CCS Options & Cost Reductions with New UOP SELEXOL™ Process Flow Schemes

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Advantages of Enhanced Selexol Flowscheme

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- Meet emission requirements when venting of CO_2 is required
- Meet CO_2 purity for Urea Production (less than 100 ppmv)
- Recover valuable H_2 and CO
- No separate thermal oxidation is required

CO_2 Purity Specifications Widely Vary.....

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Purpose

- **Transportation/Storage**
- Enhanced Oil Recovery
- Urea Production

Operational flexibility

- Emergency venting

CO_2 Pipeline Example:

	Kinder Morgan
CO_2	> 95 %
HC's	< 5 %
N_2	< 4 %
H_2S	< 20 ppmv
O_2	< 10 ppmw
H_2O	< 30 lbs/MMCF

CO_2 Purity Specifications Widely Vary.....

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- Transportation/Storage
- **Enhanced Oil Recovery**
- **Urea Production**

Operational flexibility

- Emergency venting

Examples of CO_2 in Enhanced Oil Recovery

	Canyon Reef	*Weyburn*
CO_2	> 95 %	> 96 %
HC's	< 4 %	< 3 %
H_2, N_2, CO	< 4 %	< 0.1%
H_2S	< 1500 ppmv	< 0.9 %
H_2O	< 28 lbs/MMCF	

Typical CO_2 Purity Spec for Urea Production:

	To Urea
CO_2	>99.5 mol%
H_2	<0.3 mol%
N_2	<0.1 mol%
CO	<0.06 mol%
H_2S	<0.1 ppmv

CO in CO_2 Stream is a Controlled Substance....

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Purpose

- Transportation
- Enhanced Oil Recovery
- Urea Production
- Storage

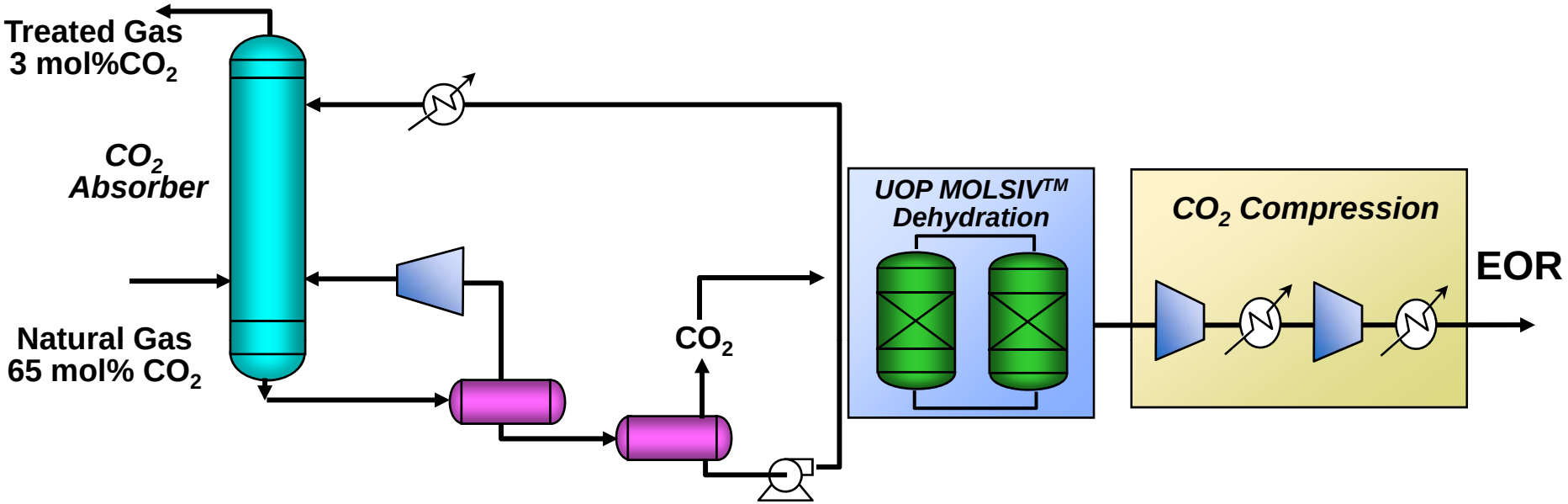
Operational flexibility

- **Venting: Start / Stop / Emergency**

Example: US Permitting Limit for Point Sources of CO:

