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Quantifying Greenhouse Gas Reduction Estimates for Surface Controlled Gas Lift

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Agenda

This presentation discusses an estimation of Greenhouse Gas emission reduction when using surface controlled gas lift valves over conventional gas lift valves. It will cover:

- Carbon Intensity Definition
- Surface Controlled Gas Lift Definition
- How to Improve Carbon Intensity
- Assumptions, Variables, and Derivations
- Results
- Conclusions

Carbon Footprint Reduction

For this conversation:

Carbon Intensity is the mass (kg) CO_2 produced per Barrel of Oil lifted.

Carbon Intensity

- Indicator of GHG (Greenhouse Gas) emissions
- Defined as the amount of CO_2 produced per barrel of oil lifted

GOAL: Reduce Carbon Intensity while maintaining profitability

As this goal relates to gas lift:

- Reduce Gas Injection
- Increase Production

Surface Controlled Gas Lift

Surface Controlled Gas Lift:

- Controlling downhole gas injection depth and rate from the surface
- Often used in conjunction with downhole monitoring

Types of Control:

- **Electric**: 1 line to control multiple GL Valves, can include pressure/temp monitoring, small surface footprint, direct feedback on valve status / position
- **Hydraulic**: Usually 2+ or N+1 hydraulic line depending on technology, no integral pressure/temp, surface system can be more complex, no direct feedback on valve status / position
- **Hydraulic/Electric**: combination of the two

Type	Control Lines	Pressure / Temp	Surface Footprint	Surface Complexity / Maintenance	Position Sensing	Inde-pendent Control	Adjustable Choking
Electric	1	Optional	Small	Low	Typically	Yes	Yes
Hydraulic	2+ or N+1	No	Medium / Large	Medium	No	Maybe	Technology Dependent

Carbon Intensity Reduction and Surface Controlled Gas Lift

$$Carbon\ Intensity = \frac{CO_2\ Production}{Oil\ Production}$$

- Reducing Carbon Intensity requires **Decreasing CO_2 Production** or **Increasing Oil Production**. Surface controlled gas lift **does BOTH**.
- **CO_2 Production Decrease:**
  - Placing gas at optimal depth
  - Precise choke sizing (eliminates over injection)
  - Maintaining full gas pressure to injection point
- **Oil Production Increase:**
  - Deeper injection
  - Precise injection rates
  - Better reservoir models
  - Optimization!!!

Simple Quantification of Carbon Intensity Reduction

What this **IS NOT:**

- Absolute Carbon Intensity calculator: would depend on specifics such as power source, compressor efficiencies, etc.
- All encompassing: does not account for reduced workovers, changes in infrastructure for reduced gas requirements and pressures, lower pressure compressors, energy wasted at surface gas flow regulator, etc.

What this **IS:**

- A **SIMPLE** way to quantify **RELATIVE** Carbon Intensity Reduction in gas lifted wells
- A calculation using only basic information from well/reservoir modeling

Assumptions

- CO_2 production is linear with amount of gas compressed and subsequently injected:
  - Ignores reduced pressure requirements
  - Ignores reduced gas infrastructure requirements
  - Independent of gas type because it is recirculated
- CO_2 production due to workover of conventional gas lift is minimal relative to ongoing gas compression/injection
  - The CO_2 impact of rigging up and working over a well is much less than the CO_2 produced from ongoing compression over the life of the well and thus is left out of the analysis
  - Ignoring workovers leads to a more conservative estimate of CO_2 intensity calculations

Variables

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Variable	Description
C_i	Initial Carbon Intensity
C_{rr}	Reduction ratio in Carbon Intensity (reduction in Carbon Intensity divided by initial Carbon Intensity)
$C_{r\%}$	Percentage reduction in Carbon Intensity
C_f	final Carbon Intensity
E_i	initial CO2 exhaust rate
E_r	reduction in CO2 exhaust rate
E_f	final CO2 exhaust rate
E_{rr}	reduction ratio in CO2 exhaust rate (reduction in CO2 exhaust divided by initial CO2 exhaust, often given as percentage instead of a ratio)

Variable	Description
$E_{r\%}$	percentage reduction in CO2 emissions
G_{rr}	reduction ratio in lift gas utilized, the first assumption implies that this is equal to Err
$G_{r\%}$	percentage reduction of lift gas used, the first assumption implies that this is equal to Er%
P_i	initial oil production rate
P_u	uptick in production rate
P_f	final oil production rate
P_{ur}	production rate uptick ratio (increase in oil production divided by initial oil production, often given as a percentage instead of a ratio)
$P_{u\%}$	percentage uptick in oil production

