

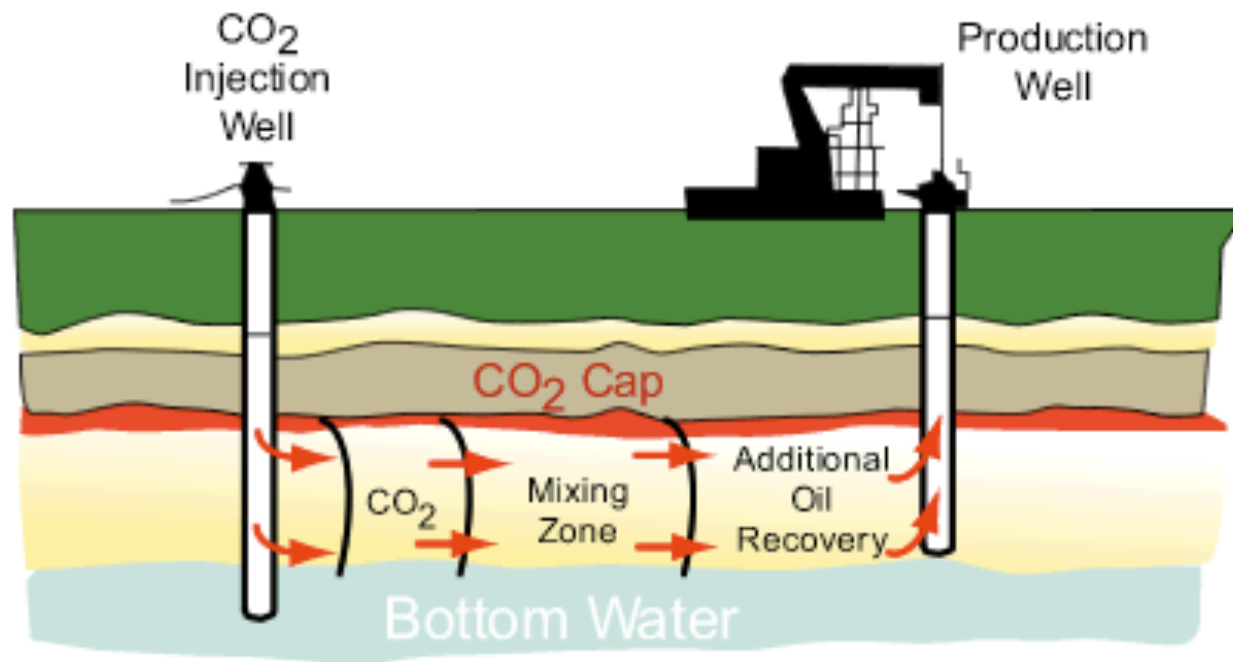
A Case Study in Allocation Methods

A Life Cycle Accounting of CO₂ Emissions from an
Enhanced Oil Recovery System

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A Presentation for the LCA IX
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What is CO₂ - EOR?



Source: AmeriWest Energy Corp

Where does the CO₂ used in EOR come from?

