인하대학교 INHA UNIVERSITY

2018 인하대 **K-MOOC** 강의 교재

인류의 그림자, 에너지 바로알기

신 현돈 교수
(hyundon.shin@inha.ac.kr)

인하대학교 에너지자원공학과

2018

6: 비전통자원의 등장

6-1: 비전통자원이란?

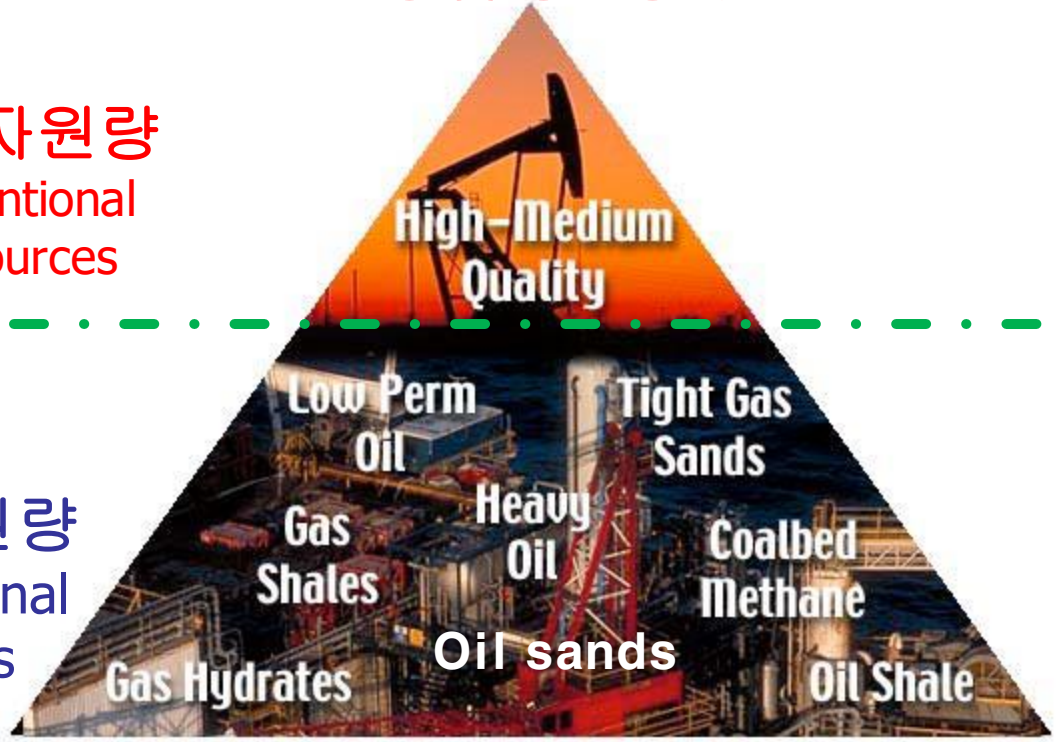
자원량 삼각형 분포

Drive Force

소량 및 생산용이

전통자원량
Conventional
Resources

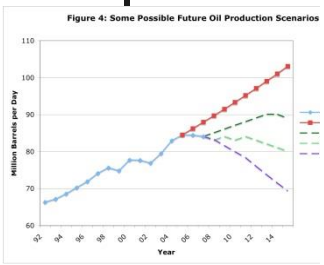
비전통자원량
Unconventional
Resources



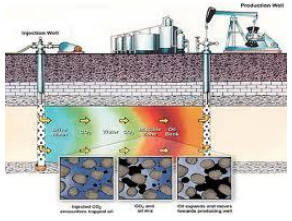
Technology and Oil Price

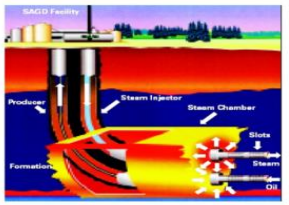
대량 / 생산의 어려움
Large volume and difficult to produce

왜 비전통자원인가 !



EOR: Enhanced Oil Recovery





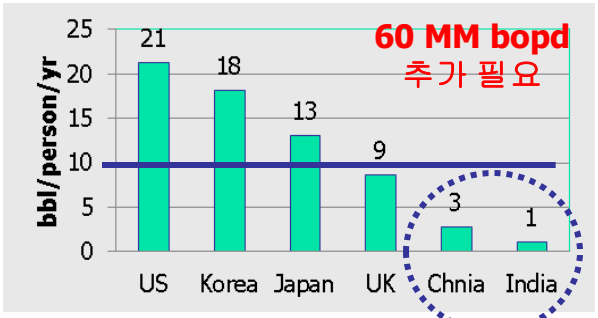
- 생산 정점
- 추가 매장량 필요
- 고유가

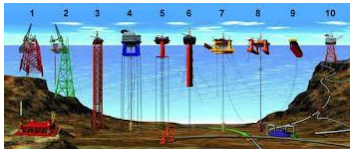
EOR 또는

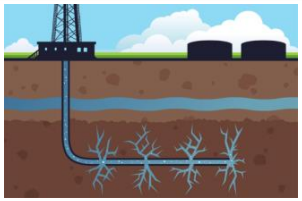
새 유전 발견

큰 유전 발견의 어려움
심해 또는 극지

- 낮은 탐사 위험
- 대량으로 부존
- 신기술 개발







Unconventional

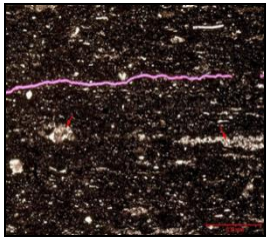
기술 발전과 비전통자원

- 비전통자원 특성: 저 투수율층 또는 고 점성도
- 해결책: 투수율 증가 및 점성도 감소

투과도
Permeability

생산량 $Q = \frac{k}{\mu} \Delta P$

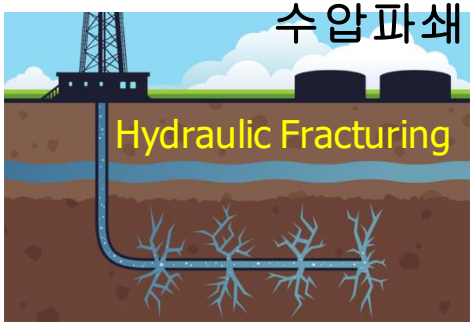
Viscosity
점성도



셰일가스
치밀가스

Increase permeability

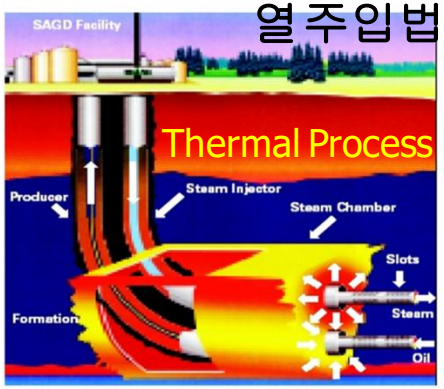
수압파쇄



Reduce viscosity

초중질유
오일샌드

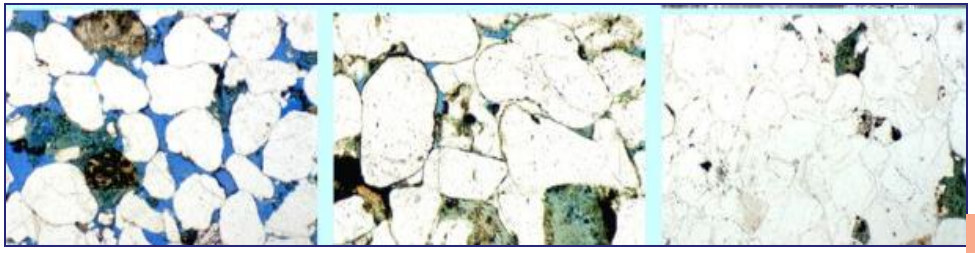
열주입법



투수율과 점성도 (Permeability and Viscosity)

High Perm

Low Perm

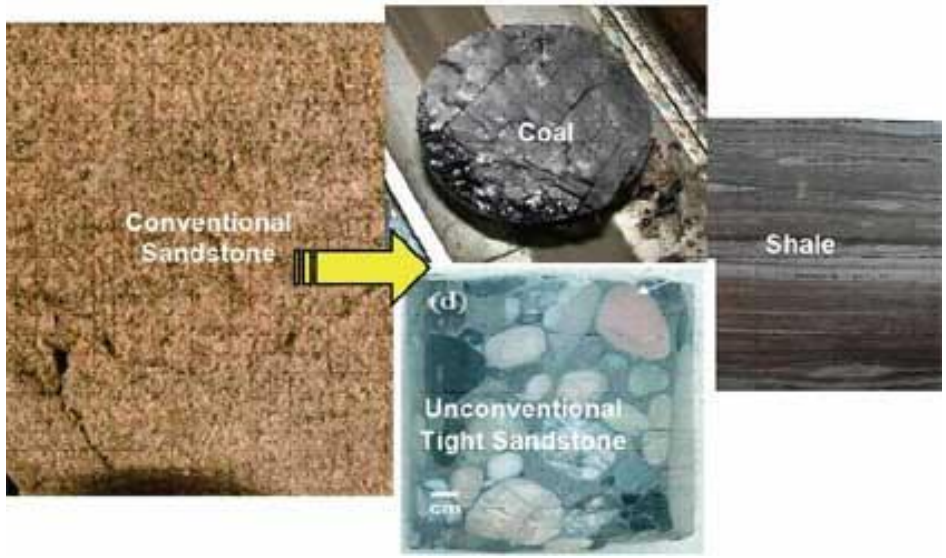


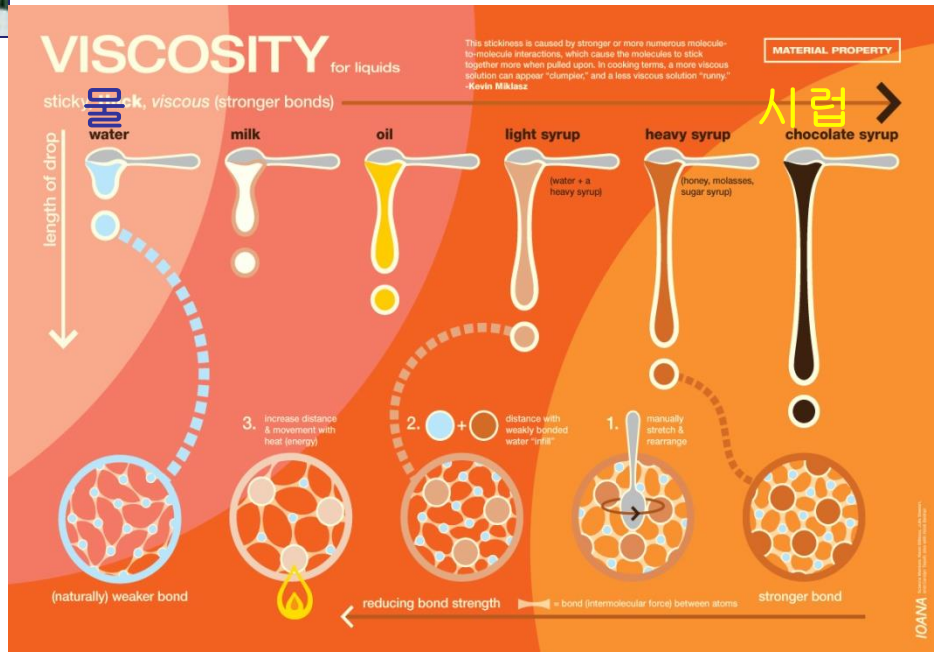
가스

Low

오일

High





주요 비전통자원 및 개발

- 주요 비전통 자원
  - 중질유(Heavy oil)
  - 오일샌드(Oil sands)
  - 오일셰일 (Oil shale)

  비전통오일 (Unconventional oil)

  - 치밀가스(Tight gas)
  - 셰일가스(Shale gas)
  - CBM (Coal Bed Methane)

  비전통가스 (Unconventional gas)

