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Performance of Dehydration Units for CO_2 Capture

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Dehydration Study Approach

Study comprises of 4 main elements

- Evaluation and characterisation of dehydration process
- Guidance on dehydration process selection
- Evaluation of moisture monitoring methods
- Analysis of future drying technology developments

3 different moisture levels investigated

- 550 ppmv
- 50 ppmv
- > 10 ppmv

2 different CO_2 flow rates considered

- 2.0 Mt/yr
- 4.5 Mt/yr

Background Issues

Several vendors assissted in this study but most others have been unable/unwilling

- Booming oil & gas market → low engagement in CCS
- Large number of cancelled CCS projects
- Issues surrounding DECC competition & NER300

Presence of inerts & impurities

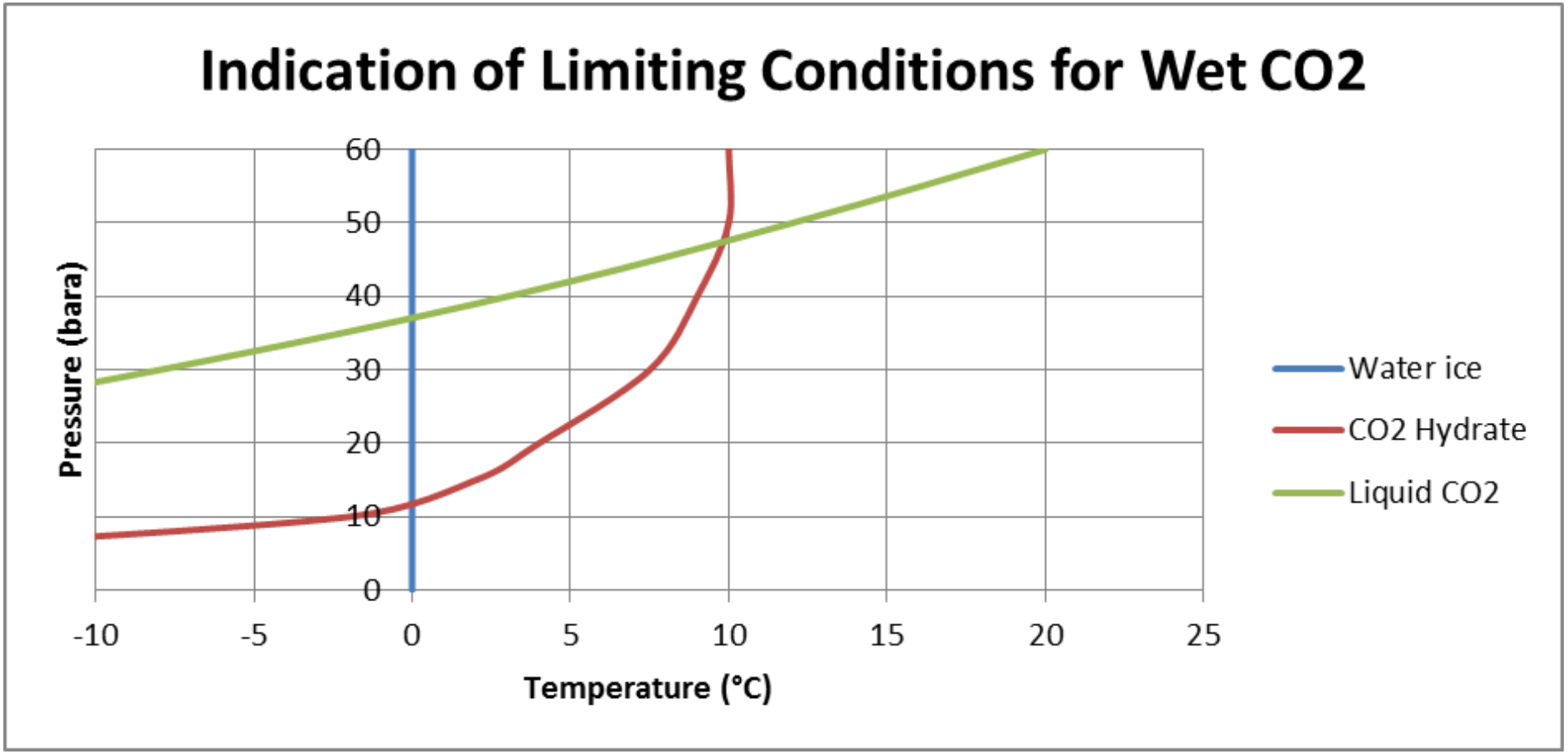
- Changes in physical properties → modified/new EOS needed
- Changes in corrosion rates & hydrate formation

