of the change in the portfolio value; confidence level is *X*%. Gains in portfolio value are positive; losses are negative.

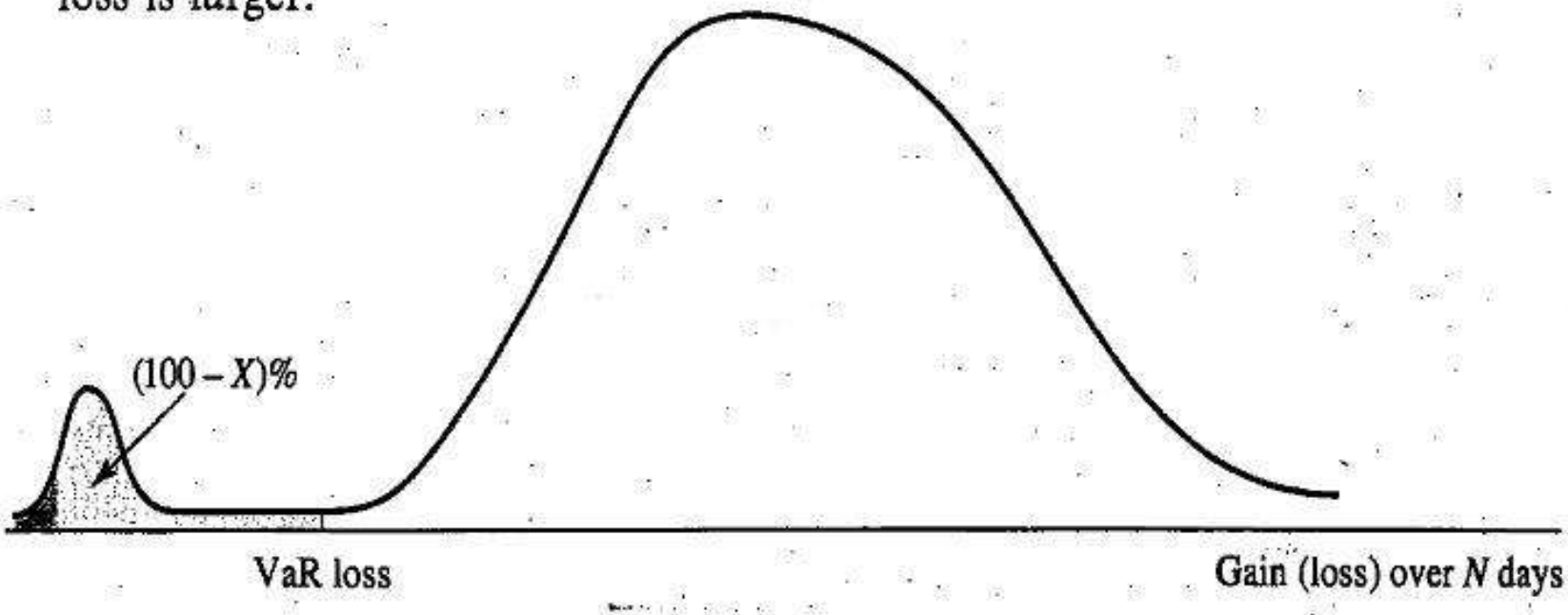
- Historical Simulation
- Variance-Covariance Method
- Monte-Carlo Simulation

- Integral part of any practical model
- Look back at the data and see how well it would have performed if it were implemented earlier
- Testing a 1-day 99% confidence VaR:
  - If over a given period we lost more money than the VaR estimate on about 1% of the days, then the model works
  - If we lost more than VaR on 7-8% or 0.002% of the days, then the model might be corrupt

- Testing how the portfolio would have performed under some of the most extreme market moves
  - Jan. 8th 1988 – S&P500 moved 6.8 S.D.
  - Apr. 10th 1992 – 10-year bond yields moved by 7.7 S.D.
  - Oct. 19th 1987 – S&P500 moved 22.3 S.D.

