Reducing Methane Emissions from Wet Seal Equipped Centrifugal Compressors

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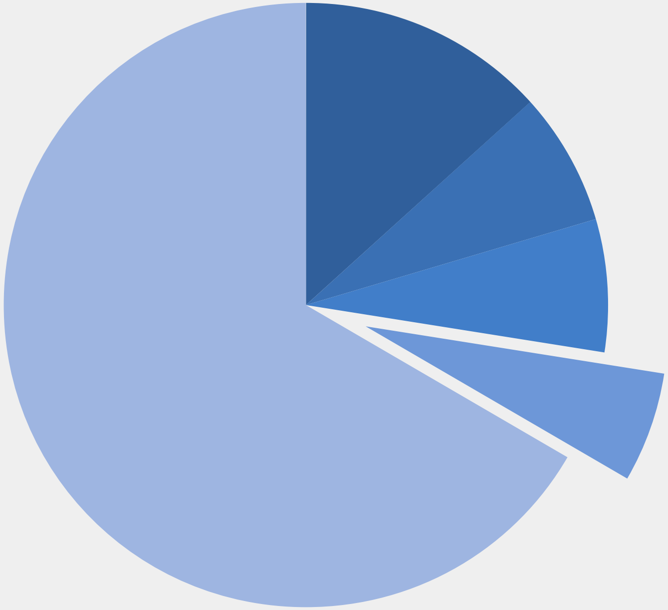
Summary

- Centrifugal compressors equipped with wet seal technology are believed to be the leading source of methane emissions offshore and the fourth most significant source in onshore natural gas operations
- The latest EPA proposed NSPS identify three approaches to reduce methane emissions from such equipment
- The EPA Natural Gas STAR program has also been active in this area. The published work necessarily cites “typical” scenarios comparing some of the options and the data is static
- This presentation showcases a decision support tool “The Life Cycle Cost Calculator” that builds on previous work and takes it to the next level

Insightful, Comprehensive, Customizable, Specific

The Problem

2018 Projected Onshore Methane Emissions
(Source: ICF/EDF March 2014)

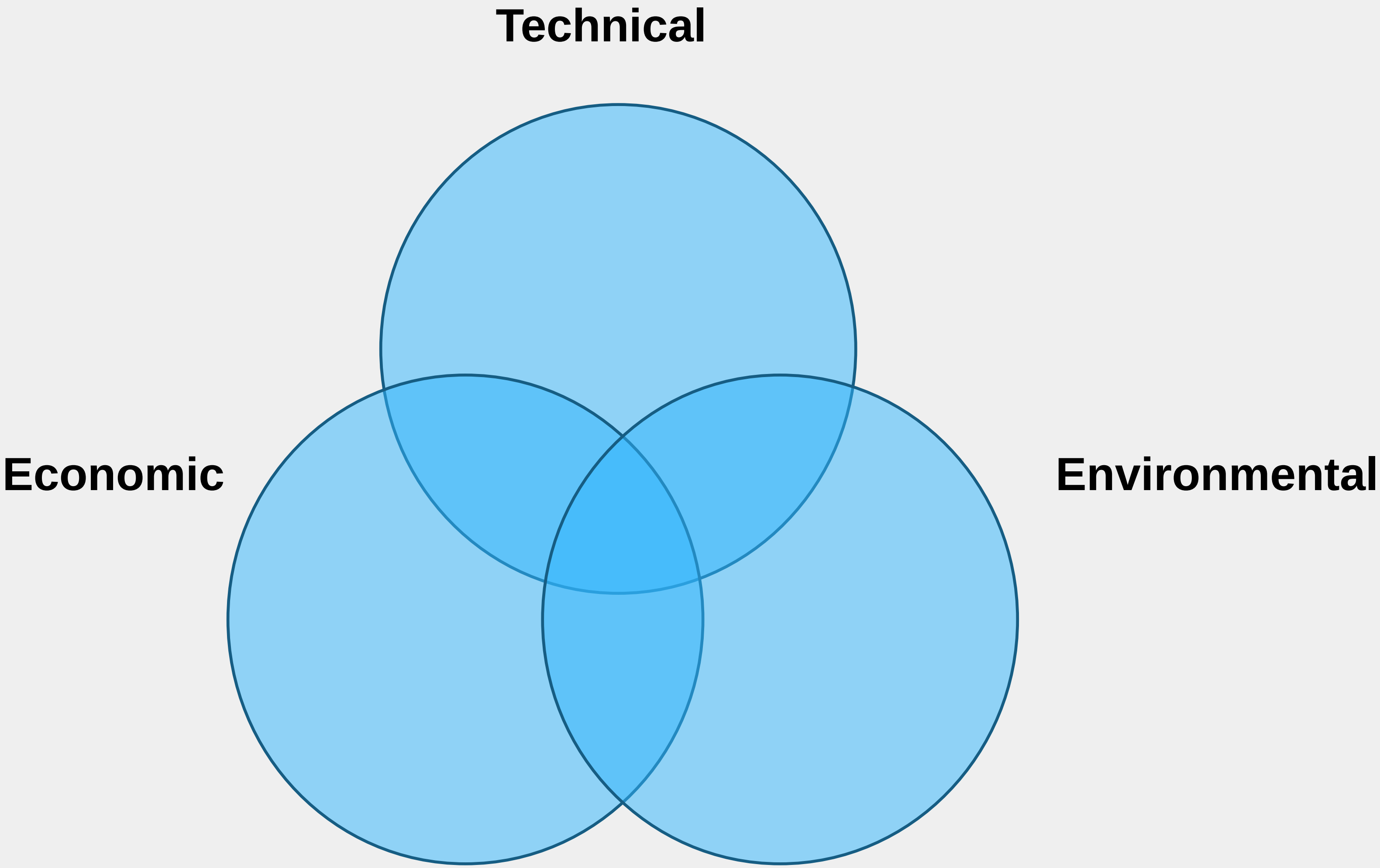


Centrifugal Compressors (Wet Seals)
5.9%

The Options

- Retrofit oil seal technology with de-gassing vent to flare
- Retrofit oil seal technology with de-gassing vent to capture / use
- Retrofit oil seal technology with gas seal technology