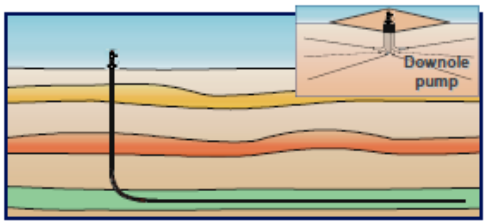
- 개발의 어려움
  - 복잡한 탄화수소 집적 구조 (Hydrocarbon System)
  - 생산 운영의 어려움 및 고 생산 비용
  - 환경문제

비전통 석유자원

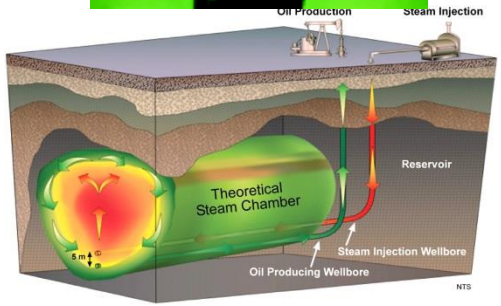
오일의 점성도가 커서 유동성에 문제

- 베네수엘라 초중질유 : **2.2** 조 배럴
- 캐나다 오일샌드 : **1.7** 조 배럴
- 미국 오일셰일 : **1.9** 조 배럴 (미성숙 유기물)

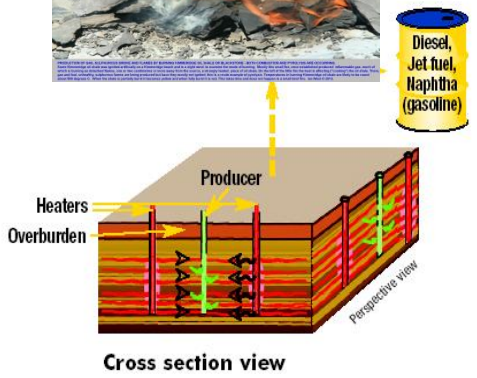
초중질유



오일샌드

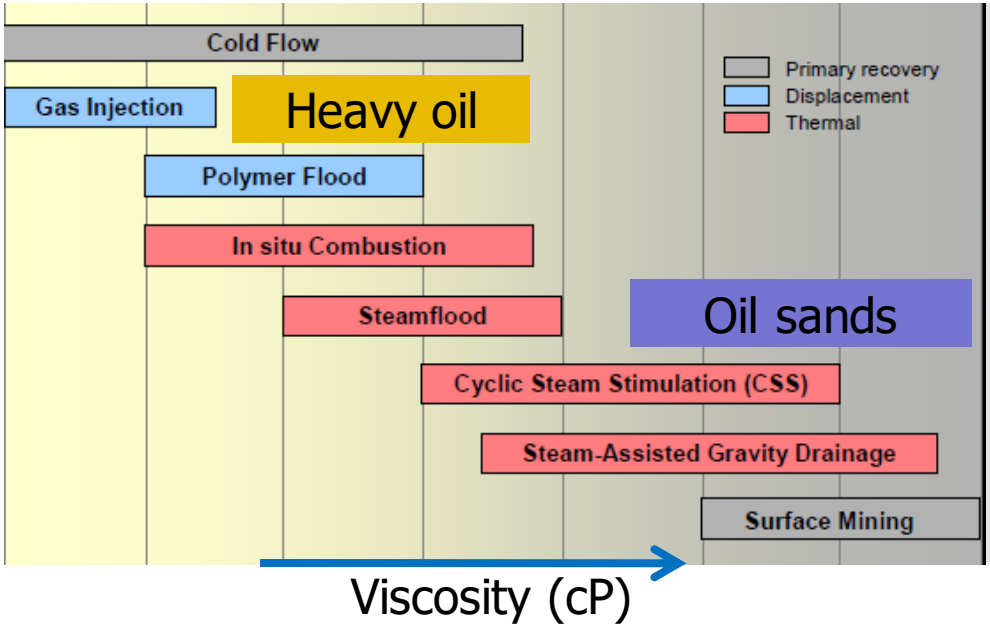


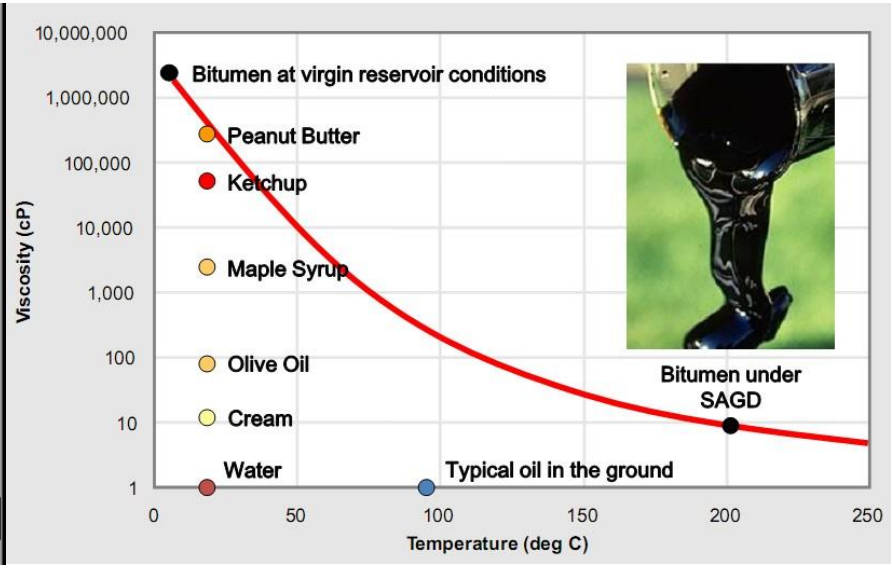
오일셰일



초중질유 및 오일샌드

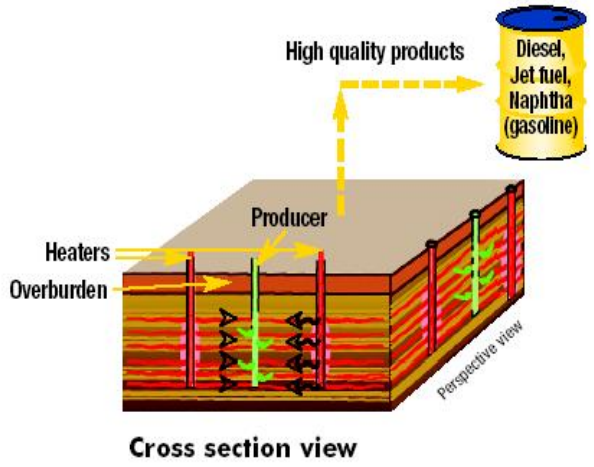
- 분류: API <22°
- 베네수엘라 초중질유 : 2.2 T bbls
- 캐나다 오일샌드: 1.7 T bbls

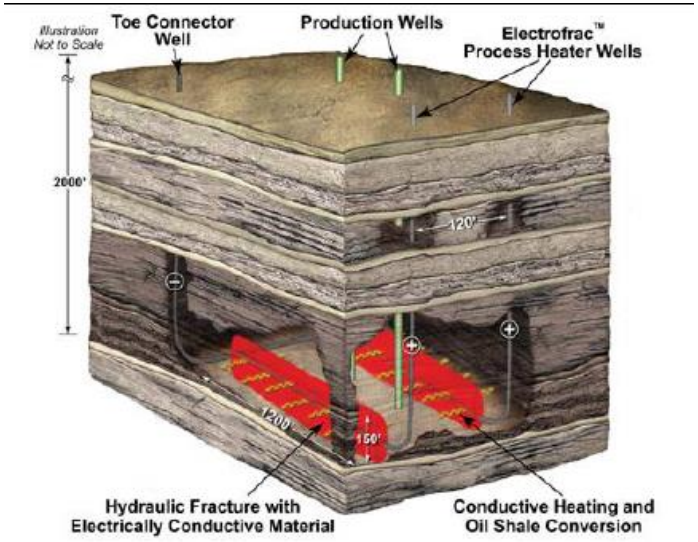




오일셰일

- 케로젠 (Kerogen) : 미성숙 유기물로 석유로 전환하기 위해 고온으로 가열 필요
- 전세계 매장량: 2.6 T bbl
  - U.S.A: 1.9 T bbls (72%)
  - Brazil (140 B bbl) Jordan, Morocco, Australia, China,
  - Estonia (30 B bbl)- commercial production
- 고유가 시기마다 상업화 노력: Shell, Chevron, Exxon Mobil

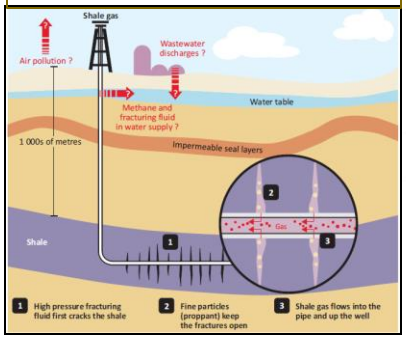


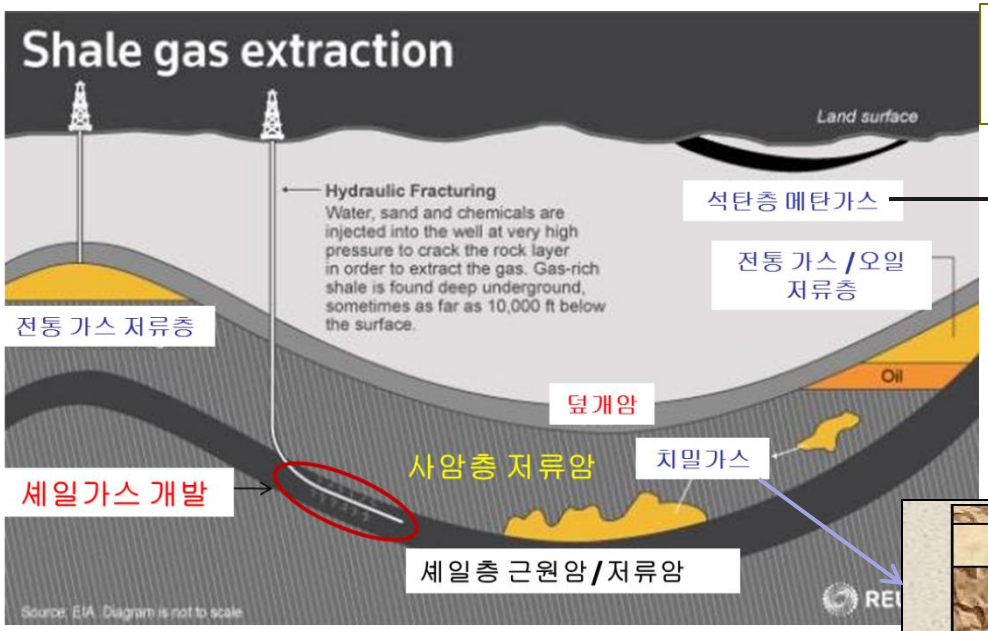


비전통 가스자원

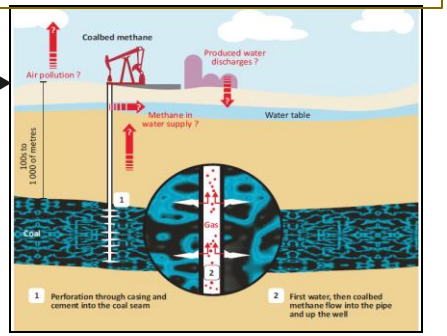
- 총 비전통 가스 자원량: 33,000 Tcf
- 세계 가스 매장량: 6,600Tcf (113 Tcf/year for 58yrs)
- 생산기술: 천공, 수평시추 및 수압파쇄