Wide range of dry CO_2 moisture specifications

Some technologies cannot achieve required low moisture levels but are straightforward & low cost → offloading

Extent of cooling limited by hydrates/water ice/liquid CO_2

Background Issues



Background Issues

- Additional amounts (make-up) of desiccant
- Acid resistant desiccants
- Protective guard layers (activated alumina, silica gel)
  - Regenerable
  - Sacrificial

Impurities in solid desiccant systems

- Remove solids with inline filtration
- Use of anti-foam & high-efficiency internals to minimise carry-over
- Corrosion & degradation

Impurities in liquid desiccant systems

→ Extremely important to know and adequately consider the impurities during design

→ Additional upstream treatment may be required

Technologies

Post-combustion

Gas is delivered water-saturated at atmospheric pressure

Pre-combustion

Rectisol

- Delivers dry gas > 1 ppmv → no additional drying required
- Small carryover of MeOH

Selexol

- Gas is water-saturated → 500-1000 ppmv when p > 10 bar → but CO_2 purity at these conditions < 98%
- If S removal not required → pure PEGDME → lower water content
- Minimal contamination with PEGDME

Oxyfuel combustion

Gas stream is water-saturated, $H_2O/NO_x/SO_x$ content can vary

Technologies

Selection of dehydration technologies

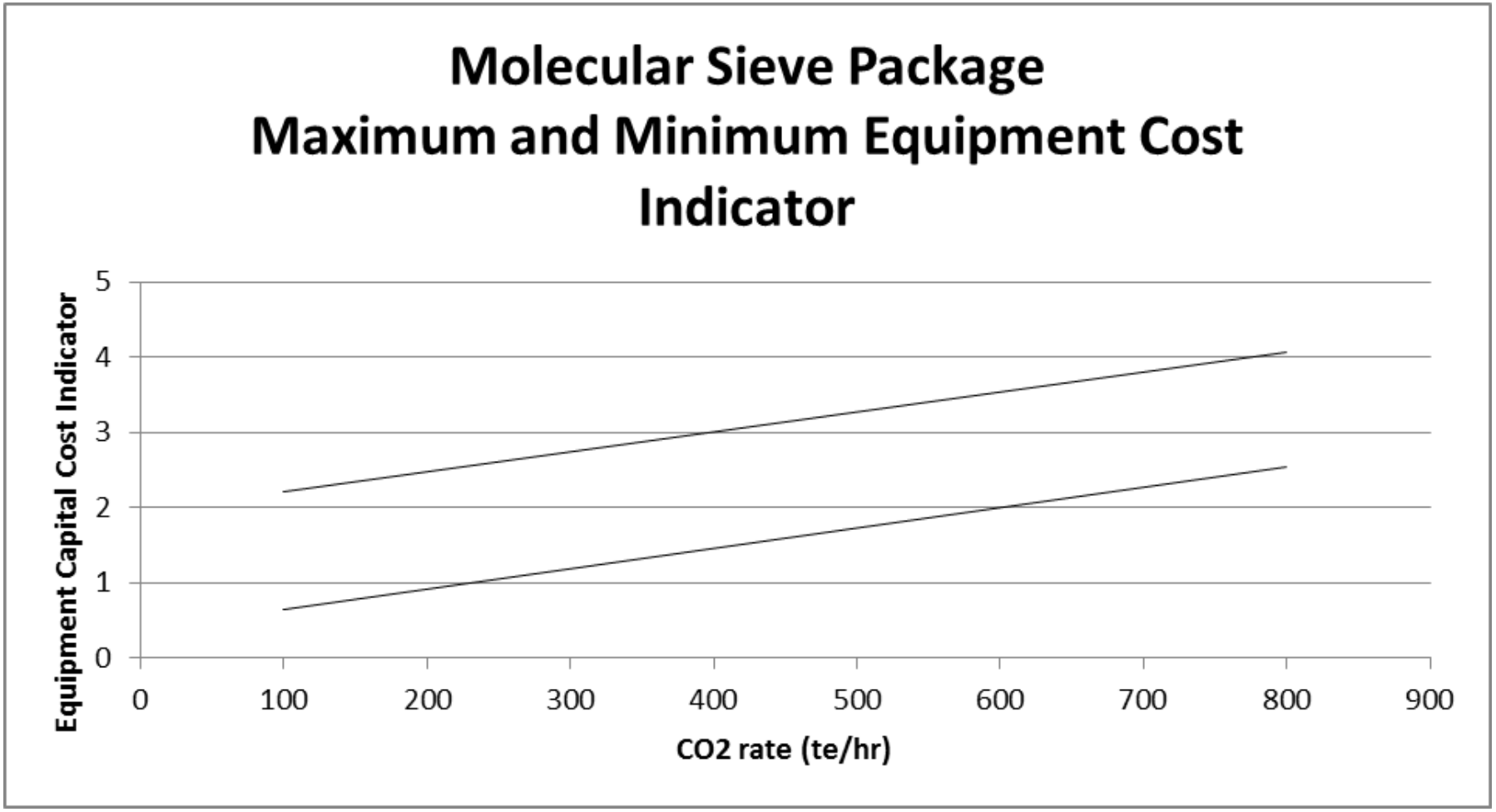
- Focus on TEG & molecular sieve at 30 bara & 30 C
- Low pressure operation requires large diameter beds
- Typical media life for both technologies ~ 3 years