The Determining Factors



Insight from Life Cycle Cost Calculator

- Economic impact
- Climate impact
- Energy impact

The complete life cycle cost

Life Cycle Cost Calculator

Process Data

- Methane content
- Flow rate
- Pressure
- Operational hours
- Process gas value

Compressor Data

- Driver
- Power
- Efficiency
- Number of seals
- Shaft Size

Reliability Data

- Planned maintenance costs
- Unplanned maintenance costs
- Spare parts cost
- Lost production time
- MTBR

Seal Support System Data

- Power requirements
- Cooling configuration

Seal Data

- Frictional power
- Leakage rate
- Gas injection source
- Leakage destination

Retrofit / Upgrade Data

- New seals and spares costs
- System upgrade/replacement costs
- Equipment modification costs
- Electrical and instrumentation costs
- Site materials and installation costs
- Decommissioning and disposal costs
- Lost production time

Utilities Data

- Driver fuel value
- Electricity value
- Purge gas value

Life Cycle Cost Calculator Outputs

Costs

Annual Operating Costs

- Maintenance cost
- Value of leaked gas
- Consumables
- Energy consumed by seal
- Energy consumed by seal system

One-Time Costs

- Total retrofit costs
- Payback

Present Value

- Present value of annual operating costs over lifespan remaining

Total Life Cycle Cost

Energy Consumed

Energy Consumed From:

- Seal and support system
- Compressed gas energy released
- Pipe friction from contamination

Carbon Footprint

Equivalent CO2 Emissions From:

- Seal leakage
- Compressor blow down
- Energy required for the seal and support system
- Compressed gas energy released
- Energy required to overcome pipe friction

Life Cycle Cost Calculator

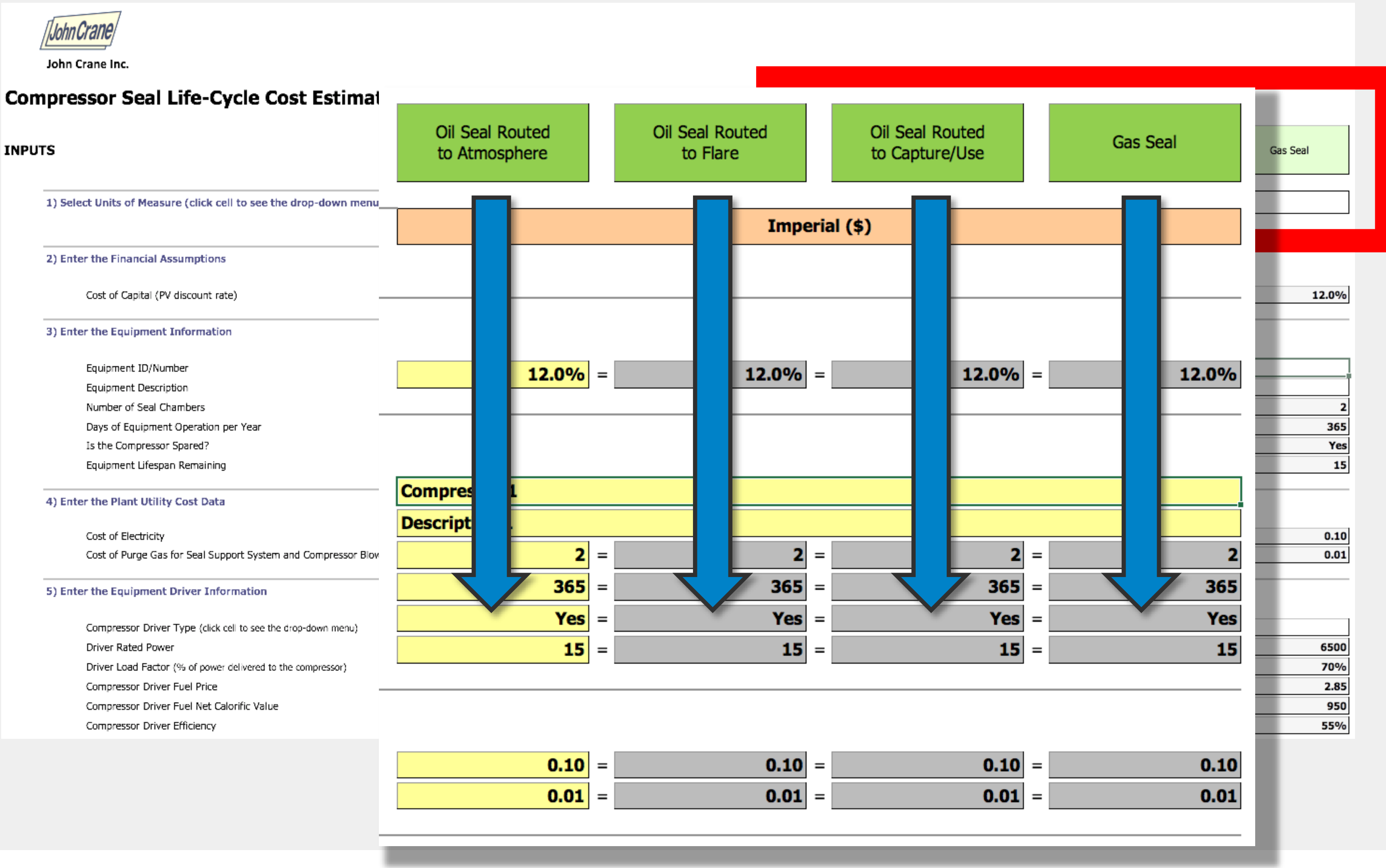
John Crane Inc.

