Analysis of Oil Shale & Oil Sands Development Scenarios in the Uinta Basin

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What is the cost in $ per barrel to develop Utah's oil shale & oil sands resources?

- What should the cost include?
  - Capital & operating expenses for production/upgrading
  - Cost to get product to market
  - Royalties, bonus & rental payments
  - Severance, income & property taxes
  - Return on investment (ROI)
- What is product & where is market?
  - Raw shale oil/bitumen/synthetic crude oil (SCO)?
  - Is it pipelineable? Other transportation options?
  - Where are refineries located? Can they process these types of crudes?
  - What is product price relative to benchmark crudes?

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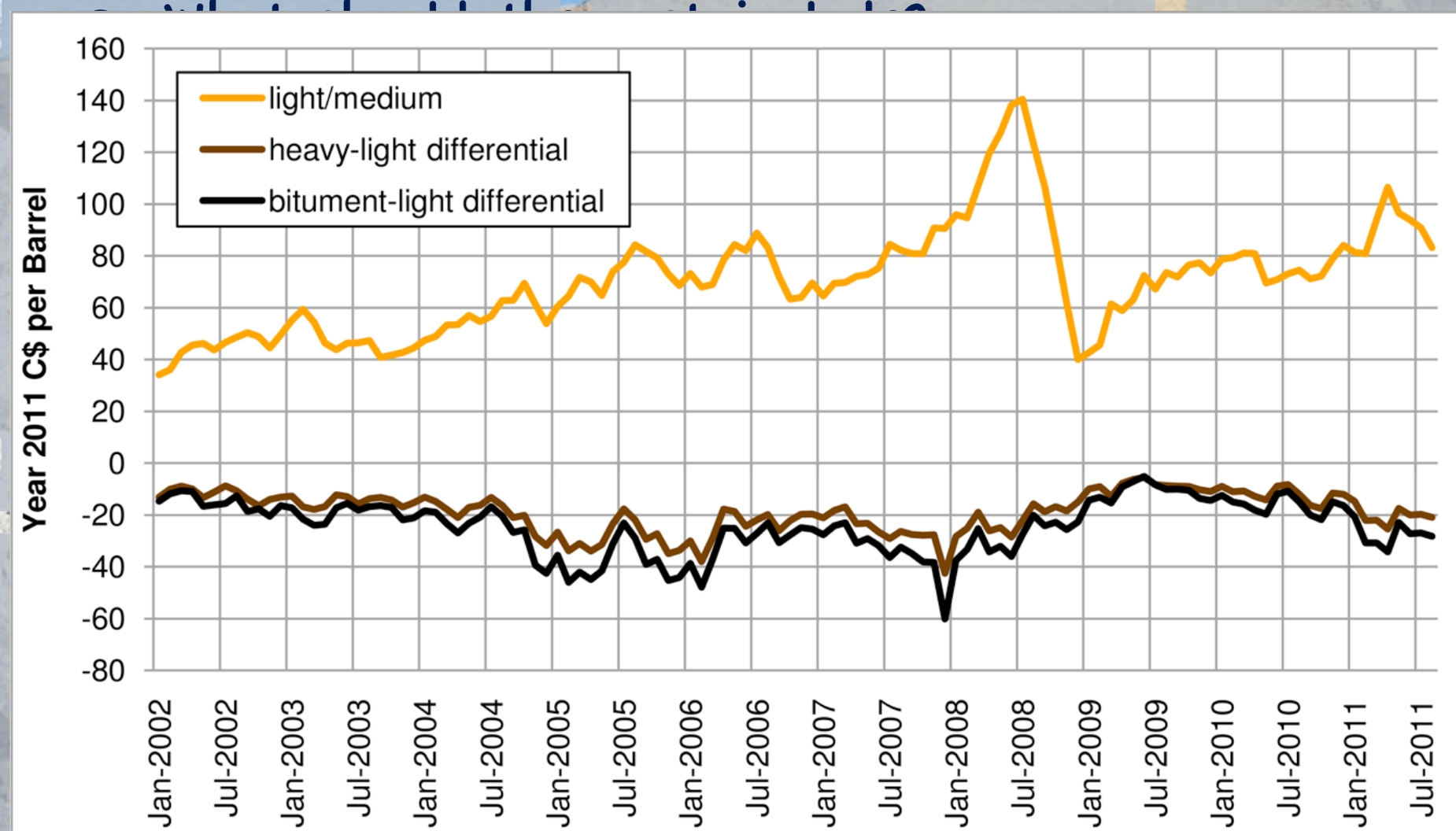

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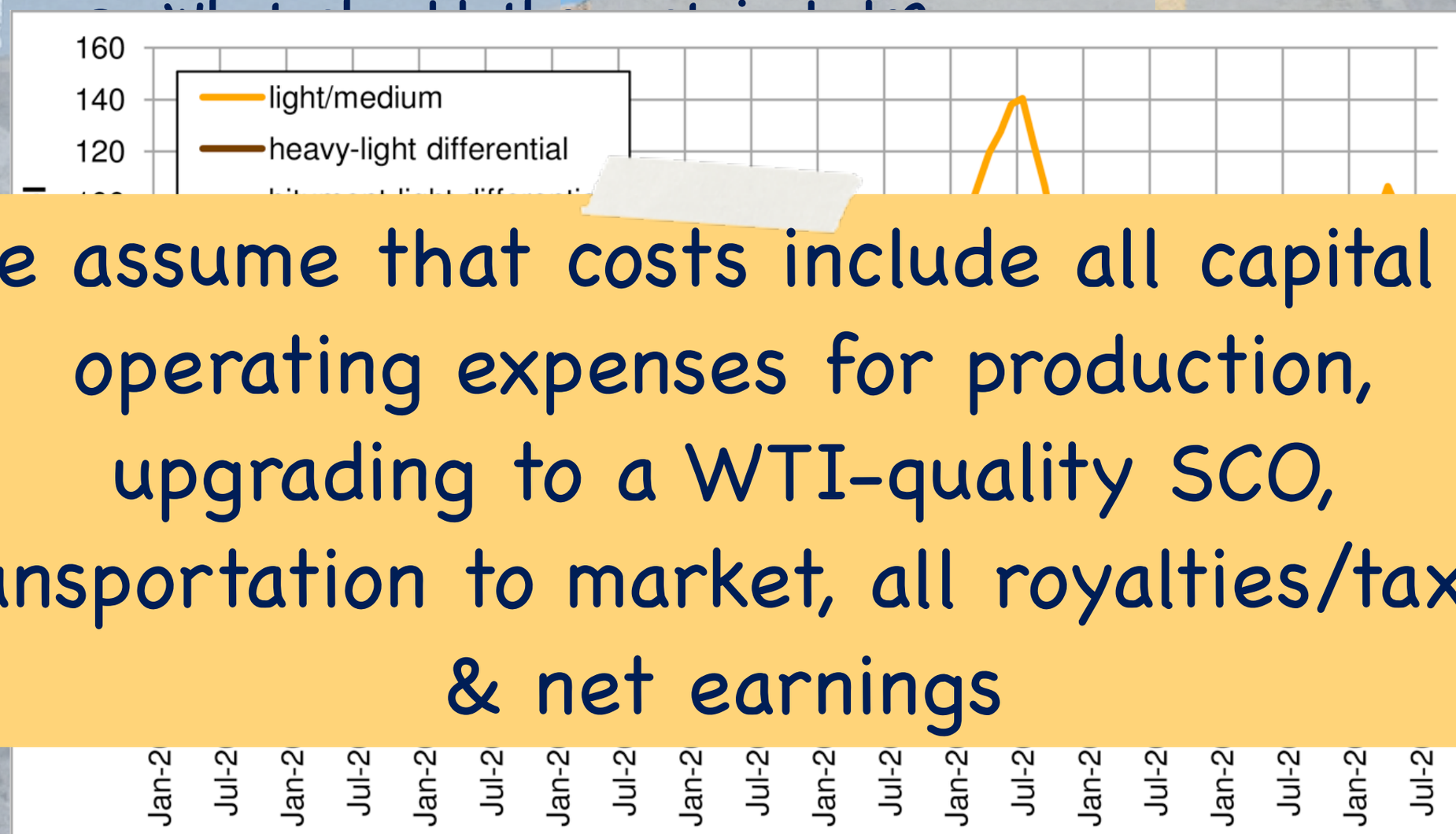

We assume that costs include all capital & operating expenses for production, upgrading to a WTI-quality SCO, transportation to market, all royalties/taxes & net earnings

- What is product price relative to benchmark crudes?