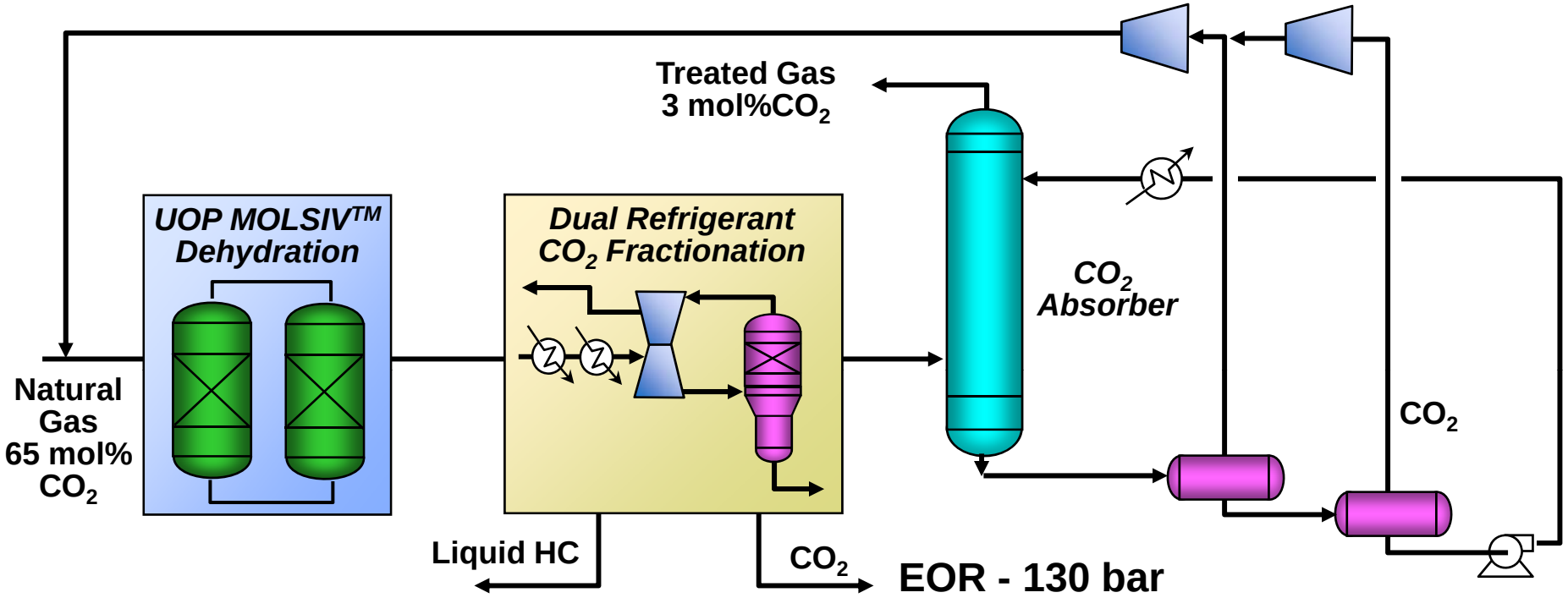
Typical purities from AGR		*Permissible Days of Venting*	
CO_2 Purity	CO in CO_2	Minor Source	Major Source
95%	2%	1.1	2.5-4.5
99%	0.2%	9	22-45
99%	0.1%	18	44-90
99.8%	100 ppmv	180	Continuous