- 셰일층 공극이나 파쇄대에 존재
- 자원량: 16,000 Tcf





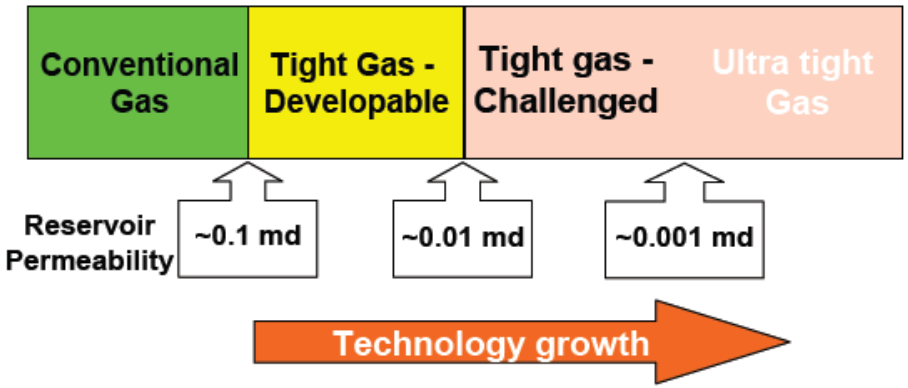
- 탄층에 함유된 메탄가스
- 자원량: 9,000 Tcf



- 치밀 사암층에 부존
- 자원량: 7,400 Tcf

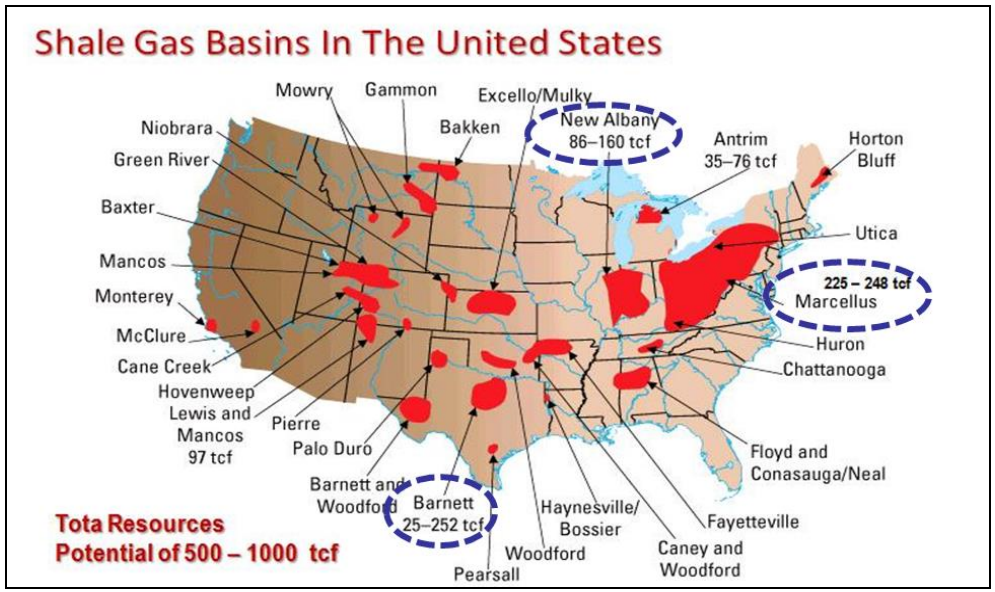
치밀 가스

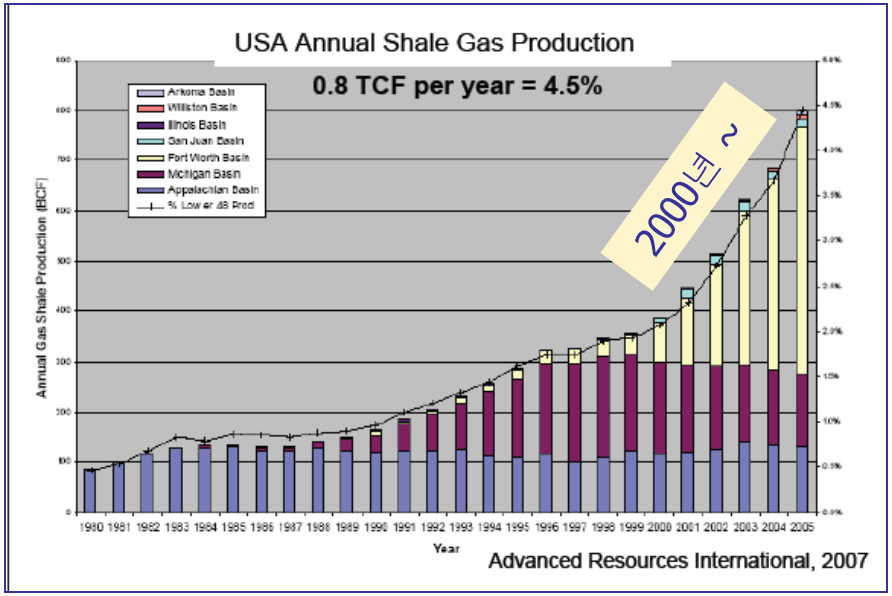
- 저류층 투수율 < 0.1 md
- 자원량: 7,406 Tcf
- 생산 기술: 천공(perforation) 및 수압 파쇄



셰일가스

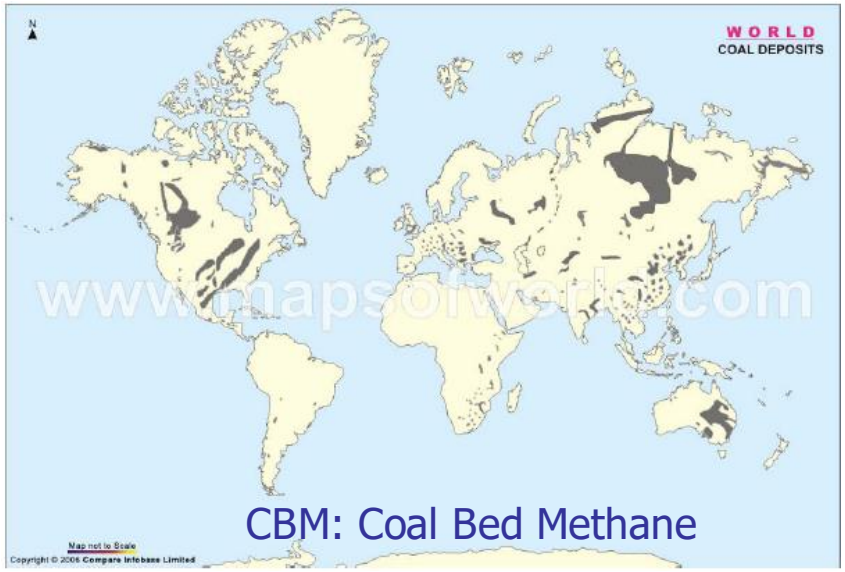
- 셰일층 공극이나 파쇄대에 자유가스(free gas) 로 존재
- 자원량: 16,112 Tcf
- 생산기술: 수평시추 및 다단계 수압파쇄



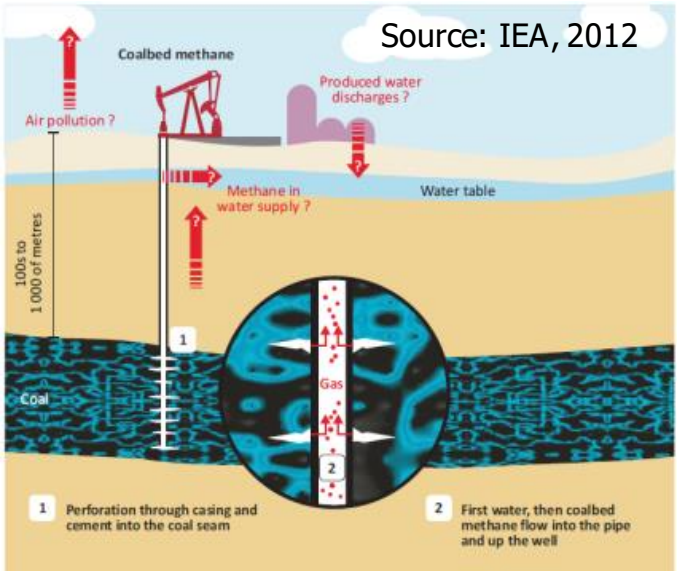


석탄층 메탄가스 (CBM)

- 탄층에 함유된 메탄가스
- 자원량: 9,051 Tcf (USA, China, Russia)
- 생산기술: 수평시추 및 다단계 수압파쇄



CBM: Coal Bed Methane

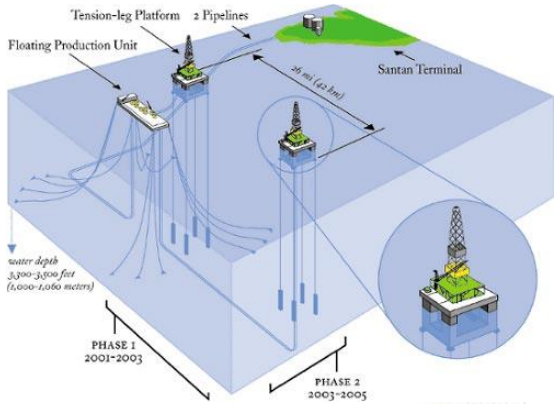


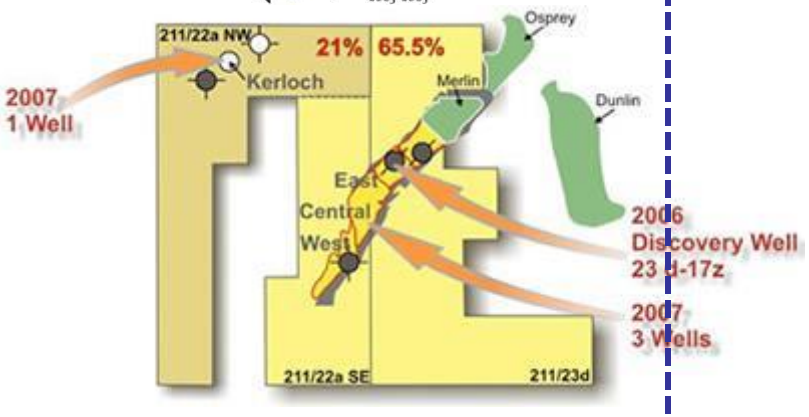
6-2: 비전통자원은 어떻게 개발할까 ?

비전통자원 개발의 특징

- 대규모 개발 및 생산 : 많은 시추공수, 대형 생산설비

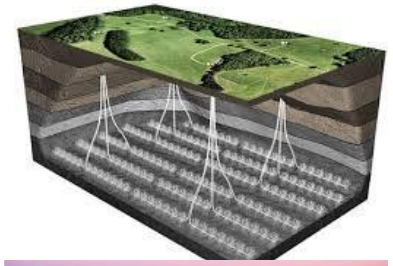
Conventional



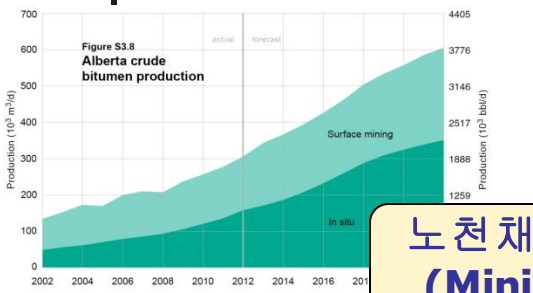


Unconventional

	세일가스 개발	오일샌드 개발
간격	**200~400m**	**100m**
길이	**1600m**	**800m**



오일샌드 생산 체인

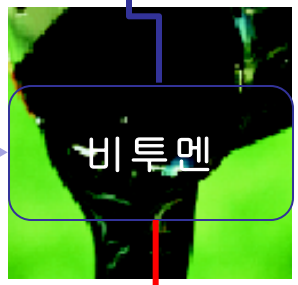


노천채굴법
(Mining)

개 질
(Upgrading)

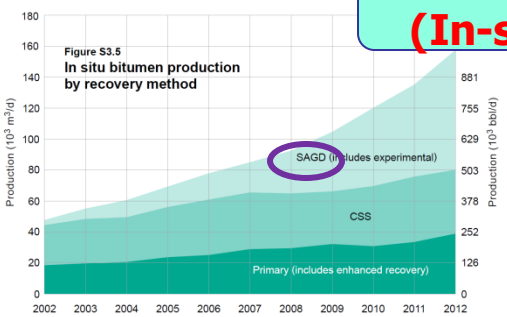
합성원유
(SCO)

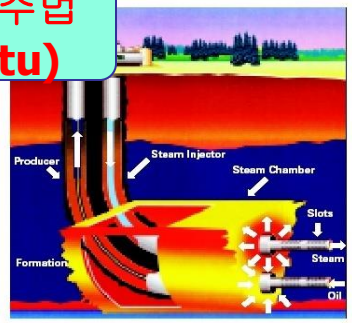
추출/분리



정제
(Refinery)