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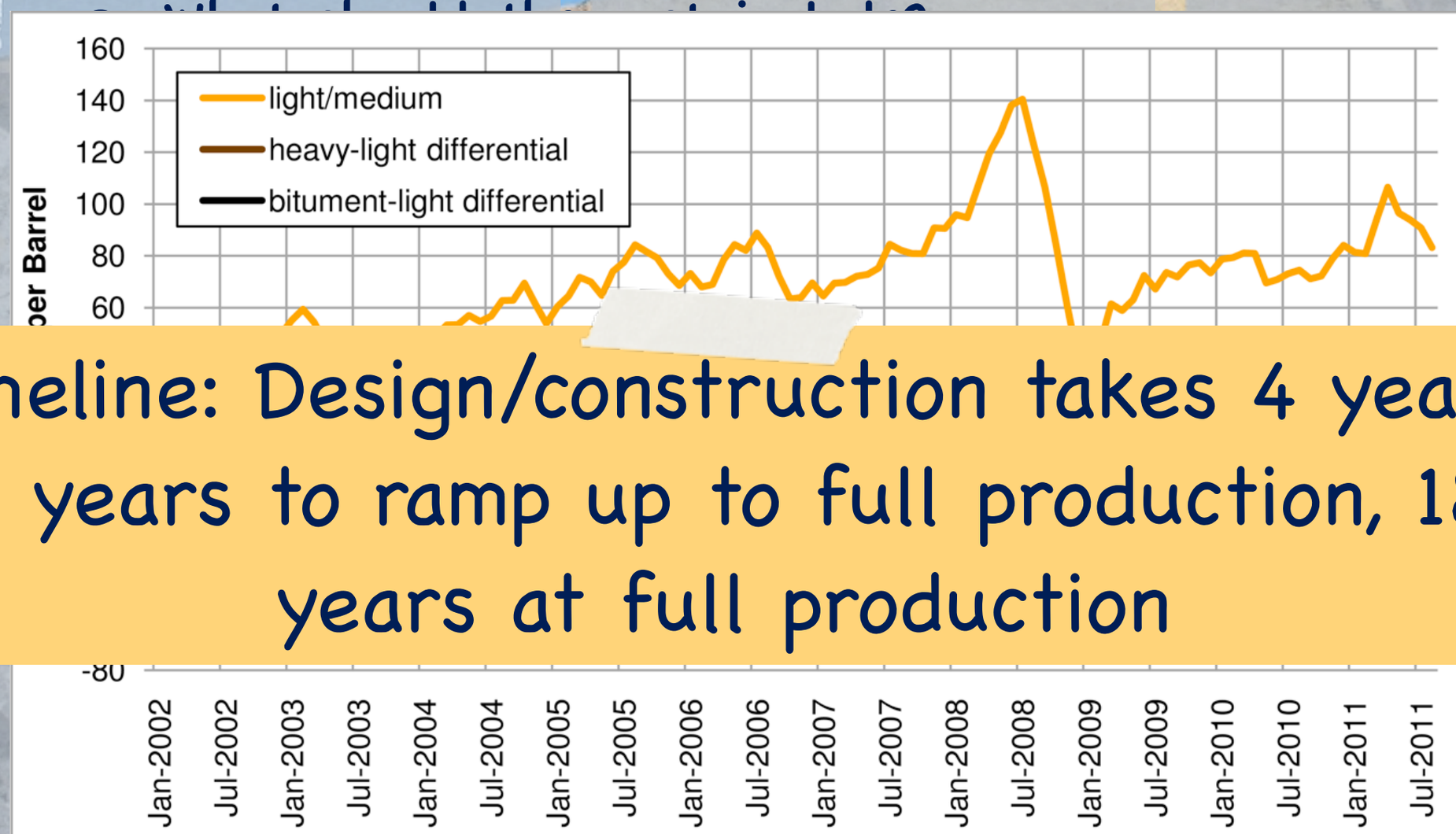

Timeline: Design/construction takes 4 years, 2 years to ramp up to full production, 18 years at full production

- What is product price relative to benchmark crudes?

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What is the cost in $ per barrel to develop Utah's oil shale & oil sands resources?

- What assumptions is cost most sensitive to?
  - Quality of resource
    - Underground oil shale mine: 50-foot mining height, 25 GPT average
    - Surface oil sands mine: 60-foot thick seam, 10 wt% bitumen saturation
  - Type of processing operation
    - Two oil shale retorts
    - Oil sand bitumen & solvent recovery

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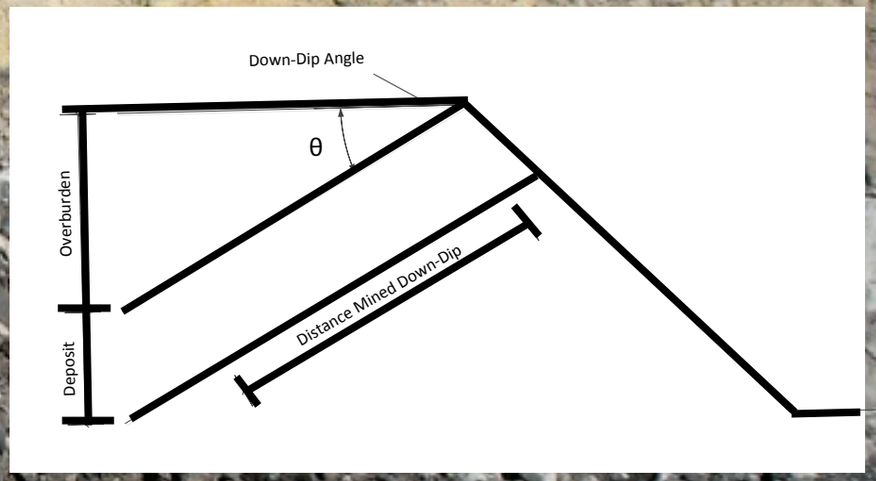

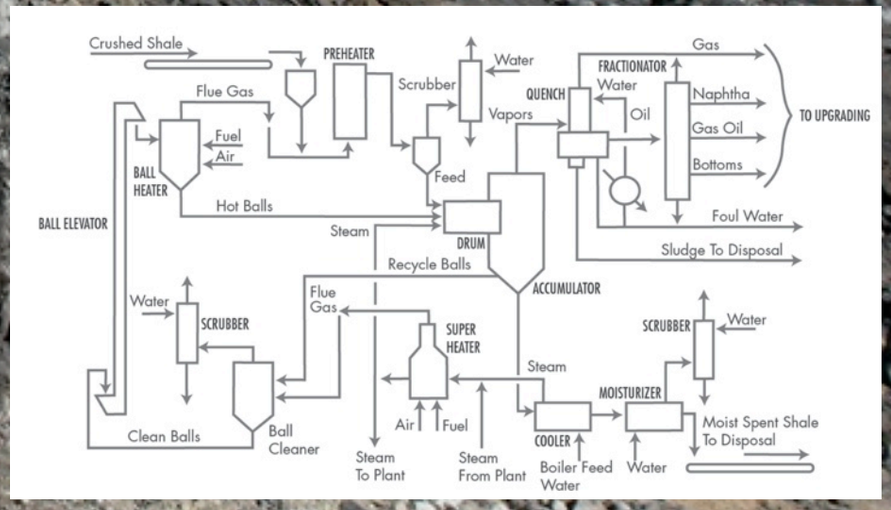

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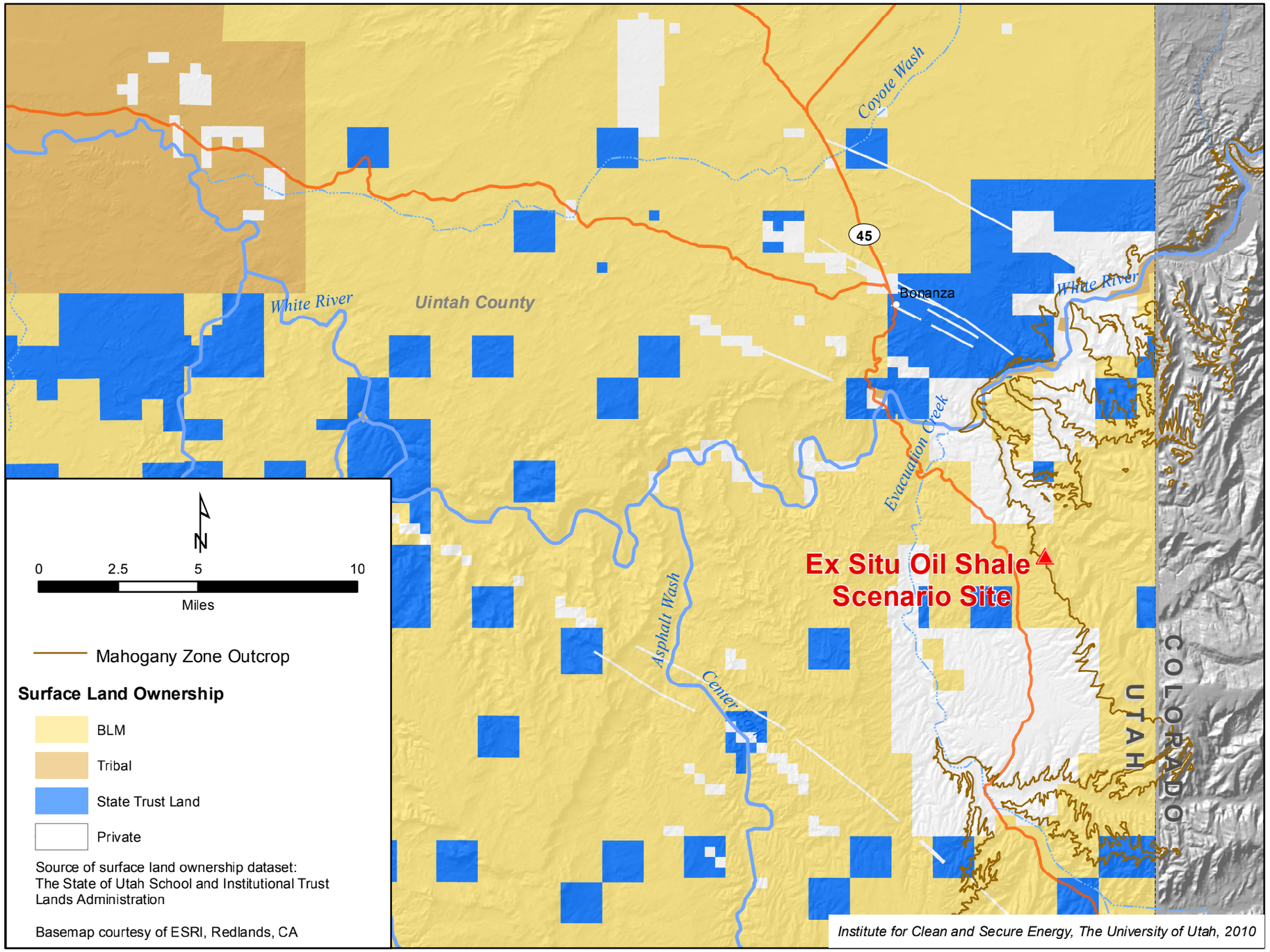
Where are the scenarios located?