Natural Gas – Initial Flow Scheme



- Natural Gas - High CO_2 Content
  - 400 MMSCFD = 20,000 kmol/h
  - 80 bar
  - 35 mol% methane, heavier hydrocarbons & nitrogen
  - 65 mol% CO_2
- Treated Gas
  - Pipeline specification: 3 mol% CO_2
- EOR = Enhanced Oil Recovery
  - CO_2 Pressure: 130 bar
- Capex
  - Selexol Unit
  - CO_2 Compression

Natural Gas – Final Flow Scheme



- Dual Refrigerant CO_2 Fractionation (DRCF)
  - Chilling of natural gas stream
  - Bulk Removal of CO_2
- UOP MOLSIV Dehydration
  - Fixed bed adsorption – thermal regeneration
  - Avoid freezing of H_2O in DRCF
- UOP Selexol Process
  - Trim CO_2 Removal

Benefits of Selexol + DRCF Flowscheme

Plant Process Option	Rotating Equipment Power Required By Process Unit (MW)				Total
	Compression		Pumping		
	CO_2 Frac.	SELEXOL	CO_2 Frac.	SELEXOL	
Conventional SELEXOL	--	71.3	--	10.6	81.9
Dual Refrig. CO_2 Frac + SELEXOL	11.5	26.1	5.0	2.9	45.5

- **Savings:**
  - **OPEX : US$ 30- 40 MM**
  - **CAPEX : US$ 39 MM**
  - **Hydrocarbon losses : - 75%**

Can this Concept be Applied in Gasification?

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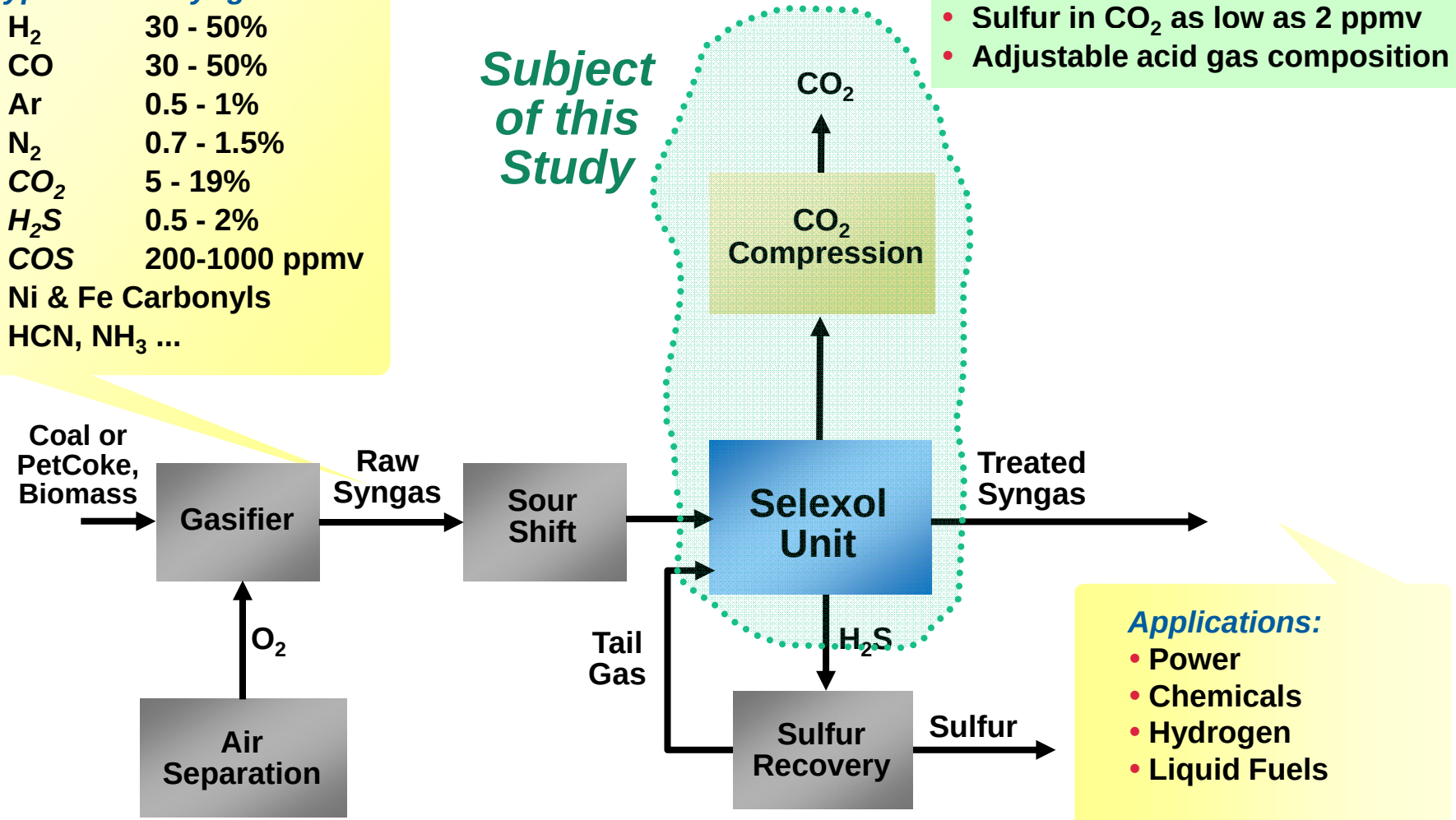
Typical Gasification Complex