Compressor Seal Life-Cycle Cost Estimator

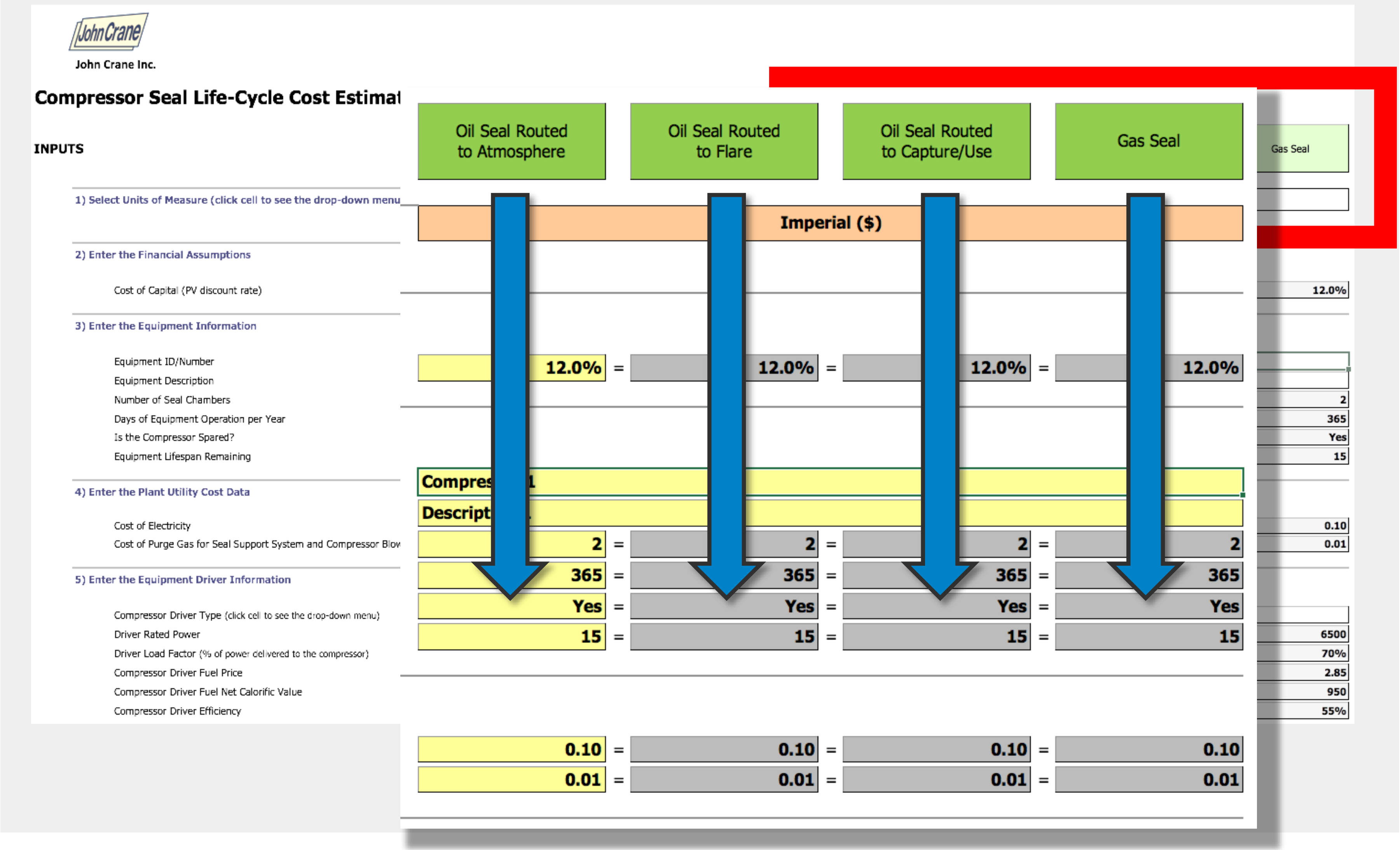
INPUTS

	Default	Units	Oil Seal Routed to Atmosphere	Oil Seal Routed to Flare	Oil Seal Routed to Capture/Use	Gas Seal
1) Select Units of Measure (click cell to see the drop-down menu)		**Units →**	**Imperial ($)**			
2) Enter the Financial Assumptions	**Default**	**Units**				
Cost of Capital (PV discount rate)	12%	-	**12.0%**	**12.0%**	**12.0%**	**12.0%**
3) Enter the Equipment Information	**Default**	**Units**				
Equipment ID/Number		(User info only)	**Compressor 1**			
Equipment Description		(User info only)	**Description 1**			
Number of Seal Chambers	2	Quantity	**2**	**2**	**2**	**2**
Days of Equipment Operation per Year	365	Days / Year	**365**	**365**	**365**	**365**
Is the Compressor Spared?	Yes	Yes / No	**Yes**	**Yes**	**Yes**	**Yes**
Equipment Lifespan Remaining	15	Years	**15**	**15**	**15**	**15**
4) Enter the Plant Utility Cost Data	**Default**	**Units**				
Cost of Electricity	0.10	$ / kWh	**0.10**	**0.10**	**0.10**	**0.10**
Cost of Purge Gas for Seal Support System and Compressor Blowdown	0.01	$ / SCF	**0.01**	**0.01**	**0.01**	**0.01**
5) Enter the Equipment Driver Information	**Default**	**Units**				
Compressor Driver Type (click cell to see the drop-down menu)	⇨	⇨	**Gas Turbine (Natural Gas Powered)**			
Driver Rated Power	6500	hP	**6500**	**6500**	**6500**	**6500**
Driver Load Factor (% of power delivered to the compressor)	70%	-	**70%**	**70%**	**70%**	**70%**
Compressor Driver Fuel Price	2.850	$ / 1000 ft³	**2.850**	**2.850**	**2.85**	**2.85**
Compressor Driver Fuel Net Calorific Value	950	BTU / ft³	**950**	**950**	**950**	**950**
Compressor Driver Efficiency	55%	-	**55%**	**55%**	**55%**	**55%**

Life Cycle Cost Calculator



Life Cycle Cost Calculator



Life Cycle Cost Calculator

John Crane Inc.

