Industrial Application of Hydrogen Manufacture from Fossil Fuels with Geological Storage of CO_2

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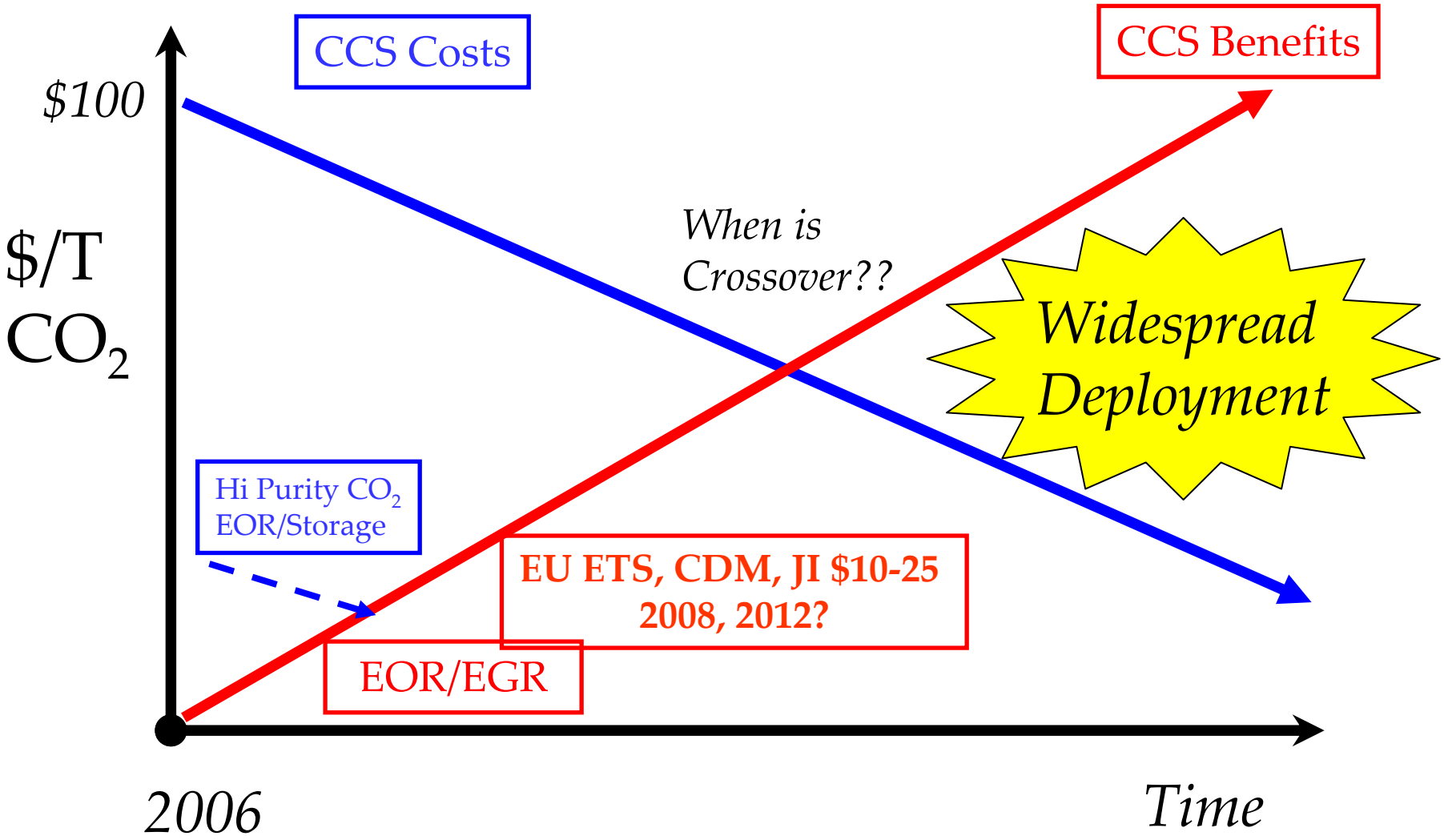
Agenda

- **What is Required for Commercial Deployment of CCS?**
- **A Business Model for Hydrogen to Power Generation**

- **Two BP-led Demonstration Projects:**
  - **Peterhead, Scotland (2010):**
    - **CO2 Storage in the Miller Depleted Oilfield**
  - **Carson California (2011)**