- Does not satisfy the subadditivity function of a coherent risk measure
- Does not put weight on anything else but the cutoff percentile – the VaR
- Traders find cheating the VaR measure easy

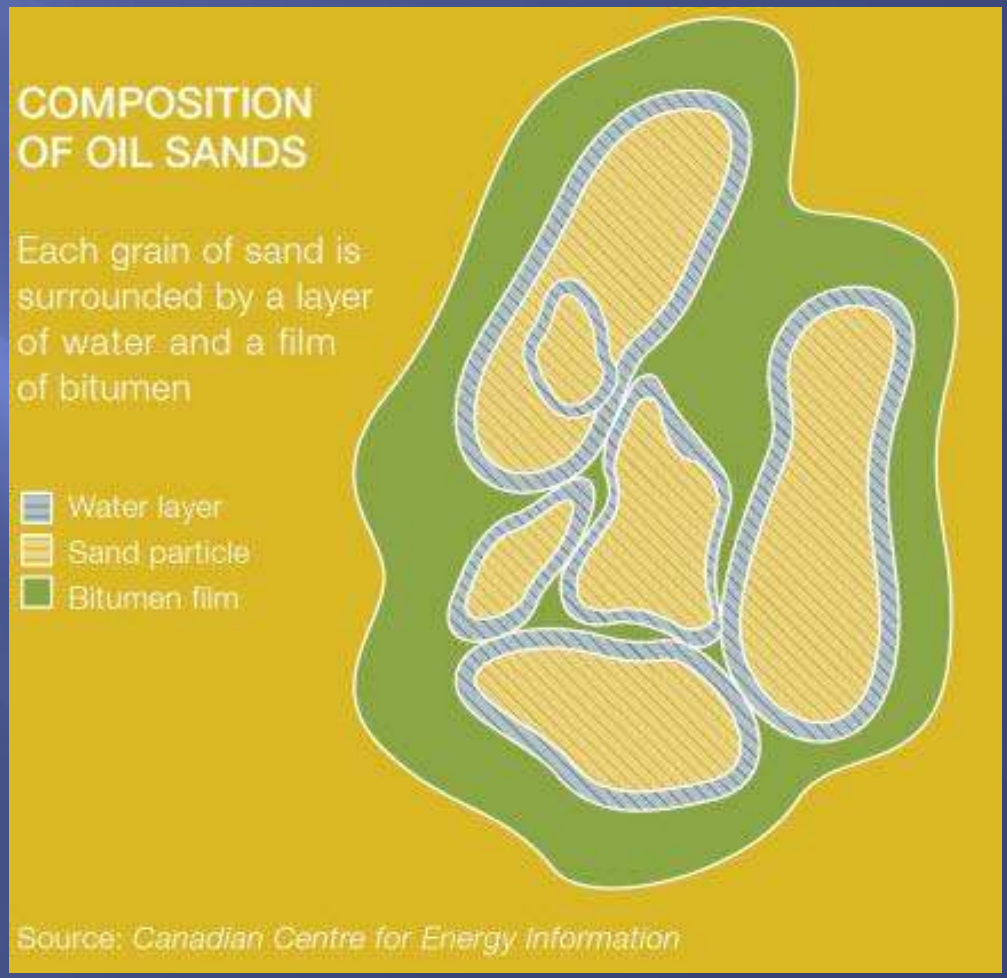
Figure 20.2 Alternative situation to Figure 20.1. VaR is the same, but the potential loss is larger.