Compressor Seal Life-Cycle Cost Estimator

INPUTS

	Default	Units	Oil Seal Routed to Atmosphere		Oil Seal Routed to Flare		Oil Seal Routed to Capture/Use		Gas Seal
1) Select Units of Measure (click cell to see the drop-down menu)		Units →	**Imperial ($)**						
2) Enter the Financial Assumptions	Default	Units							
Cost of Capital (PV discount rate)	12%	-	12.0%	=	12.0%	=	12.0%	=	12.0%
3) Enter the Equipment Information	Default	Units							
Equipment ID/Number		(User info only)	Compressor 1						
Equipment Description									
Number of Seal Chambers			2	=	2	=	2	=	2
Days of Equipment Operation per Year			365	=	365	=	365	=	365
Is the Compressor Spared?			Yes	=	Yes	=	Yes	=	Yes
Equipment Lifespan Remaining			15	=	15	=	15	=	15
4) Enter the Plant Utility Cost Data									
			0.10	=	0.10	=	0.10	=	0.10
			0.01	=	0.01	=	0.01	=	0.01
5) Enter the Equipment Driver Information									
Compressor Driver Type (click cell to see the drop-			ral Gas Powered)						
Driver Rated Power	6500	HP	6500	=	6500	=	6500	=	6500
Driver Load Factor (% of power delivered to the compressor)	70%	-	70%	=	70%	=	70%	=	70%
Compressor Driver Fuel Price	2.850	$ / 1000 ft³	2.850	=	2.850	=	2.85	=	2.85
Compressor Driver Fuel Net Calorific Value	950	BTU / ft³	950	=	950	=	950	=	950
Compressor Driver Efficiency	55%	-	55%	=	55%	=	55%	=	55%

5) Enter the Equipment Driver Information

- Compressor Driver Type (click cell to see the drop-down menu)
- Driver Rated Power
- Driver Load Factor (% of power delivered to the compressor)
- Compressor Driver Fuel Price
- Compressor Driver Fuel Net Calorific Value
- Compressor Driver Efficiency

Life Cycle Cost Calculator

John Crane Inc.

Compressor Seal Life-Cycle Cost Estimator

INPUTS

	Default	Units	Oil Seal Routed to Atmosphere		Oil Seal Routed to Flare		Oil Seal Routed to Capture/Use		Gas Seal
1) Select Units of Measure (click cell to see the drop-down menu)		Units →	Imperial ($)						
2) Enter the Financial Assumptions	Default	Units							
Cost of Capital (PV discount rate)	12%	-	12.0%	=	12.0%	=	12.0%	=	12.0%
3) Enter the Equipment Information	Default	Units							
Equipment ID/Number		(User info only)	Compressor 1						
Equipment Description									
Number of Seal Chambers			2	=	2	=	2	=	2
Days of Equipment Operation per Year			365	=	365	=	365	=	365
Is the Compressor Spared?			Yes	=	Yes	=	Yes	=	Yes
Equipment Lifespan Remaining			15	=	15	=	15	=	15
4) Enter the Plant Utility Cost Data									
			0.10	=	0.10	=	0.10	=	0.10
			0.01	=	0.01	=	0.01	=	0.01
5) Enter the Equipment Driver Information									
Compressor Driver Type (click cell to see the drop-			ral Gas Powered)						
Driver Rated Power	6500	HP	6500	=	6500	=	6500	=	6500
Driver Load Factor (% of power delivered to the compressor)	70%	-	70%	=	70%	=	70%	=	70%
Compressor Driver Fuel Price	2.850	$ / 1000 ft³	2.850	=	2.850	=	2.85	=	2.85
Compressor Driver Fuel Net Calorific Value	950	BTU / ft³	950	=	950	=	950	=	950
Compressor Driver Efficiency	55%	-	55%	=	55%	=	55%	=	55%

5) Enter the Equipment Driver Information

Compressor Driver Type (click cell to see the drop-down menu)
Driver Rated Power
Driver Load Factor (% of power delivered to the compressor)
Compressor Driver Fuel Price
Compressor Driver Fuel Net Calorific Value
Compressor Driver Efficiency