- **Summary**

Commercial Deployment of CCS



Hydrogen to Power: A Business Model

Hydro-Carbon

syngas manufacture

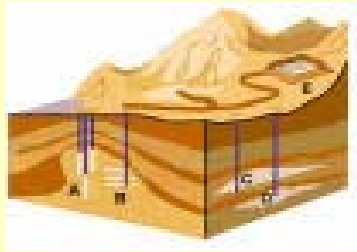
H_2

Combined Cycle Power Generation

e^-

'Carbon Free' Electricity

CO_2



CO_2 Storage

- ✓Advantaged feedstock
- ✓Policy
- ✓Storage
- ✓Energy market

Provides optionality for future to supply H_2 into other sectors

H_2

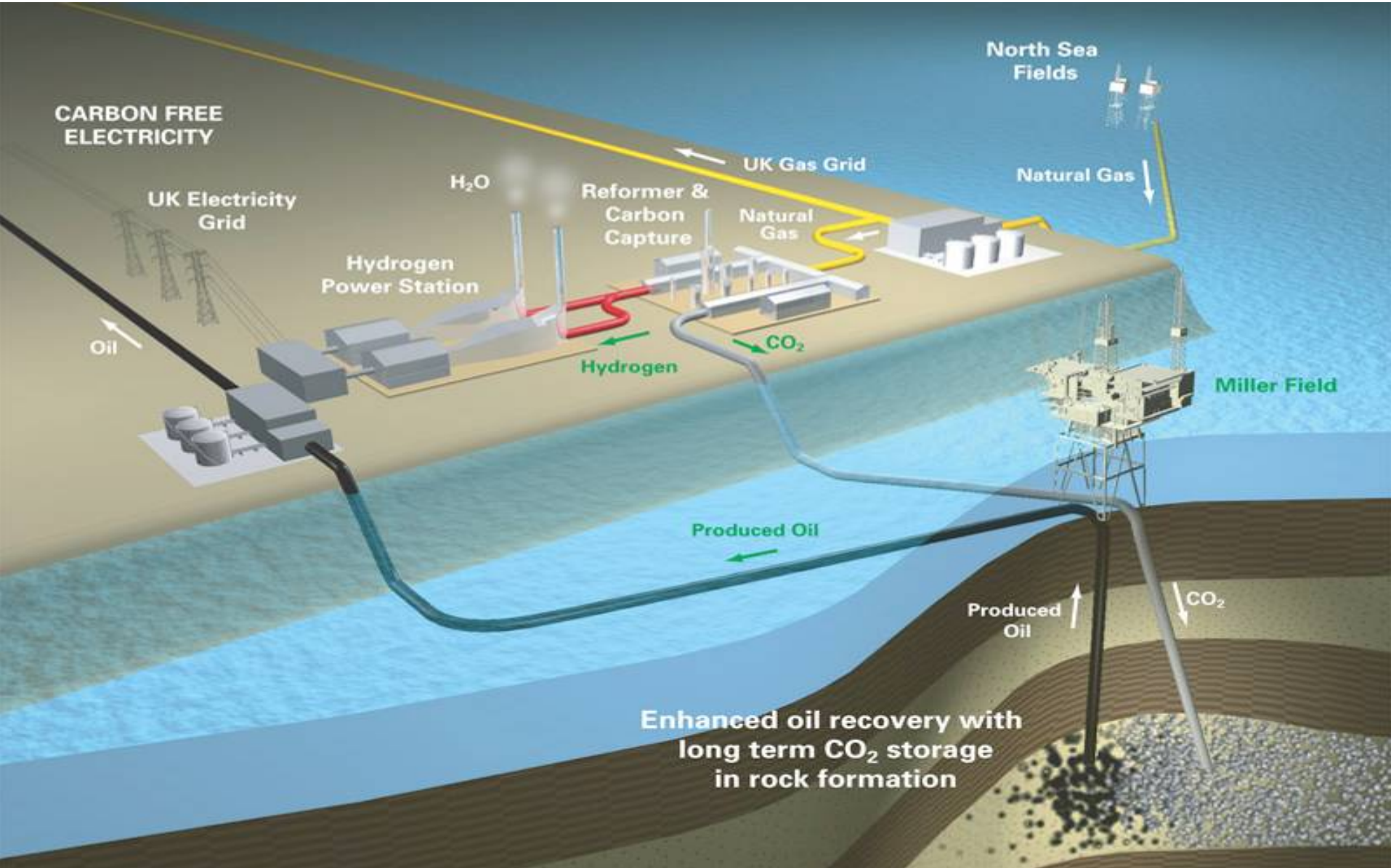
Transportation

Peterhead Hydrogen Project (Scotland)