Maximum train size

- Molecular sieve → 300-600 t/hr
- TEG preliminary estimate → 3,500 t/hr (multiple contactors)
- Limitations:
  - Maximum vessel diameter
  - Capital cost of vessel
  - Maximum number of parallel beds
  - Adsorption time / size of each bed
  - Regeneration rate

If considered at point of design → future capacity expansion possible

Costs – Molecular Sieves



Costs – Molecular Sieves

Wide spread in capital cost from different vendors (for fixed operating pressure)

Differences due to:

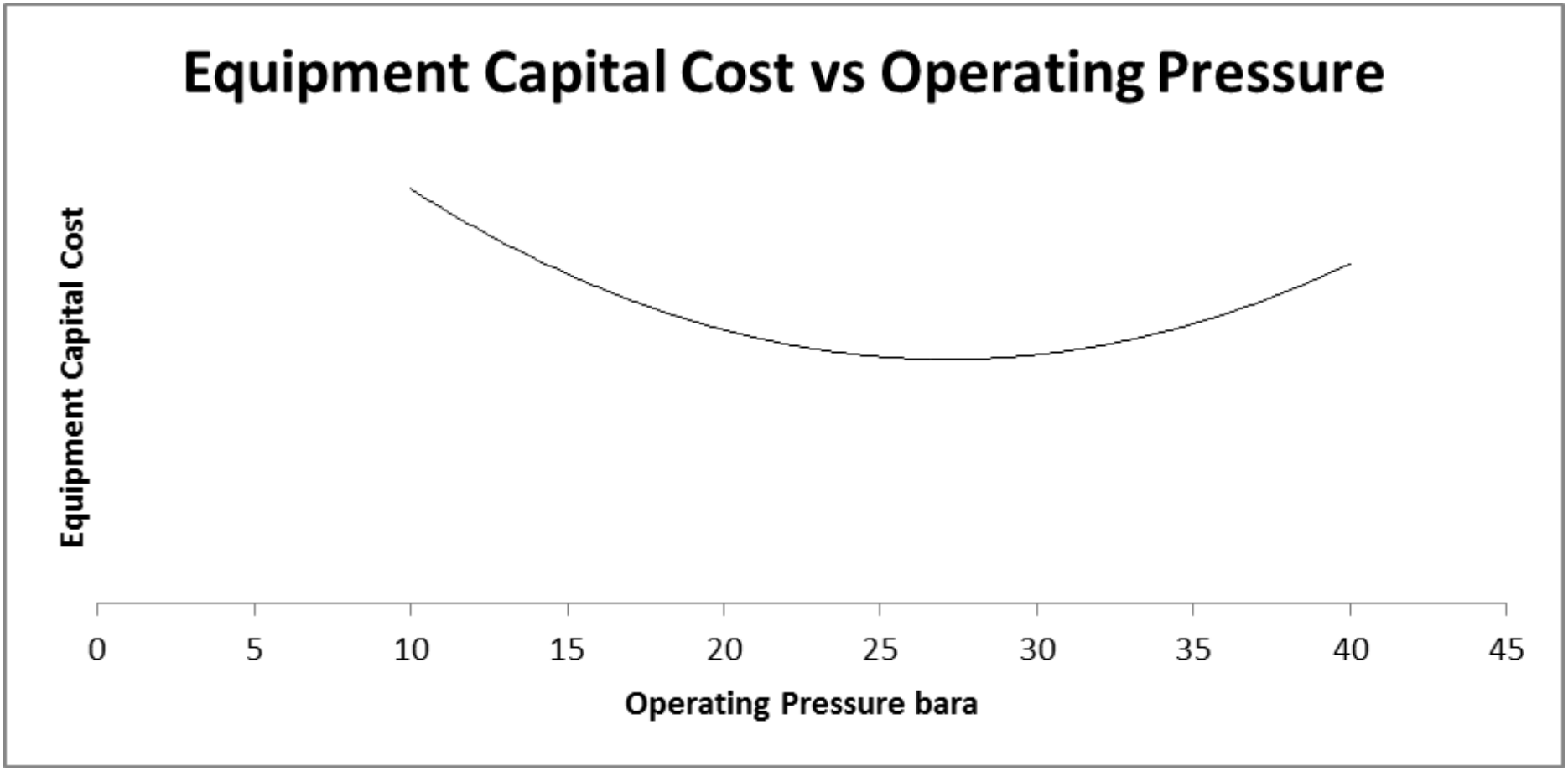
- Regeneration techniques
- Use of CO_2 compression facility for regeneration gas
- Materials of construction
- Number and size of adsorption bed(s)
- Number of parallel dehydration trains possible