- CO in the CO_2 stream is <100 ppmv
- CO_2 purity as high as 99.7 mol%
- Sulfur in treated gas as low as 0.1 ppmv
- Sulfur in CO_2 as low as 2 ppmv
- Adjustable acid gas composition

Typical Raw Syngas

- H_2 30 - 50%
- CO 30 - 50%
- Ar 0.5 - 1%
- N_2 0.7 - 1.5%
- *CO_2* 5 - 19%
- *H_2S* 0.5 - 2%
- *COS* 200-1000 ppmv
- Ni & Fe Carbonyls
- HCN, NH_3 ...



Applications:

- Power
- Chemicals
- Hydrogen
- Liquid Fuels

Selexol Flow Schemes - Gasification
Sulfur Removal & CO_2 Capture—Conventional

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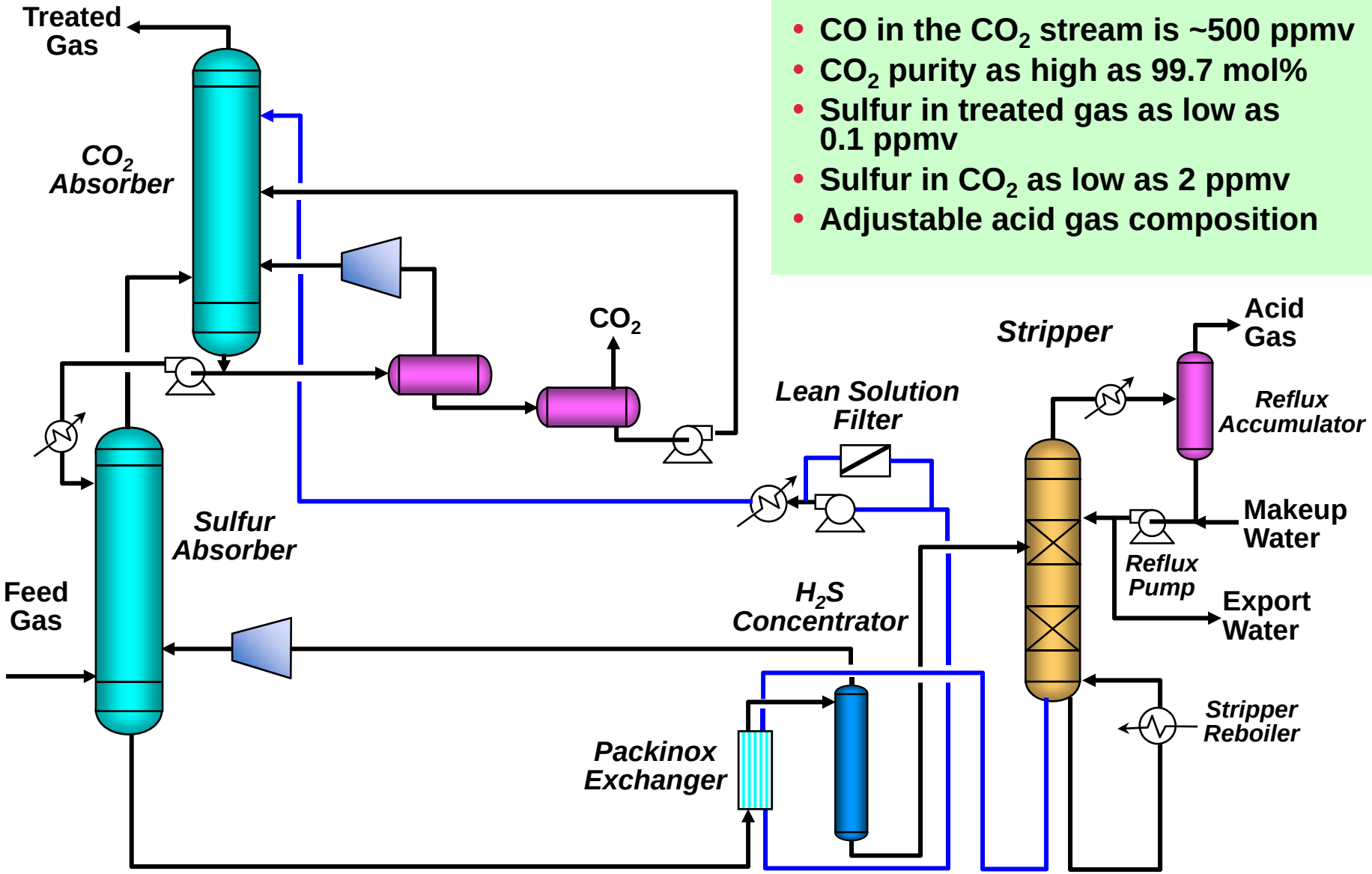
- CO in the CO_2 stream is ~500 ppmv
- CO_2 purity as high as 99.7 mol%
- Sulfur in treated gas as low as 0.1 ppmv
- Sulfur in CO_2 as low as 2 ppmv
- Adjustable acid gas composition