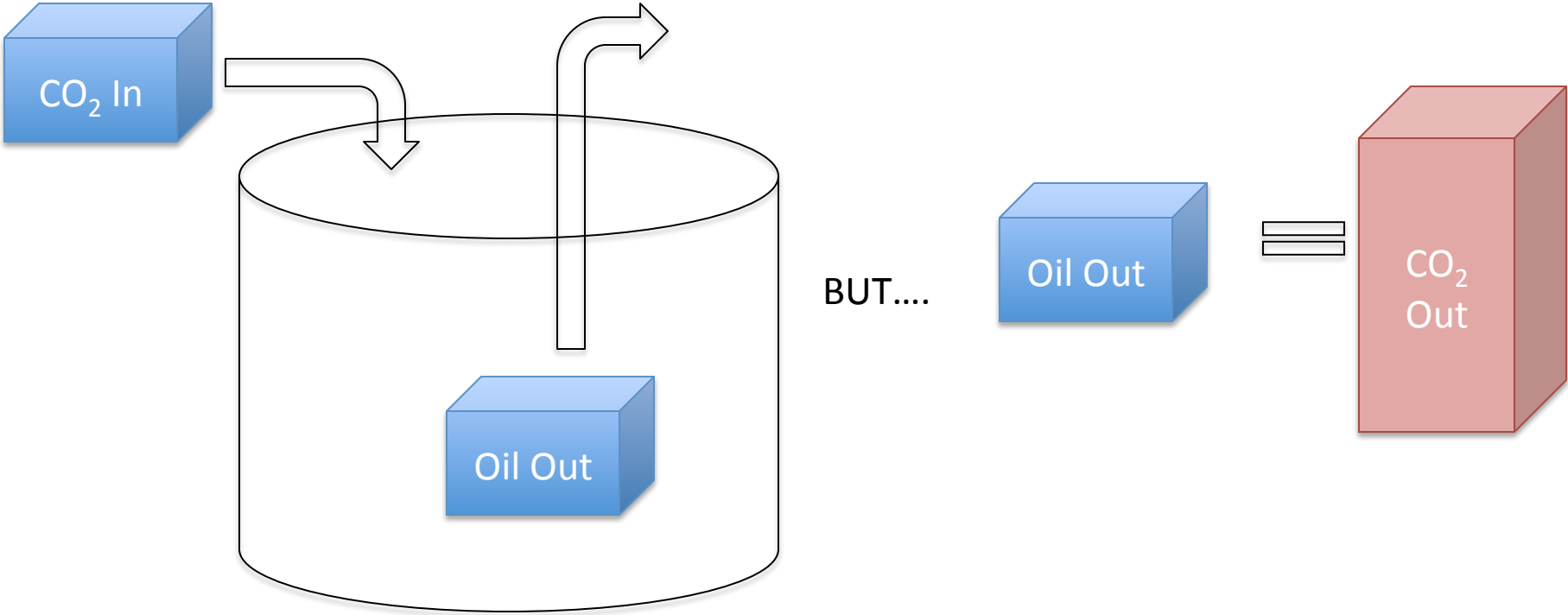
- Currently most of the CO₂ used for enhanced oil recovery is produced from natural CO₂ reservoirs.
- Increasingly, there is a call to use CO₂ captured from fossil-based power plants in EOR projects

“CO₂ enhanced oil recovery (CO₂-EOR) offers the potential for **storing** significant volumes of carbon dioxide emissions while increasing domestic oil production.” NETL 2008

