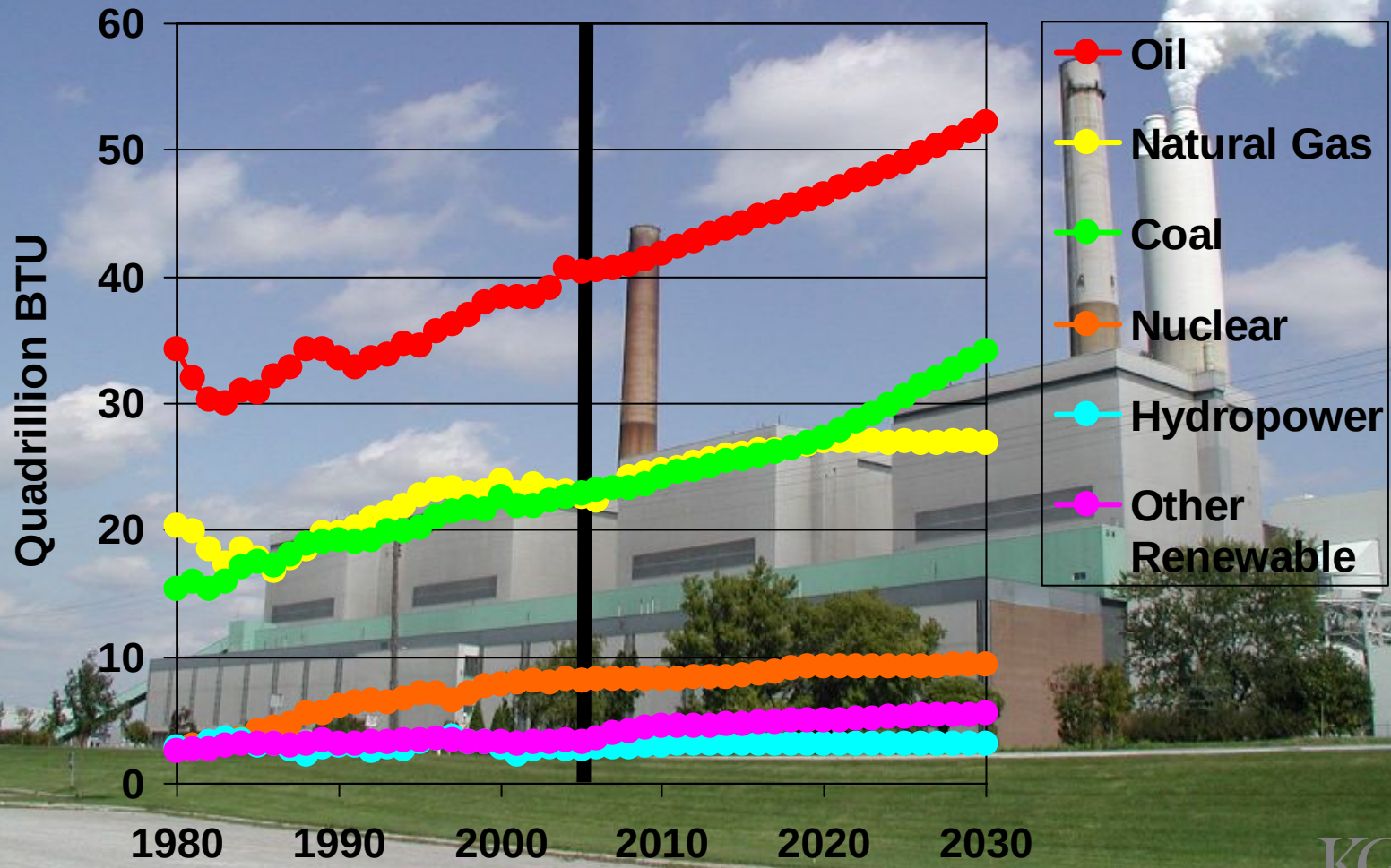
Testing Carbon Storage in the Mississippian/Devonian Black Shale of Eastern Kentucky

Pikeville, KY

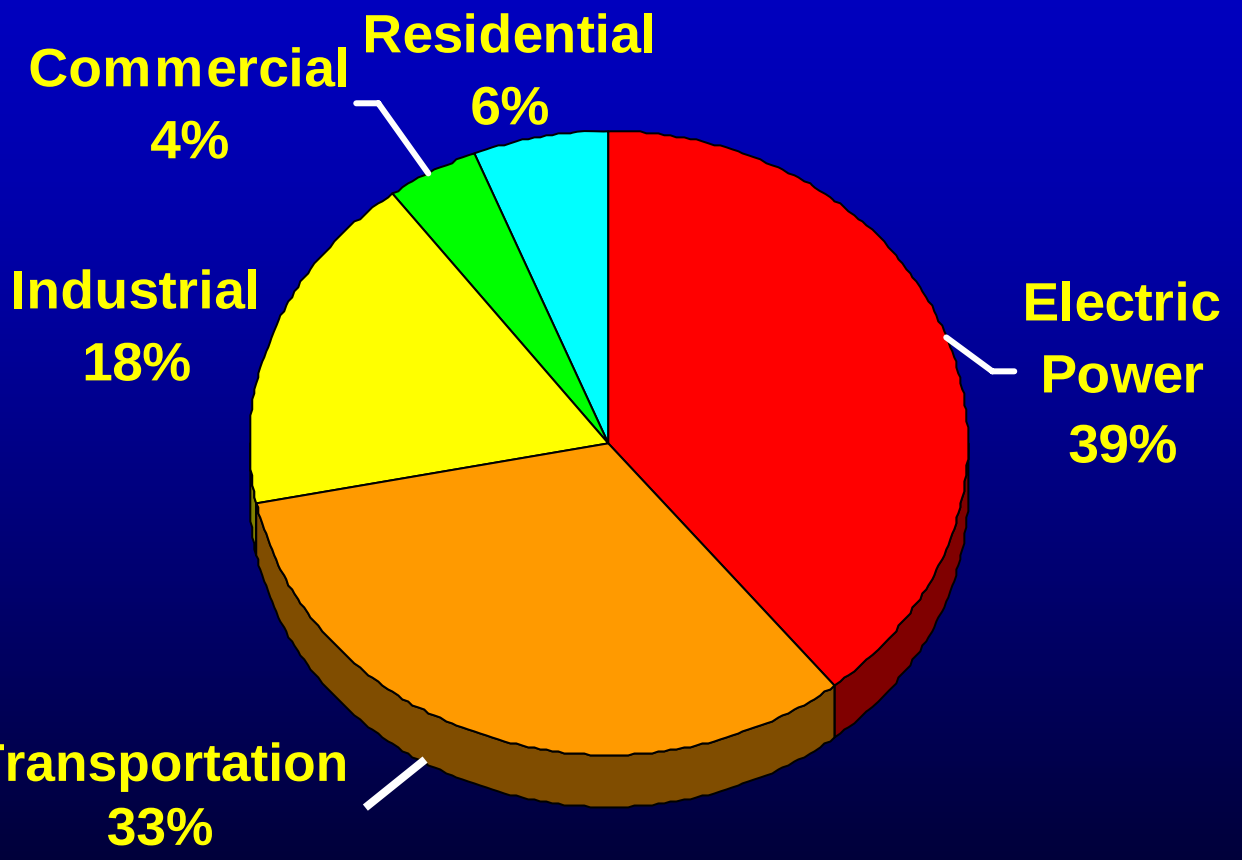
30-Apr-2008

The Energy Crystal Ball



EIA Annual Energy Outlook

U.S. CO_2 Emissions, 2004



5.96 billion metric tonnes

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www.eia.doe.gov/environment.html