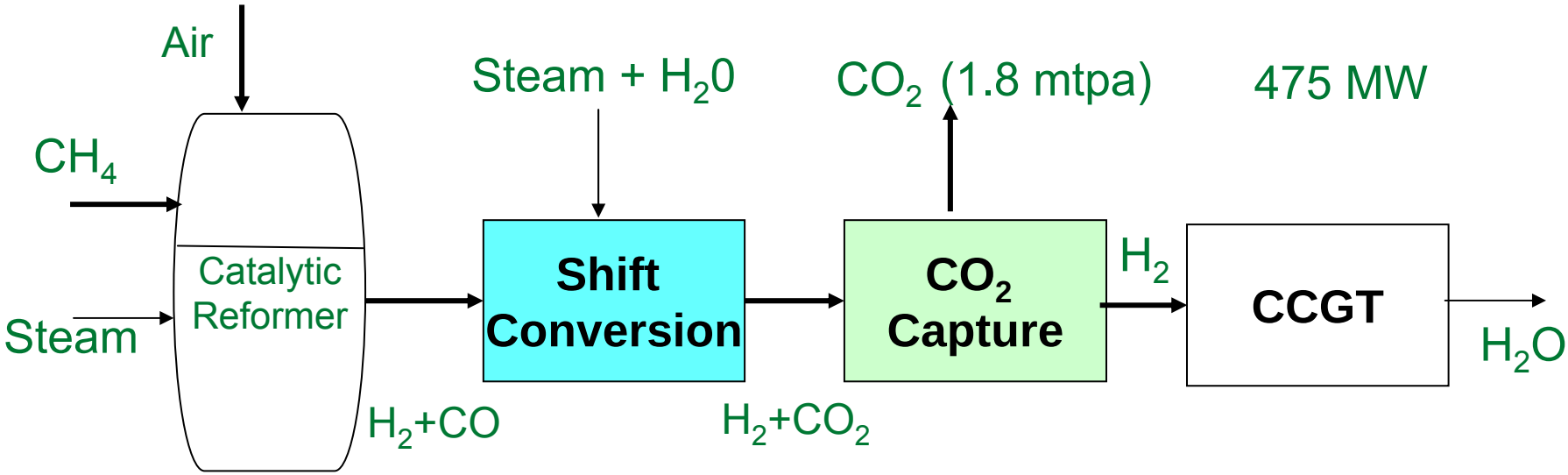
- Project Partners: Scottish & Southern Energy, ConocoPhillips and Shell
- Industrial-Scale Demonstration of Hydrogen Manufacture from Natural Gas with CO2 Capture & Storage
- Recycles Existing Infrastructure for Power Generation and Oil Production
- 475MW Power Generation with >90% capture
- 1.8mmtpa CO2 Could be Avoided
- CO2 Storage: CO2 used enhance oil recovery (50mmbbl)
- $600+mm Investment
- Planned to start in 2010
- Needs a Policy Framework to compete with Fossil Fuels and kick-start the Hydrogen Economy

DF1 based upon current state of the technology: How does this fit with Dynamis objectives?