지하회수법
(In-situ)



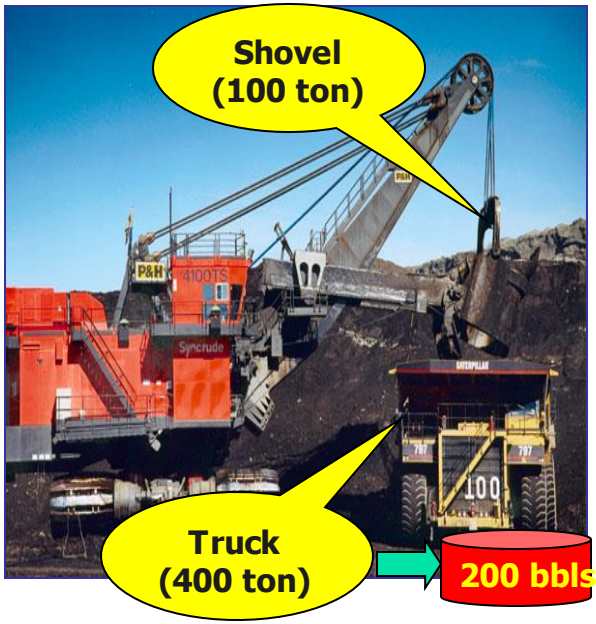


Diluent 혼합
(Dil-bit)

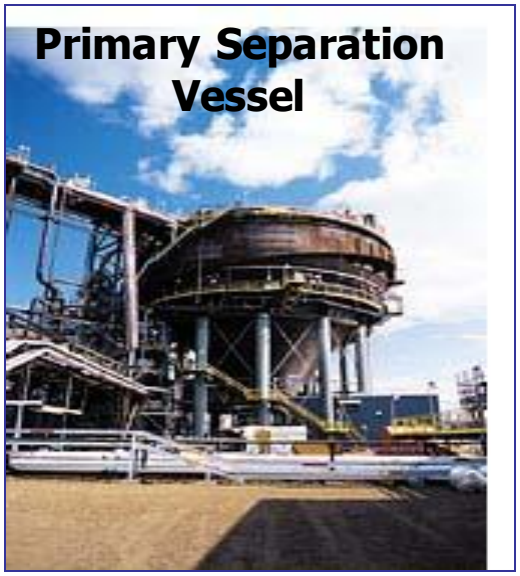
오일샌드 노천채굴

- 노천채굴 - 분리 - 개질

- Remove Overburden, Mining oil sands
- Crushing, Slurrying, Transporting



- Separation of bitumen froth
- Froth treatment

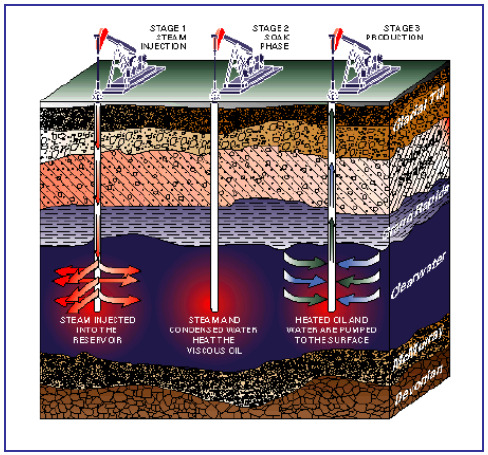


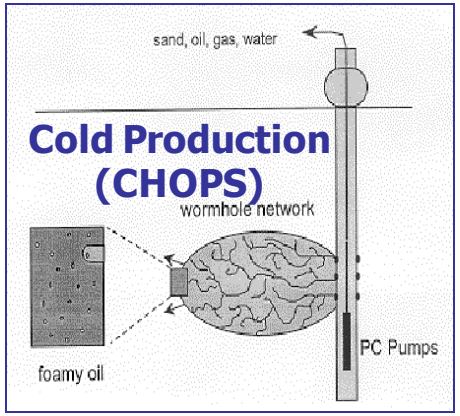
- Upgrading bitumen to lighter oils
- Coking or Hydrocraking

오일샌드 지하회수

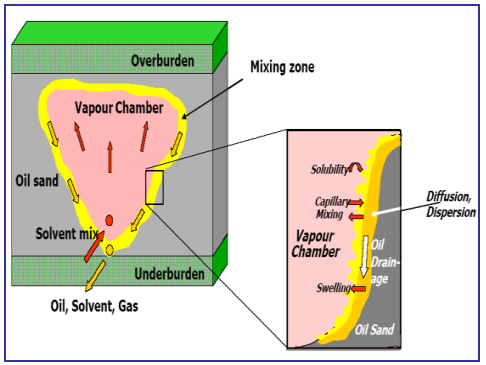
- 일차생산, 스팀주입법, 지하연소법

Cyclic Steam Stimulation (CSS)

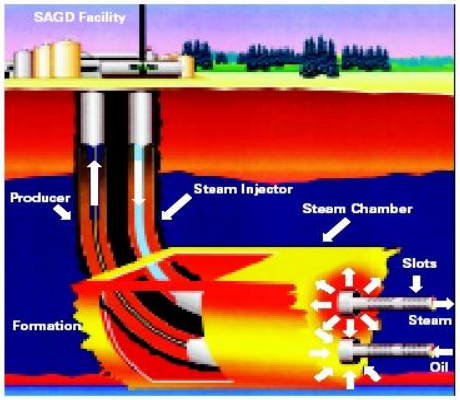




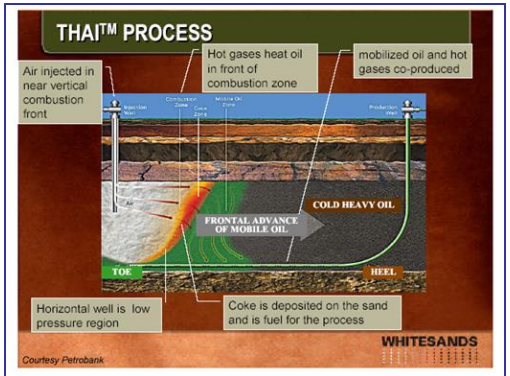
Vapex Process



Steam-Assisted Gravity Drainage (SAGD)



In-situ Combustion



오일샌드 생산비용 - 2010

- Supply and Capex costs (ERCB ST98-2011)

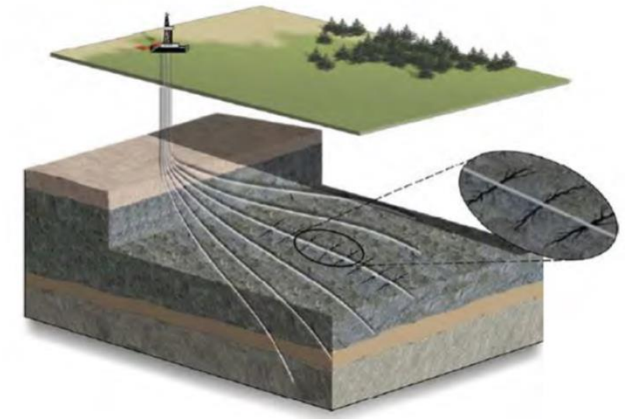
Project type	Production (10^3 m^3/d)	Production (bbl/d)	Capital cost range (millions of dollars)	Estimated supply cost $US WTI equivalent per barrel
In situ SAGD	4.8	30 000	900 to 1350	47 to 57
Stand-alone mine	15.9	100 000	5 000 to 7500	63 to 81
Integrated SCO	15.9	100 000	8 500 to 11500	88 to 102

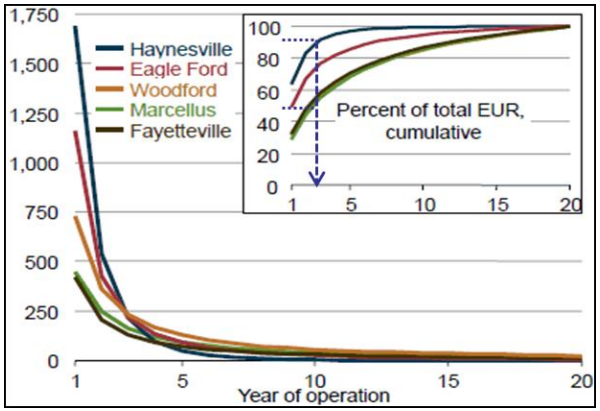
- Supply costs per flow bbl
  - In-situ SAGD: U$30,000 ~ U$45,000 (1만 배럴규모: 3~4.5억 불)
  - Mining alone: U$50,000 ~ U$75,000 (10만 배럴: 50~75억 불)
  - Integrated SCO: U$85,000 ~ U$115,000

셰일가스 생산 기술

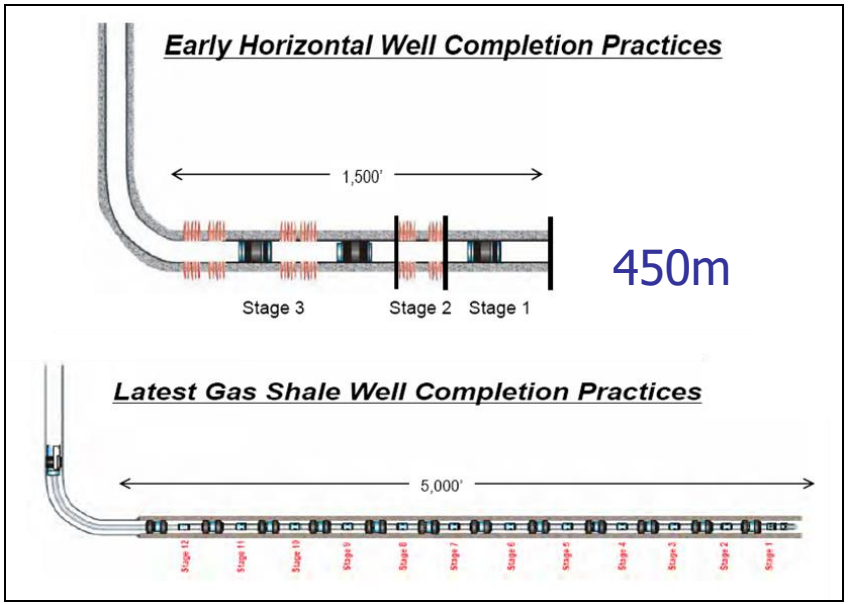
- 수평시추 및 수압파쇄 기술의 진보

시추기술 (**Pad** 형)