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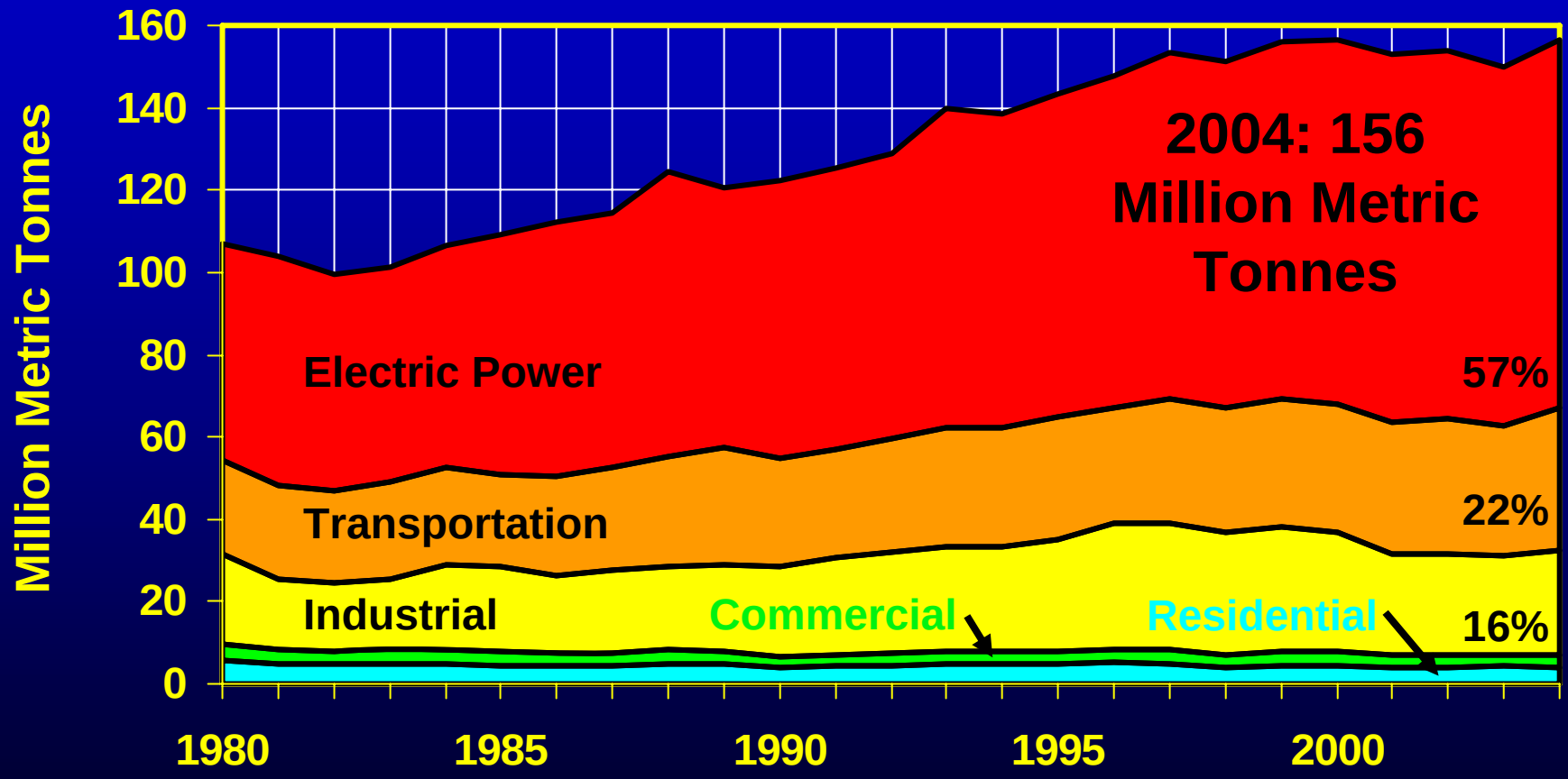
Kentucky CO_2 Emissions



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www.eia.doe.gov/oiaf/1605/state/state_emissions.html

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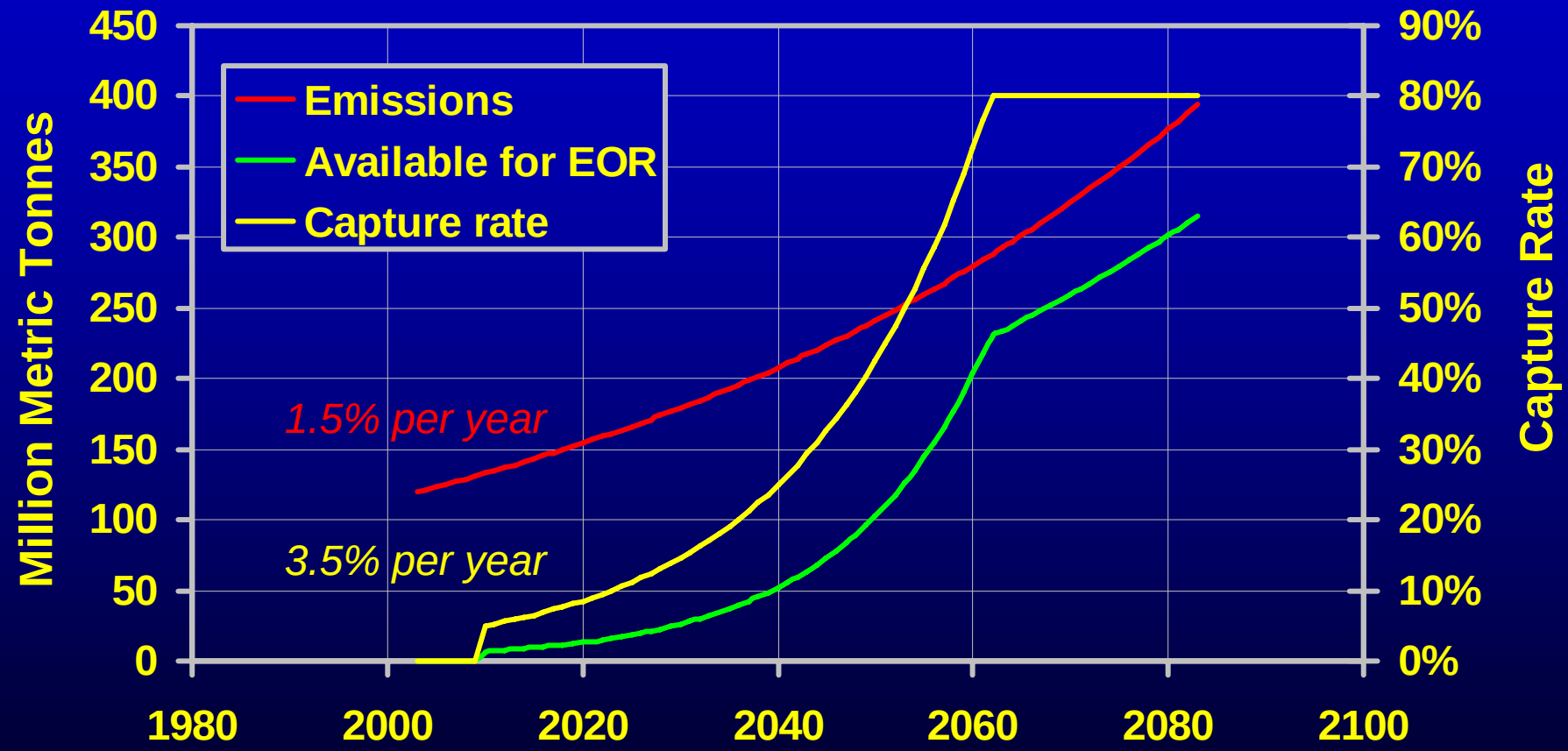
CO_2 Supply & Availability