Life Cycle Cost Calculator

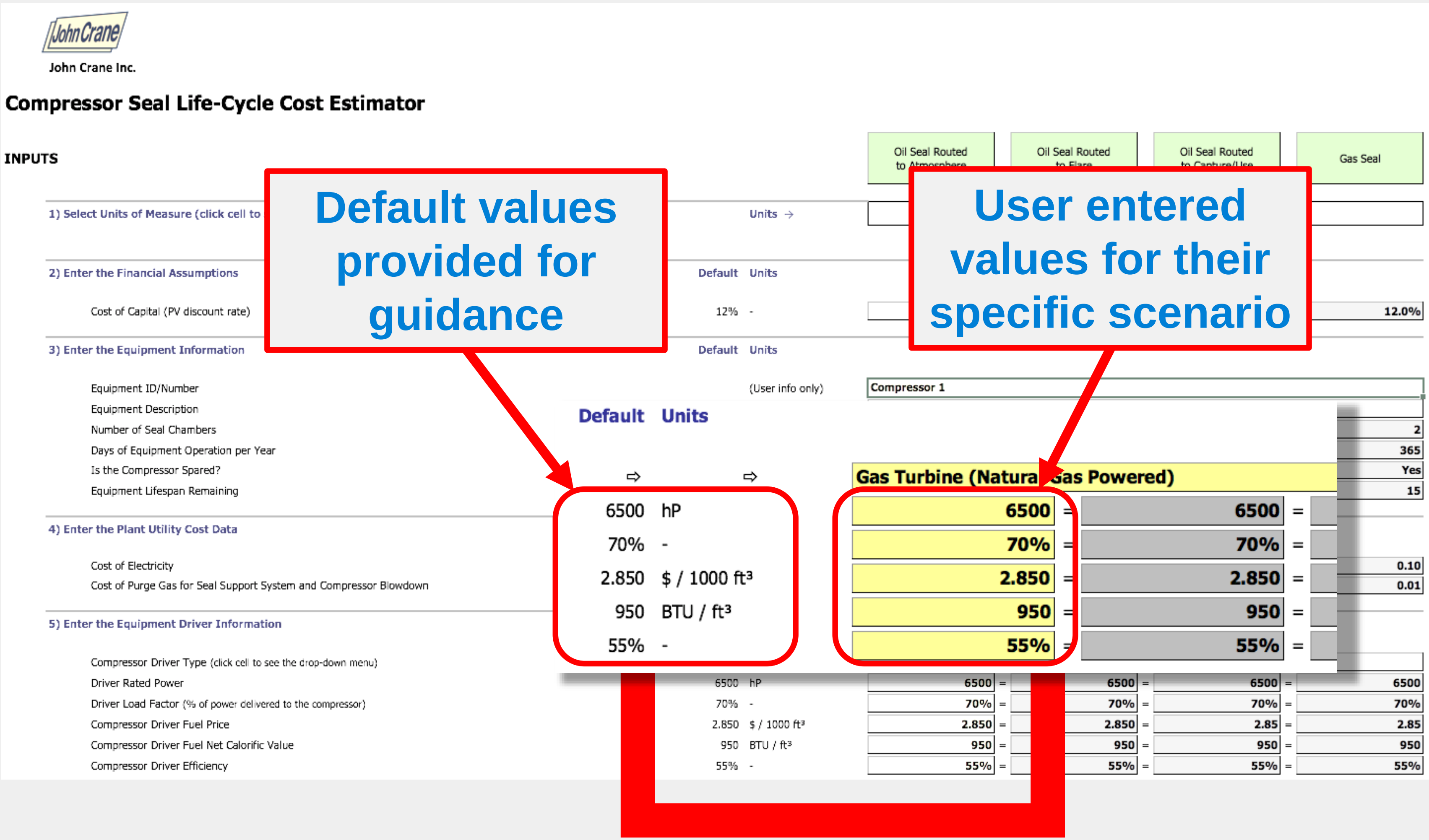


Illustration One

Pipeline compressor

Natural Gas:	96% Methane
	\$3.00 / Mcf
Flow:	17,000 scfm (480 m^3/min)
Pressure:	600 psig (41.3 Barg) Suction
	1,100 psig (75.8 Barg) Discharge
Shaft Speed:	9,000 RPM
Driver:	Gas Turbine 10,500 hp (7,800 kW)
Shaft Diameter:	5” (127 mm)
Operational hours:	4,000 hr/year
Spared:	Yes

Equipment operator owns the compressed gas

Illustration One Outputs

- Annual operating costs

1) Annual Operating Calculations

			Oil Seal Routed to Atmosphere	Oil Seal Routed to Flare	Oil Seal Routed to Capture/Use	Gas Seal
C_{fs}	Operating Cost of Lost Energy from Seal Friction	$ / year	3,351	3,351	3,351	98
C_{rr}	Operating Cost of Energy Required to Operate Seal Oil System	$ / year	12,637	12,637	12,637	0
C_l	Operating Cost of Lost Energy and Product Loss due to Leakage	$ / year	219,514	219,514	37,138	29,608
C_{fp}	Operating Cost of Lost Energy to Overcome Pipe Friction Due To Oil Contamination	$ / year	21,518	21,518	21,518	0
C_{en}	Operating Cost to Replace Consumed Seal Oil	$ / year	39,000	39,000	39,000	0
C_m	Maintenance and Downtime Costs	$ / year	11,000	11,000	11,000	7,500
C_p	Cost of Process and Purge Gas Used During Compressor Blowdown	$ / year	1	1	1	0
C_g	Cost of Gas Seal Separation Gas Consumption	$ / year	0	0	0	5,002
C_{total}	**Total Operating Costs**	$ / year	307,022	307,022	124,645	42,208

No change as value of leakage is not recovered (either vented to atmosphere or combusted)

Base operating cost is reduced

Value of leakage is recovered. Base operating cost unchanged

Illustration One Outputs

- One time costs

2) One-time Costs

			Oil Seal Routed to Atmosphere	Oil Seal Routed to Flare	Oil Seal Routed to Capture/Use	Gas Seal
C_{ic}	**Initial Purchase Cost (Investment)**	$		5,000	25,000	305,000
C_{in}	**Installation Cost**	$		110,000	50,000	190,000
C_d	**Decommissioning and Disposal Cost**	$		0	0	10,000
	Total Retrofit Costs	$		115,000	75,000	505,000
	Payback	Months		No Payback	5	23