Selexol Flow Schemes - Gasification
Sulfur Removal & CO_2 Capture – Conventional

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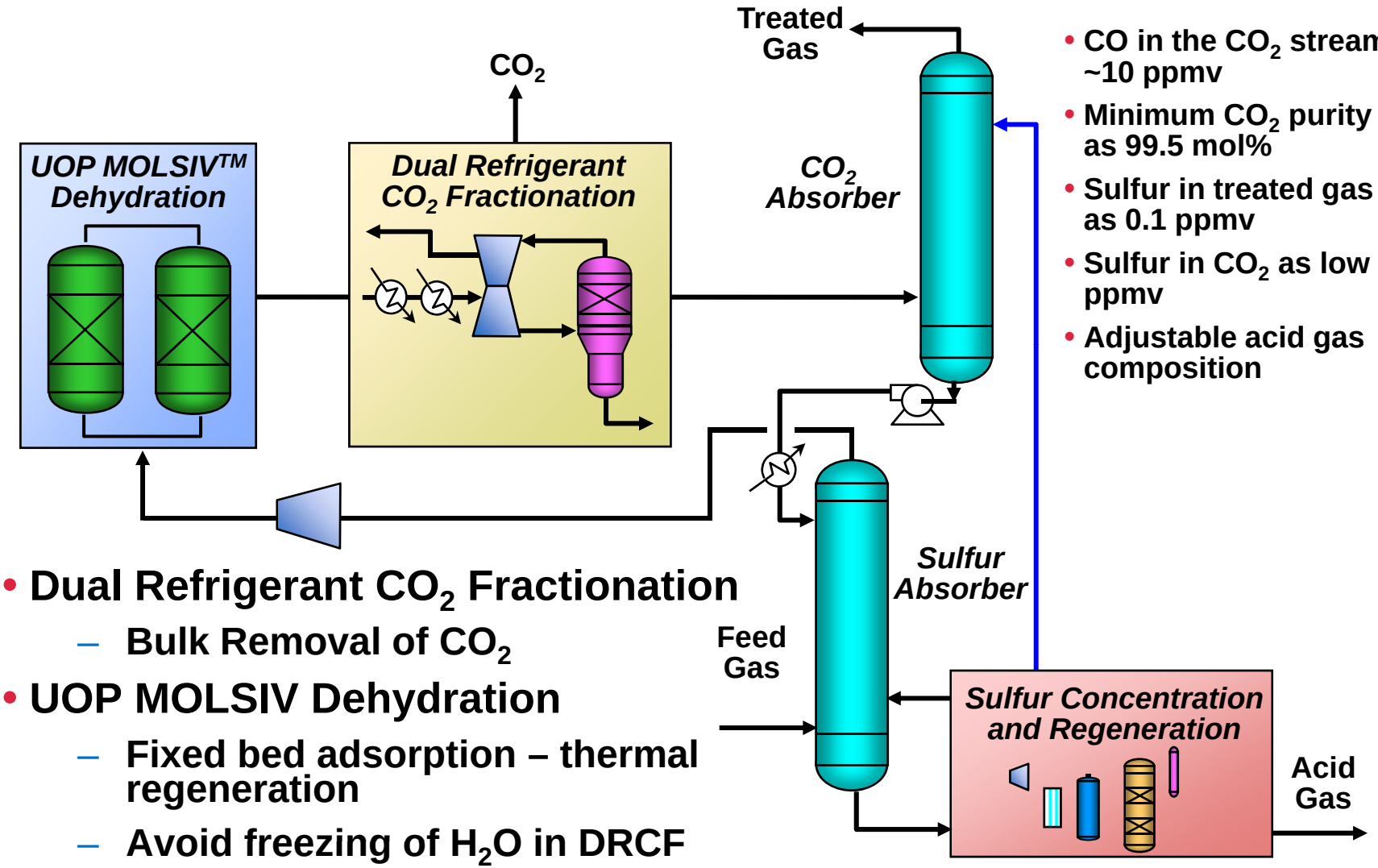
- Syngas Feed Flow: 409 MMSCFD
- Feed Syngas Pressure: 629 psig
- Feed: CO_2: 41.15 mol% and H_2S: 0.86 mole%
- CO_2 Product: 2.91 MM Tons
- CO_2 Pressure: 2200 psia
- CO Recovery: 99.05%

- Equipment Costs : BASE
- CAPEX : BASE
- OPEX : BASE

BASE Case	*Unit*	*Specification*	*Simulated Value*
Total Sulfur in Treated Gas	ppmv	<1	0.10
Total CO_2 in Treated Gas	mol%	<3.5	3.3
CO_2 Purity	mol%	>99.5	99.5
Total CO_2 Recovery	mol%	90	92
Total Sulfur (dry) in Combined CO_2 Product	ppmv	<10	7.8
CO (dry) in Combined CO_2 Product	ppmv	<500	431
H_2S (dry) in Acid Gas to SRU	mol%	>30	38

Integration of Selexol Process and Upstream DRCF



- CO in the CO_2 stream is ~10 ppmv
- Minimum CO_2 purity as high as 99.5 mol%
- Sulfur in treated gas as low as 0.1 ppmv
- Sulfur in CO_2 as low as 2 ppmv
- Adjustable acid gas composition