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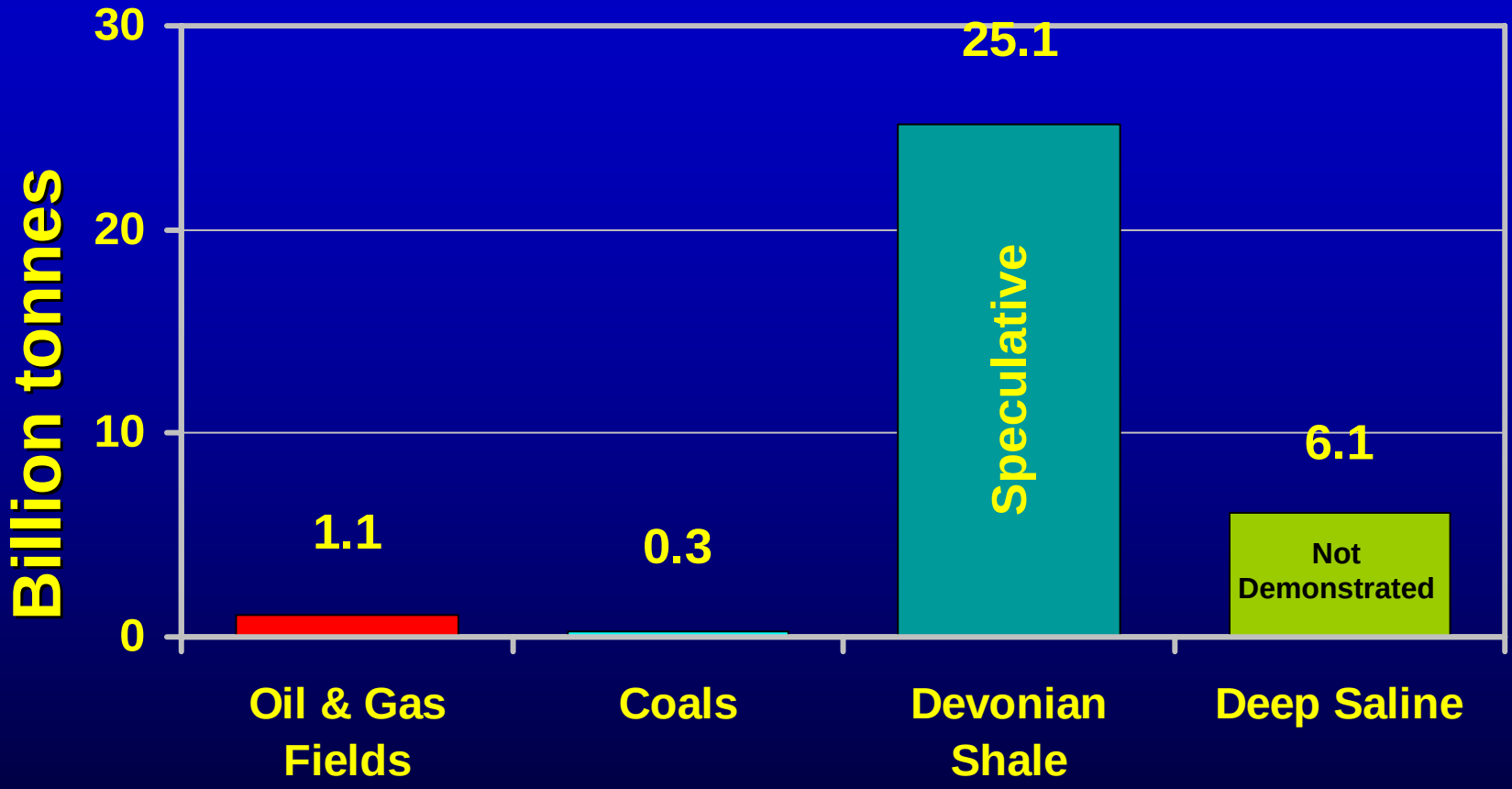
Phase I: CO_2 Storage



32.5 billion tonnes total (>300 years)

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The “Black Shale”

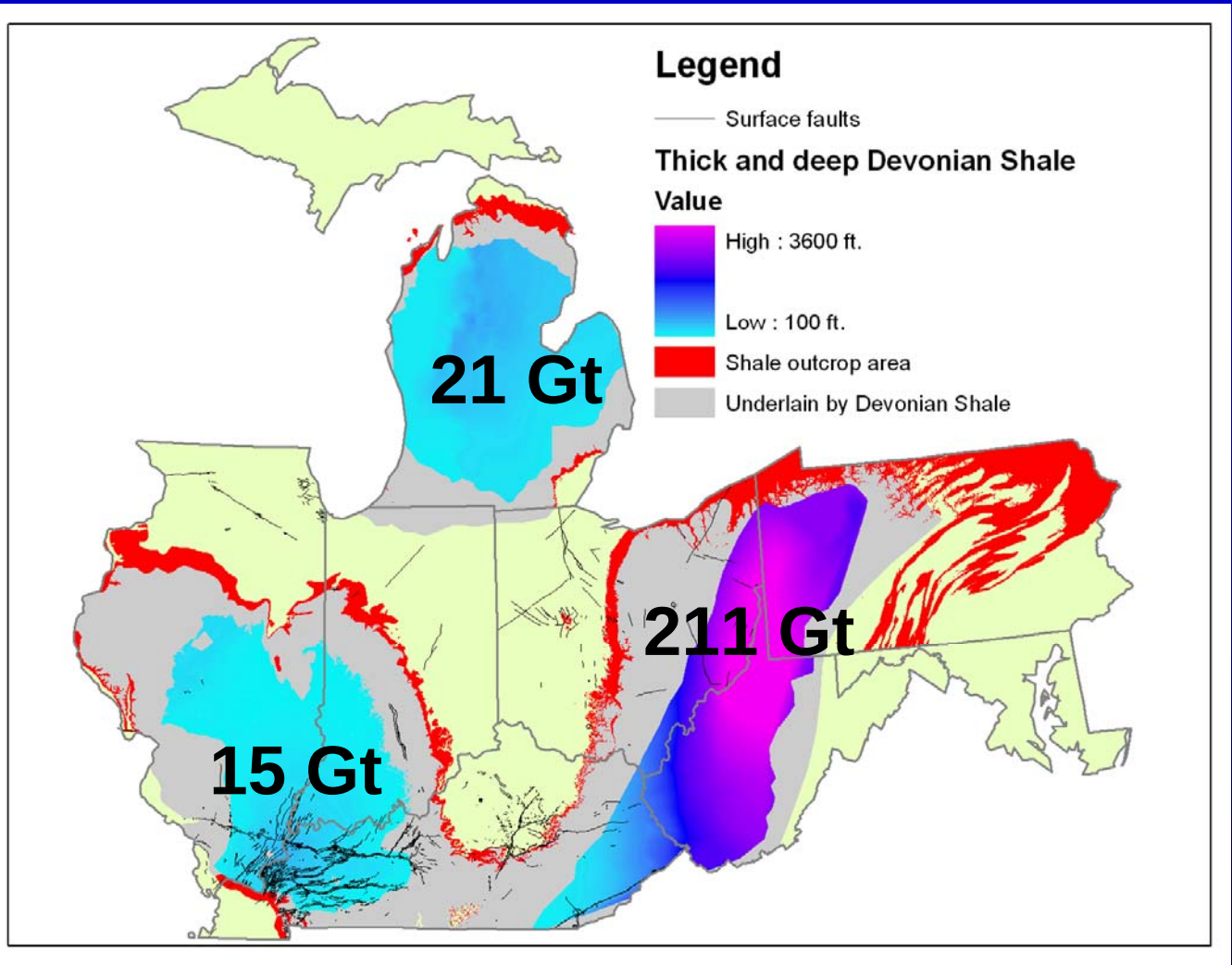
- Fissile
- Alternating
  - Gray (Q+C)
  - Black (organic)