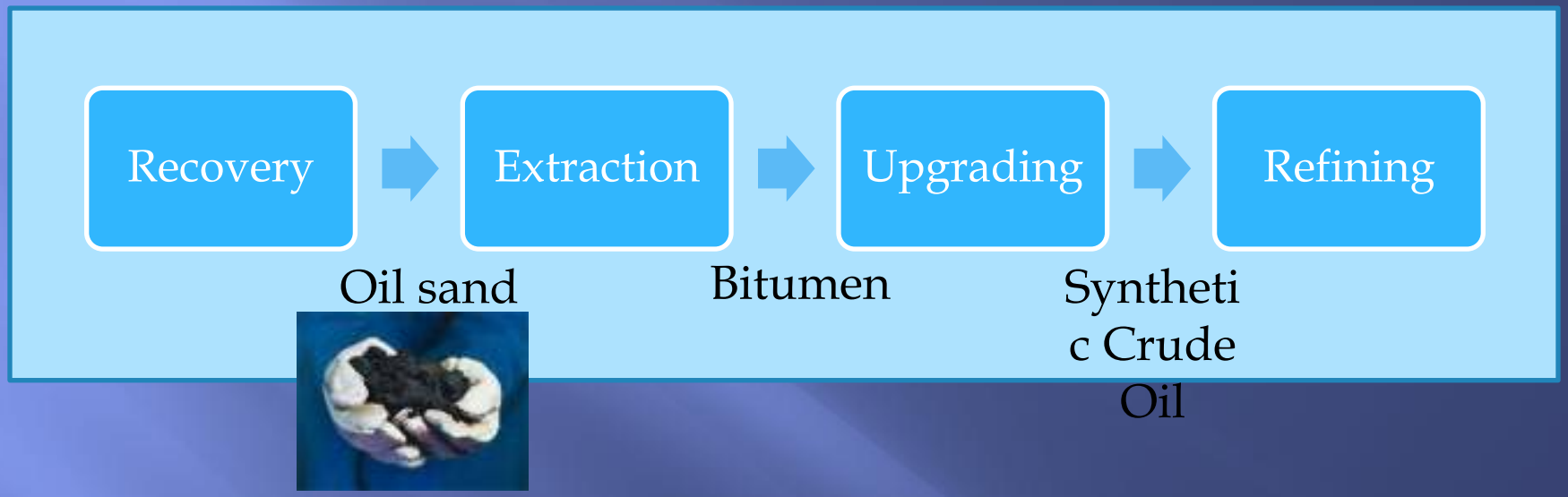

...Thank you very much...

What Are Oil Sands?

- Oil sands (also referred to as Tar sands) are a combination of clay, sand, water, and bitumen, a heavy black viscous oil.
- Oil sands contain a mixture of sand, water, clay and bitumen, an extra-heavy oil that is too thick to be pumped without first being diluted or heated.
- Oil sands can be mined and processed to extract the oil-rich bitumen, which is then refined into oil. Usually using strip mining or open pit techniques, or the oil is extracted by underground heating with additional upgrading.



Oil Sands Production Process



Oil Sand Resources

- Much of the world's oil (more than 2 trillion barrels) is in the form of tar sands, although it is not all recoverable. While tar sands are found in many places worldwide, the largest deposits in the world are found in Canada (Alberta) and Venezuela, and much of the rest is found in various countries in the Middle East. In the United States, tar sands resources are primarily concentrated in Eastern Utah, mostly on public lands.