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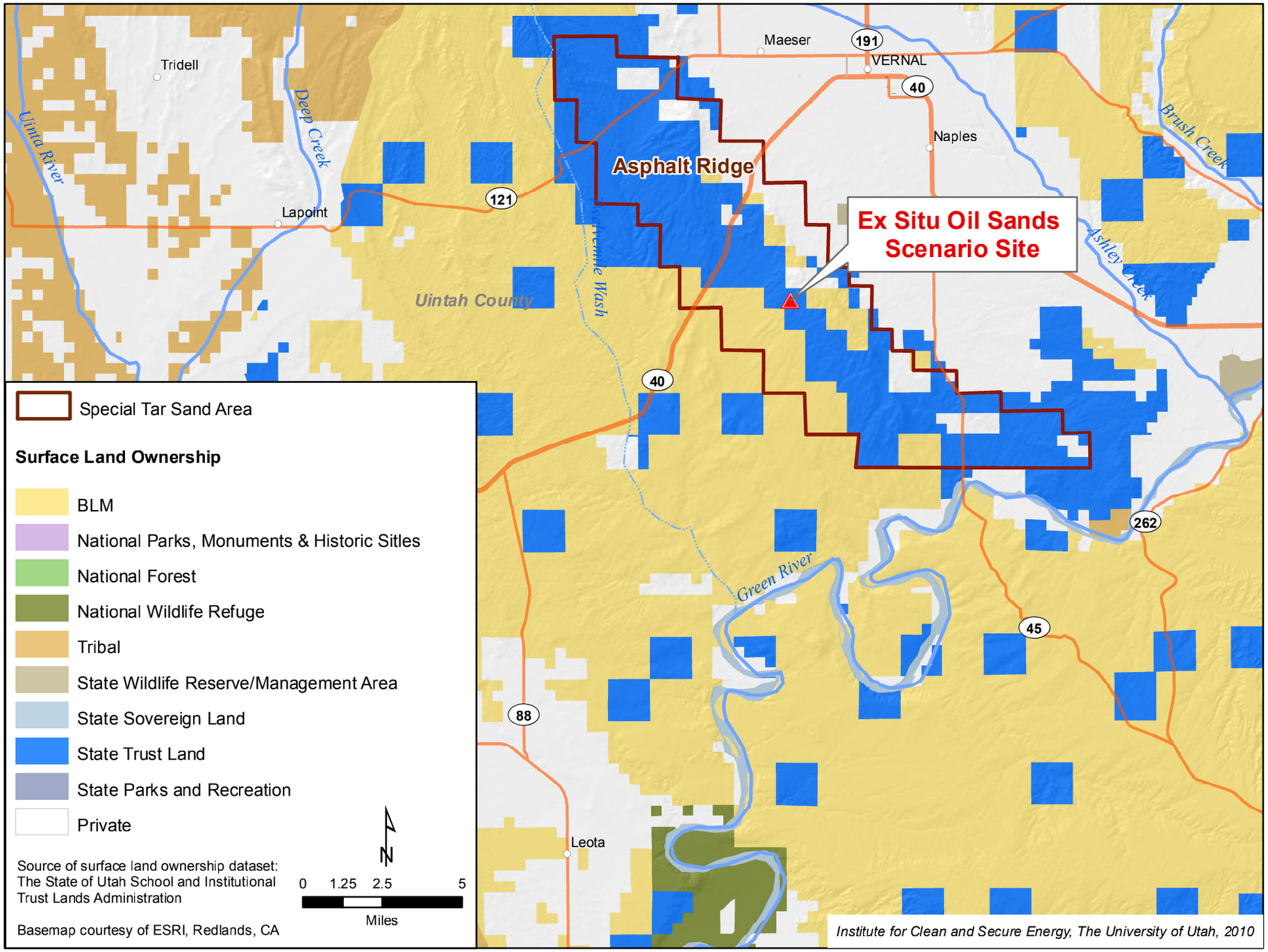

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What are environmental impacts of developing these resources?

- Will there be a big mine? Where? What about waste disposal & its impact?
  - Proposed Uinta Basin developments involve mining/surface processing
    - 168 large mines in Utah (100 active)
  - What is the scale?
  - Waste disposal
    - Spent shale/sand tailings disposed of onsite
    - Sales of material/effects of disposal not analyzed

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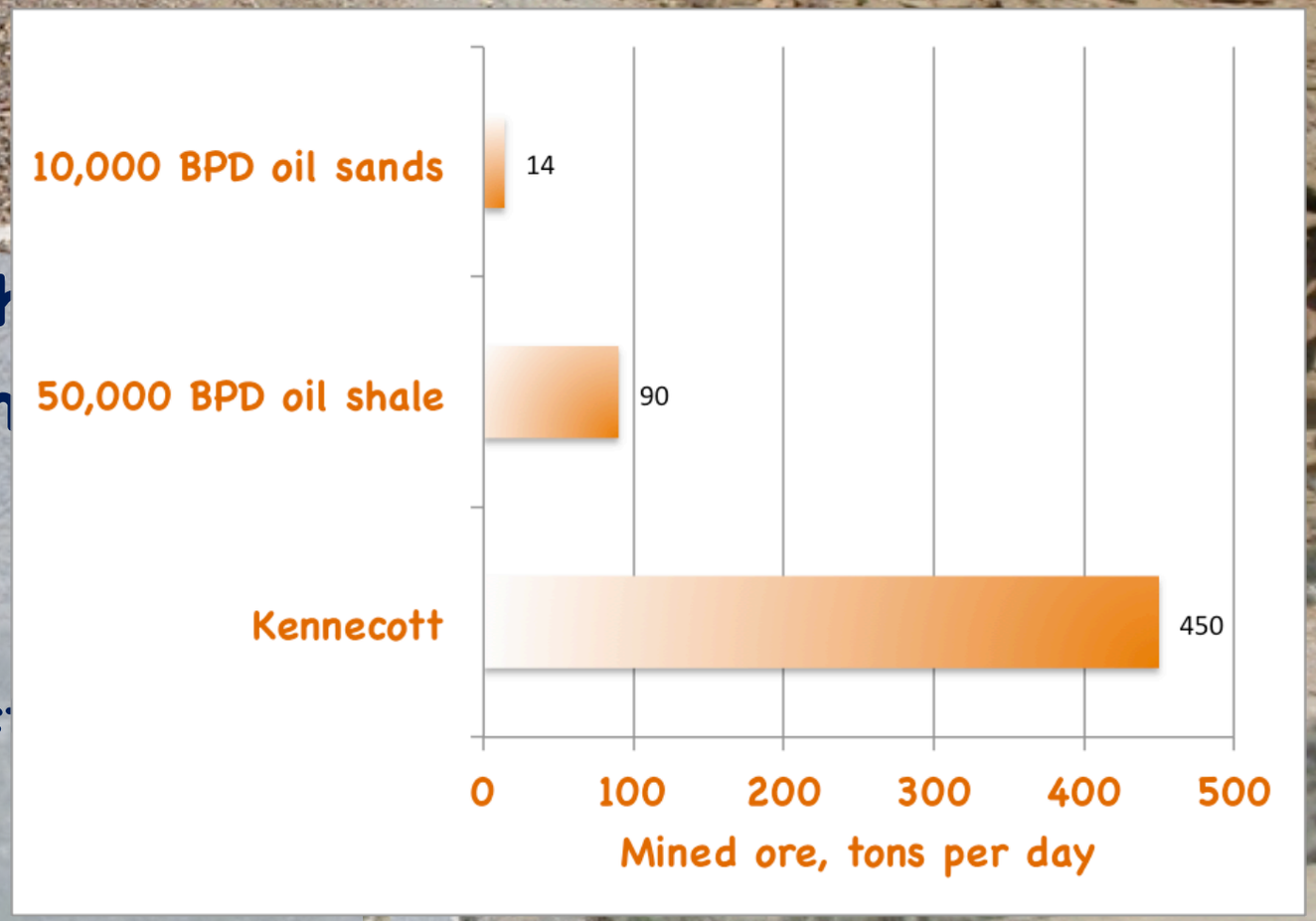

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What are environmental impacts of developing these resources?