(Not to scale)

New Albany

Ohio

Sequestration Capacity



247 Gt

The fine print

- **Volumetric –** ***based on typical gas adsorption***
- **Speculative –** ***not demonstrated***

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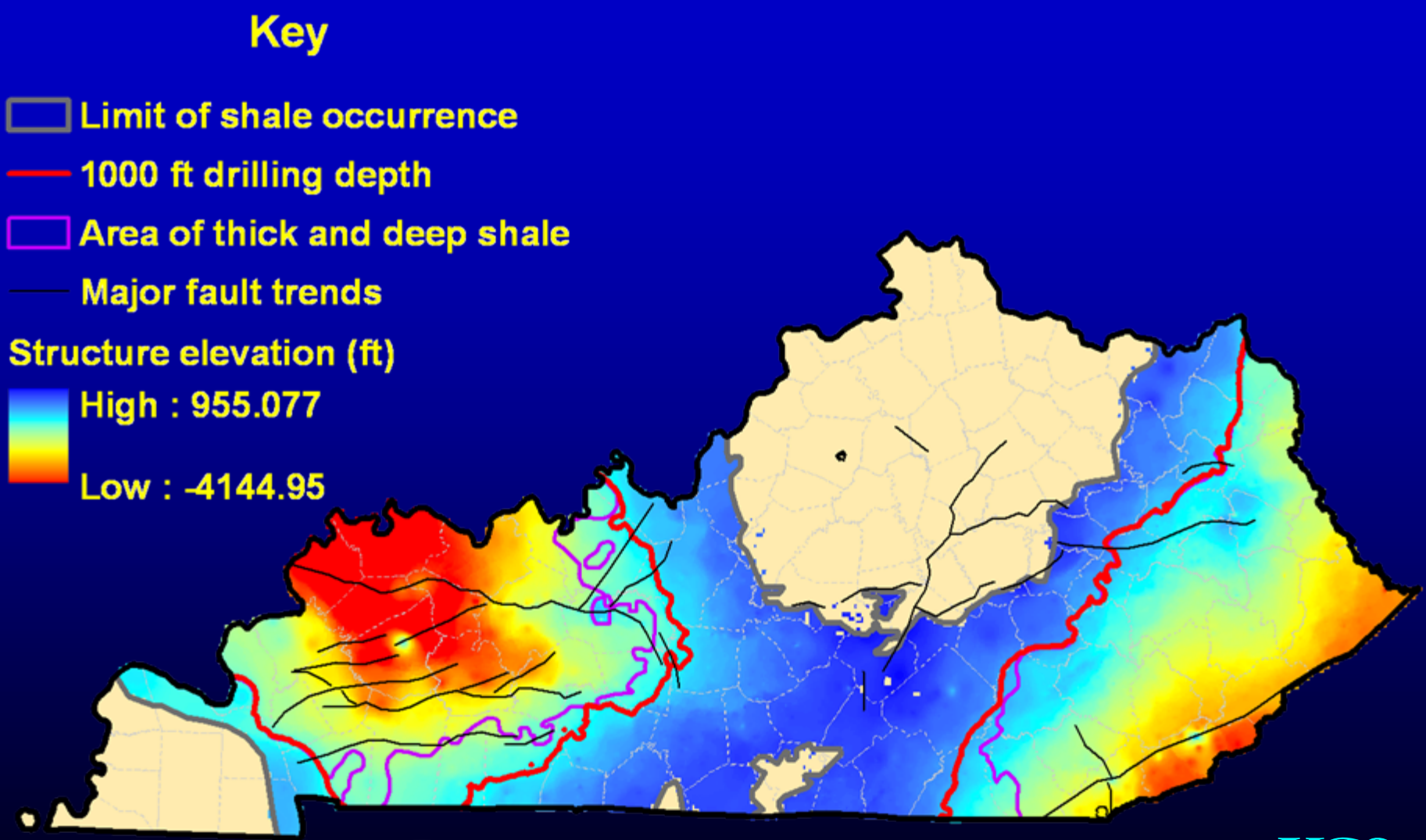
Geology of Devonian Shale