No difference in CAPEX for the different target moistures

Equipment CAPEX minimum location depends upon:

- Equipment design pressure
- Type of regeneration and extent of regeneration equipment

Costs – Molecular Sieves



Costs - TEG

Data on liquid desiccant systems lacking from vendors

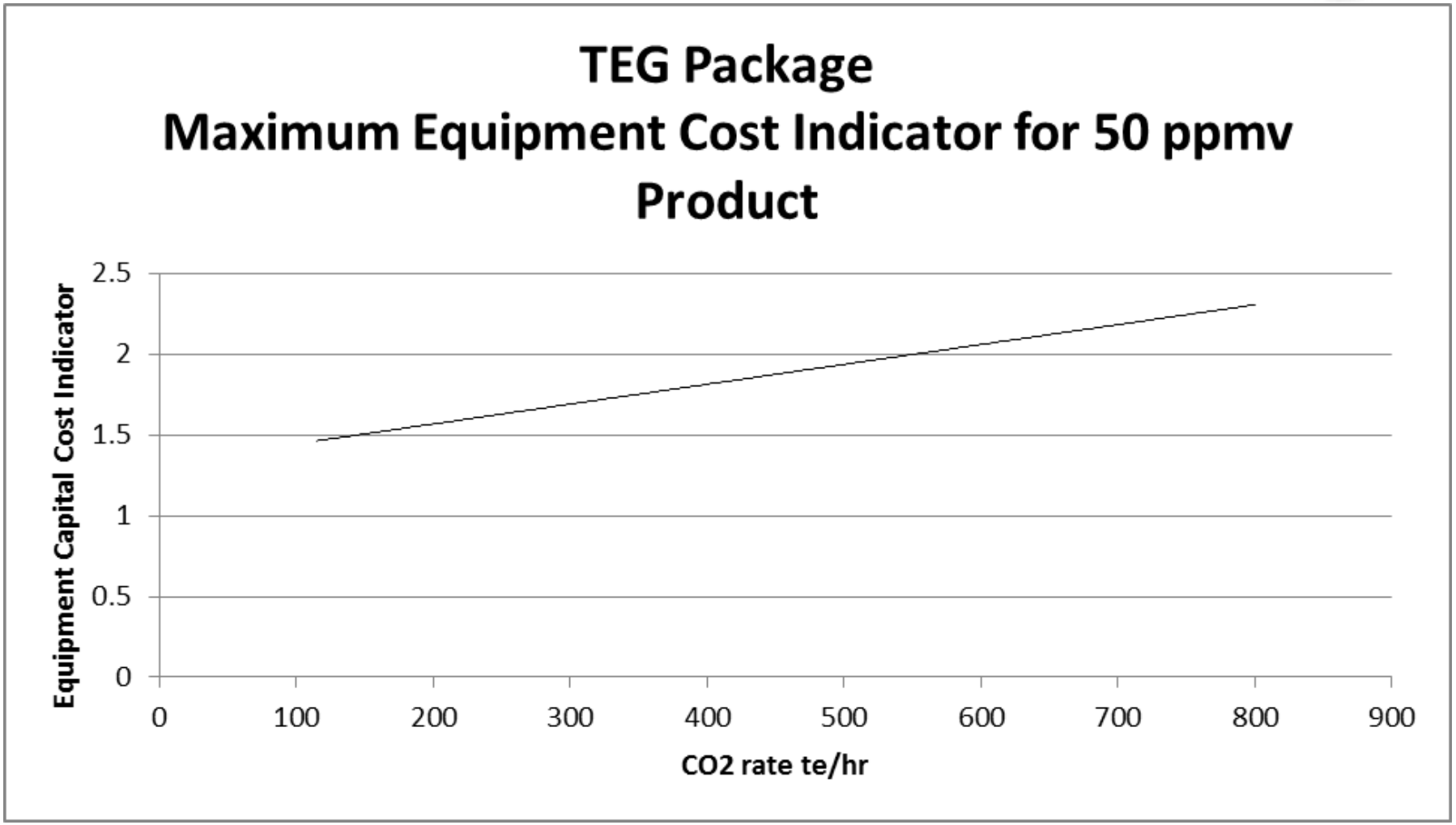
Product moisture is 50 ppmv

Stripping gas used to increase TEG concentration

Higher levels of target product moisture (> 150 ppmv)

- Only basic equipment needed
- Stripper not required

Costs - TEG


TEG Package
Maximum Equipment Cost Indicator for 50 ppmv Product
Equipment Capital Cost Indicator
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
700
800
900
CO2 rate te/hr

Costs

High impurities:

Molecular sieve

- Increased O_2 levels (300 ppmv) have no effect
- Presence of NO_x, SO_x & H_2S:
  - Acid resistant molecular sieve → 5% higher media volume → 15% higher media cost
  - 7% increase in molecular sieve equipment CAPEX

TEG

- O_2 degrades TEG → acceptable limits & effect on costs unknown
- Effect of NO_x, SO_x & H_2S cannot be evaluated

High inerts:

Equipment CAPEX higher for both TEG & molecular sieve

- Increased gas volume → larger diameter for TEG contactor and molecular sieve bed
- Higher water content → larger TEG circulation rate and larger molecular sieve volume required

OPEX Estimates

Molecular sieve at 265 t/h

- Minimum CAPEX case:
  - Low pressure regeneration with atmospheric air
- Maximum CAPEX case:
  - Regeneration with CO_2 at pressure