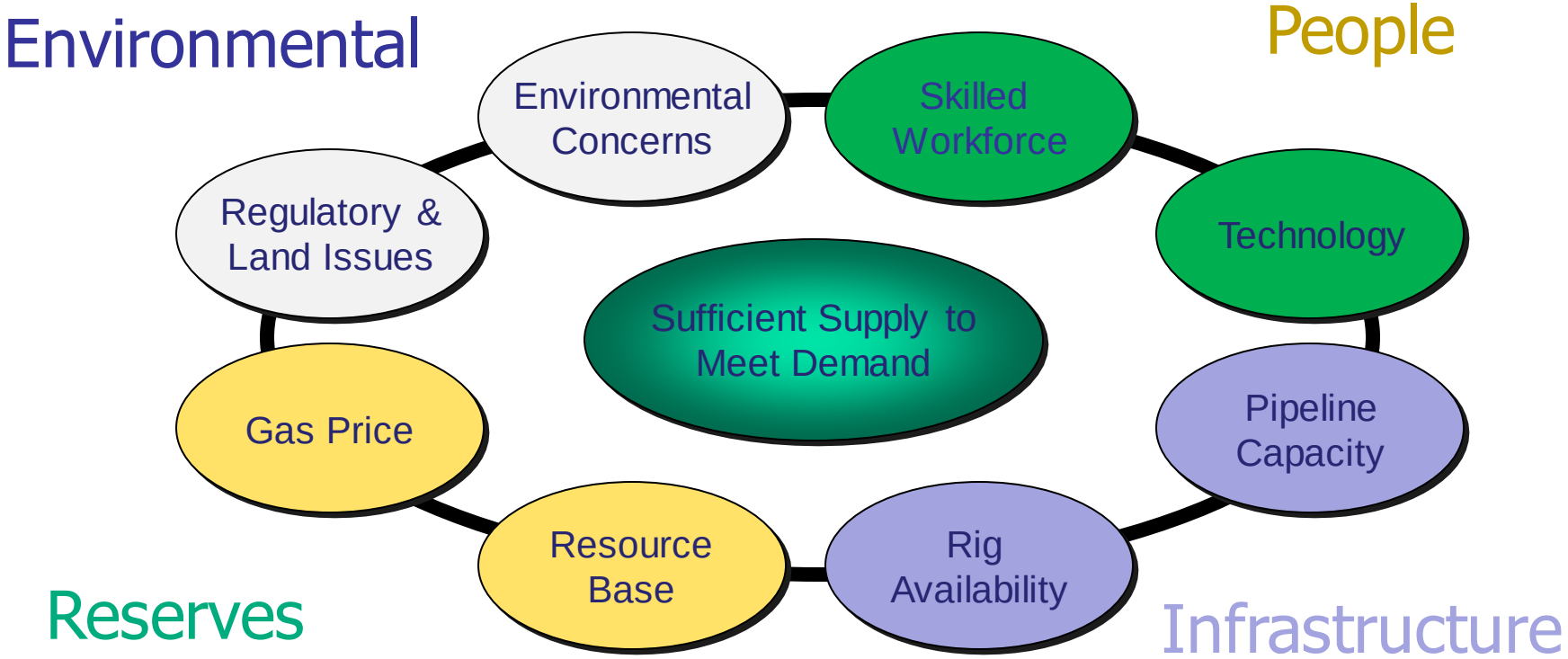


다단계수압파쇄기술



- 파쇄공정수: 물, 모래, 첨가물
- 주입: 200~300m 단위로 파쇄
- 생산특징: 2년 내 50~90% 이상 생산 (20~40년)

향후 셰일가스 개발 제약요소



6-3: 비전통자원의 문제점은 무엇일까?

오일샌드 개발에 따른 환경문제

- 주요문제: 다량의 물 소비, GHG 방출, 지표 난개발

오일샌드 주요 부산물

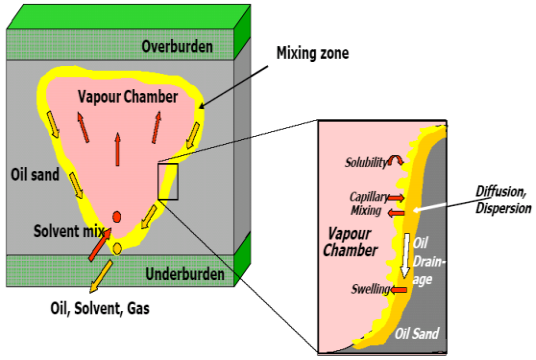
- 코크 **(Petroleum Coke): 7** 백만 톤/년
  - 전력생산, 합성가스, 수소
- 황**: 2** 백만 톤/년

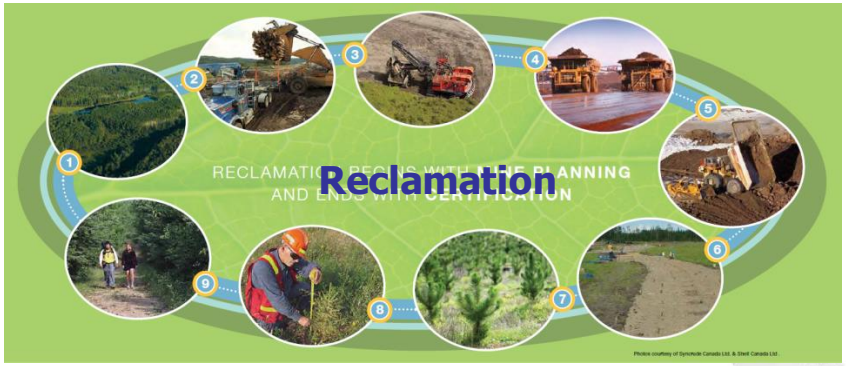
Athabasca River and the original "Tar Island" tailings pond at the Great Canadian Oil Sands (GCOS; Suncor) Mine. Coke (black) and sulphur (yellow) are major byproducts of oil sand processing.

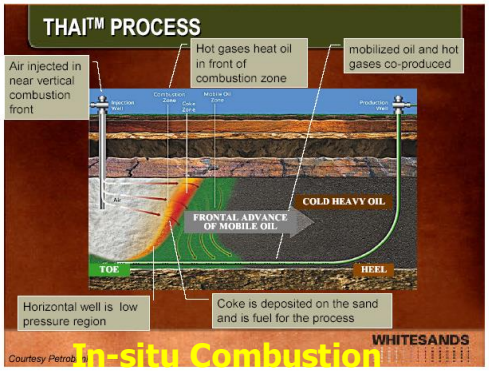
오일샌드 환경영향 최소화 노력

- 열효율성 향상
- 점성도를 낮추는 신기술
- 물 사용량 저감 및 생산수 재활용

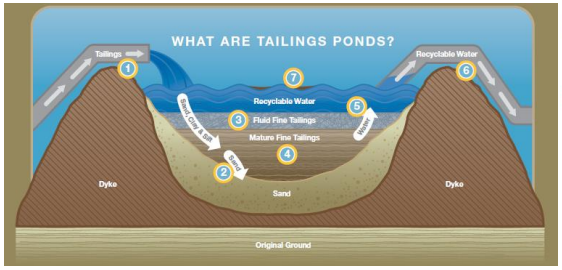
New Technologies



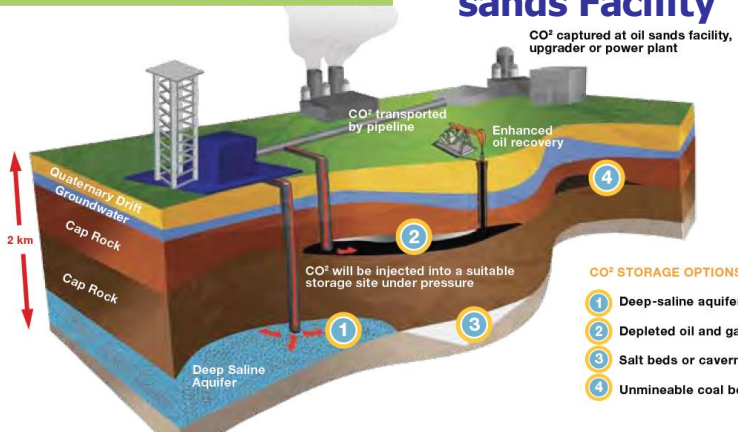




Water recycle

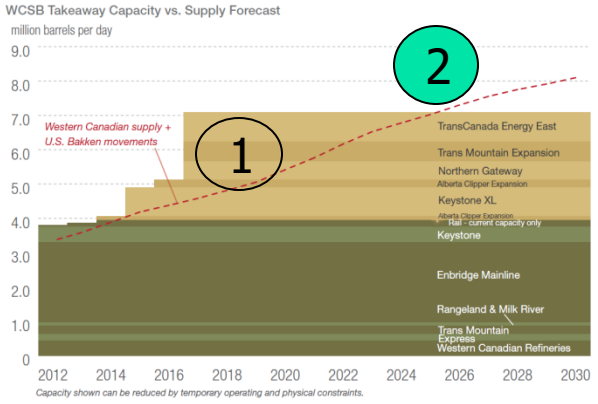


CCs from Oil sands Facility



비튜멘 상-하류부문 균형

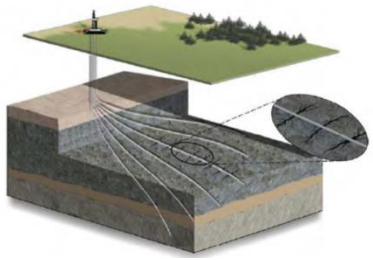
- 생산, 운송, 개질/정제 용량간 균형
- 오일샌드 사업 전략
  - 생산 및 정제부문 전략적 제휴: Cenovus and COP, Husky and BP
  - 중질유 정제설비: 대부분 미국 내 위치



Plan @ 2015	Bitumen production 3Million bbls	Pipeline 5.1Million bbls	Upgrader in Alberta 3.3Million bbls

셰일가스 개발과 환경문제

- 지하수 오염, 다량의 물 사용, 미세지진

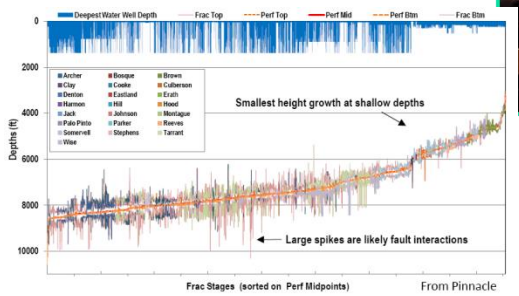


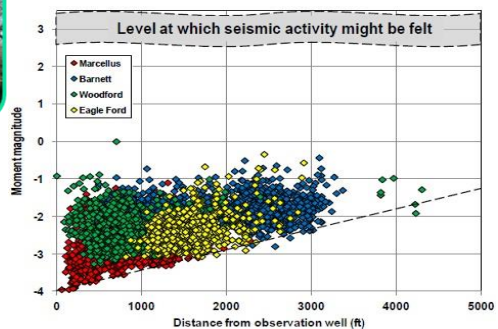
Protection of Groundwater

Wildlife Impacts

Community Impacts

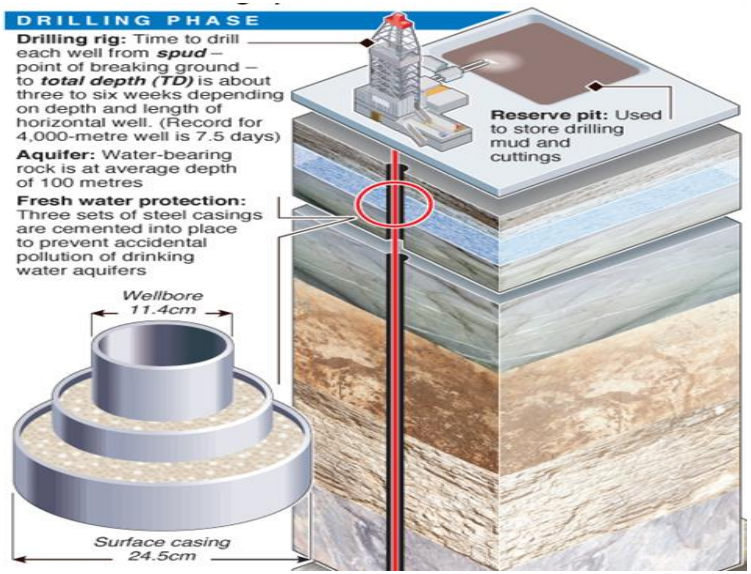
Surface Disturbances





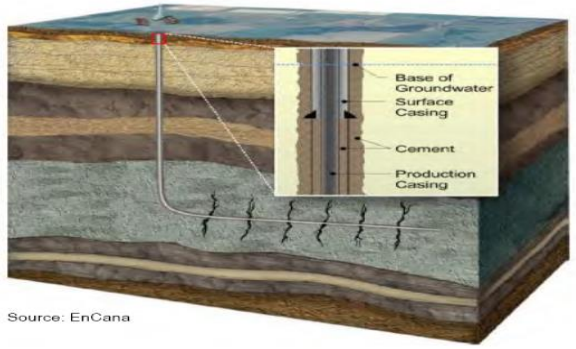
셰일가스 환경영향 최소화 기술발전

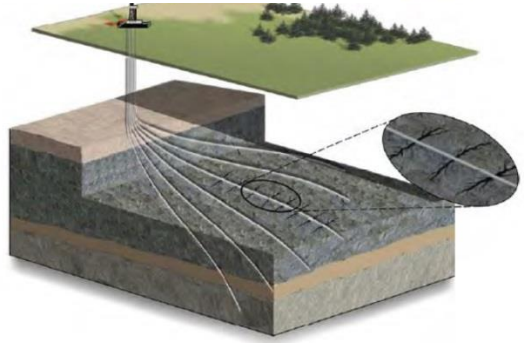
- 긴 수평정, 다중 수평정, 여러 겹의 케이징 및 시멘팅
- 기초 수질 검사 및 지속적이고 체계적인 모니터링
- 친환경 수압파쇄 첨가제