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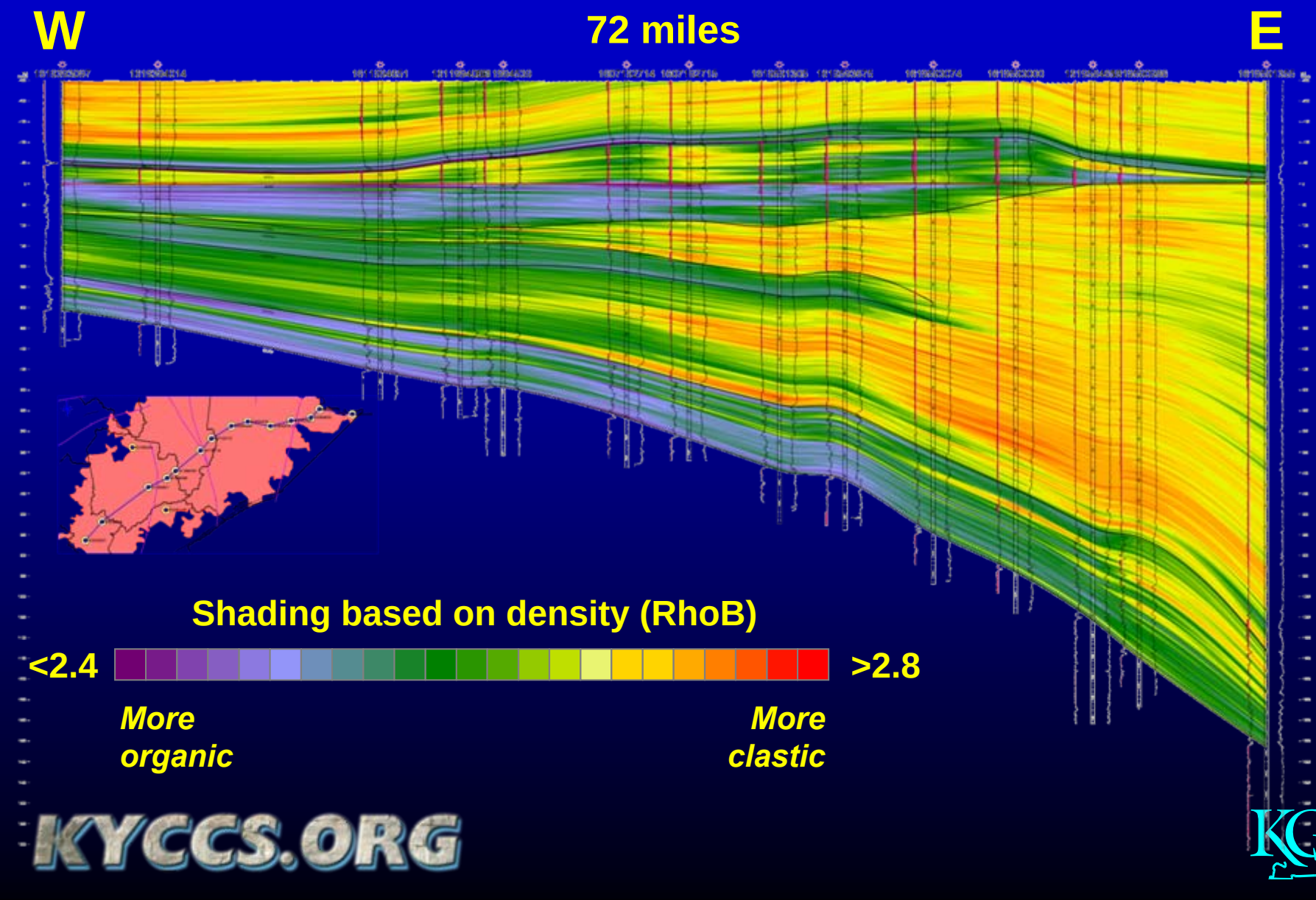
Cross Section



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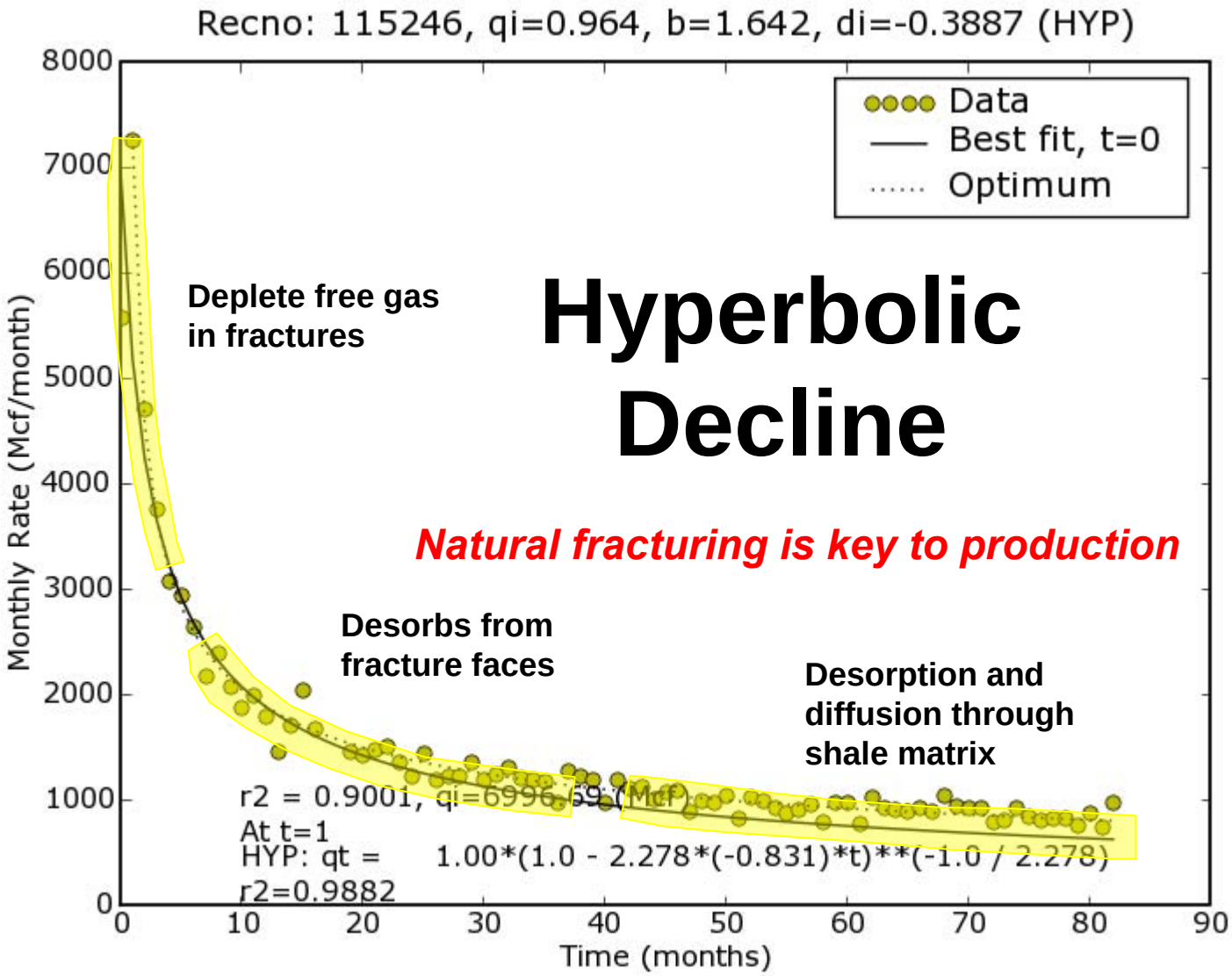
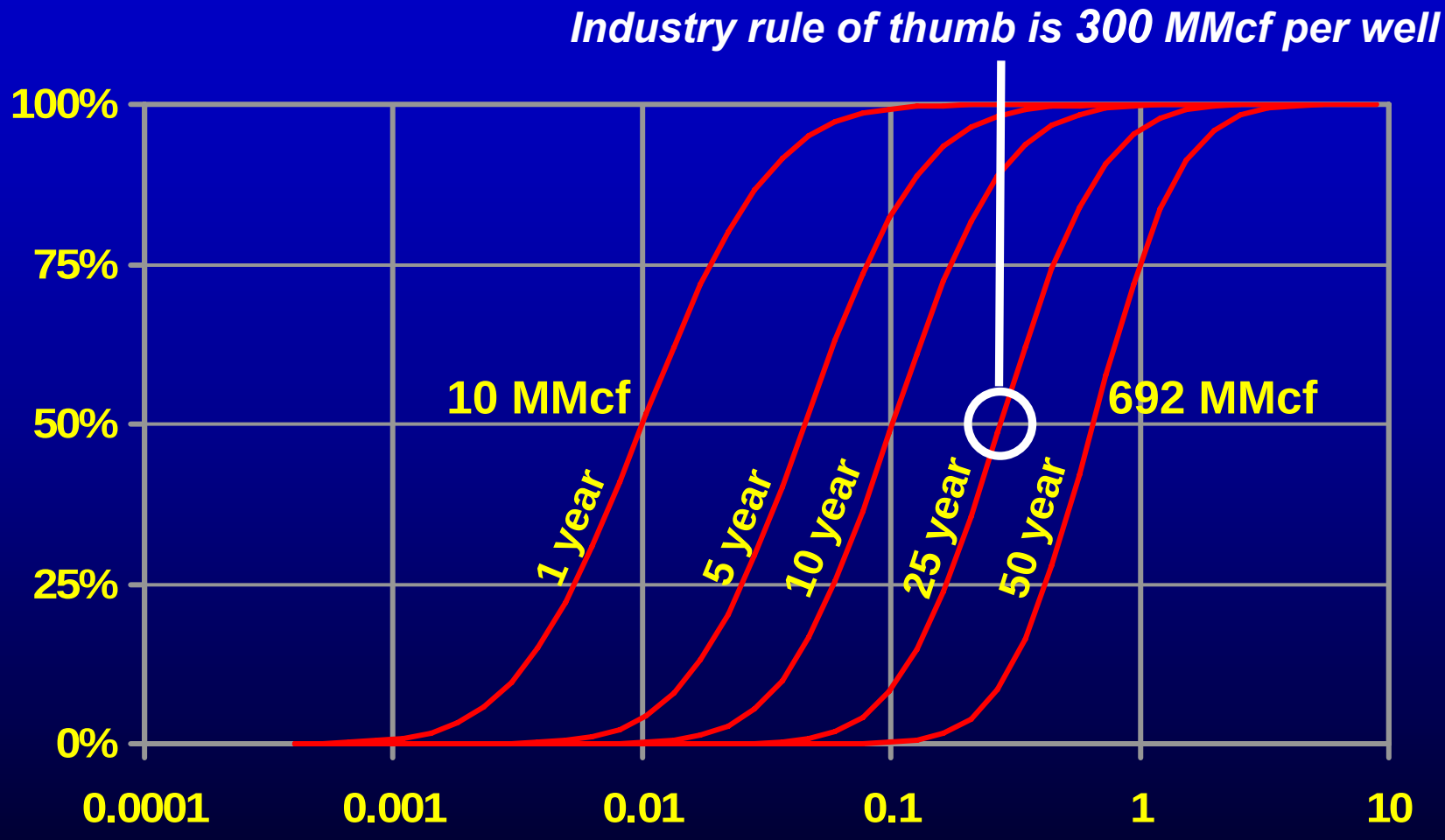
Devonian Shale Reservoir