- How will Uinta Basin air quality be impacted?
  - Topic in another session; assume air quality issues will not constrain development
  - SCO has more N & S than conventional oil; include cost of their removal, credit for sale of ammonium sulfate, S
- What about increased CO_2 emissions & global impacts of climate change?
  - Oxy-firing option
  - \$25/ton CO_2 tax (price is \$9.16/ton in CA)

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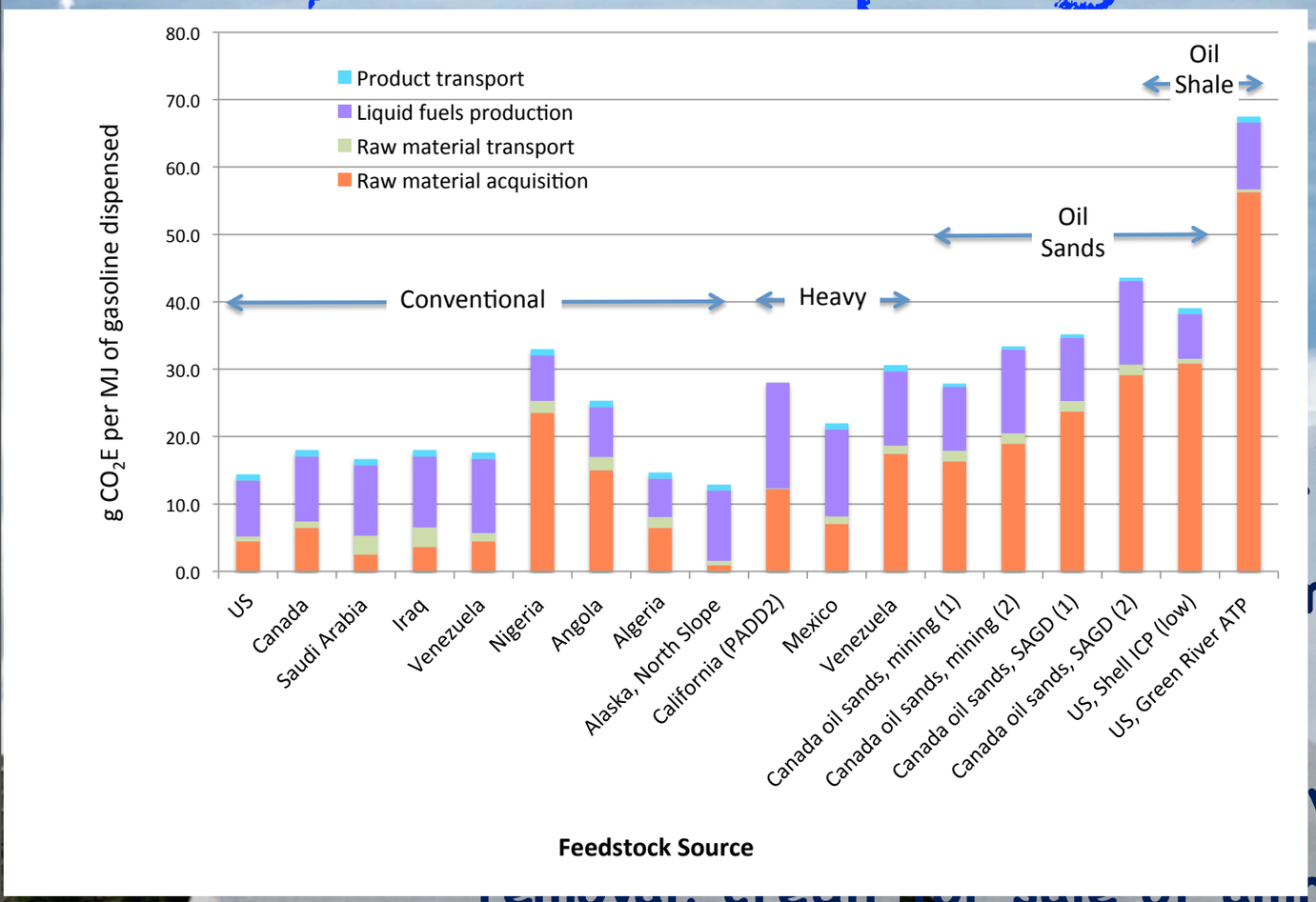

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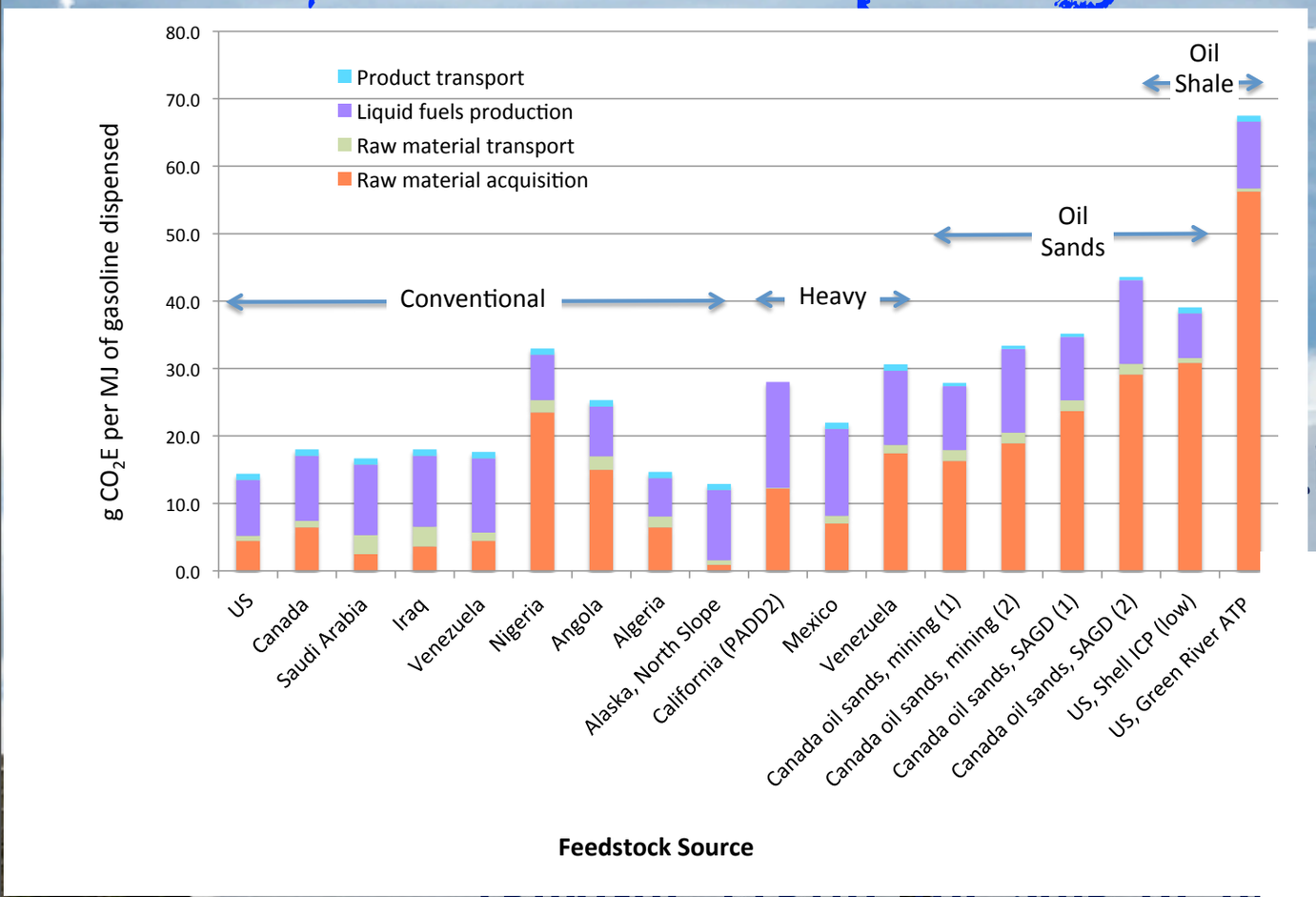

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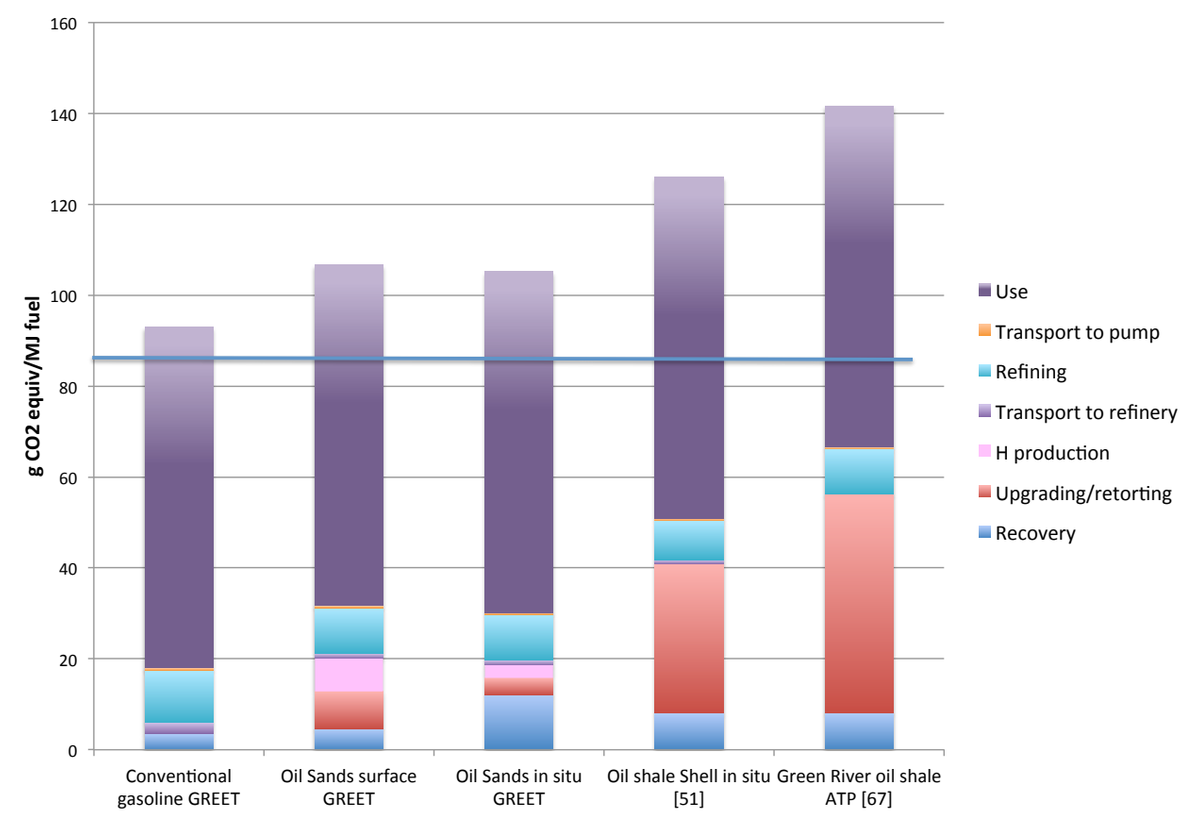