Multi casing/cementing

Longer horizontal well

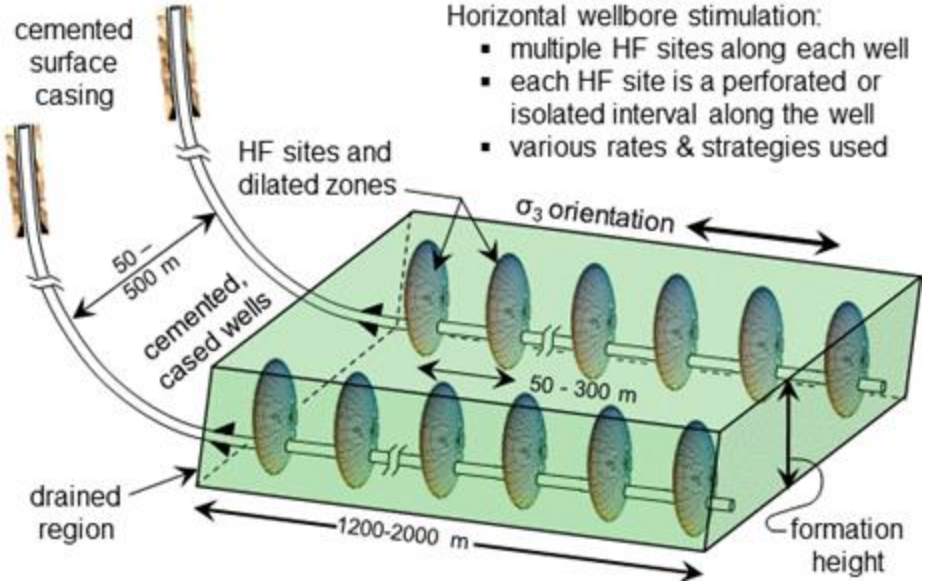




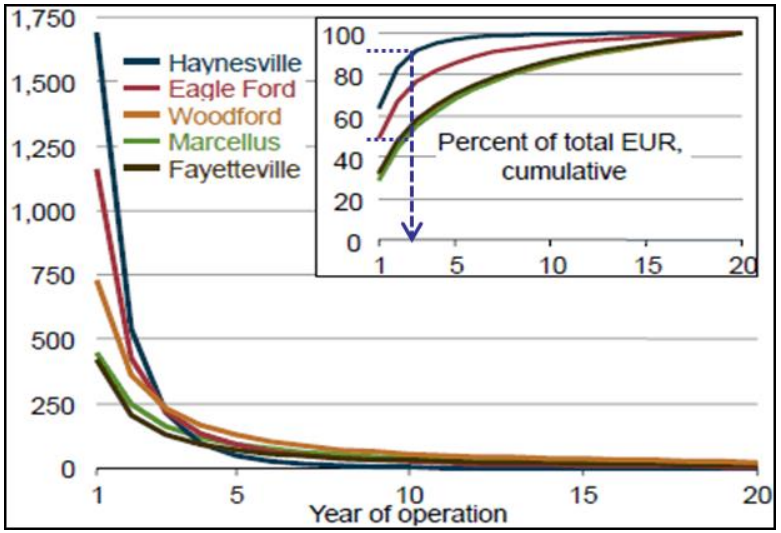
Multi wells from one Pad

수압파쇄 기술과 생산특성

- 급격한 생산감소 : 유지 위해 지속적인 시추 필요

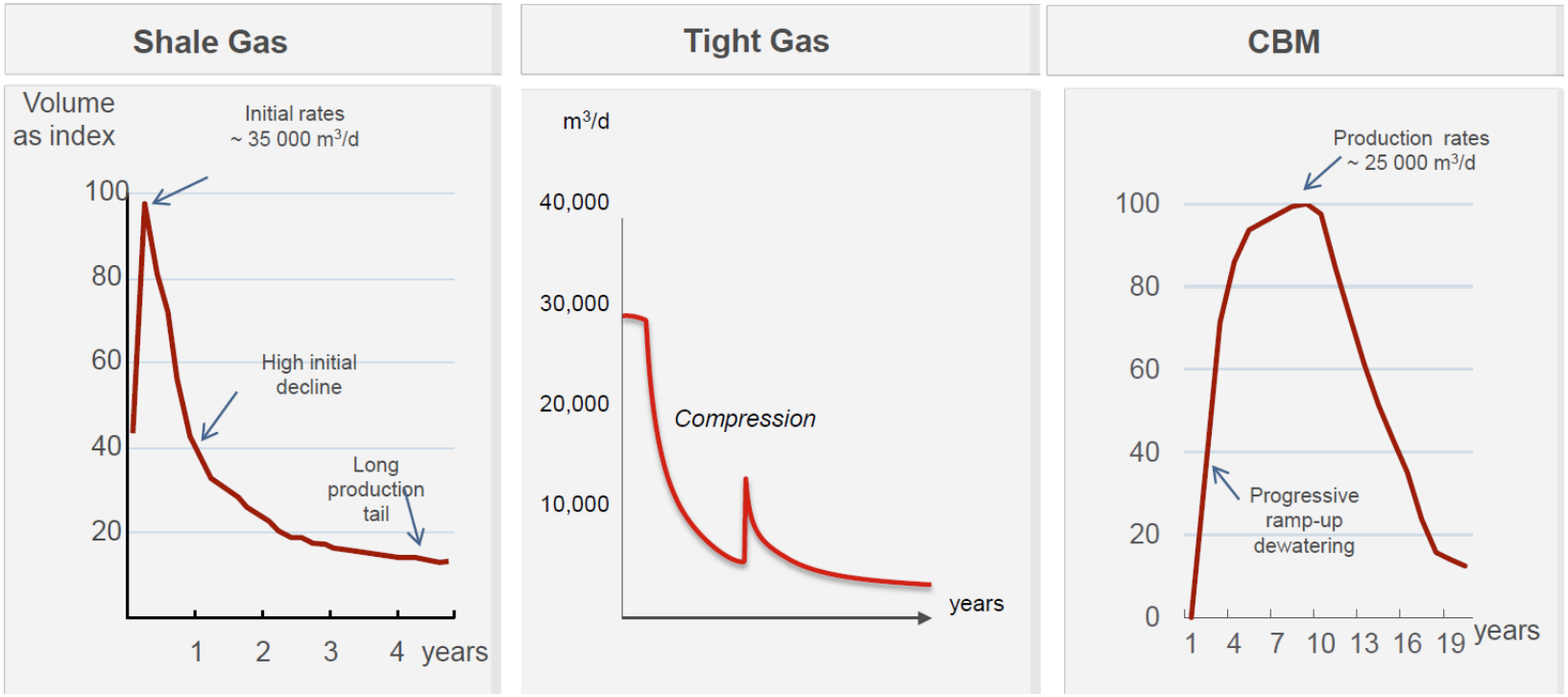


생산량 변화



비전통가스 생산곡선 특성

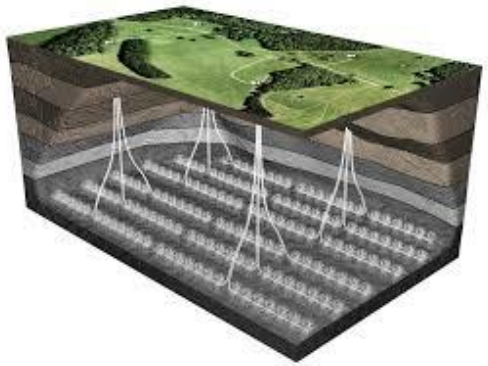
- 셰일가스 및 치밀가스: 초기 생산



(Total, IPTC 2012)

가스 상류-하류간 균형

- 생산, 운송(Pipeline), 시장간 균형: 상류, 하류 부문 균형
  - 생산량 및 시장 접근성 : 파이프 라인(국내), LNG(국외)
  - 국외 시장 (LNG) 규모: LNG 설비 규모



Production

국내시장

해외시장

Pipeline

LNG/ 운송

Market

6-4: 비전통자원의 미래는 ?

오일샌드 생산 예측

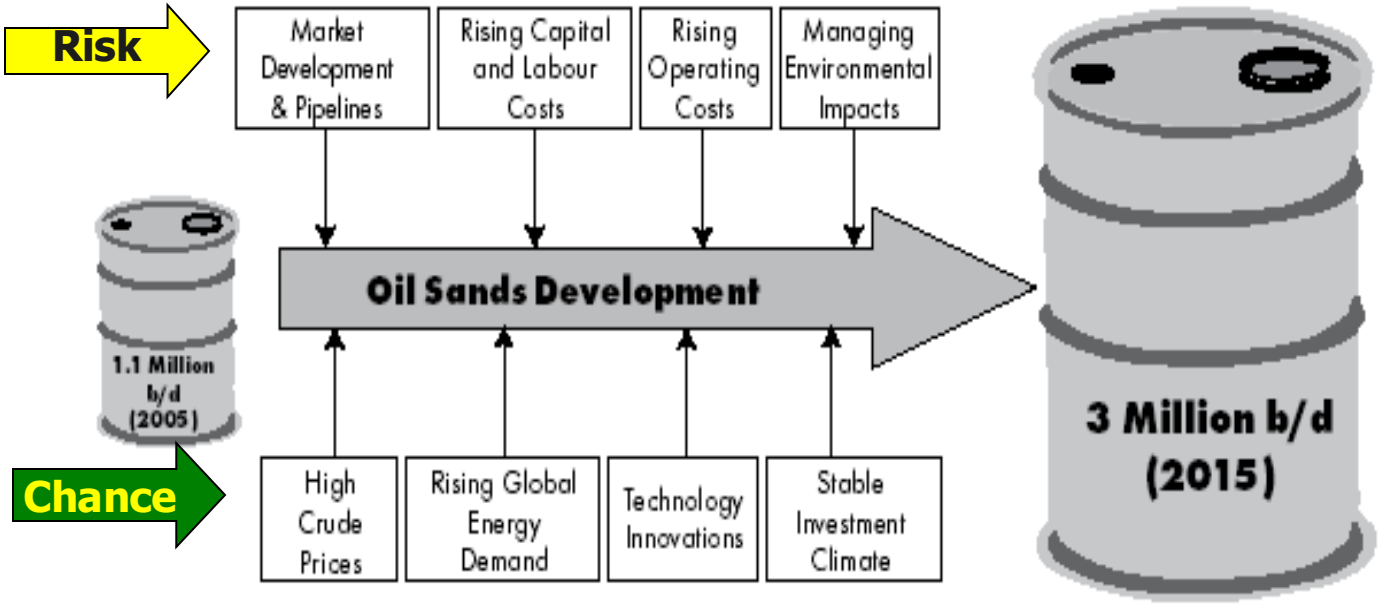
(Alberta Government, 2014)

Type Unit: k bbl	Mining	In-situ	Total	Cum Projection
Producing Projects	921	933	1,854	1,854
Under Construction	295	420	715	2,569
Approval	1,390	810	2,200	4,768
Under Review	600	1,381	1,981	6,749
Announced	100	1,390	1,490	8,239
	3,310	**4,930**		