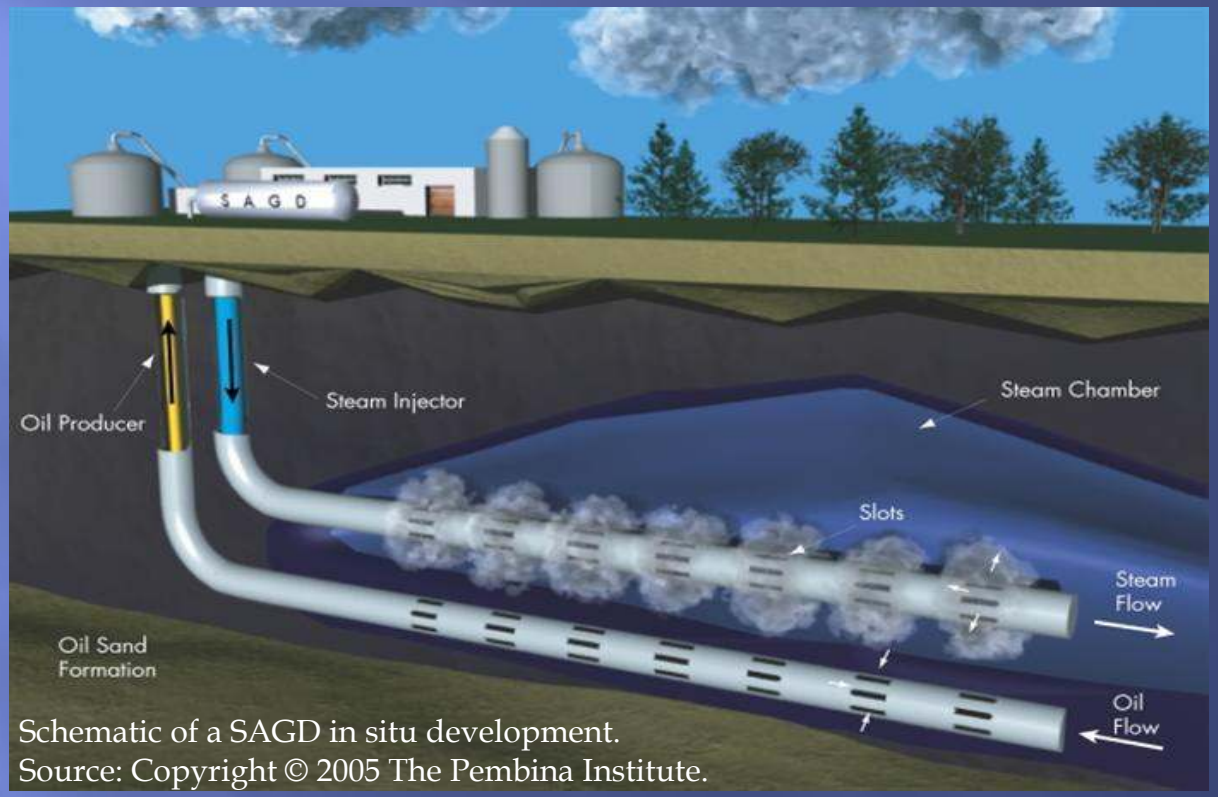
Mining

- Oil sands within 75 m of the surface are mined using electric and hydraulic shovels with a capacity of 45 m^3 and trucks that can carry up to 400 tons of ore that take three passes to fill.
- Trucks move the oil sand to a cleaning facility where it is mixed with hot water and diluent (naphthanic, parafanic) to separate the bitumen from the sand.
- Sand, water, fine clays and minerals, or tailings, are separated from the bitumen and diluent and sent to tailings ponds where the sand settles.
- The diluted bitumen can be piped to an upgrader on site, if one has been built in conjunction with the mine.

In Situ

- In situ recovery is used for bitumen deposits buried too deeply - more than 75 m - for mining to be practical. Most of heavy oil production comes from deposits buried more than 350-600 m below the surface.
- Steam, solvents or thermal energy make the bitumen flow to the point that it can be pumped by a well to the surface, then diluted with condensate for shipping by pipelines.
- **Cyclic steam stimulation (CSS)** and **steam-assisted gravity drainage (SAGD)** are effective in situ recovery methods. ExxonMobil and Imperial Oil invented and held the first patents on both of these technologies.
- No tailings ponds are required for in situ methods of recovery. Sand remains in the ground; only bitumen is removed.

Steam-Assisted Gravity Drainage (SAGD)