- What about increased CO_2 climate change?
  - Oxy-firing option
  - $25/ton CO_2 tax (price is $9

Inputs & outputs – 50,000 BPD oil shale operation

Category	Item	Air-Fired	Oxy-Fired	Paraho	(Units) / bbl of oil
Outputs	Ammonium Sulfate	20.94	20.94	20.94	lb
	CO_2	566	320	566	lb
	Spent Shale	3,607	3,607	3,400	lb
	Steam (600 psig, 700°F)	396	396	396	lb
	Sulfur	1.96	1.96	1.96	lb
Inputs	Catalyst	0.02	0.02	0.02	lb
	Electricity	88.77	105.42	88.77	kWh
	Fuel [a]	1.93	1.89	1.93	MMBtu
	Makeup Water	3.00	3.03	3.00	bbl
	O_2	-	249	-	lb
	Refrigerant	2.72	2.72	2.72	MJ
	Steam				
	50 psig	250	250	250	lb
	450 psig	184	184	184	lb

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What are environmental impacts of developing these resources?

- How much water is needed?
  - Estimates based on published data, process engineering calculations, but no recent commercial-scale data
  - Assume water rights can be acquired or water can be purchased from willing seller

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Water requirements – 50,000 BPD oil shale operation

Category	Item	Water (bbl / bbl of oil)			Water (acre-ft/yr)		
		Tosco II Air-Fired	Tosco II Oxy-Fired	Paraho Air-Fired	Tosco II Air-Fired	Tosco II Oxy-Fired	Paraho Air-Fired
Recycled	Cooling Water						
	Hydrotreater	0.10	0.10	0.10	244	246	244
	H_2 Plant	2.32	2.32	2.32	5,460	5,459	5,460
	CO_2 Compressor	-	34.34	-	-	80,783	-
	Sulfur Recovery Unit	0.10	0.10	0.10	246	245	246
	Boiler Feed Water						
	Sulfur Recovery Unit	0.02	0.02	0.02	37	37	37
	Retort	Unknown					
	Steam	1.67	1.67	1.24	3,927	3,927	2,922
	Subtotal	**4.21**	**38.56**	**3.79**	**9,914**	**90,698**	**8,909**
Consumed	H_2 Plant	0.83	0.83	0.83	1,942	1,942	1,942
	Mine	0.59	0.59	0.46	1,390	1,390	1,075
	Retort						
	Cooling Tower Makeup	2.18	2.18	1.87	5,134	5,134	4,403
	Retorting	1.06	1.06		2,505	2,505	
	Other [a]	0.69	0.69	0.31	1,626	1,626	740
	Spent Shale	1.49	1.49	0.67	3,509	3,509	1,582
	Upgrading						
	Cooling Tower Makeup	0.19	1.22	0.14	458	2,881	334
	Steam Recycle Losses	0.05	0.05	0.04	118	118	88
	Subtotal	**7.09**	**8.12**	**4.32**	**16,681**	**19,105**	**10,165**
Generated	CO_2 Compressor	-	0.99	-	-	2,320	-
	Retort						
	Cooling Tower Blowdown [b]	0.70	0.70	0.80	1,650	1,650	1,889
	Retort Condensate [c]	0.47	0.47	0.26	1,106	1,106	607
	Other [d]	0.35	0.35	0.26	812	812	620
	Subtotal	**1.52**	**2.50**	**1.32**	**3,567**	**5,887**	**3,116**
Water In		**5.58**	**5.62**	**3.00**	**13,114**	**13,218**	**7,049**

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Water requirements – oil shale/sands vs. conventional

	bbl/bbl of oil	acre-feet/year
Tosco II air-fired	5.58	13,100
Tosco II oxy-fired	5.62	13,200
Paraho Direct air-fired	3.00	7,000
Oil sands air- & oxy-fired	2.66	1,250
Conventional oil (primary & secondary recovery)	8.6	

Notes: Conventional oil water consumption from E. Mielke, L. D. Anadon &V. Narayanamurti (2010)
One acre-foot is average annual water usage for one household

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Supply cost as a function of opportunity cost of capital- 50,000 BPD oil shale operation

Tosco II oxy-fired

Tosco II air-fired

Paraho Direct air-fired

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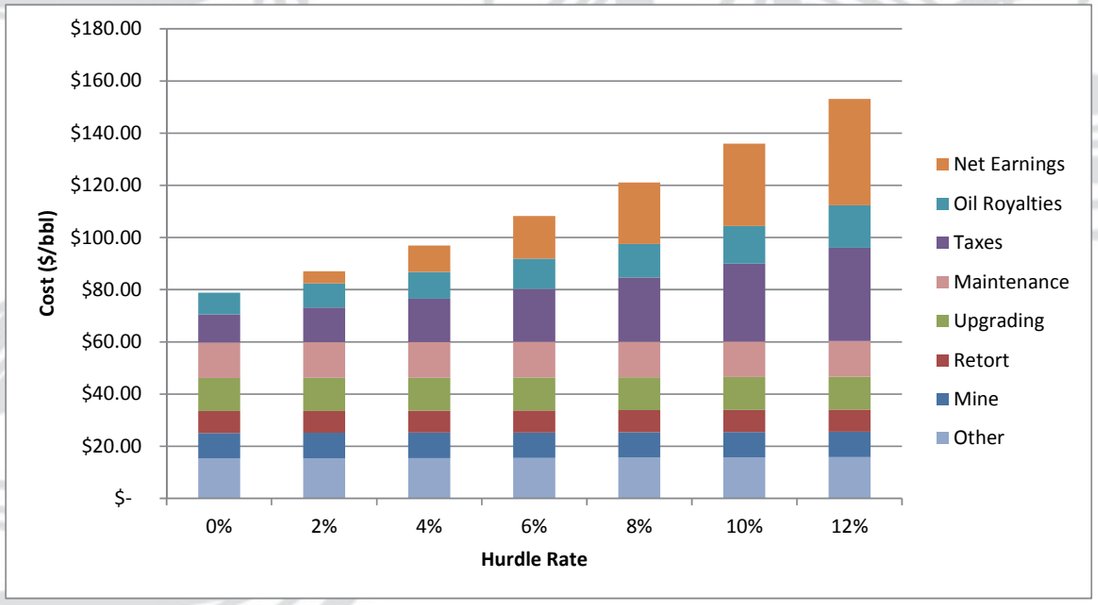
Tosco II oxy-fired



Tosco II air-fired

Paraho Direct air-fired

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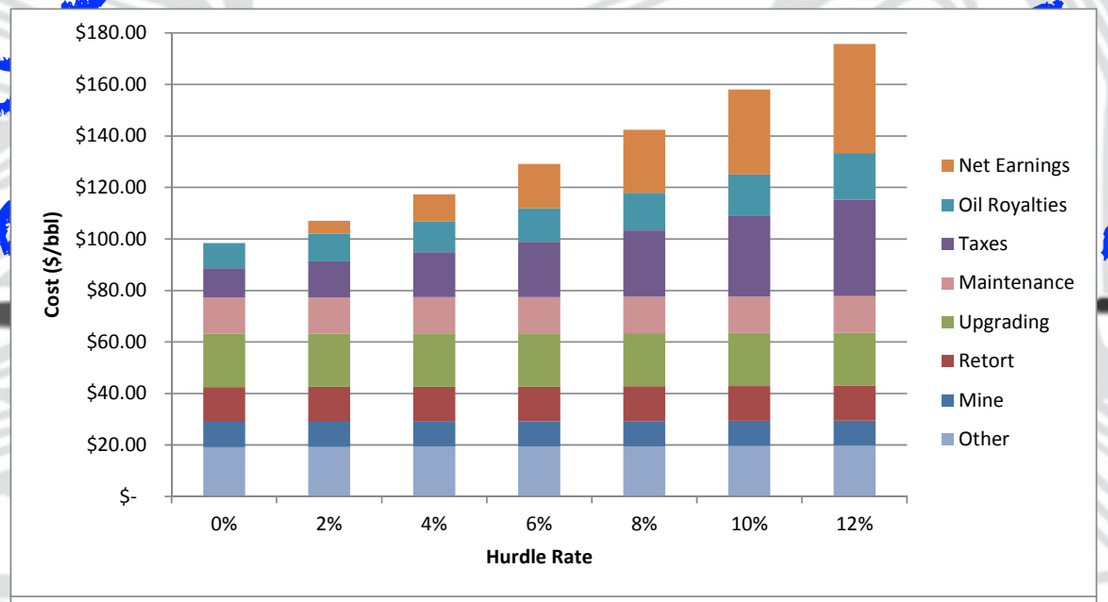
Supply cost as a function of opp capital-50,000 operation