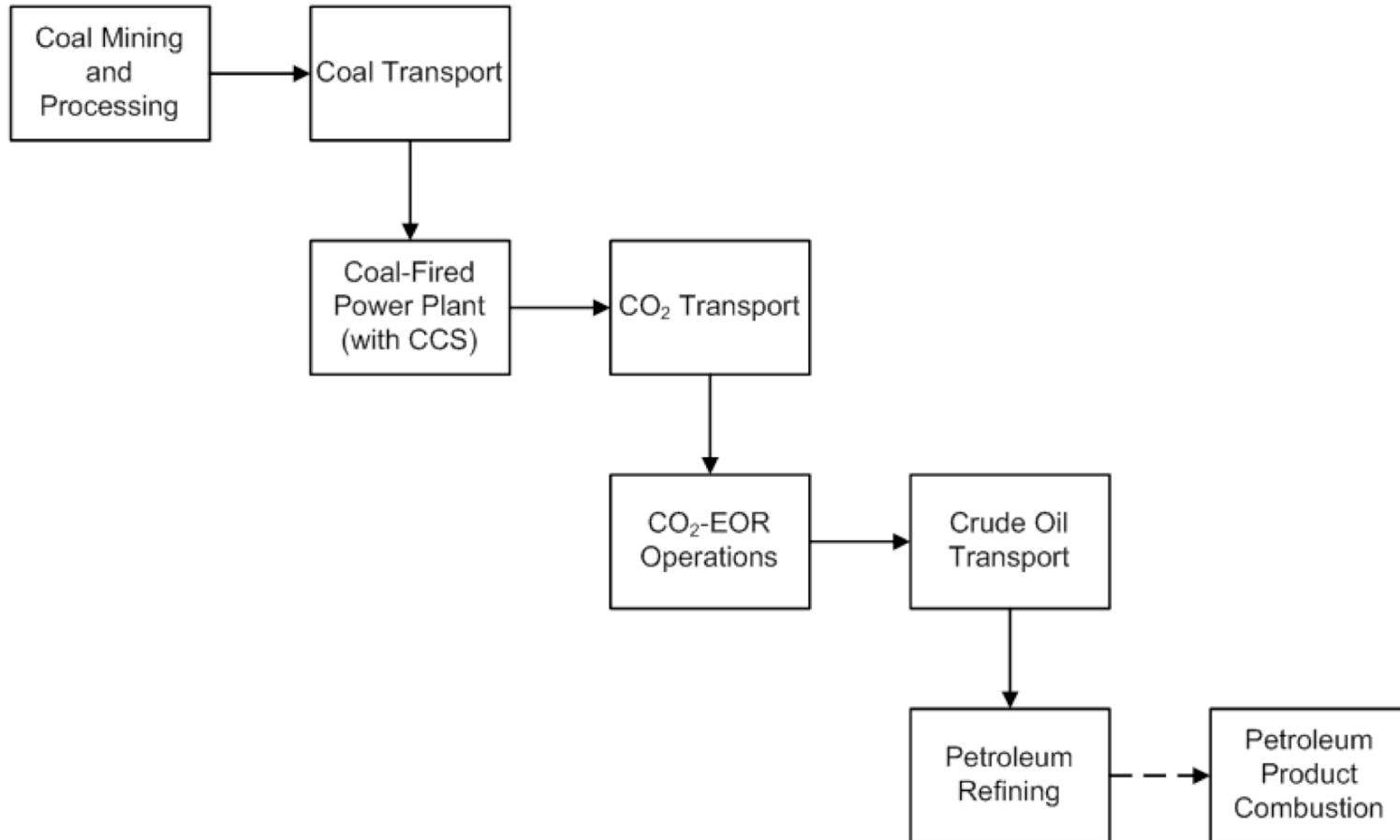
Previous Studies

- Suebsiri et al: “Net Storage is 18.6 million tonnes of CO₂...”
- Khoo et al, also find net storage of CO₂ from EOR Projects.
- Aycaguer et al: EOR process “ could provide a significant means to storing CO₂ underground.”

In Essence...