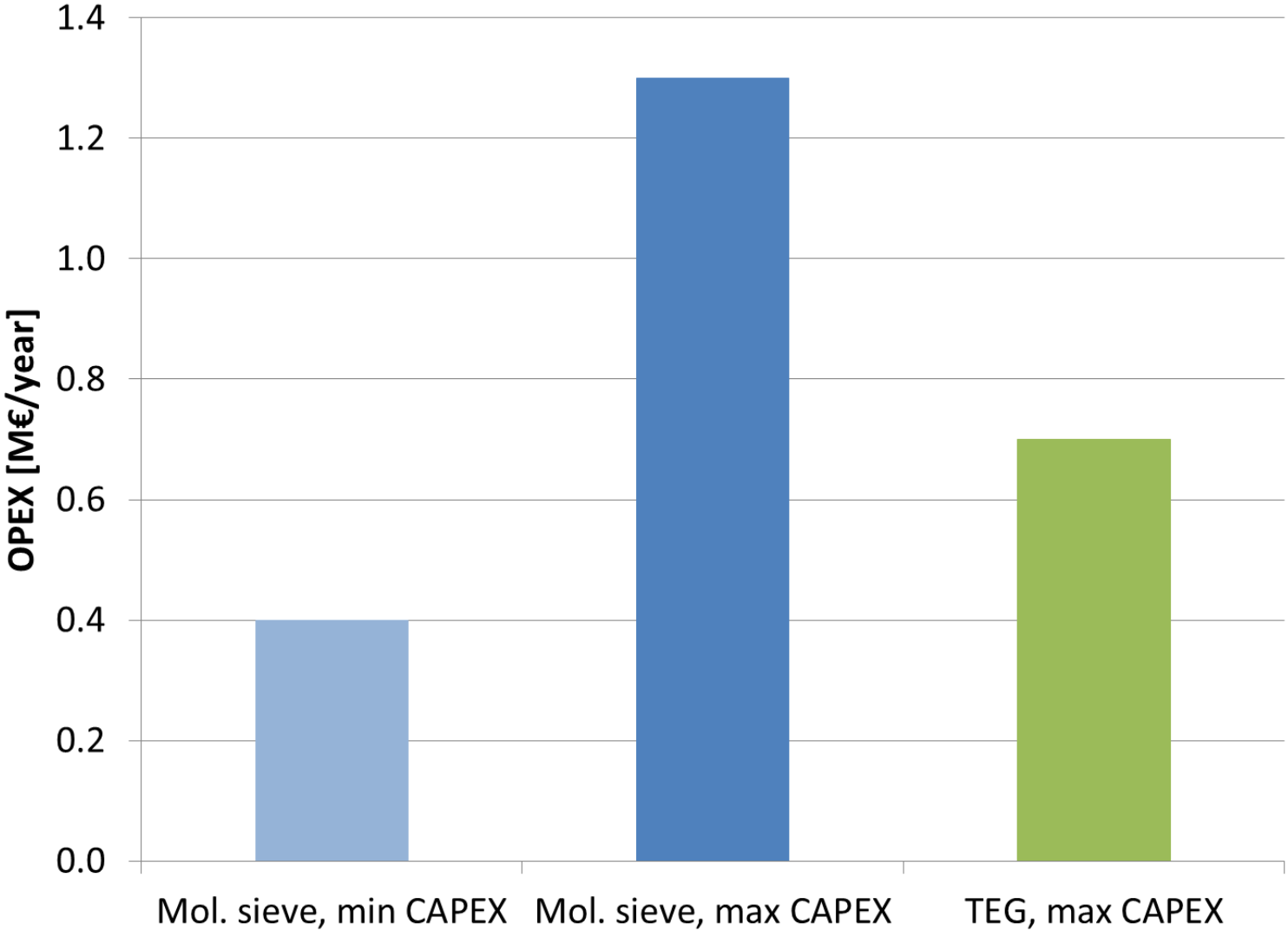
TEG at 265 t/h

- Only maximum CAPEX case due to lack of vendor data

Further indications

- OPEX depends on operating pressure
- Effect of impurities on molecular sieve OPEX considered negligible