Base Equation Definitions

Equation Definition	Equation Number
$C_i = \frac{E_i}{P_i}$	EQ 1
$E_f = E_i - E_r$	EQ 2
$P_f = P_i + P_u$	EQ 3
$C_f = \frac{E_f}{P_f}$	EQ 4
$E_{rr} = \frac{E_r}{E_i}$	EQ 5
$P_{ur} = \frac{P_u}{P_i}$	EQ 6
$C_{rr} = \frac{C_i - C_f}{C_i}$	EQ 7
$G_{rr} = E_{rr}$	EQ 8
$G_{r\%} = E_{r\%}$	EQ 9

Derivation of Carbon Intensity % Reduction

Explanation	Operation	Equation Number
Simplifying	$C_{rr} = \frac{C_i - C_f}{C_i} = 1 - \frac{C_f}{C_i}$	EQ 10
Substituting EQ 1 AND EQ 4	$C_{rr} = 1 - \frac{(\frac{E_f}{P_f})}{(\frac{E_i}{P_i})}$	EQ 11
Substituting EQ 2 AND EQ 3	$C_{rr} = 1 - \frac{(\frac{E_i - E_r}{P_i + P_u})}{(\frac{E_i}{P_i})}$	EQ 12
Rearranging	$C_{rr} = 1 - \left(\frac{E_i - E_r}{P_i + P_u}\right) * \left(\frac{P_i}{E_i}\right)$	EQ 13
---and	$C_{rr} = 1 - \left(\frac{E_i - E_r}{E_i}\right) * \left(\frac{P_i}{P_i + P_u}\right)$	EQ 14
---and	$C_{rr} = 1 - \frac{\left(\frac{E_i - E_r}{E_i}\right)}{\left(\frac{P_i + P_u}{P_i}\right)}$	EQ 15
---and	$C_{rr} = 1 - \frac{\left(1 - \frac{E_r}{E_i}\right)}{\left(1 + \frac{P_u}{P_i}\right)}$	EQ 16
Substituting EQ 5 and EQ 6	$C_{rr} = 1 - \frac{(1 - E_{rr})}{(1 + P_{ur})}$	EQ 17
If preferable, both sides can be multiplied by 100% to yield	$C_{r\%} = 100\% - 100\% * \frac{(100\% - E_{r\%})}{(100\% + P_{u\%})}$	EQ 18

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Derivation of Final Carbon Intensity

Explanation	Operation	Equation Number
Substituting EQ 10 into EQ 19 for C_{rr}	$1-\frac{C_f}{C_i}=1-\frac{(1-G_{rr})}{(1+P_{ur})}$	EQ 21
Subtracting 1 from each side yields	$-\frac{C_f}{C_i}=-\frac{(1-G_{rr})}{(1+P_{ur})}$	EQ 22
Multiplying both sides by $-C_i$	$C_f=C_i\frac{(1-G_{rr})}{(1+P_{ur})}$	EQ 23

Results

- Table shows the percent reduction in carbon intensity realized vs percent reduction in injected gas and percent increase in production
- Derived using EQ 18 in the table below

Carbon Intensity Reduction Ratio	$C_{rr} = 1 - \frac{(1 - G_{rr})}{(1 + P_{ur})}$	EQ 17
Carbon Intensity Reduction Percentage	$C_{r\%} = 100\% - 100\% * \frac{(100\% - G_{r\%})}{(100\% + P_{u\%})}$	EQ 18
Final Carbon Intensity Value	$C_f = C_i \frac{(1 - G_{rr})}{(1 + P_{ur})}$	EQ 23