Existing equipment baseline

Moderate implementation cost. No payback as operating cost is unchanged

Low implementation cost. Payback based on value of recovered leakage

High implementation cost. Payback based on reduced operating cost

Illustration One Outputs

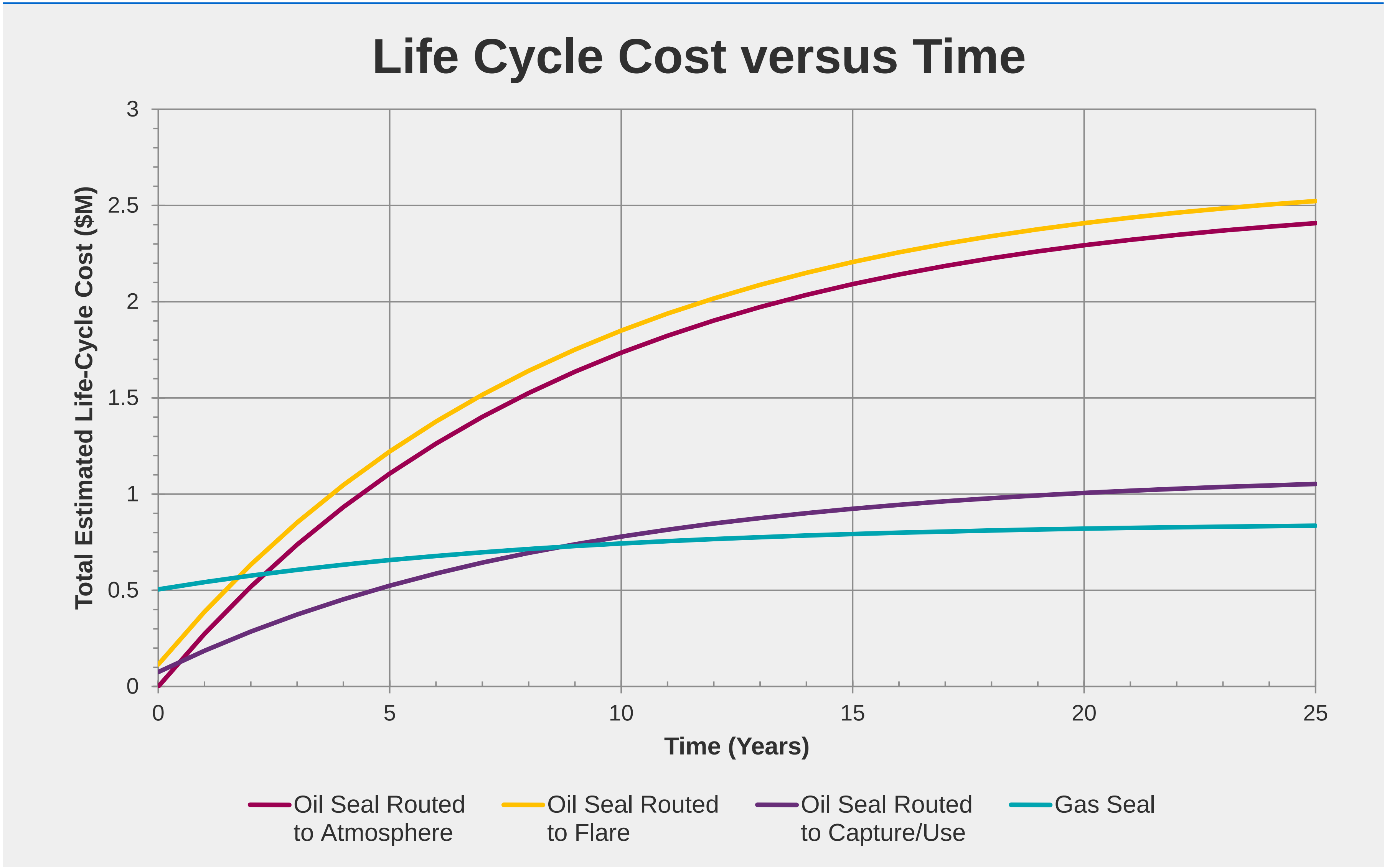
- Energy and carbon footprint

No change in energy requirements of the sealing system as the seals remain unchanged

		Oil Seal Routed to Atmosphere	Oil Seal Routed to Flare	Oil Seal Routed to Capture/Use	Gas Seal
4) Power Consumption Calculations					
Seal Friction Energy Lost	MWh / year	244	244	244	7
Energy Required to Operate Seal Oil System	MWh / year	123	123	123	0
Energy Lost to Compress Gas That is Leaked	MWh / year	1,691	1,691	1,691	1,270
Energy Lost to Overcome Pipe Friction Due To Oil Contamination	MWh / year	1,569	1,569	1,569	0
Energy Lost to Compress Gas That is Vented During Compressor Blowdown	MWh / year	1.3	1.3	1.3	0.2
Total Power Consumption	MWh / year	3,629	3,629	3,629	1,277
5) Carbon Footprint					
CO2 Equivalent Emissions from Seal Friction Lost Energy	Metric tons / year	44	44	44	1
CO2 Equivalent Emissions to Operate Seal Oil System	Metric tons / year	68	68	68	0
CO2 Equivalent Emissions Resulting From Leakage and Energy Required to Compress Gas That is Leaked	Metric tons / year	43,324	4,115	3,362	2,901
CO2 Equivalent Emissions Resulting From Pipe Friction Due To Oil Contamination	Metric tons / year	284	284	284	0
CO2 Equivalent Emissions Resulting From Compressor Blowdown	Metric tons / year	0.3	0.2	0.3	0.0
Total CO_2 Equivalent Emissions	Metric tons / year	43,721	4,512	3,759	2,902

Carbon footprint is reduced with each variation of the sealing solution

Illustration One Outputs



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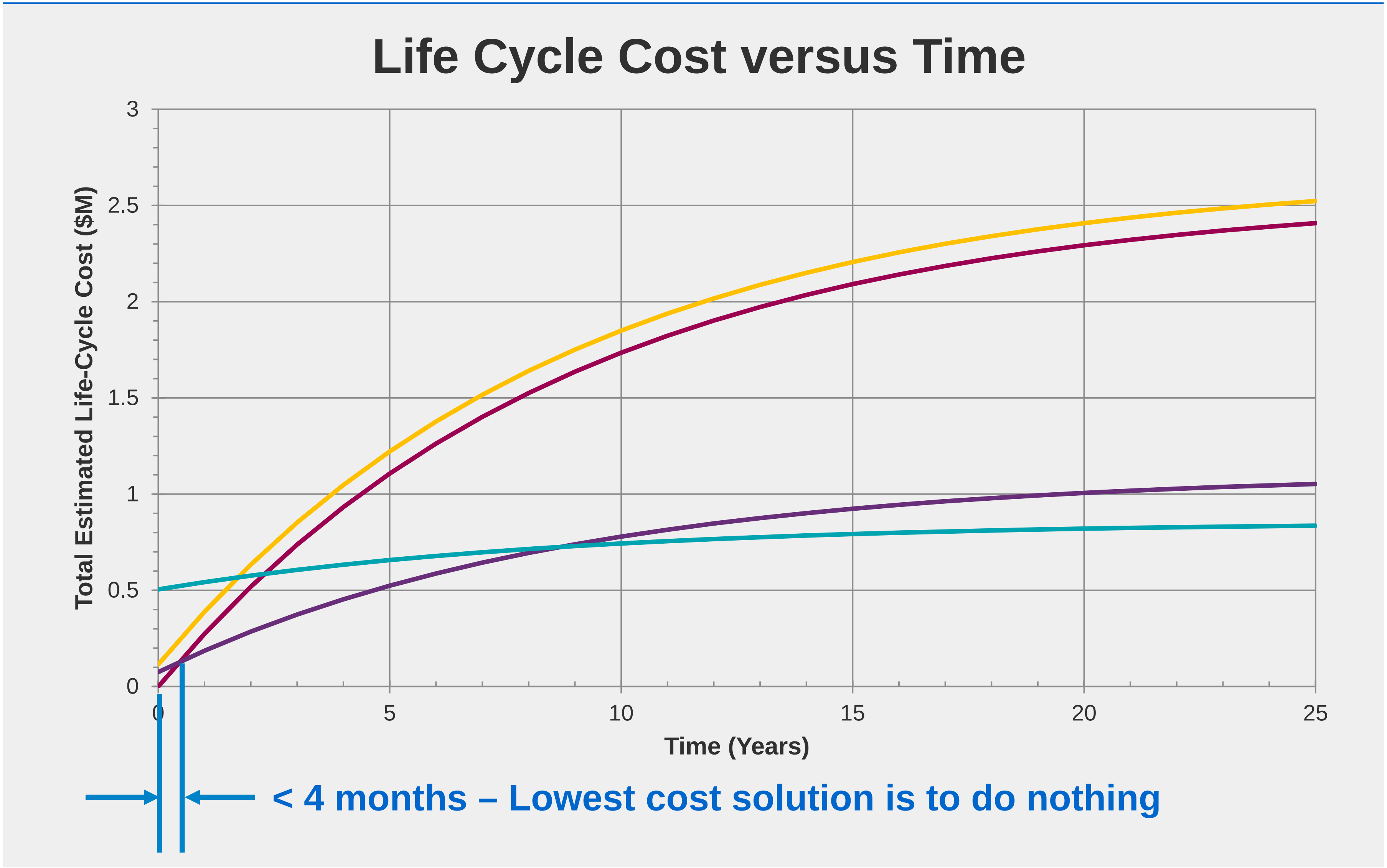