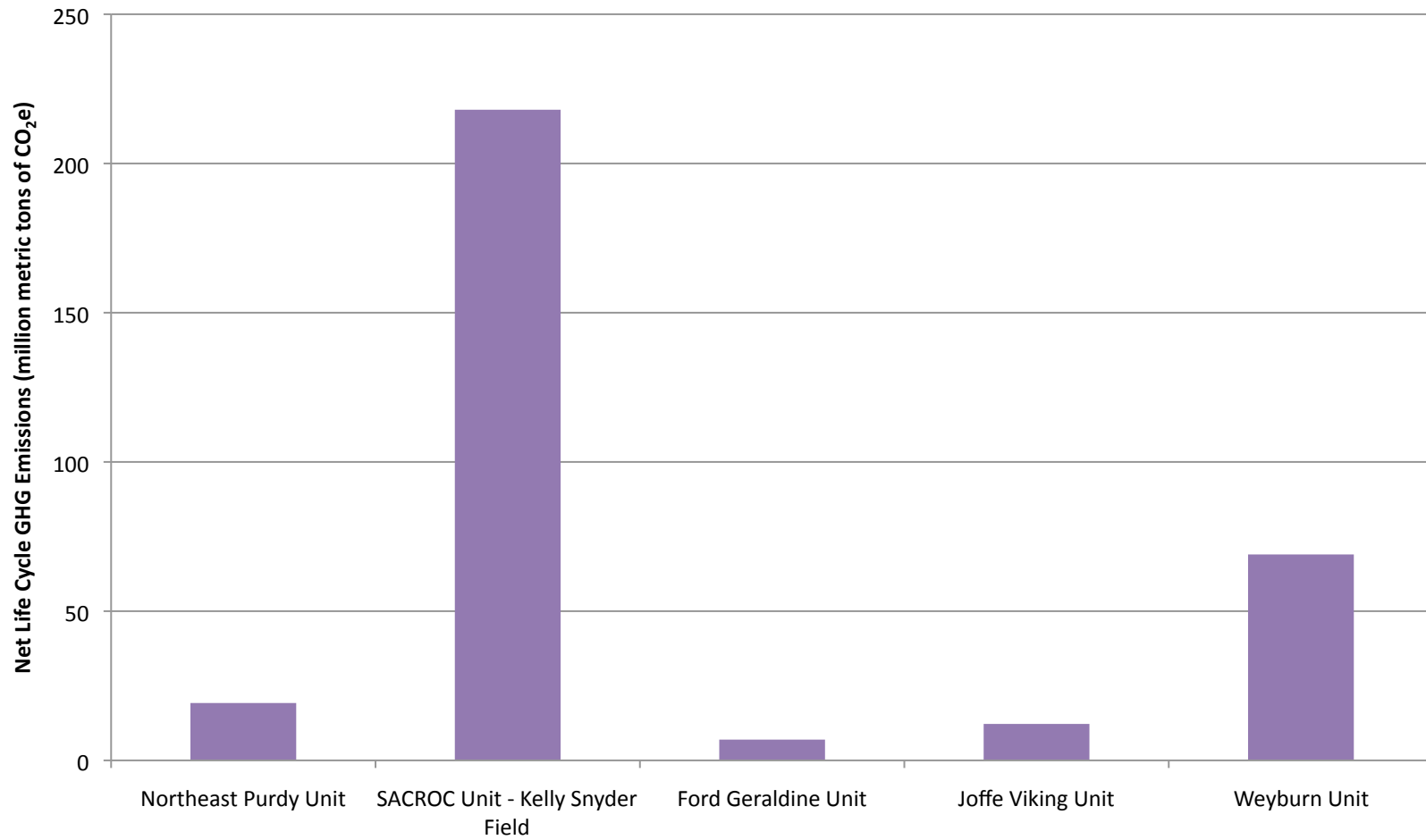
The Life Cycle of EOR System



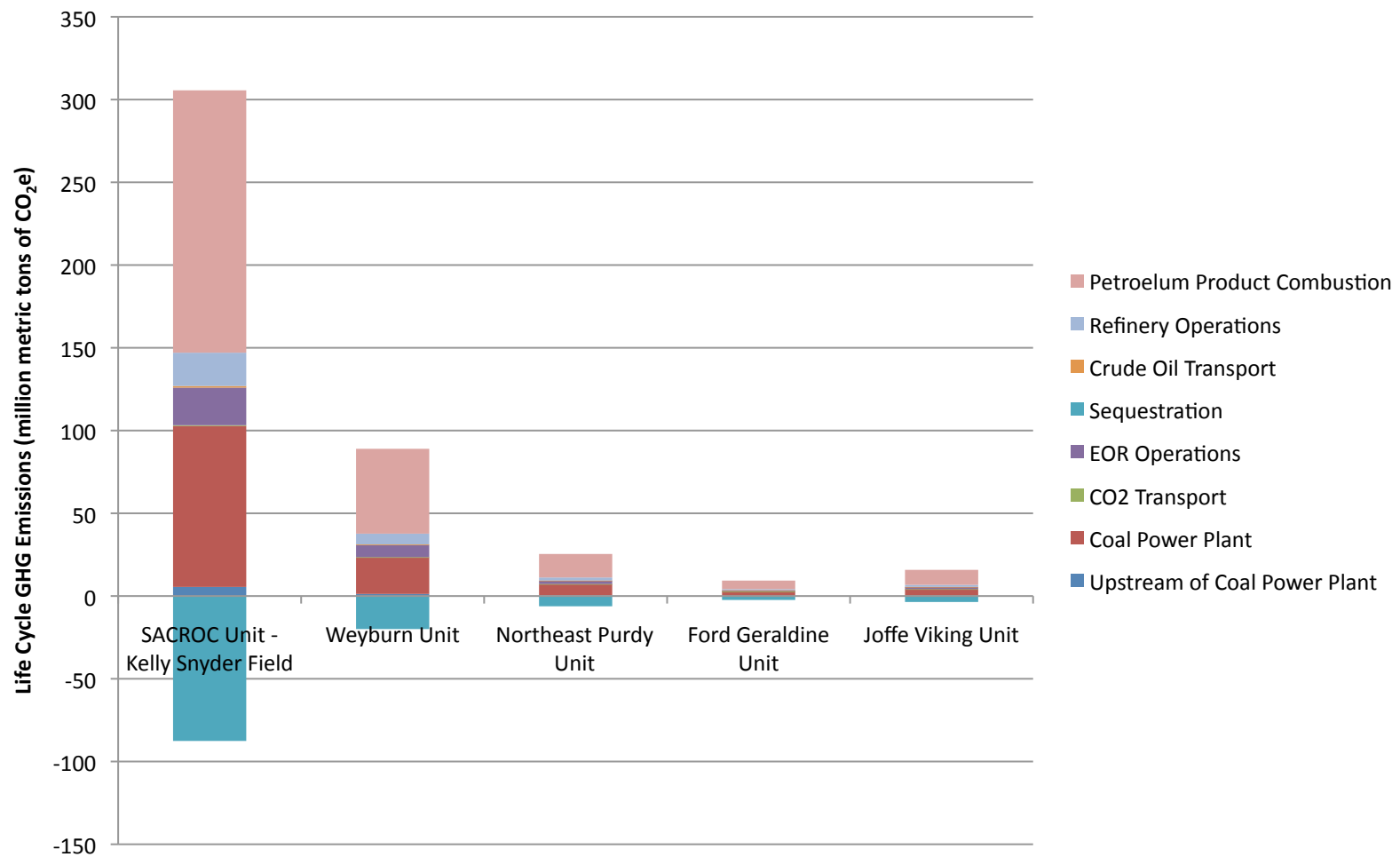
5 EOR Case Studies

Case	Northeast Purdy Unit	SACROC Unit - Kelly Snyder Field	Ford Geraldine Unit	Joffe Viking Unit	Weyburn Unit
Project Lifetime (yrs)	9	21	8	17	15
Incremental Oil Recovered (million STB)	36	402	13	23	130
Total CO ₂ Purchased (million metric tons)	6.2	87.5	2.37	3.6	20
Implied Electricity Generation (million MWh)	7.0	99.7	2.7	4.1	22.7

Net Life Cycle CO₂ Emissions



Life Cycle CO₂ Emissions by Source



How much CO₂ do you need to breakeven?

- Simple optimization model used to determine how much CO₂ needs to be injected and stored underground so that the net CO₂ emissions from the boundary are 0:
 - 0.62 metric tons of CO₂/bbl of oil produced

Can you inject that much CO₂ in EOR field?

- To inject enough CO₂ to breakeven, CO₂ density would have to be raised to 3,250 kg/m³
- Density of CO₂ at atmospheric conditions: 1.87 kg/m³
- Density of CO₂ in reservoir: 750 kg/m³

Who is responsible for these emissions?

- Electricity and oil are produced within the system boundary
- Some CO₂ is injected underground
- Currently, electricity generators and oil producers are claiming the CO₂ credit
 - Double counting the benefit

Allocation Methods

- Attributional
 - By energy
 - By economic value
- Consequential
 - Which is the primary product?
 - What is the secondary displacing?

Allocation Method		Electricity Emission Factor (kg CO _{2e} /MWh)	Crude Oil Emission Factor (kg CO _{2e} /bbl)
Current Emissions [20, 27]		655	530
Allocation by Energy		280	475