- **Dual Refrigerant CO_2 Fractionation**
  - Bulk Removal of CO_2
- **UOP MOLSIV Dehydration**
  - Fixed bed adsorption – thermal regeneration
  - Avoid freezing of H_2O in DRCF
- **UOP Selexol Process**
  - Trim CO_2 Removal

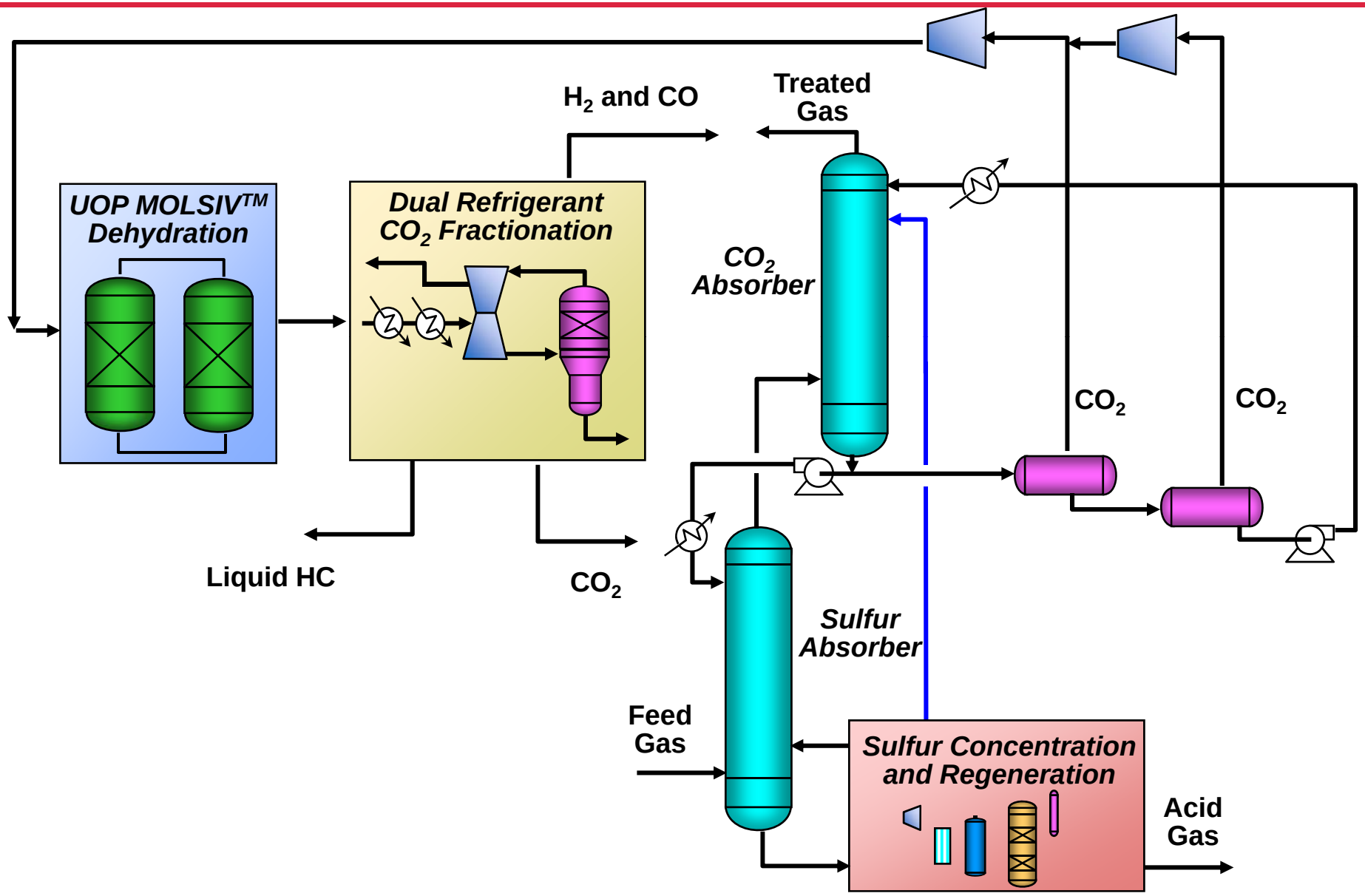
Integration of Selexol Process and Upstream DRCF