Peterhead & Miller (Scotland): 2010



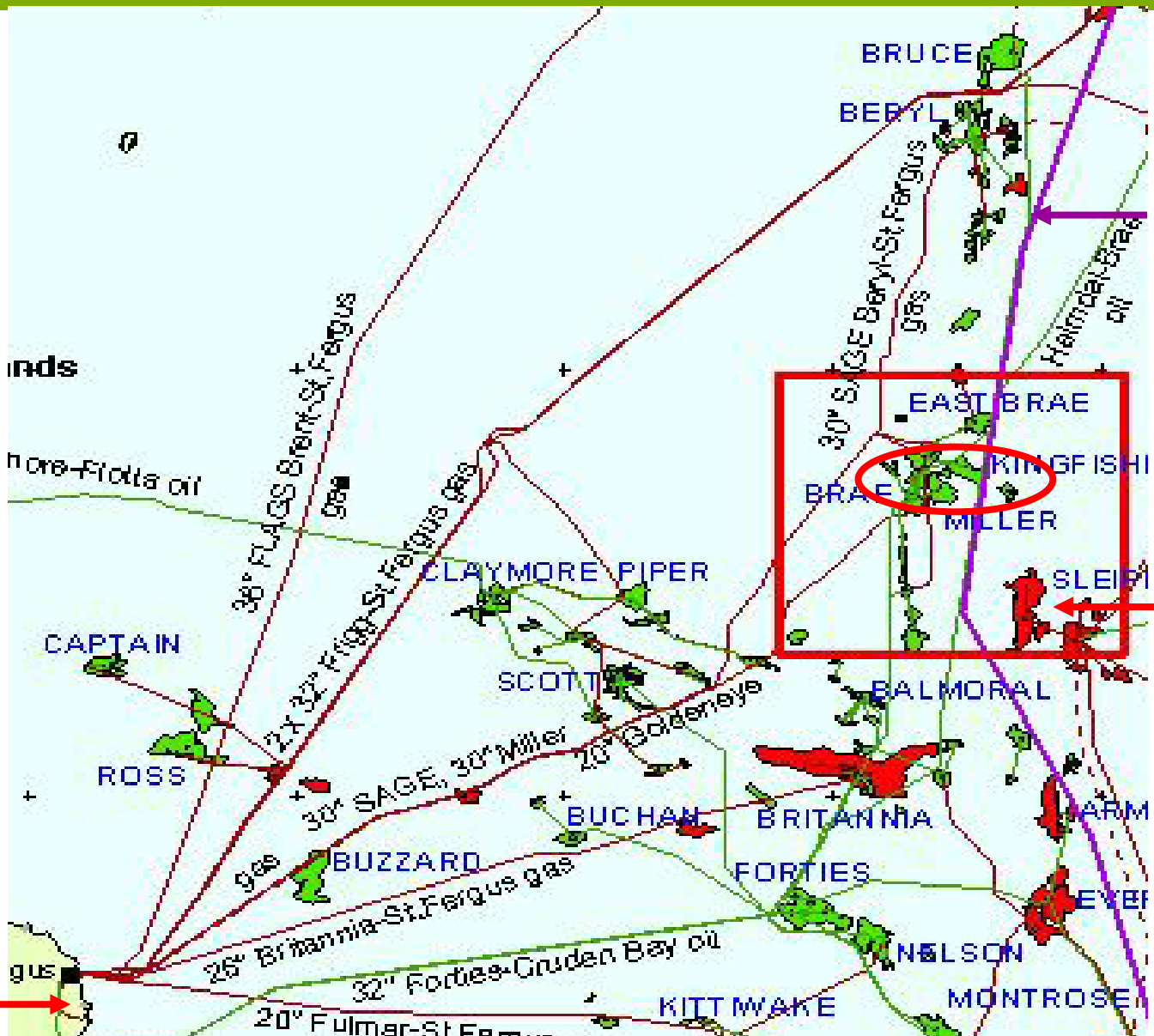
Process Summary



Proven Technology

- **Uses proven reforming technology to manufacture syngas from CH_4 (BP Trinidad)**
- **Uses proven shift reaction then performed to generate H_2 and CO_2**
- **Uses proven amine capture technology to capture remove CO_2 (BP Algeria)**
- **Hydrogen fired CCGT proven and warranted by vendors**
- **Duplex steel well completions of Miller proven capable of handling CO2**

Project Location (UK North Sea)



Project Timeline

Activity	Timing
FEED	**Q2 2006**
Sanction (Investment Decision)	**Q1 2007**
Mechanical Completion	**2009**
Operation	**2010**

Miller Storage Program

1. Inject CO_2 into the Miller reservoir

- **6,000 tpd (100 mmscfd at 90%) from 2010 to 2030**
- **Assure CO_2 disposal – well number, injectivity, availability**

2. Assure storage of injected CO_2

- **Maintain reservoir pressure below original**
- **Assess CO_2 seal integrity over 1,000 yrs**
- **Assess and mitigate potential CO_2 migration**
- **Monitor for potential leakage during injection**
- **De-commission wells as required to mitigate leakage**