오일샌드 사업 전망

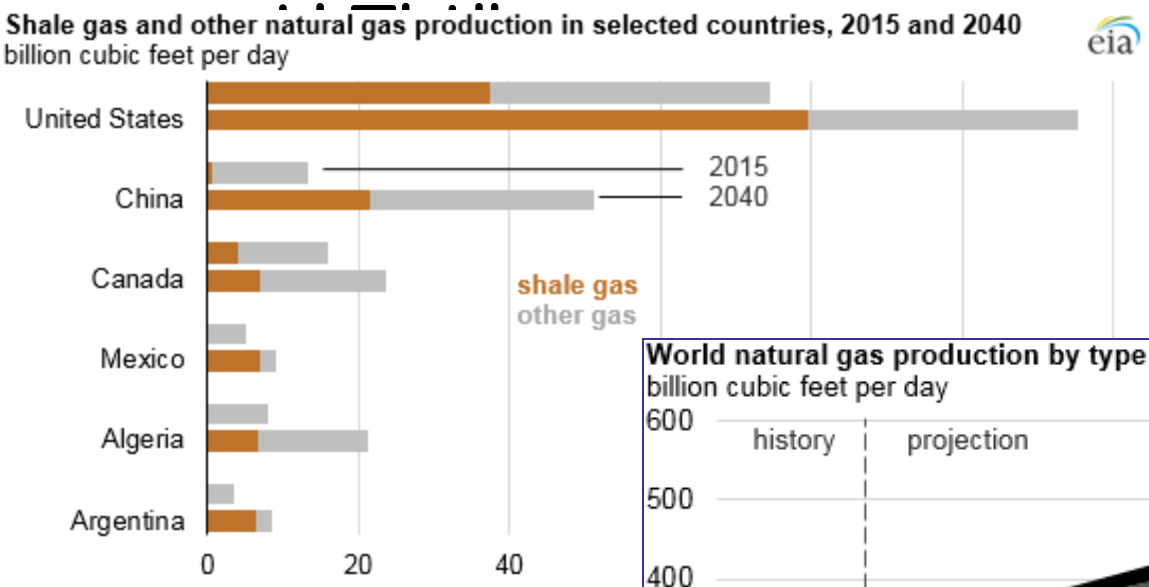
- 발견비용 없음
- 확보된 개발/생산 기술
- 낮은 가스가격: 스팀 비용 감소
- 고유가 유지
- 매장량 확보 용이

- 높은 **CAPEX** 및 **OPEX**
- 새로운 시장 진출의 어려움
- 비튜멘 가격 변동
- 환경 오염에 의한 사회적 허가**(Social License)** 어려움



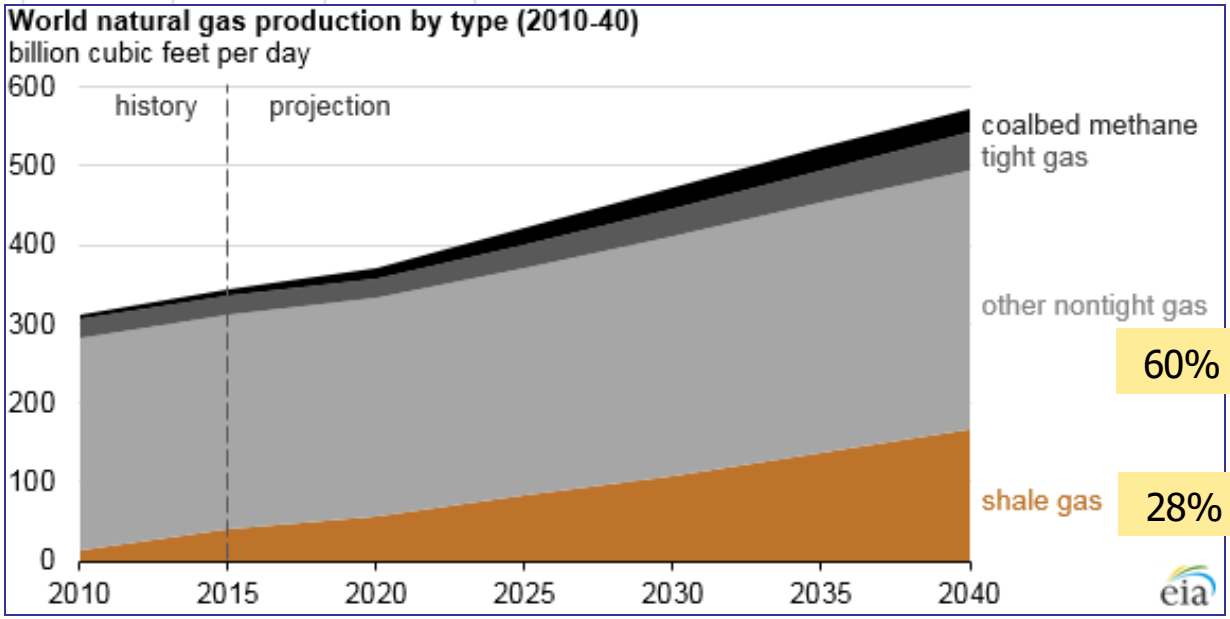
세계 가스 유형별 생산 예측

- 전통 가스자원이 주로 하고 비전통가스



왜 미국일까?

미국: 40% -> 70%
중국: -> 40%
캐나다: 20% -> 30%
멕시코: -> 75%

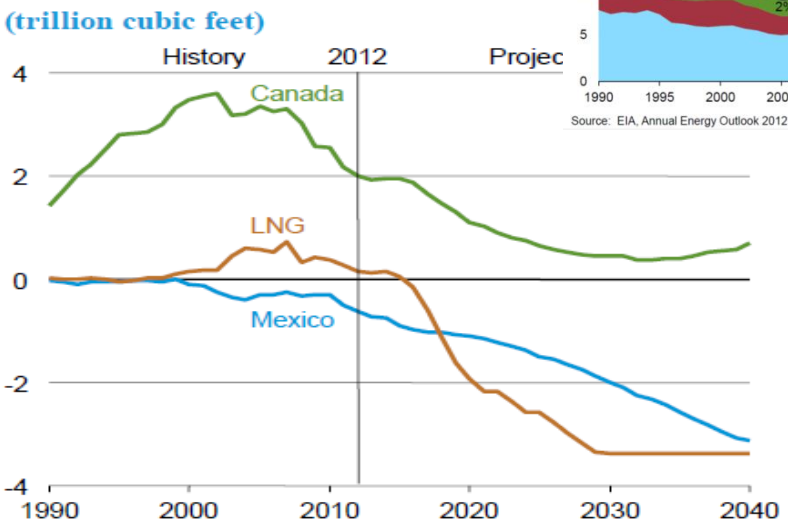


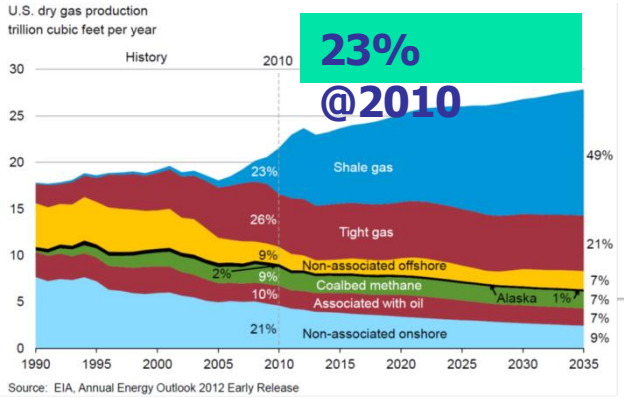
(Source: IEA, 2016)

미국 비전통가스 생산량 예측

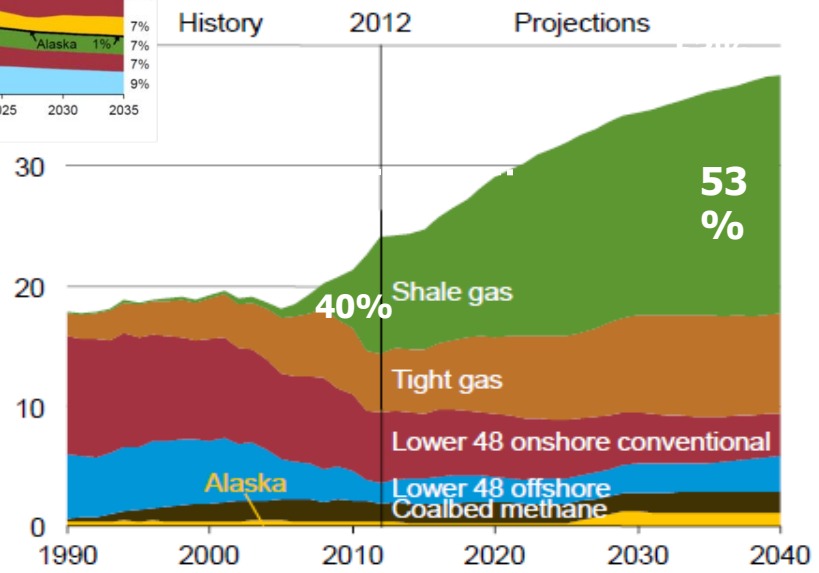
- 셰일가스, 치밀가스 등 비전통 가스 생산이 주를 이룸

US net gas import





40 % @2012

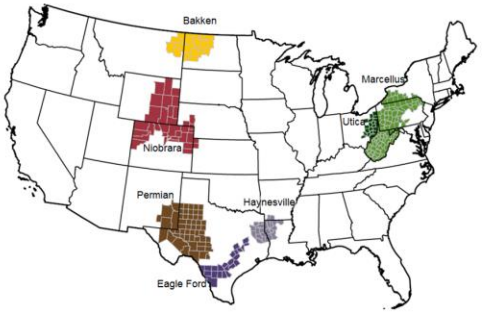


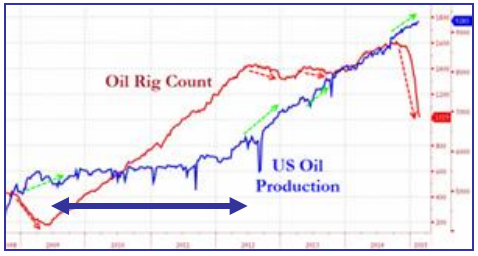
(Source: EIA Annual Energy Outlook 2014)

미국의 셰일가스/오일

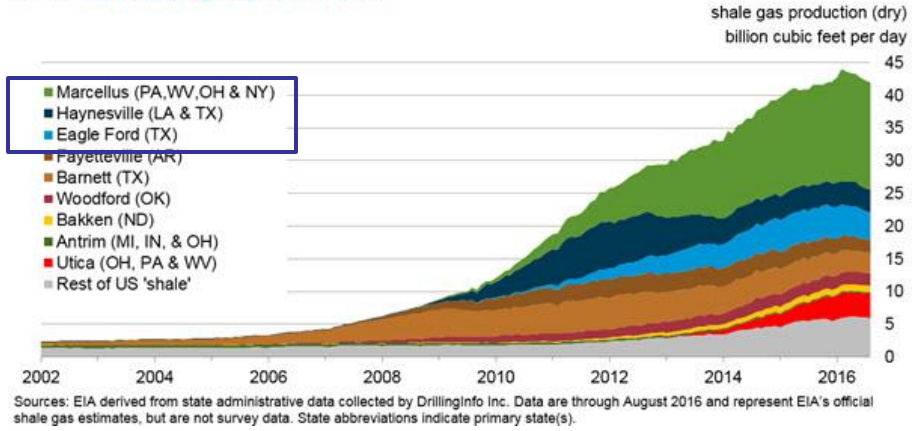
- 매장량규모: 862 Tcf (500 ~ 1000 Tcf)
- 33 Bcfd (미국 천연가스 생산량의 40%) in 2013
- 개발지역: Barnett, Fayetteville -> Marcellus, Haynesville

(저 가스 가격으로 Dry gas -> Wet gas 지역으로 이동)



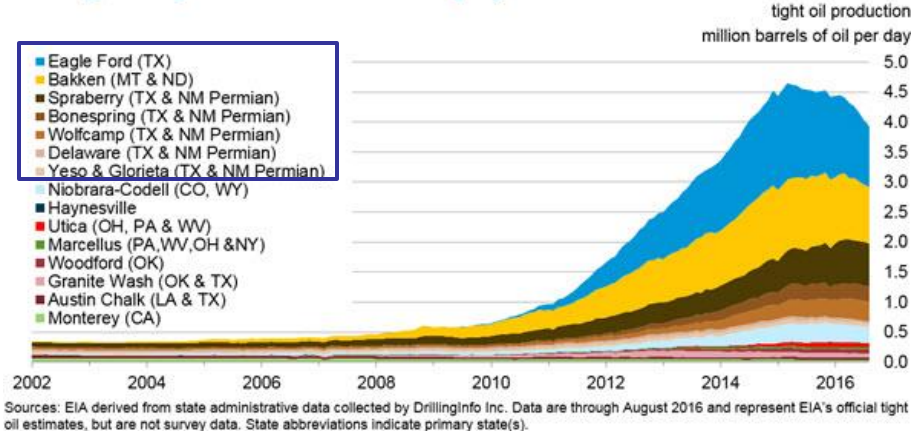


U.S. dry shale gas production



Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through August 2016 and represent EIA's official shale gas estimates, but are not survey data. State abbreviations indicate primary state(s).