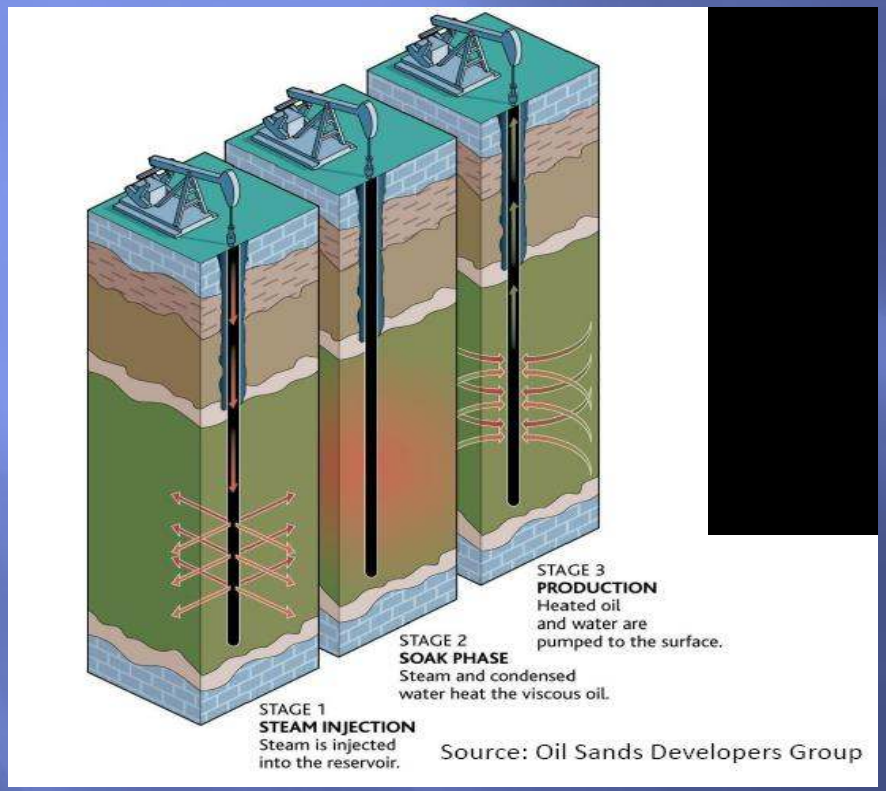
Schematic of a SAGD in situ development.
Source: Copyright © 2005 The Pembina Institute.

- The most commonly used *in situ* recovery method. This method requires the drilling of two horizontal wells through the oil sands deposit. Heated steam is injected into the upper well, where the build-up of pressure and heat melts the bitumen and causes it to flow downward to the second horizontal well, from which it is pumped to the surface. Water is injected into the deposit to maintain stability after the bitumen is removed.

VDO

http://www.cenovus.com/operations/technology/sagd

Cyclic steam stimulation (CSS)



- high-pressure, high temperature (350°C) steam is injected into a vertical wellbore in the oil sands deposit, which is fractured by the stream pressure. As the steam soaks through the oil sands, the bitumen melts and flows to a producing well, from which it is pumped to the surface. Each cycle of this process can take from four months to two years, and several cycles can be completed in a formation.

Upgrading

Bitumen from the oil sands has been degraded by millions of years of organic processes, resulting in a thick, viscous substance with a deficiency of hydrogen. Upgrading either adds hydrogen or removes carbon in order to achieve a balanced, lighter hydrocarbon that is more valuable and easier to refine.

The upgrading process also removes contaminants such as heavy metals, salt, oxygen, nitrogen and sulphur.

The upgrading process:
Step 1: distillation. Separates various compounds by physical properties.
Step 2: coking, hydro-conversion, solvent deasphalting. Improves hydrogen to carbon ratio.
Step 3: hydrotreating. Removes contaminants such as sulphur.

Impacts

Climate: The emissions from the development of the tar sands are 2-4 times more greenhouse gas intensive than conventional oil and are the fastest growing source of GHG pollution in Canada. In fact, the amount of GHGs from the tar sands is growing faster than in any other sector.

Source: Louis Helbig

Source: David Dodge, The Pembina Institute, www.pembina.org

Land: The tar sands deposits cover approximately 140,000 square kilometres of Alberta, an area about the size of Florida. The oil is extracted using open pit mines and in situ, or drilling, operations. The open pit mines have removed 686 square kilometers of boreal forest and the in situ sites are threatening wild caribou herd.

Impacts

Water Contamination: Tailings are the toxic sludge created by the process of mining tar sands. The tailings are kept in large "lakes" created to store the waste indefinitely. The tailings lakes seep into natural water ways and contaminate the fish and other wildlife, however, the amount of seepage is not public.

Water Use: Mining operations in the tars sands are licensed to use 652 million cubic metres of water each year. Almost none of that water is returned, threatening ecosystems such as the Athabasca River, which flows into one of the world's largest freshwater deltas.

Air: In addition to greenhouse gases, tar sands operations release large volumes of sulphur dioxide and nitrogen oxides into the environment. rain.


...Thank you very much...