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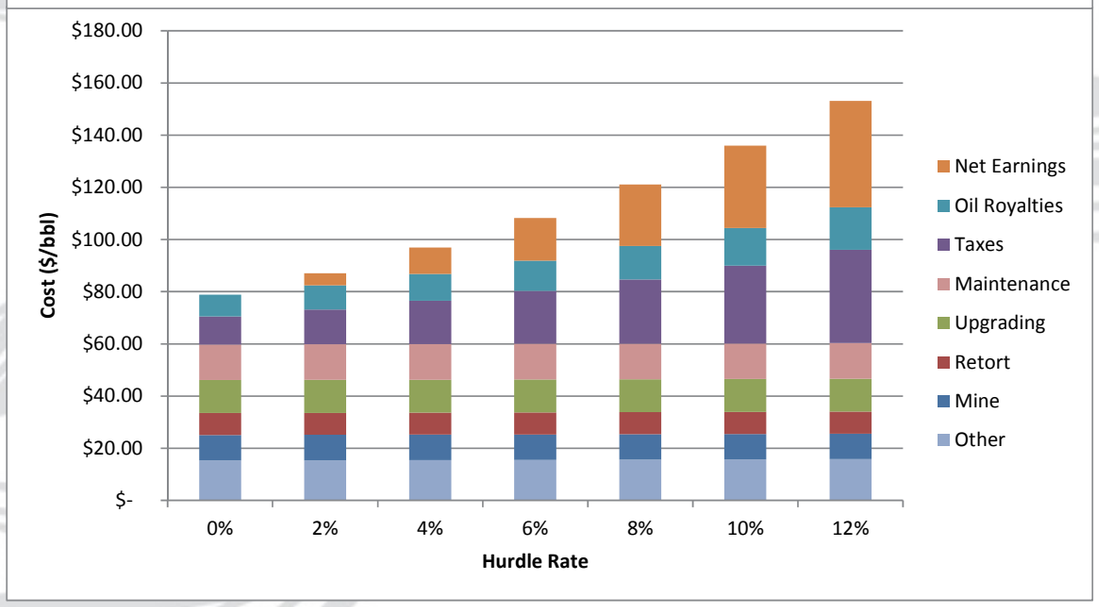

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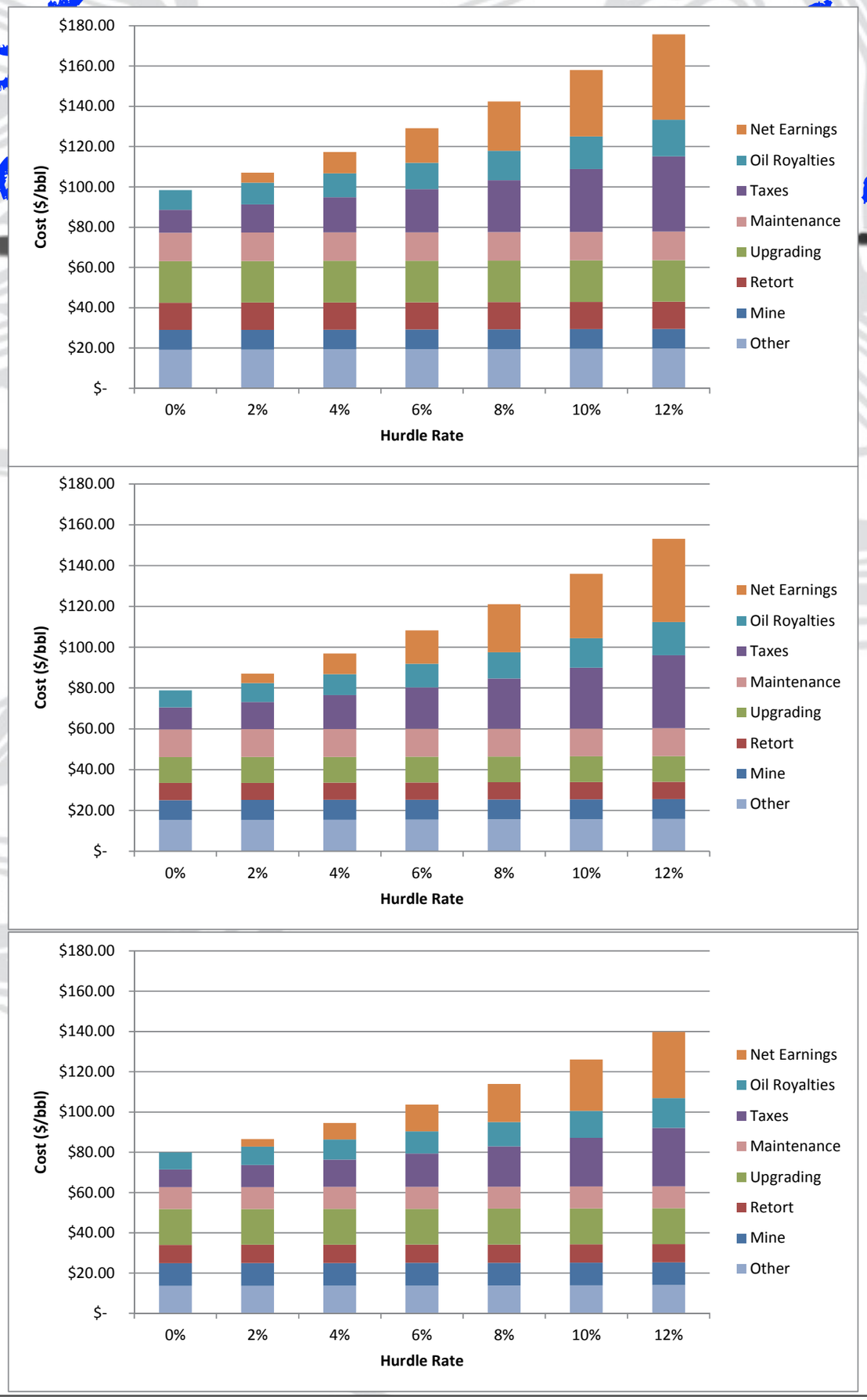

Tosco II oxy-fired

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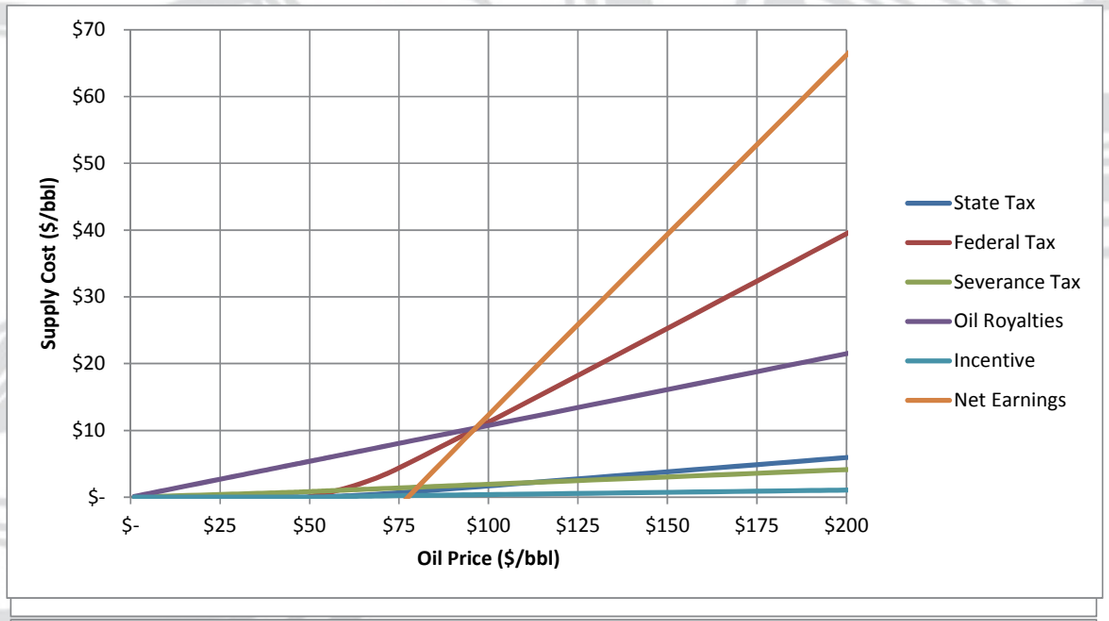
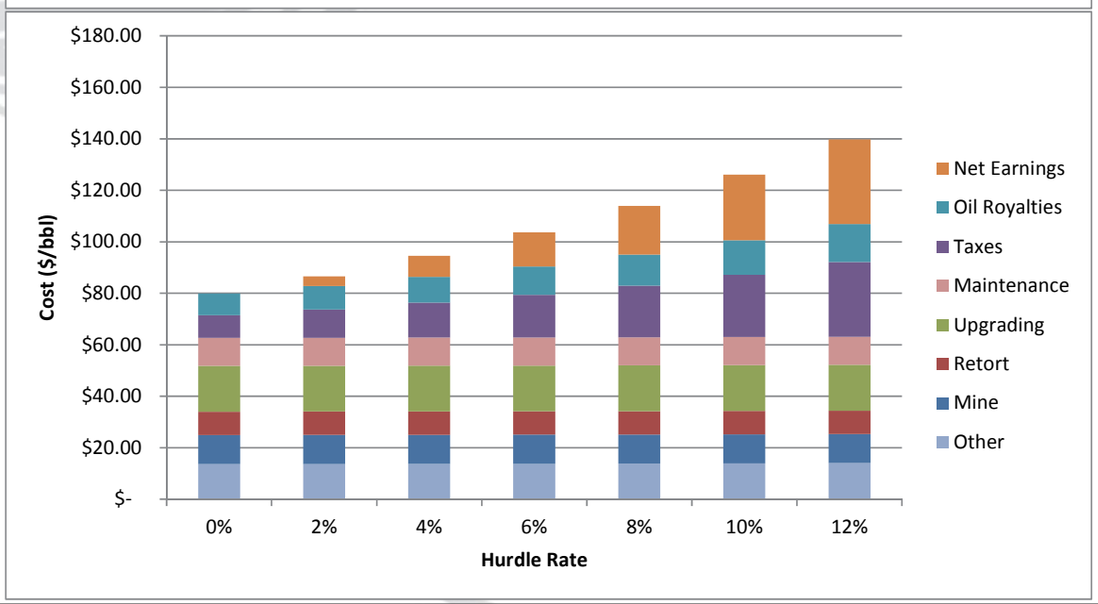