- Low permeability (microdarcies)
- Micro-porosity
- Organic-rich (up to 25% TOC)
- Thickness
  - > 1,600 feet (eastern Kentucky)
  - > 400 feet (western Kentucky)
- Kentucky's most active and prolific gas producer



Cumulative Production



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Proprietary GTI data

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Cumulative Production Notes

- 50% of shale wells produce at least 692 million cubic feet (MMcf) in 50 years
- Long production history indicates large adsorbed gas content


Why Test the Devonian Shale?
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Paradigm

If natural gas can diffuse through the shale matrix to be produced, carbon dioxide should be able to diffuse into that same matrix.

CO_2 Enhanced Gas Recovery

- Demonstrated in coal
  - Low-permeability
  - Organic-rich
  - Fractured
  - Continuous
- Potentially huge storage volume
  - > 25 billion tonnes

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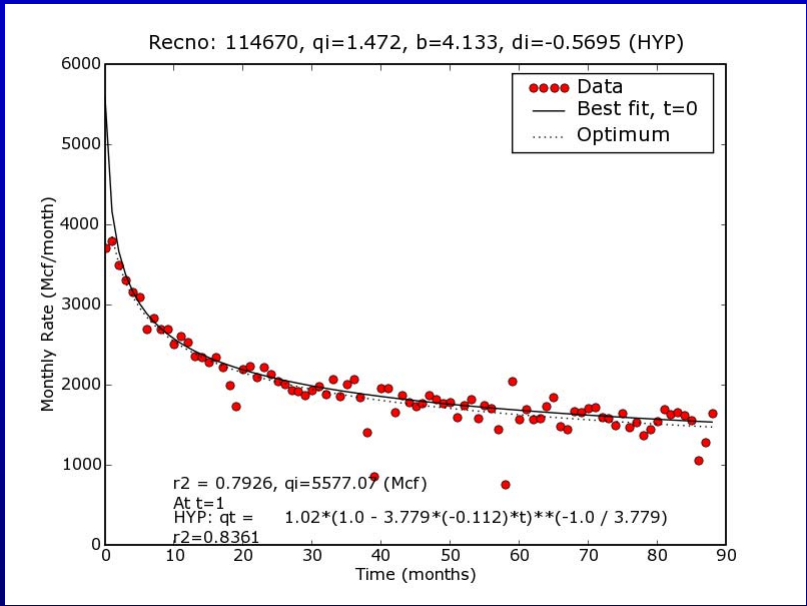
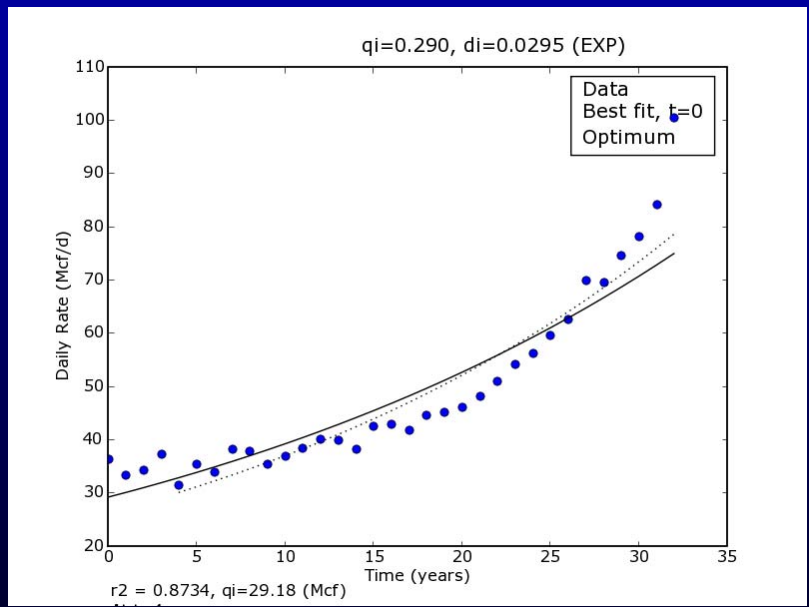
Production Data