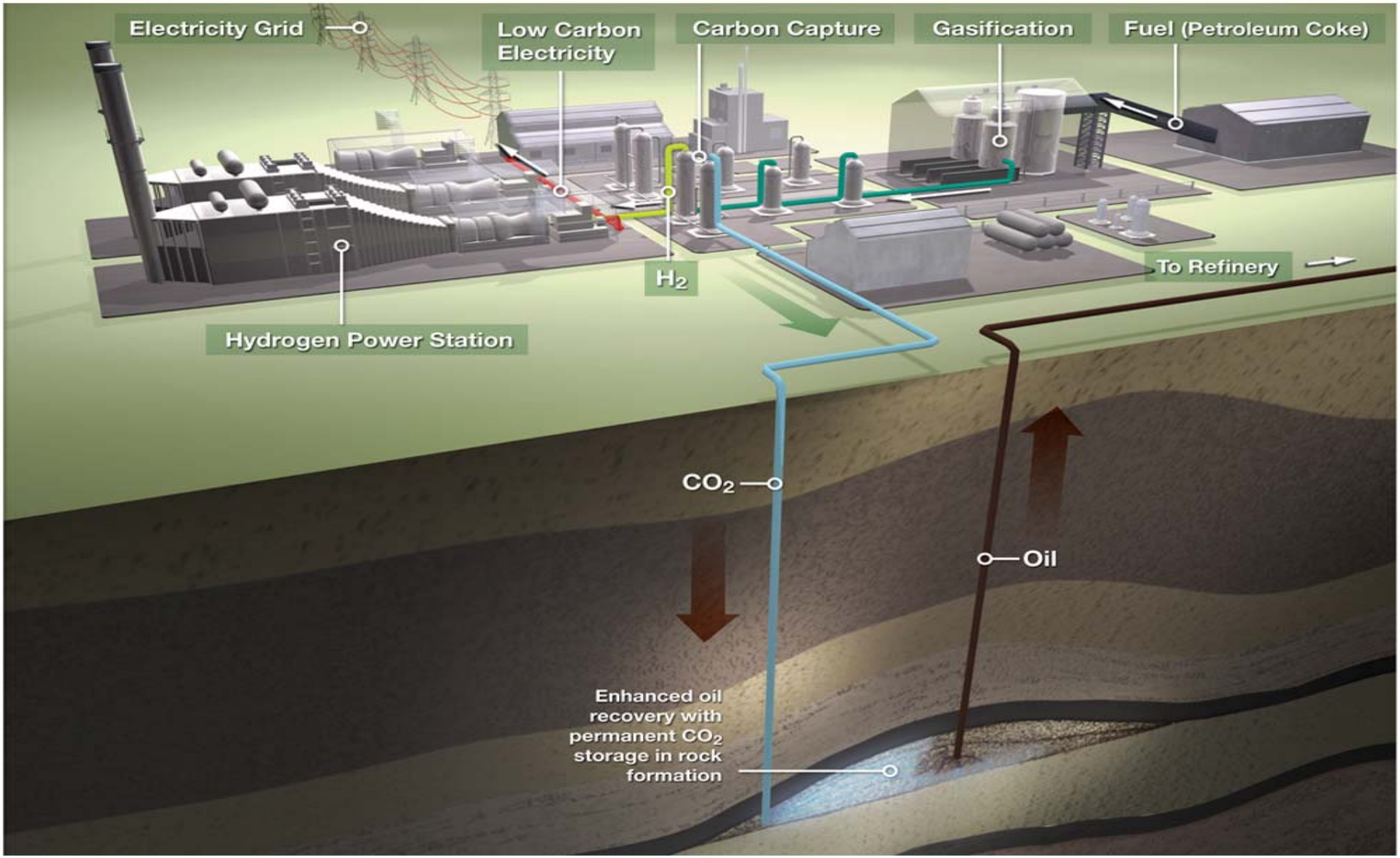
3. Produce incremental oil

- **Re-inject the re-produced CO_2 (100 mmscfd, rising to 200 mmscfd with recycle)**
- **Manage CO2 flood to maximise oil production and minimise water production**
- **Use existing wells, workover as required**

Carson Hydrogen Power Project (California)

- Project Partners: Edison Mission Energy
- Industrial-Scale Demonstration of Hydrogen Manufacture from Petroleum Coke with CCS
- Brownfield site
- 500MW Power Generation
- 4mmtpa CO2 Could be Avoided
- $1,000mm Investment
- Planned to start in 2011
- To be competitive, this project needs access to the new policy frameworks being put in place in California and at Federal level