Tosco II air-fired



Paraho Direct air-fired

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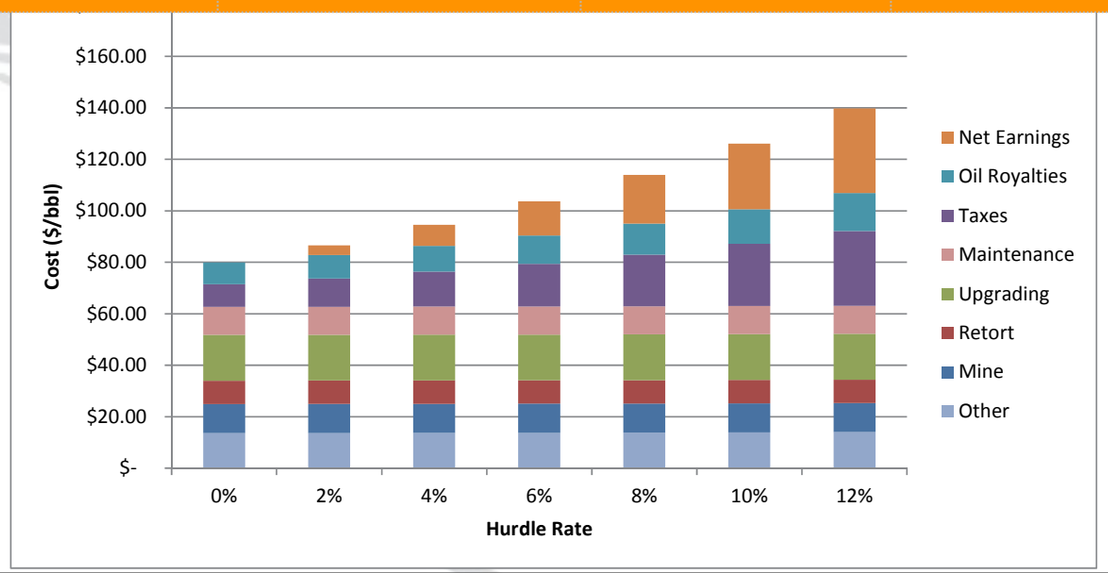
Supply cost as a function of opportunity cost of capital- 50,000 BPD oil shale operation

Oil Price Forecast	Average Price ($/bbl)	2011 Price ($/bbl)	2035 Price ($/bbl)
Low	$52.35	$47.70	$62.39
Reference	$112.35	$87.05	$123.79
High	$173.81	$114.52	$195.93



Paraho Direct air-fired

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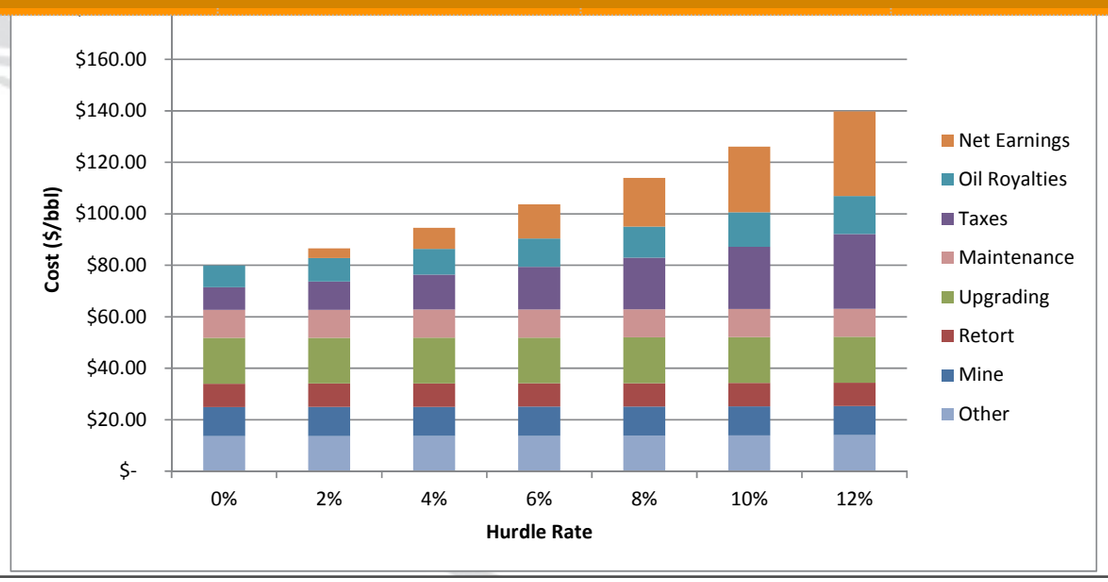
Supply cost as a function of opportunity cost of capital- 50,000 BPD oil shale operation

Taxing CO_2 at $25/ton increases supply price for Tosco II air-firing by $6.37 to $83.74 (0% hurdle rate). This supply price is less than $91.69/bbl supply price for oxy-firing. To equalize prices & thus drive investment in CCS and EOR, CO_2 tax of $56/ton is needed.



Paraho Direct air-fired

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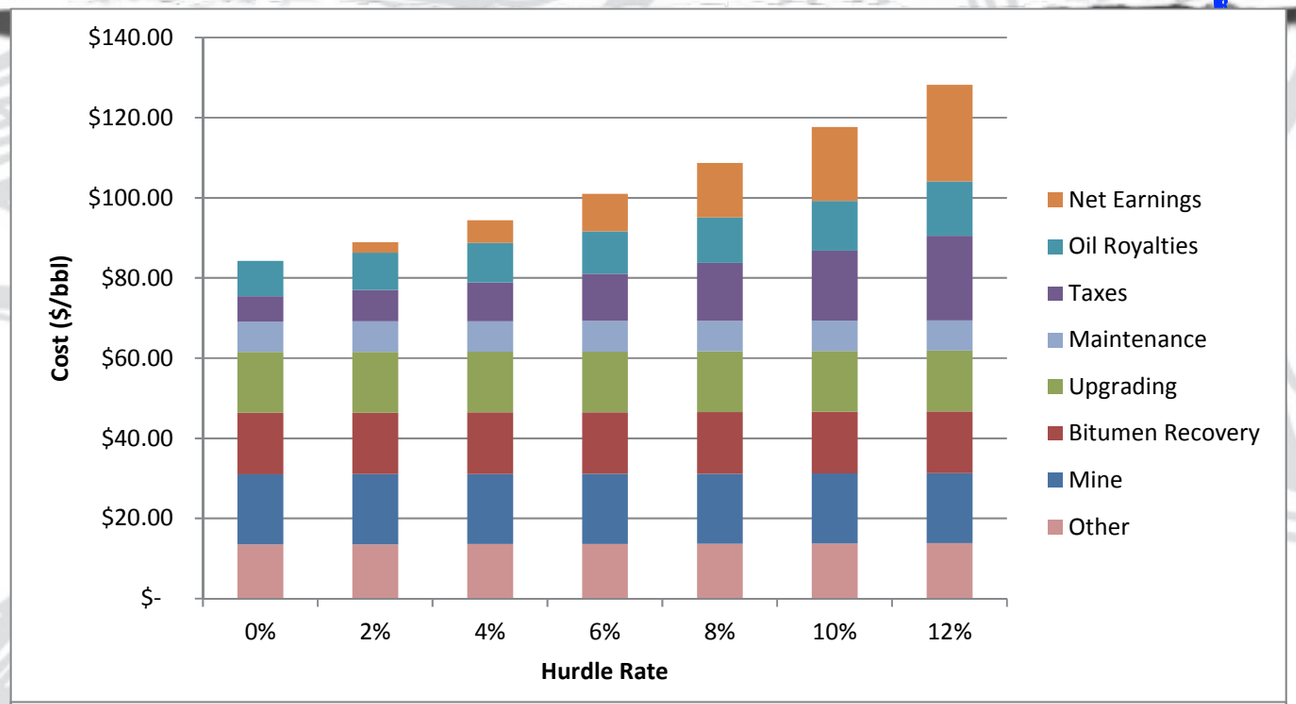
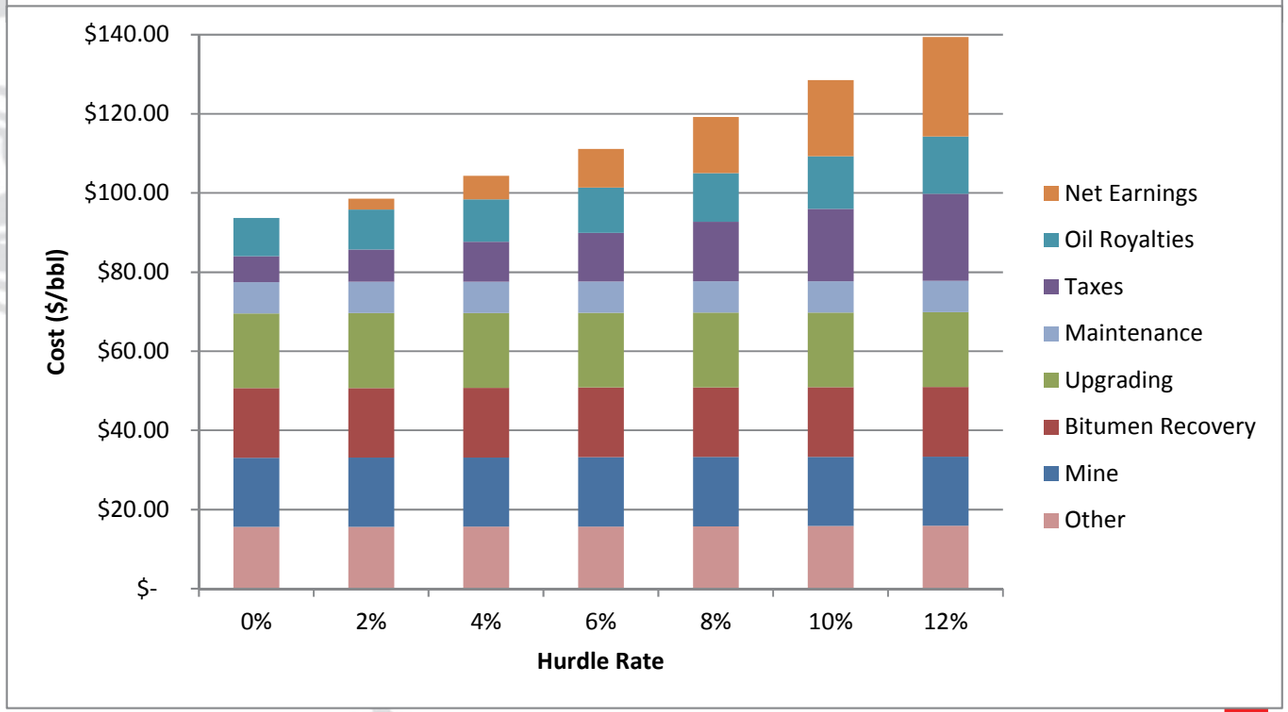
Supply price as a function of opportunity cost of capital – 10,000 BPD oil sands operation