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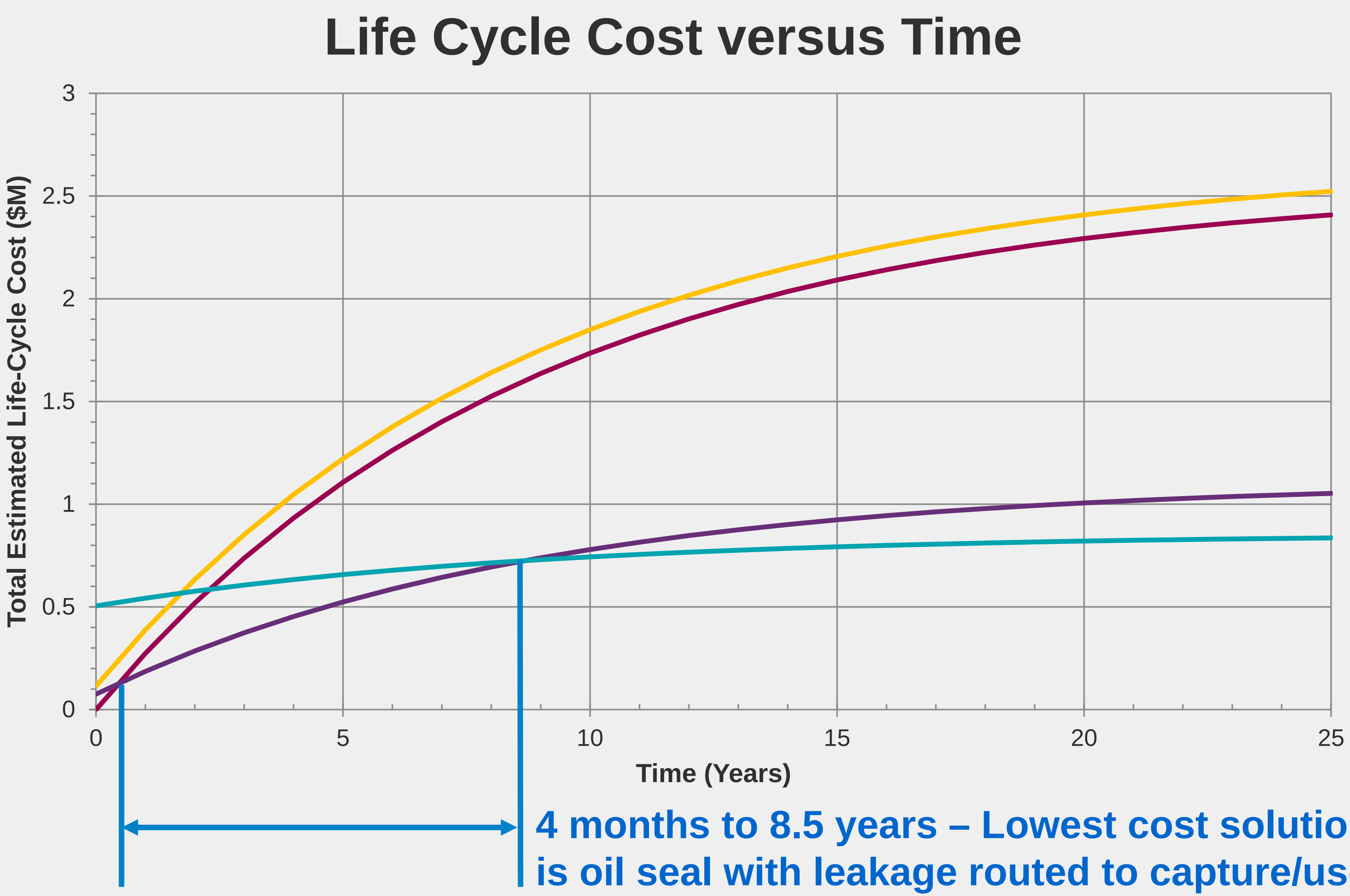
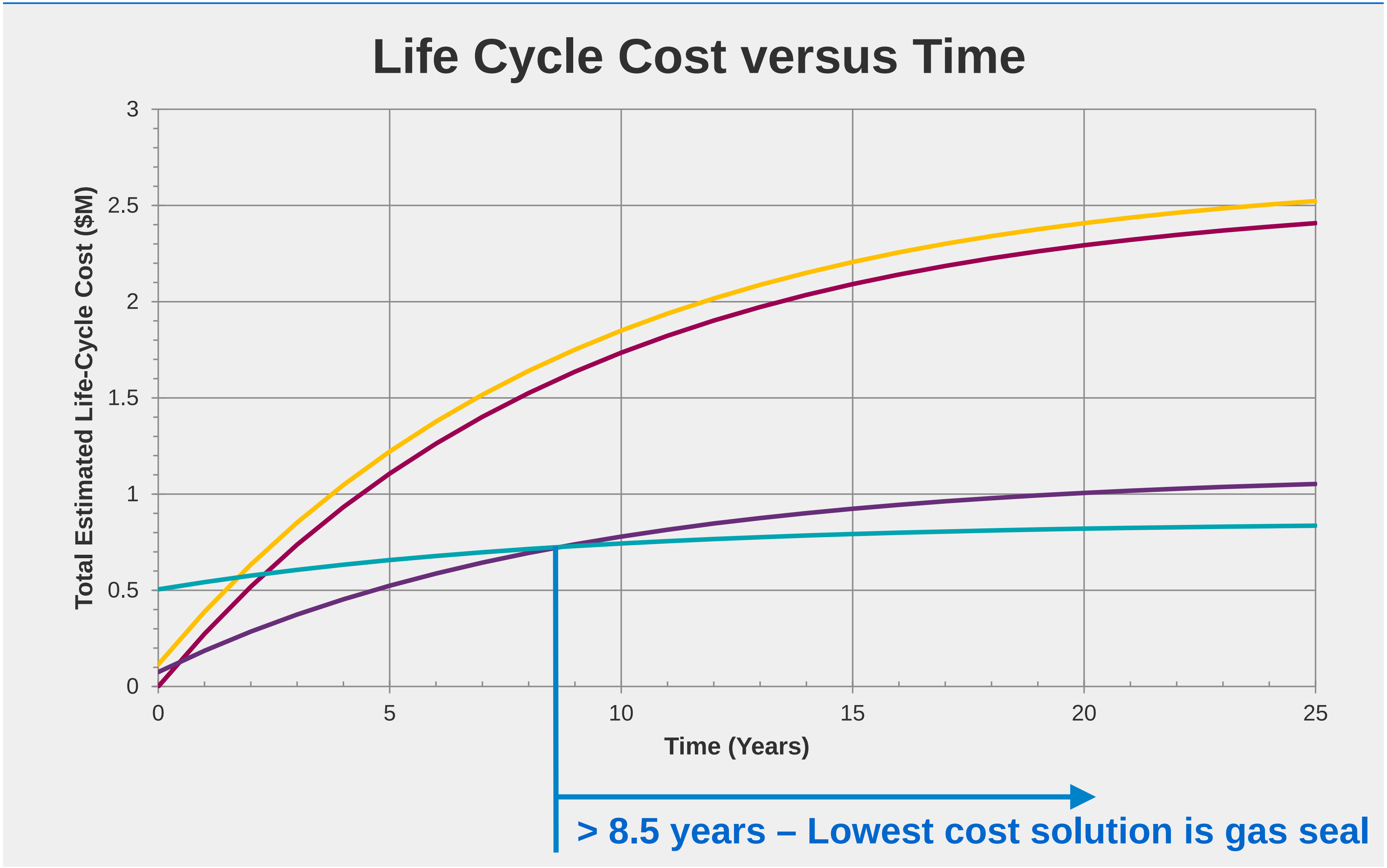