Carson Hydrogen Power Project (CA): 2011

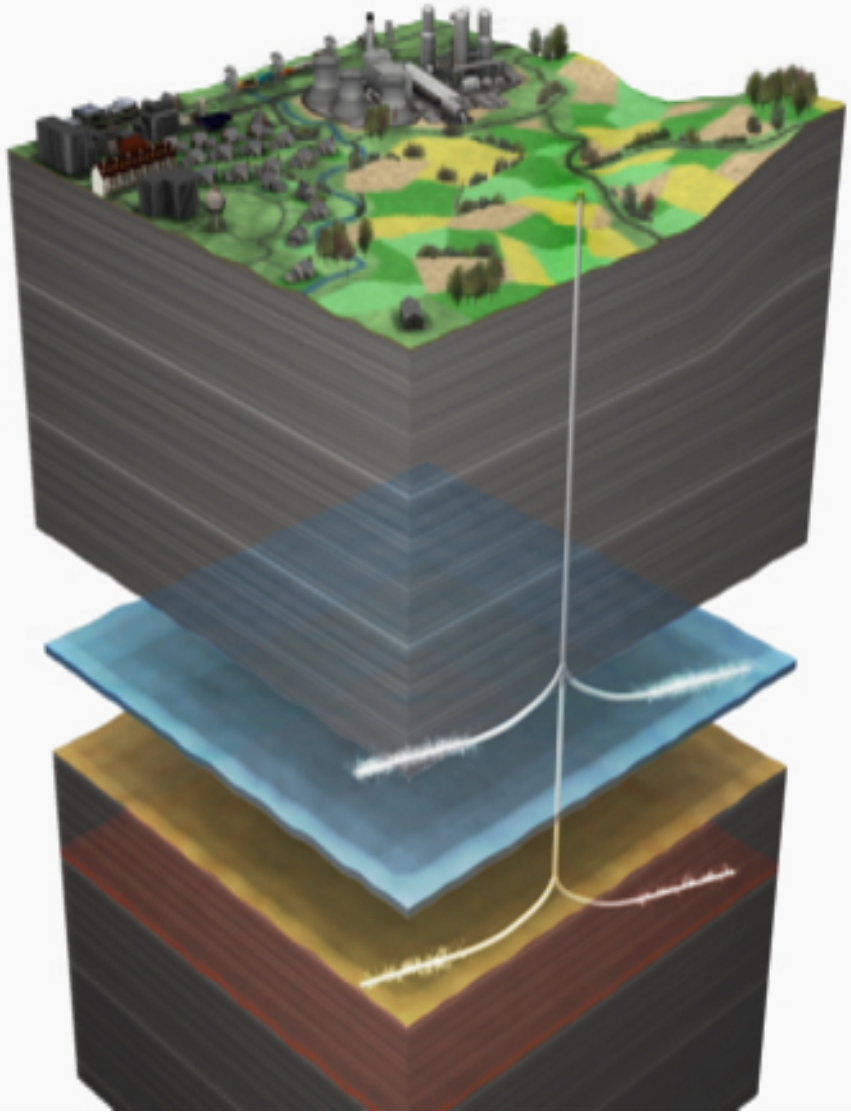


Summary

- **BP is Taking Steps Towards CCS Deployment**
- **What's required:**
  - **Regulatory Framework: Is it Legal?**
  - **Policy Framework: Can Investors get Paid?**
  - **How to deal with: Long-term Liability?**
- **Peterhead and Carson are helping to develop answers to the three key questions**
- **BP is ready to invest in CCS projects in locations where there is a chance that the three key questions get answered in the near future**
- **BP is evaluating other opportunities for CCS Projects……..**

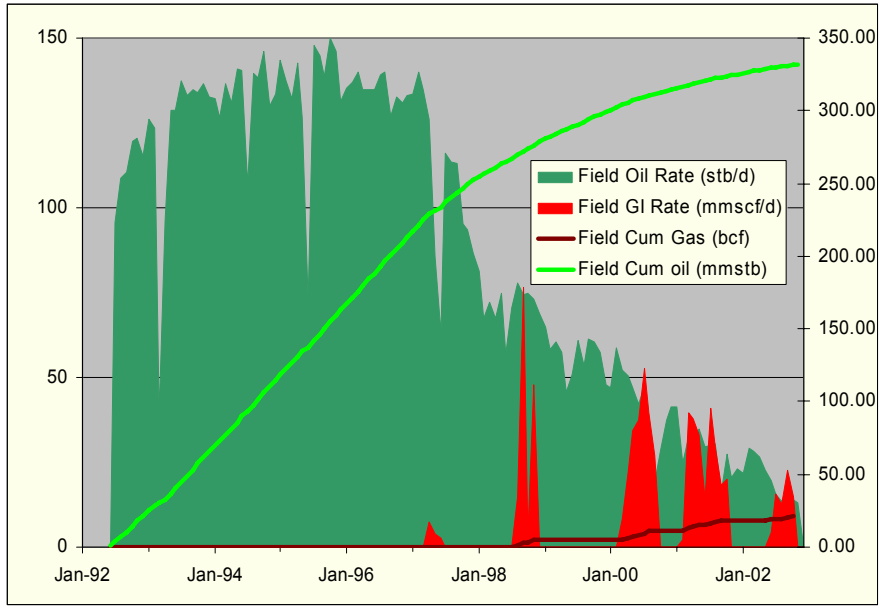
Back-up Slides

CO2 Storage from a Power Plant



Miller Field: History

Depth	4090 m (OWC)
Temperature	120 C
Initial pressure	7300 psia
Current pressure	6400 psia
Bubble point	4680 psia
GOR	1900-2100 scf/bbl
Gas	24% CO_2, 29% C_2+
Oil viscosity	0.14 cP
MMP Assoc Gas	~3000 psia