U.S. tight oil production – selected plays



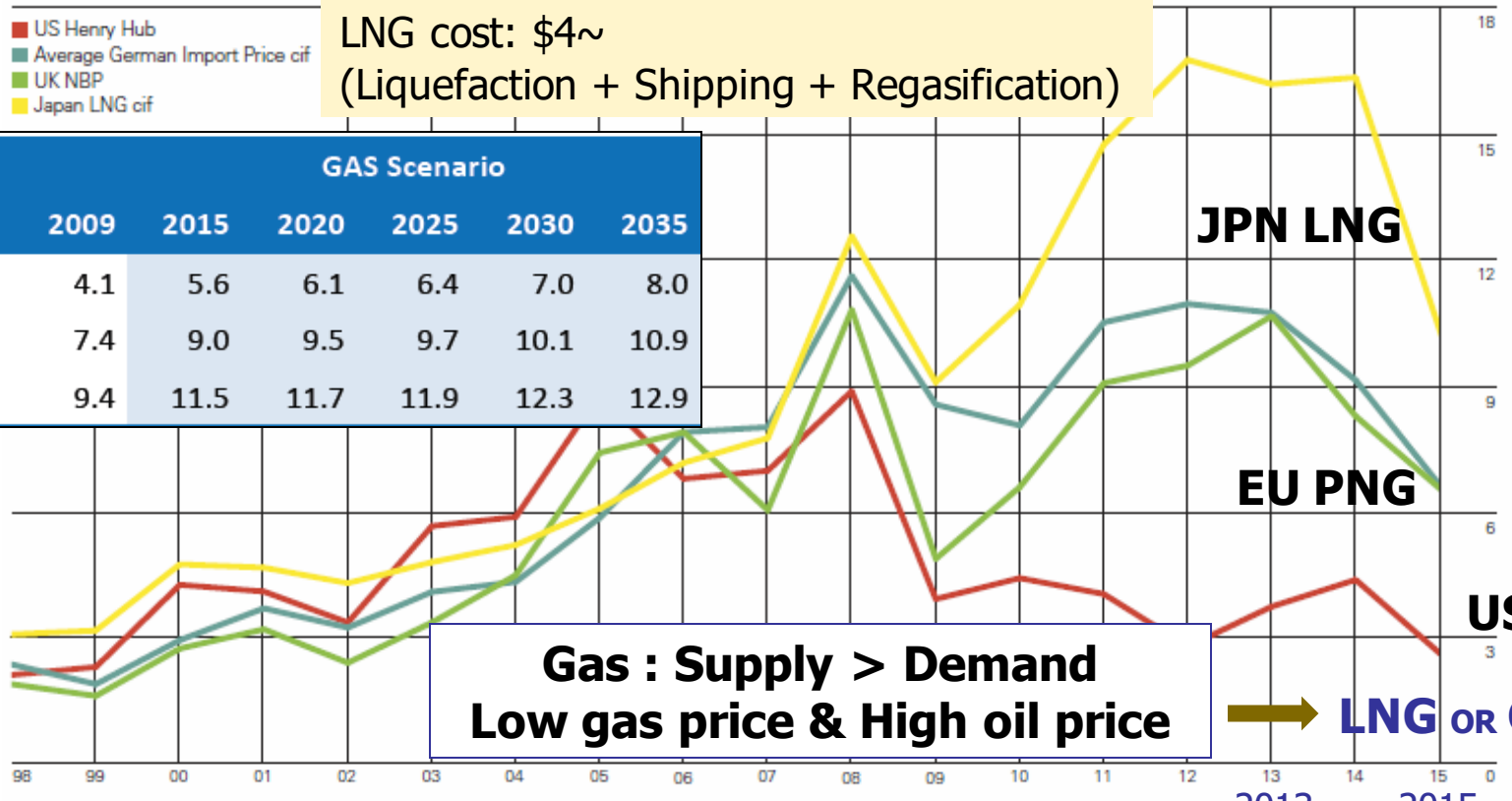
Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through August 2016 and represent EIA's official tight oil estimates, but are not survey data. State abbreviations indicate primary state(s).

국제 가스 가격

- 가스가격 : 공급과 수요에 따른 지역적 편차가 심함
- 미국:$3, 독일:$7, 영국:$7, 일본 LNG:$10 (@2015)

LNG cost: $4~
(Liquefaction + Shipping + Regasification)

GAS Scenario	2009	2015	2020	2025	2030	2035
United States	4.1	5.6	6.1	6.4	7.0	8.0
Europe	7.4	9.0	9.5	9.7	10.1	10.9
Japan	9.4	11.5	11.7	11.9	12.3	12.9



유가하락

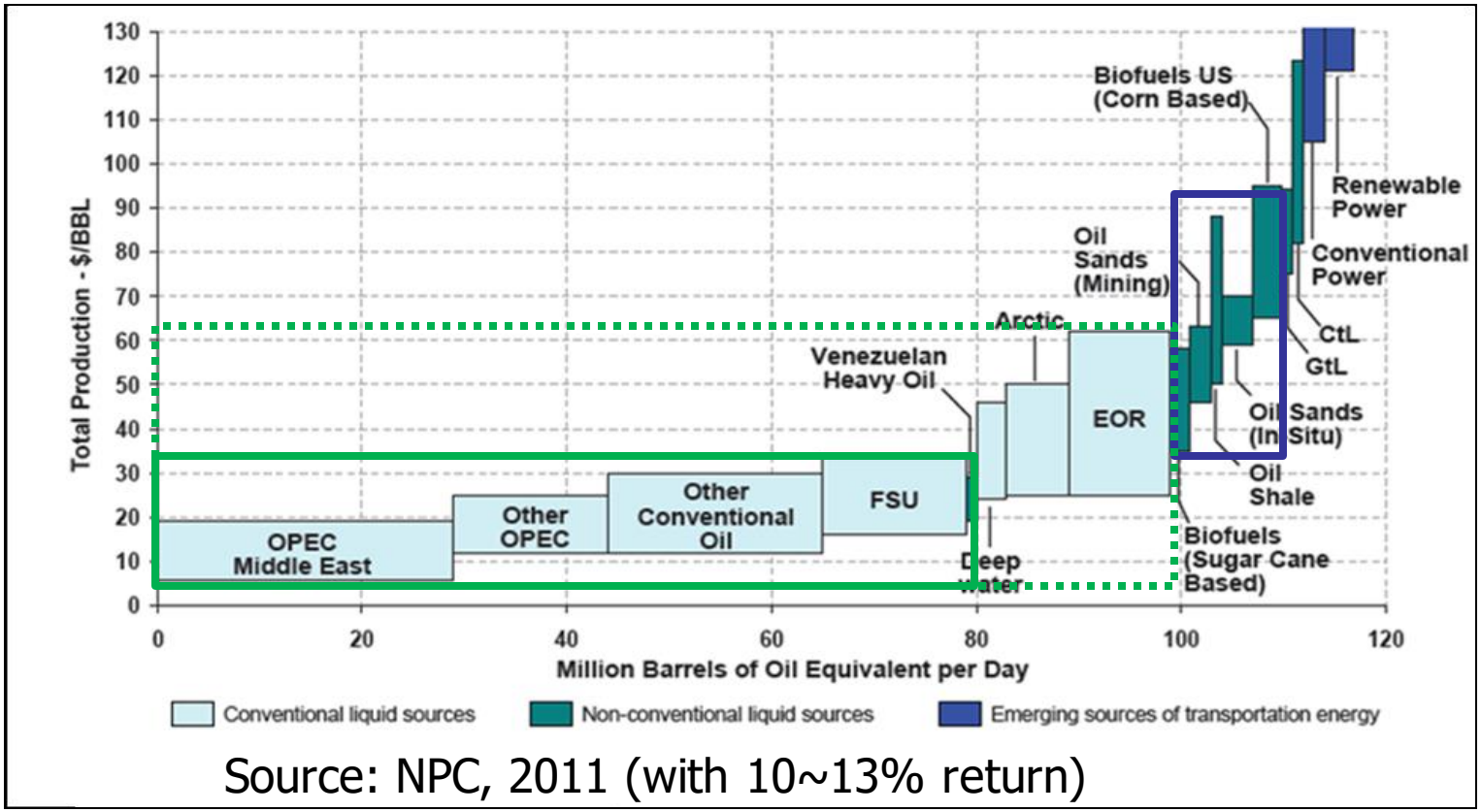
Gas : Supply > Demand
Low gas price & High oil price

→ **LNG OR GTL?**

(Source: BP Statistical Review, 2016)

석유자원 공급 가격 비교

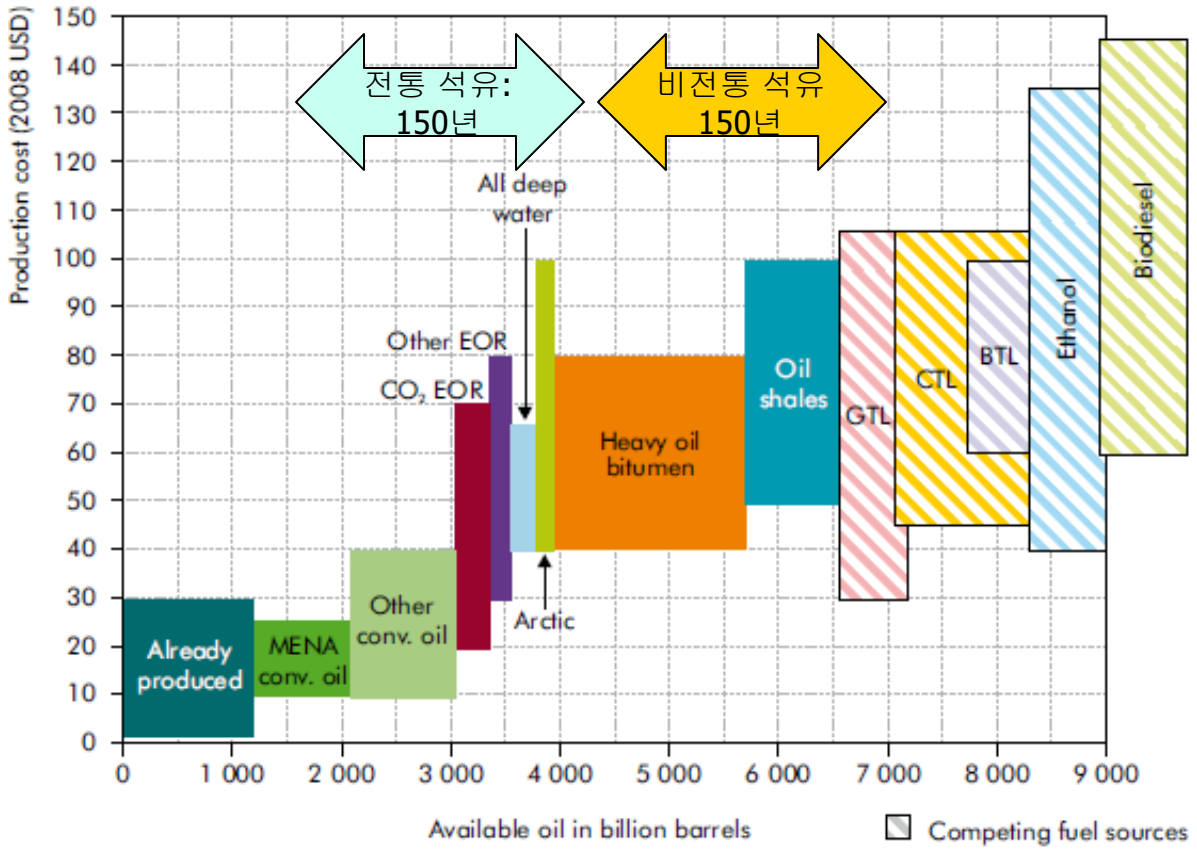
- 전통 에너지 : 5~30$/배럴
- 비전통 에너지 : 45~90$/배럴



Source: NPC, 2011 (with 10~13% return)

석유 자원별 생산 비용 곡선

- 전통석유자원 및 비전통 석유자원: 6조 배럴



There is no free lunch !

- 기술개발을 위한 오랜 시간과 노력 필요