Long-term, nearly flat decline

Production for some wells inclines



GTI Proprietary Data

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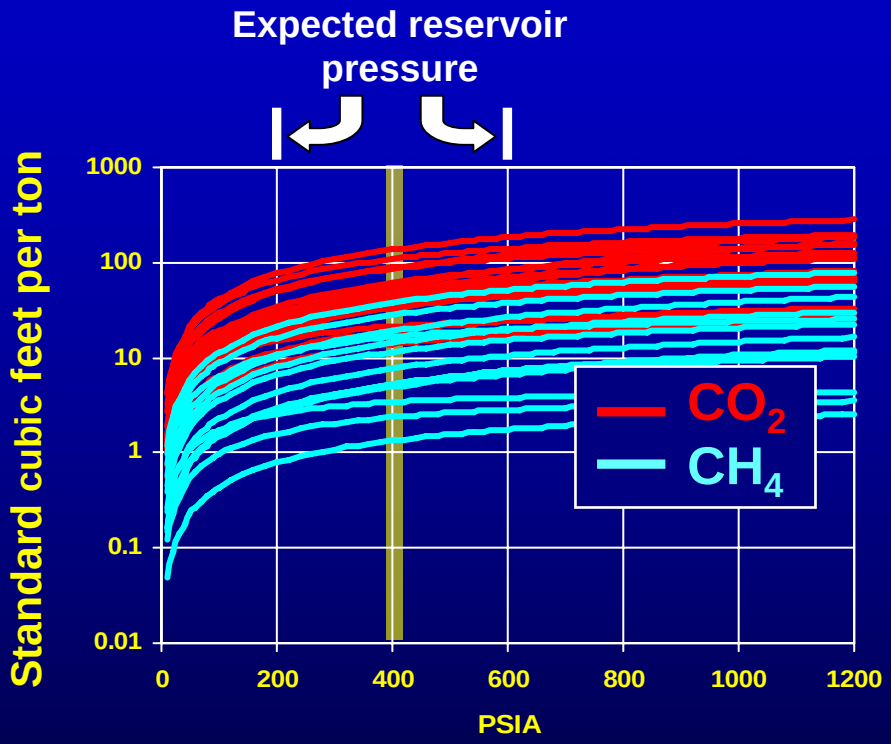
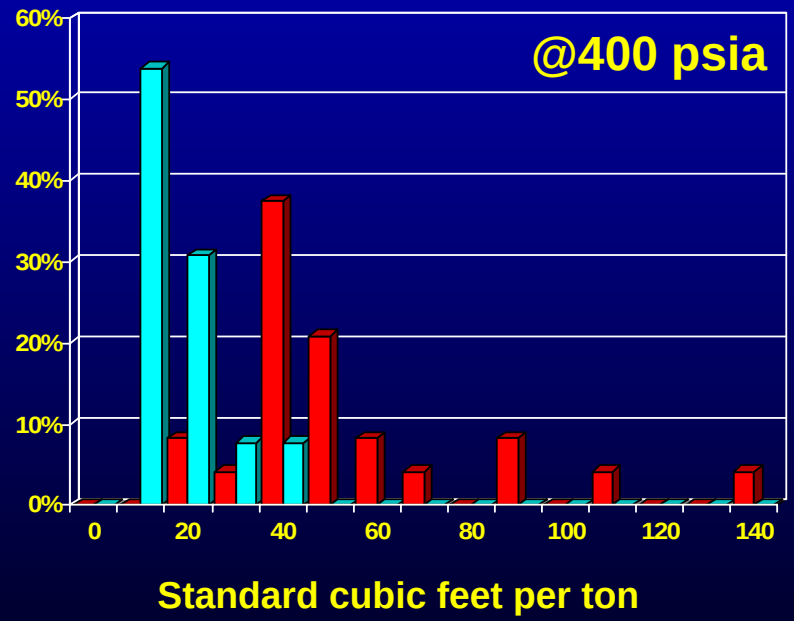
Isotherms Indicate Preferential Adsorption



$CO_2 = 5.3 \times CH_4$

Average CO_2: 42.9 scf/ton

Average CH_4: 8.1 scf/ton



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CO_2/Sand Frac Study

- Yost, Mazza, & Gehr, 1993, SPE 26925
- Fast flowback (2 to 3 days)
- Preliminary production
  - 56% > N_2 frac wells
  - 4.8 x shot wells
- Consistent with CO_2 adsorption


Testing CO_2 Injection for Enhanced Gas Recovery in the Shale
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HB-1 (2007), Section 57

- Specifies: “At least one of the wells will test the Devonian shale for enhanced gas recovery and sequestration potential.”
- Encourages: the Survey to “…use these funds to match available federal and private funds to the extent possible.”

Site Selection Criteria

- Sufficient size pad for equipment
- Access for CO_2 delivery
- Operated by company willing to risk future production (assume liability)
  - Surface, royalty, and working interest owners agree
- Control of all wells within “area of review” for EPA Class V permit

Project Outline

- Consortium
- Site selection
- Data collection, analysis, modeling
  - Background MMV
- Injection
- Data analysis and reporting
  - Model refinement and confirmation
  - MMV

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CO_2 Injection

- EPA Class V
- Small quantities of CO_2
  - Implement procedures for safe handling during injection and testing
  - Not expected to pose long term public hazard (can safely be vented to atmosphere)

Well Selection Criteria

- Standard open-hole nuclear logs
- Logging and sampling
  - Rotary sidewall cores, ECS, and others
- Detailed production data
- Preferred: Nitrogen/foam or slickwater frac, sand-propped (or not yet stimulated)

The Injection Well

- Access to open hole
  - Logging and sampling
- Set 4.5” casing
  - Perforate and stimulate
- Background data acquisition
- Injection
- Site monitoring.

Pre-injection: Data Acquisition

- **Well sampling**
  - **Digital Logs, *Φ*, *k*, mineralogy, TOC, cores**
  - **Gas composition**
  - **Microseismic (VSP) or logging for fracture identification**
- **Stimulation**
  - **Injection rate, volume, pressure, breakdown pressure, flowback period**
- **Background MMV**

Pre-injection: Modeling

- Simulation
  - Multi- Φ, multi-k model
  - Production history match
  - Cyclic Huff-'n'-puff (single well)
  - CO_2 flood (multi-well)
  - Determine optimum shut-in (soak) times and injection rates
- EPA permitting (must submit required data)
- Background MMV

Injection

- Injection volume, rate, pressure, and shut-in times
- Production data
  - Continuous, for injection and monitor wells
  - Rate & composition (variations in CO_2 content)
  - Pressure
  - Mass balance calculations

Post-injection

- History match & model verification
- Assessment & analysis
- MMV continues
- Reporting