Mobile oil column

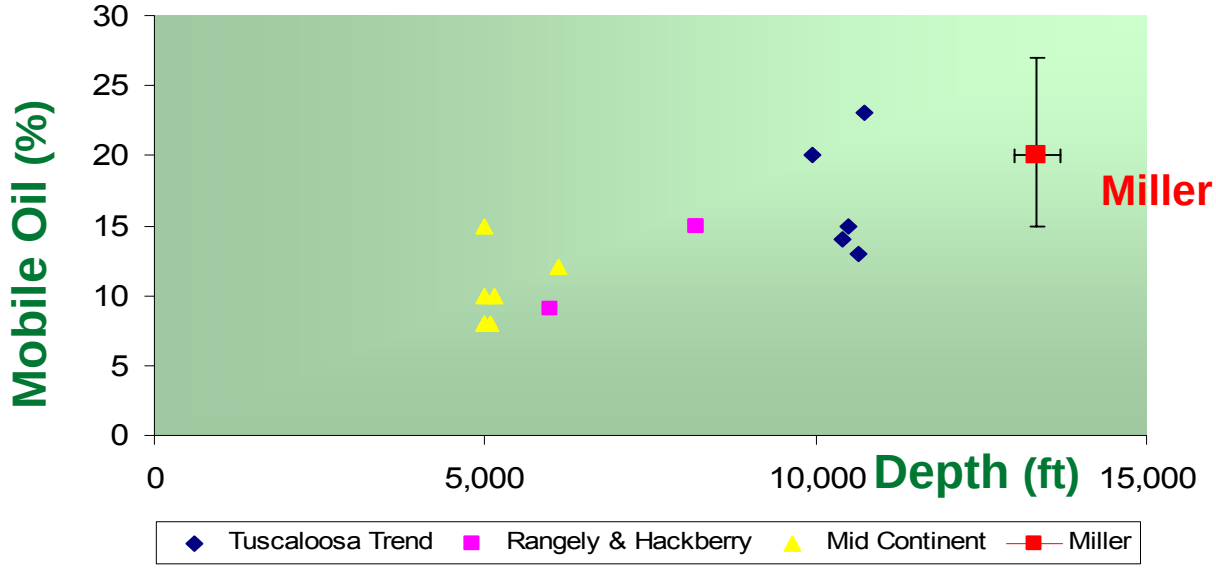
STOIIP	586 mmstb
Produced (05)	333 mmstb (56%)

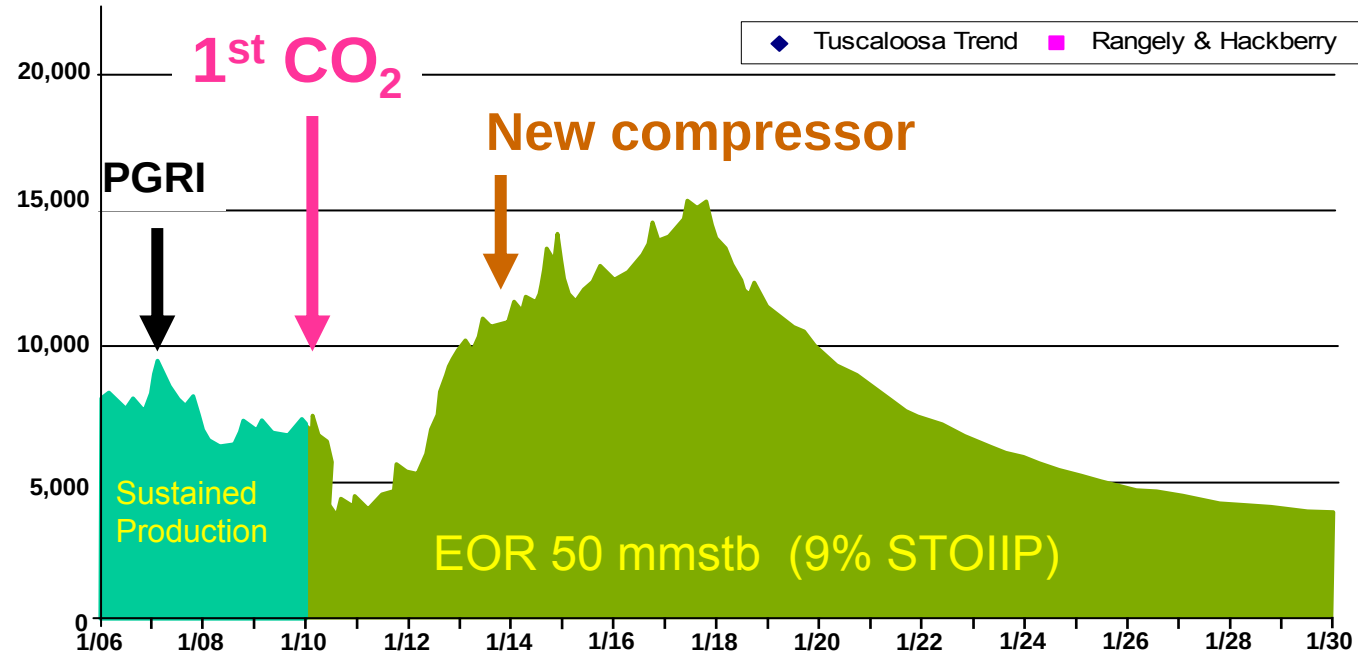
- **Water flood started 1992**
- **AGI 1997 - 2003**
  - **halted on commercial grounds**
- **Planned COP 2006**
- **CO2 Project first considered: 2005**
- ***Sustained Production 2007 -2009***
- ***CO2 Flood 2010 - 2029***