CO2 Reduction		Reduction in Injection										
		0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
Increase in Production	0%	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
	2%	2%	7%	12%	17%	22%	26%	31%	36%	41%	46%	51%
	4%	4%	9%	13%	18%	23%	28%	33%	38%	42%	47%	52%
	6%	6%	10%	15%	20%	25%	29%	34%	39%	43%	48%	53%
	8%	7%	12%	17%	21%	26%	31%	35%	40%	44%	49%	54%
	10%	9%	14%	18%	23%	27%	32%	36%	41%	45%	50%	55%
	12%	11%	15%	20%	24%	29%	33%	38%	42%	46%	51%	55%
	14%	12%	17%	21%	25%	30%	34%	39%	43%	47%	52%	56%
	16%	14%	18%	22%	27%	31%	35%	40%	44%	48%	53%	57%
	18%	15%	19%	24%	28%	32%	36%	41%	45%	49%	53%	58%
	20%	17%	21%	25%	29%	33%	38%	42%	46%	50%	54%	58%
	22%	18%	22%	26%	30%	34%	39%	43%	47%	51%	55%	59%
	24%	19%	23%	27%	31%	35%	40%	44%	48%	52%	56%	60%
	26%	21%	25%	29%	33%	37%	40%	44%	48%	52%	56%	60%
	28%	22%	26%	30%	34%	38%	41%	45%	49%	53%	57%	61%
	30%	23%	27%	31%	35%	38%	42%	46%	50%	54%	58%	62%
	32%	24%	28%	32%	36%	39%	43%	47%	51%	55%	58%	62%
	34%	25%	29%	33%	37%	40%	44%	48%	51%	55%	59%	63%
	36%	26%	30%	34%	38%	41%	45%	49%	52%	56%	60%	63%
	38%	28%	31%	35%	38%	42%	46%	49%	53%	57%	60%	64%
	40%	29%	32%	36%	39%	43%	46%	50%	54%	57%	61%	64%
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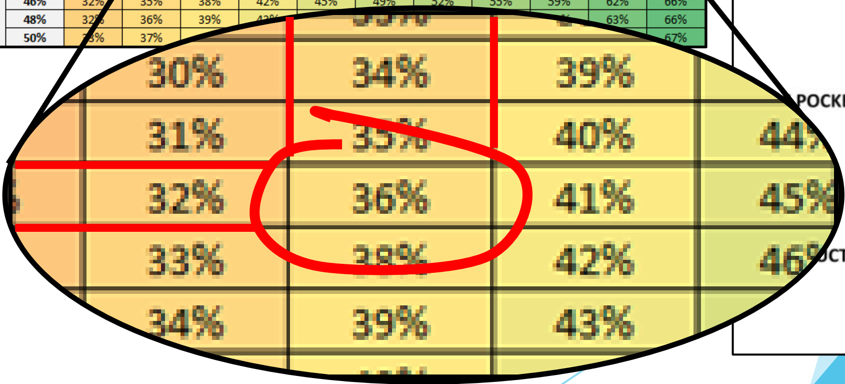
	44%	31%	34%	38%	41%	44%	48%	51%	55%	58%	62%	65%
	46%	32%	35%	38%	42%	45%	49%	52%	55%	59%	62%	66%
	48%	32%	36%	39%	43%	46%	49%	53%	56%	59%	63%	66%
	50%	33%	37%	40%	43%	47%	50%	53%	57%	60%	63%	67%