Air-fired



Oxy-fired

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Detailed cost breakout – 50,000 BPD oil shale operation

Category	Item	Capital	Labor	Electricity	Fuel	Water	Steam	O_2	Other*	Total
Extraction	Oil Shale Mine	$ 2.39	$ 2.87	$ -	$ -	$ 0.01	$ -	$ -	$ 4.53	$ 9.79
	Oil Shale Retort	$ 4.45	$ 1.30	$ 0.02	$ 1.64	$ 0.32	$ 0.51	$ -	$ 0.14	$ 8.37
Upgrading	Hydrotreater	$ 3.07	$ 0.43	$ 0.46	$ 0.47	$ 0.00	$ -	$ -	$ 0.07	$ 4.51
	H_2 Plant	$ 0.32	$ 0.14	$ 0.04	$ 5.41	$ 0.08	$ -	$ -	$ -	$ 5.99
	Fractionator	$ 0.16	$ 0.05	$ 0.03	$ 0.19	$ 0.00	$ 0.07	$ -	$ -	$ 0.50
	Sour Water Stripper	$ 0.24	$ 0.10	$ 0.12	$ -	$ 0.00	$ 0.80	$ -	$ -	$ 1.26
	Amine Treatment Unit	$ 0.01	$ 0.10	$ 0.00	$ -	$ 0.00	$ 0.65	$ -	$ -	$ 0.75
	Sulfur Recovery Unit	$ 0.02	$ 0.14	$ 0.00	$ -	$ 0.00	$ -	$ -	$ -	$ 0.17
Delivery	Oil Pipeline	$ 0.42	$ -	$ 0.13	$ -	$ -	$ -	$ -	$ -	$ 0.54
Other	Water Pipeline	$ 0.04	$ -	$ 0.06	$ -	$ -	$ -	$ -	$ -	$ 0.10
	CO_2 Compressor	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Tosco II air-fired		Paraho Direct air-fired	
Catalyst		Catalyst	
Chemicals for Retort		Chemicals for Retort	
Refrigerant R-134a		Refrigerant R-134a	
Operating cost model for mine		Operating cost model for mine	
Allocated Costs for Utility Plants	$ 0.28	Allocated Costs for Utility Plants	$ 0.34
Water Reservoir	$ 0.12	Water Reservoir	$ 0.07
Site Preparation	$ 1.07	Site Preparation	$ 0.83
Service Facilities	$ 1.07	Service Facilities	$ 0.83
Contigency	$ 2.05	Contigency	$ 1.63
Permitting	$ 0.12	Permitting	$ 0.12
Maintenance	$ 13.65	Maintenance	$ 10.87
Overhead	$ 2.18	Overhead	$ 1.83
Research	$ 0.74	Research	$ 0.74
Administration	$ 0.77	Administration	$ 0.77
Incentive Compensation	$ 0.24	Incentive Compensation	$ 0.19
Insurance	$ 1.44	Insurance	$ 1.15
Taxes**	$ 10.73	Taxes**	$ 8.84
Royalties - oil	$ 8.31	Royalties - oil	$ 8.42
Royalties - IP	$ 2.22	Royalties - IP	$ 2.26
Working Capital	$ -	Working Capital	$ -
Land	$ 0.31	Land	$ 0.25
Startup	$ 1.57	Startup	$ 1.25
Net Earnings	$ -	Net Earnings	$ -
Supply Costs Subtotal	**$ 78.84**	**Supply Costs Subtotal**	**$ 79.90**
CO_2	$ -	CO_2	$ -
Export Steam	$ 1.38	Export Steam	$ 1.38
Petroleum Coke	$ -	Petroleum Coke	$ -
Sulfur	$ 0.09	Sulfur	$ 0.09
Non-Oil Revenue Subtotal	**$ 1.47**	**Non-Oil Revenue Subtotal**	**$ 1.47**
Oil Supply Price	**$ 77.37**		**$ 78.43**

Notes

* Other includes:

** Taxes includes:

State Tax
Federal Tax
Severance Tax
Property Tax

Sensitivity analysis – 50,000 BPD oil shale operation

Ex Situ Oil Shale (Air-Fired)		Supply Price of Oil ($/bbl)			
		Hurdle Rate			
Variable	Range	0%	4%	8%	12%
Base Case	---	$ 77.37	$ 95.49	$ 119.61	$ 151.65
Shale Grade (GPT)	25				
Low	10	$ 125.51	$ 152.31	$ 187.95	$ 235.37
High	40	$ 63.04	$ 78.29	$ 98.60	$ 125.57
Retort - Capital & Op. Expenses	100%				
Low	50%	$ 62.11	$ 76.48	$ 95.58	$ 120.91
High	150%	$ 92.54	$ 114.38	$ 143.47	$ 182.17
Paraho	---	$ 78.43	$ 93.07	$ 112.49	$ 138.25
Upgrading H_2 Consumption (SCF/bbl)	2,000				
Low	1,000	$ 67.62	$ 85.50	$ 109.35	$ 141.00
High	3,000	$ 86.85	$ 105.14	$ 129.45	$ 161.77
Maintenance (% of C_{TDC})	5%				
Low	2%	$ 66.28	$ 84.04	$ 107.88	$ 139.95
High	8%	$ 88.48	$ 106.93	$ 131.38	$ 163.36
Site Prep. & Service Facilities (% of C_{TBM})	20%				
Low	10%	$ 73.32	$ 90.07	$ 112.34	$ 141.93
High	30%	$ 81.42	$ 100.91	$ 126.87	$ 161.37
Fuel Costs	100%				
Low	50%	$ 72.81	$ 90.88	$ 114.97	$ 146.94
High	150%	$ 81.93	$ 100.09	$ 124.25	$ 156.36
Royalties (% of Sales) [a]	5.0%-12.5%				
Federal Land [b]	12.5%	$ 79.27	$ 98.22	$ 123.84	$ 157.39
SITLA [c]	8.0%-12.5%	$ 77.44	$ 95.63	$ 120.00	$ 152.06
Low [d]	5.0%	$ 73.18	$ 90.57	$ 114.07	$ 144.77
Federal Taxes (% of Taxable Income) [e]	35%				
Low [f]	15%	$ 73.51	$ 88.36	$ 108.20	$ 133.36
State Taxes (% of Taxable Income) [g]	5%				
SB65 Tax Credit [h]	< 2%	$ 76.80	$ 94.50	$ 118.09	$ 149.12

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Conclusions

- What is the cost in $ per barrel to develop Utah's oil shale & oil sands resources?
  - Range of values depending on assumptions
- What is the impact on the environment of developing these resources?
  - Comparable to other mineral development (mining) & oil development projects
  - Difficult to include some impacts in cost analysis (these are externalities)

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