Focus on CO_2 Storage at Miller

- **Miller Field**
- **CO_2 injection**
  - **New CO_2 = 100mmscf/d**
  - **Recycling = 200mmscf/d**
- **CO_2 EOR**
  - **Design rate = 150mbd, 15 years**
  - **EOR rate = 10mbd, 30 years**
- **Storage Monitoring Program Development**

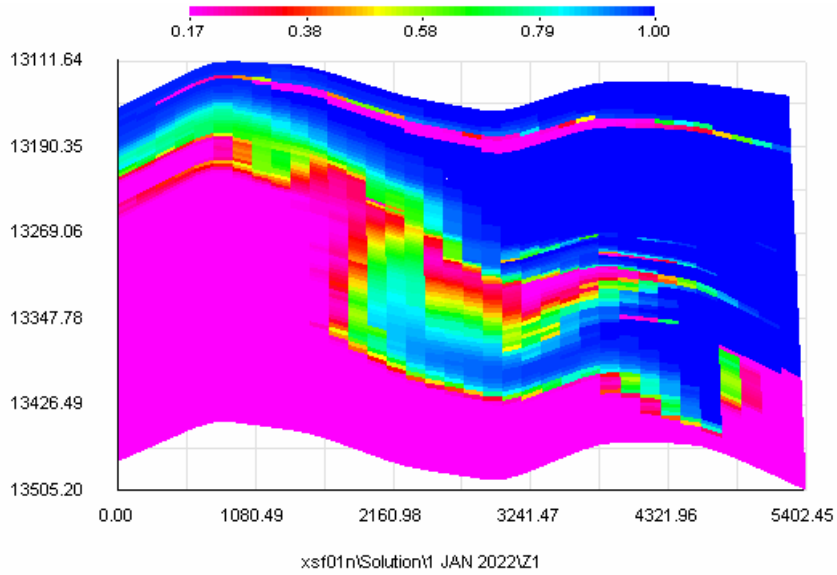
CO_2 EOR Analogues & Production Forecast





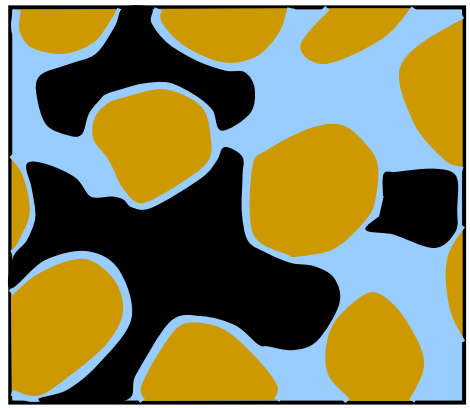
CO_2 Enhanced Oil Recovery

- **Miller produced gas (24% CO_2) displaces nearly 100% of residual oil at pore scale (lab experiments)**
- **Volumetric sweep efficiency of water flood was very high**
- **Key determinant of CO_2 sweep efficiency is degree of vertical layering (buoyancy vs viscous forces)**

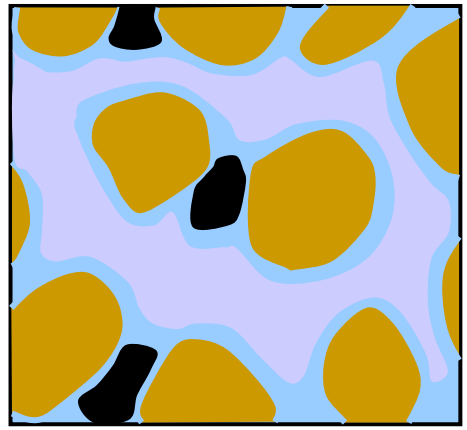


CO_2 saturation in fine scale vertical slice of flow simulation model

Post water 29-32% oil



Mobile oil target 15-27% of pore volume



Post $C0_2$ 5-14% oil

- **Predicted incremental recovery 9% of original oil in place**
- **Analogues range 7-17% incremental recovery**

A Storage Monitoring Program?

EOR Reservoir surveillance

- CO_2 tracer
- Reservoir logging in observation wells
- CO_2 material balance

Well surveillance

- Annular gas pressures and compositions
- ‘Noise logs’ for flow behind casing in injectors

Seabed imaging

- High-res side-scan sonar + swathe bathymetry

Gas sampling

- Sample any seeps (including natural) for tracer

Water chemistry

- Monitor pH or CO_2 directly to compute seabed flux

Additional surveys

- Shallow seismic + high-res 2D for near-surface gas accumulations
- Logs during workovers