- Syngas Feed Flow: 409 MMSCFD
- Feed Syngas Pressure: 632 psig
- Feed: CO_2:41.15 mol% and H_2S: 0.86 mole%
- CO_2 Product: 3.01 MM Tons
- CO_2 Pressure: 2200 psia
- CO Recovery: 99.92%

- Equipment Costs : BASE x 0.93
- CAPEX : BASE x 1.37
- OPEX : BASE x 1.20

Future Gen Ortloff Syngas Frac Case HP wo CO_2 Flash	*Unit*	*Specification*	*Simulated Value*
Total Sulfur in Treated Gas	ppmv	<1	0.01
Total CO_2 in Treated Gas	mol%	<3.5	3.49
CO_2 Purity	mol%	>99.5	99.56
Total CO_2 Recovery	mol%	90	91.68
Total Sulfur (dry) in Combined CO_2 Product	ppmv	<10	4.00
CO (dry) in Combined CO_2 Product	ppmv	<100	39.30
H_2S (dry) in Acid Gas to SRU	mol%	30%	38.28

Integration of Selexol Process and Downstream DRCF



Integration of Selexol Process and Downstream DRCF

- Syngas Feed Flow: 409 MMSCFD
- Feed Syngas Pressure: 632 psig
- Feed: CO_2:41.15 mol% and H_2S: 0.86 mole%
- CO_2 Product: 3.01 MM Tons
- CO_2 Pressure: 2200 psia
- CO Recovery: 99.70%

- Equipment Costs : BASE x 1.03
- CAPEX : BASE x 1.09
- OPEX : BASE x 0.98

Future Gen Ortloff Syngas Frac Case HP wo CO_2 Flash	*Unit*	*Specification*	*Simulated Value*
Total Sulfur in Treated Gas	ppmv	<1	0.01
Total CO_2 in Treated Gas	mol%	<3.5	3.49
CO_2 Purity	mol%	>99.5	99.6
Total CO_2 Recovery	mol%	90	92
Total Sulfur (dry) in Combined CO_2 Product	ppmv	<10	4.00
CO (dry) in Combined CO_2 Product	ppmv	<100	39
H_2S (dry) in Acid Gas to SRU	mol%	30%	39

With Little/No Additional Cost for this Flowscheme

Comparison with Conventional Scheme

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- **"Conventional Scheme" vs Selexol Process + DRCF**

	Conventional Scheme	*Selexol Process + DRCF*
CO_2 Purity	> 99.5 mol% CO_2 < 500 ppmv CO <400 ppmv H_2	> 99.5 mol% CO_2 < 50 ppmv CO < 50 ppmv H_2
H_2 Recovery	99.7	99.9
CO Recovery	99.0	99.7
Op Cost	Base	0.98% x Base
SELEXOL Unit Equipment	Base	2 Flash Drums removed 1 Compressor removed
CapEx	Base	1.09 x Base
CO_2 Compression	Conventional	DRCF Scheme

Conclusions

- **Selexol + DRCF can easily meet CO_2 purity specification with little/no additional cost for this flowscheme**
  - **Meet emission requirements when venting of CO_2 is required**
  - **Recover valuable H_2 and CO**
  - **No separate thermal oxidation is required**
- **Different applications have different purity standards**
  - **Designing for *unnecessary stringent* purity levels adds *unnecessary cost* to the plant**

Q&A