4 months to 8.5 years – Lowest cost solution is oil seal with leakage routed to capture/use

Illustration One Outputs



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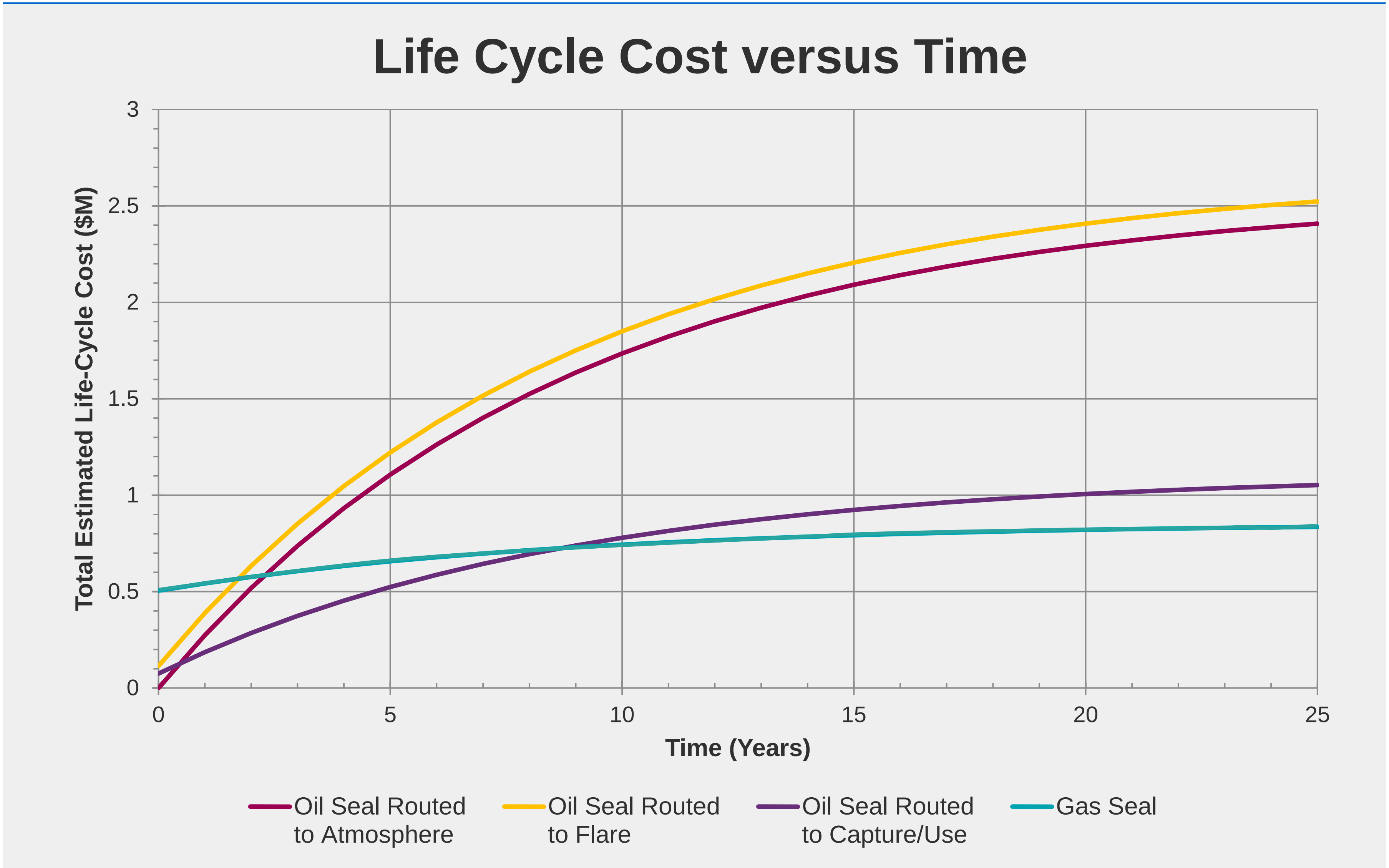

Concluding Comments

In the drive to **reduce methane emissions** from wet seal equipped centrifugal compressors…

…The Lifecycle Cost Calculator provides decision support that is:

Insightful

Comprehensive

Customizable

Specific

Further Information

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Natural Gas STAR Annual Implementation Workshop

Exhibition Area Booth 19