Allocation by \$ (\$95/bbl oil and \$98/MWh electricity)		450	430
Allocation by \$ (\$37.5/bbl oil and \$98/MWh electricity)		860	330
Allocation by System Boundary Expansion: Oil as Primary Product			
Electricity Displacement	Current Mix	N/A	380
	Low Carbon Sources ¹	N/A	540
	Pulverized Coal	N/A	330
	IGCC	N/A	720
	NGCC ²	N/A	440
Allocation by System Boundary Expansion: Electricity as Primary Product			
Oil Displacement	U.S. Domestic Crude Oil	44.3	N/A
	Canadian Crude Oil	77.1	N/A
	Saudi Crude Oil	86.2	N/A
	Canadian SCO ³ (<i>in-situ</i>)	-230	N/A
	Canadian SCO ³ (Mining)	-190	N/A
	Venezuelan Crude	1.86	N/A
	Mexican Crude	-52.2	N/A
1- Low Carbon Sources include wind, solar, nuclear, and other renewables 2- Natural gas was domestically supplied. 3- Synthetic crude oil derived from oil sands.			

Energy Displacement

Field		Northeast Purdy Unit	SACROC Unit - Kelly Snyder Field	Ford Geraldine Unit	Joffe Viking Unit	Weyburn Unit
EOR System	Net Emissions (million metric tons CO ₂ e)	19	220	7	12	69
	CO ₂ Injected in Field (million metric tons CO ₂ e)	6.2	88	2.4	3.6	20
Emission from Oil & Electricity Produced with other Sources	Current Oil, Current Electricity Emissions (million metric tons CO ₂ e)	24	280	8.6	15	84
	IGCC and Canadian SCO (In-Situ) (million metric tons CO ₂ e)	30	330	10	17	98
	Low Carbon Electricity and Saudi Arabian Oil (million metric tons CO ₂ e)	19	210	6.8	12	68

What does it mean?

- The atmosphere sees net emissions as a result of EOR project.
- Allocation is key. Can be easily manipulated to show best results.
- Energy displacement needs to be understood better.

Thank you for your attention

QUESTIONS?