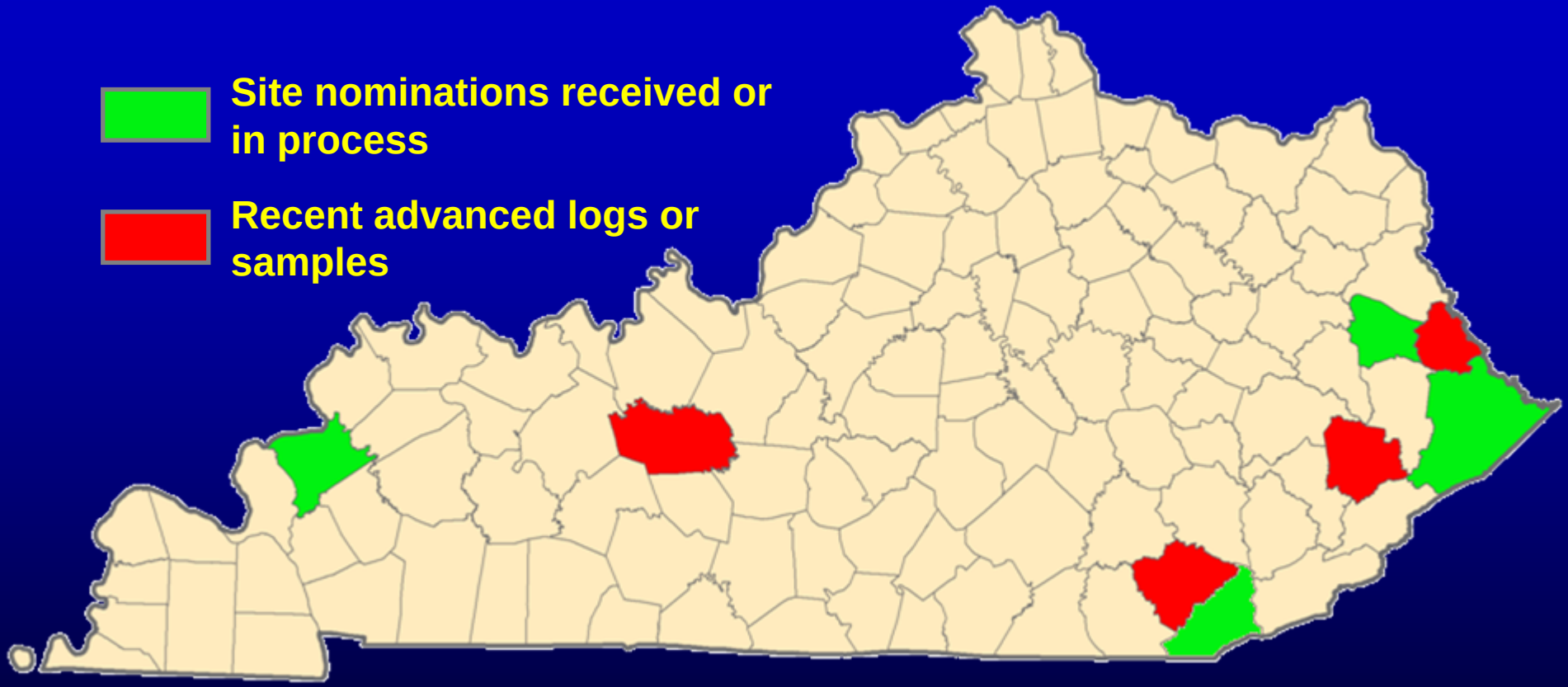
Indicators of Success

- Increase in gas production rate
- Mass balance indicates CO_2 adsorption
- After flowback and cleanup, pipeline quality gas

Status

Site nominations received or in process

Recent advanced logs or samples



KGS Well Sample and Core Library is being searched for additional cores.

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Contact Info

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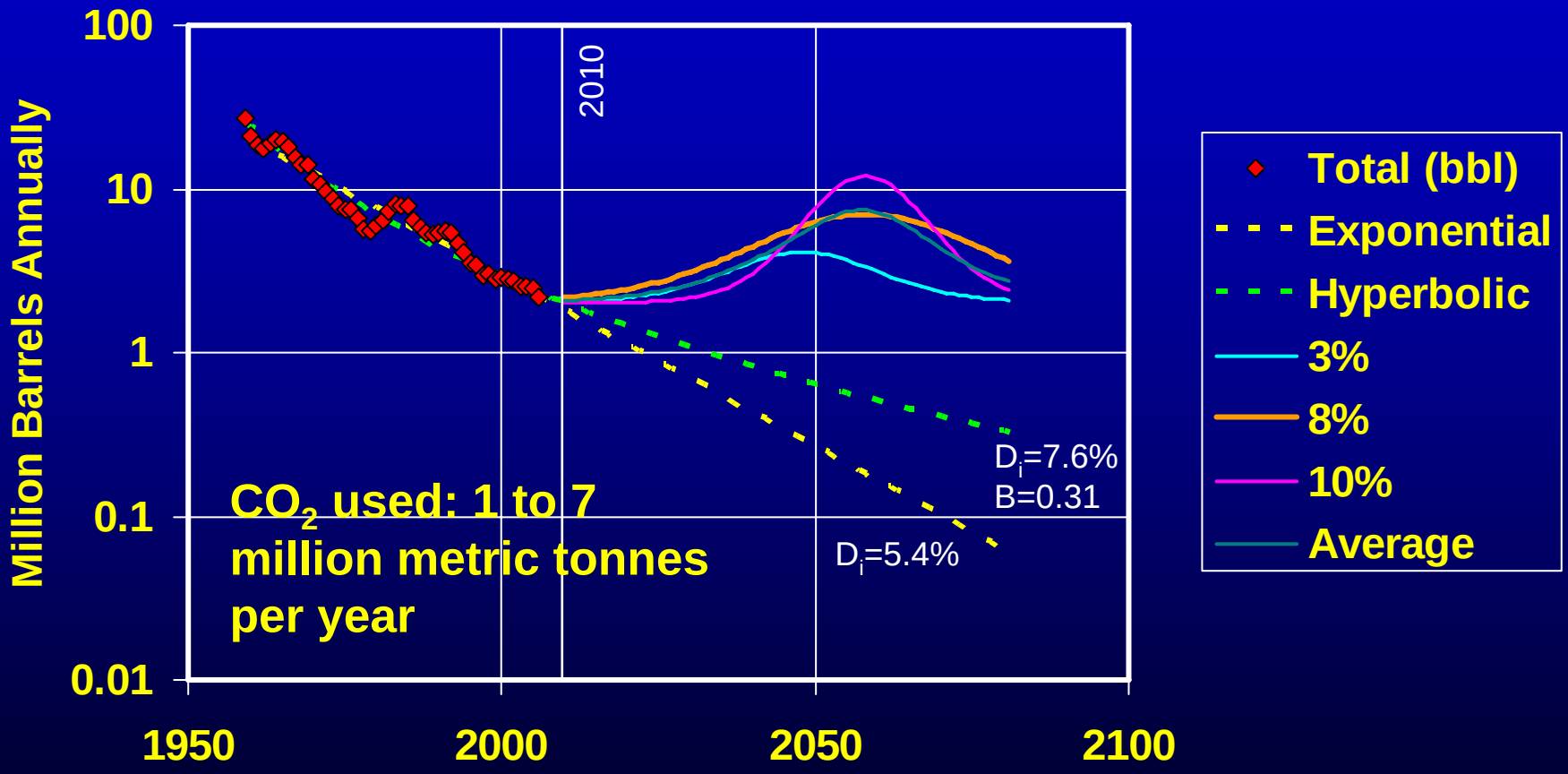
EOR Scenarios

Incremental production from CO_2 EOR: 60 to 200 million barrels



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