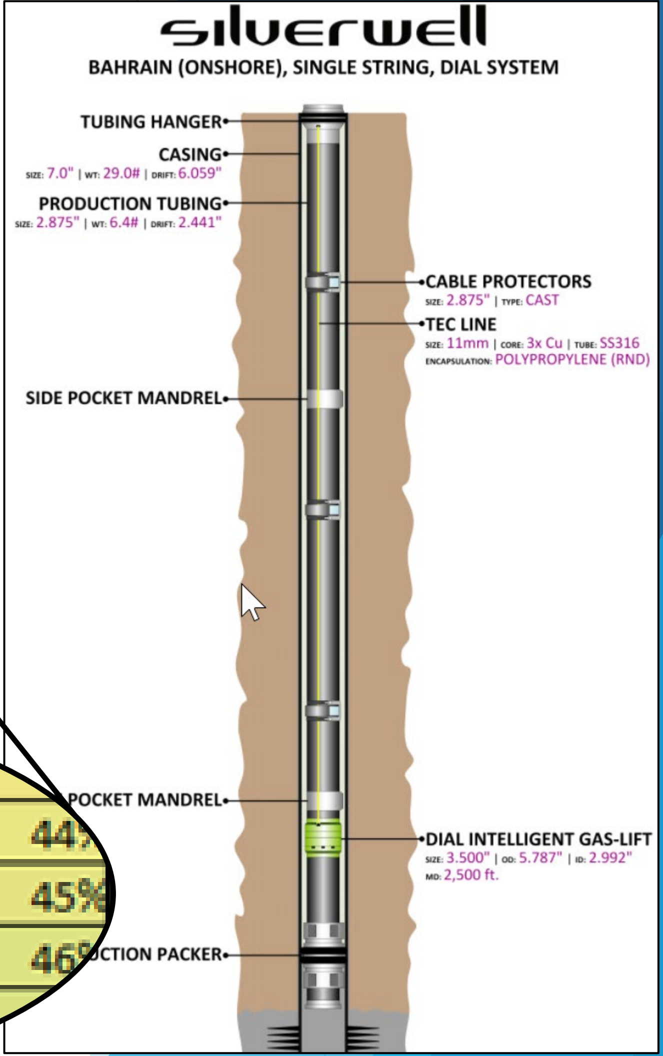
Carbon Intensity Reduction Example

Case Study: "DIAL System's Digital Capabilities Enable Lift Gas Efficiency and Production Increase for Middle East Operator" Silverwell website

- Example of Carbon Intensity reduction calculations applied to a previous Case Study
- Very basic completion (single drop Surface Controlled Gas Lift Valve vs. multi drop)
- Surface Controlled Gaslift System allowed the operator to adjust injection rates and monitor downhole pressure conditions
- Optimized gas injection resulted in 18% production increase and 25% reduction in gas injected
- Calculations show
  36% REDUCTION IN CARBON INTENSITY

CO2 Reduction		Reduction in Injection										
		0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
Increase in Production	0%	0%	5%	10%	15%	20%	[illegible]	30%	35%	40%	45%	50%
	2%	2%	7%	12%	17%	22%	26%	31%	36%	41%	46%	51%
	4%	4%	9%	13%	18%	23%	28%	33%	38%	42%	47%	52%
	6%	6%	10%	15%	20%	25%	29%	34%	39%	43%	48%	53%
	8%	7%	12%	17%	21%	26%	31%	35%	40%	44%	49%	54%
	10%	9%	14%	18%	23%	27%	32%	36%	41%	45%	50%	55%
	12%	11%	15%	20%	24%	29%	[illegible]	38%	42%	46%	51%	55%
	14%	12%	17%	21%	25%	30%	34%	39%	43%	47%	52%	56%
	[illegible]	14%	18%	22%	27%	31%	35%	40%	[illegible]	48%	53%	57%
	18%	15%	19%	24%	[illegible]	32%	36%	41%	[illegible]	49%	53%	58%
	[illegible]	17%	21%	25%	[illegible]	33%	38%	42%	[illegible]	50%	54%	58%
	22%	18%	22%	26%	30%	[illegible]	39%	43%	47%	51%	55%	59%
	24%	19%	23%	27%	31%	35%	[illegible]	44%	48%	[illegible]	56%	60%
	26%	21%	25%	29%	33%	37%	40%	44%	48%	[illegible]	56%	60%
	28%	22%	26%	[illegible]	34%	38%	41%	45%	49%	53%	57%	61%
	30%	23%	27%	[illegible]	35%	38%	42%	46%	50%	54%	58%	62%
	32%	24%	28%	32%	36%	39%	43%	47%	51%	55%	[illegible]	62%
	34%	25%	29%	33%	37%	40%	44%	48%	51%	55%	[illegible]	63%
	36%	26%	30%	34%	38%	41%	45%	49%	52%	56%	60%	63%
	38%	28%	[illegible]	35%	38%	42%	46%	49%	53%	57%	60%	64%
	40%	29%	[illegible]	36%	39%	43%	46%	50%	54%	57%	61%	[illegible]
	42%	30%	33%	37%	40%	44%	47%	51%	54%	58%	61%	[illegible]
	44%	31%	34%	38%	41%	44%	48%	51%	55%	58%	62%	65%
	46%	32%	35%	38%	42%	45%	49%	52%	55%	59%	62%	66%
	48%	[illegible]	36%	39%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	63%	66%
	50%	[illegible]	37%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	67%





Conclusions

- Well modeling can be used to predict performance improvements when utilizing surface control for gas lift:
  - Increased Production
  - Reduced Gas Injection
- In addition to increased profits, surface controlled gas injection reduces ongoing Greenhouse Gas Emissions
- Using basic assumptions, performance improvement data can be used to estimate Carbon Intensity reduction
- This is a conservative estimate: does not include reduced workovers, trips to well, and infrastructure reduction
- Details on this derivation can be found as a white paper on www.SilverwellEnergy.com under resources – technical papers

Acknowledgements/Thanks & Questions

I would like to thank:

- ALRDC for the opportunity to present
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- The oil industry for the strides it continues to make towards more efficient use of our Earth's resources with less impact to the environment

Questions? Comments?

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