OPEX Estimates



Selection

Consider series of multiple dehydration techniques

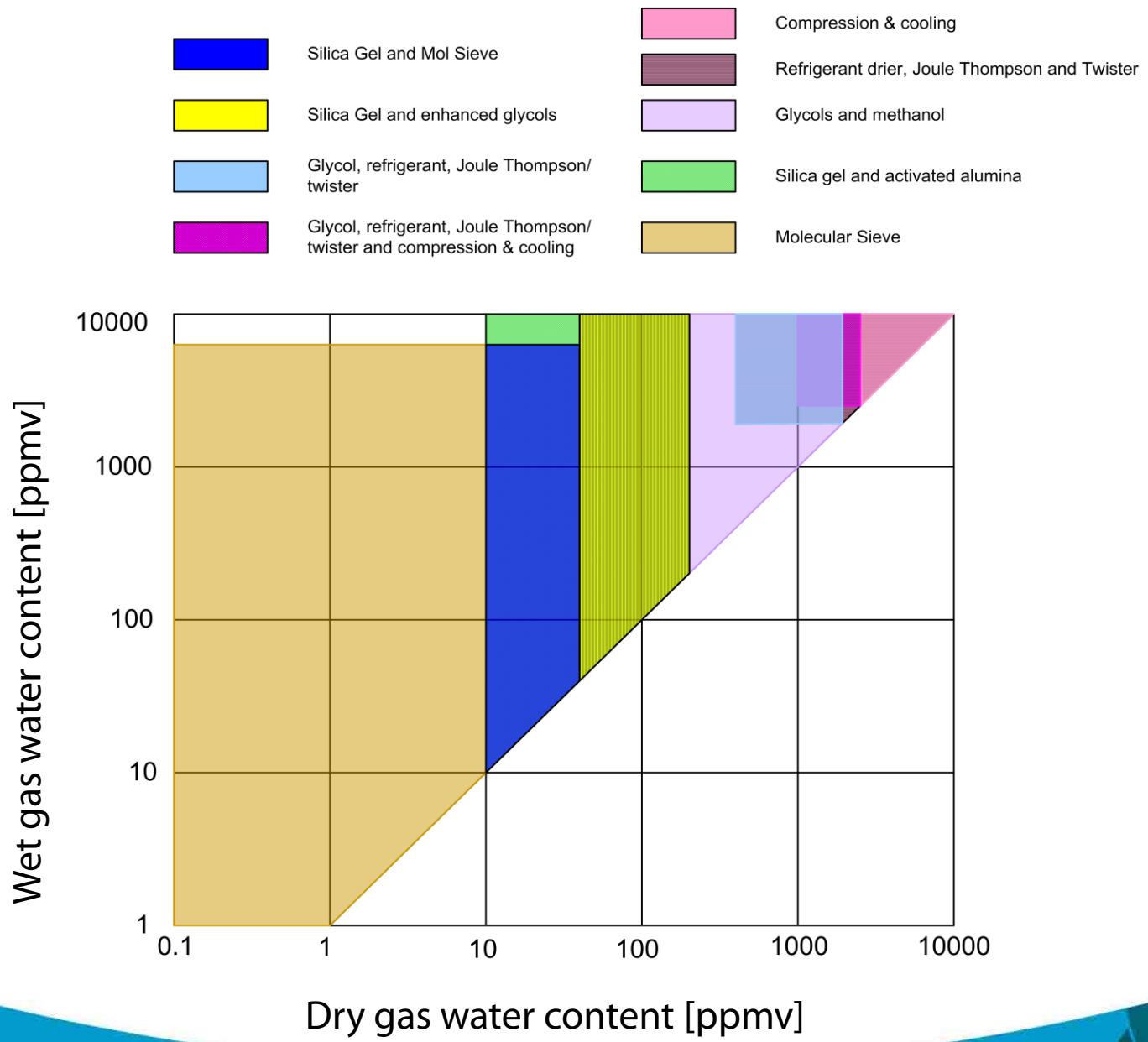
Cheaper to offload the final system with basic techniques

- Minimises the moisture fed to the final dehydration package
- Reduces the gas volume that has to be processed → smaller equipment

Molecular sieves can be protected with guard layers

- Silica gel or activated alumina
- Can better deal with the impurities
- Regenerable or sacrificial

Selection


Silica Gel and Mol Sieve
Silica Gel and enhanced glycols
Glycol, refrigerant, Joule Thompson/ twister
Glycol, refrigerant, Joule Thompson/ twister and compression & cooling
Compression & cooling
Refrigerant drier, Joule Thompson and Twister
Glycols and methanol
Silica gel and activated alumina
Molecular Sieve
Wet gas water content [ppmv]
10000
1000
100
10
1
0.1
1
10
100
1000
10000
Dry gas water content [ppmv]

Operation & Monitoring

Continuous automated sampling is required

Available analysis techniques:

- Laser absorption spectroscopy
- Phosphorous pentoxide cell
- Quartz crystal cell
- Silicon sensor

Maintenance frequency depends on gas quality

- Impurities
- Particulates

Min. 2 moisture analysis points recommended

- Immediately after dehydration
- Further downstream (e.g. after compression)

Further Work

Effect of inerts & impurities on physical properties

- Significant changes in phase envelop
- Increased/decreased saturated water content of CO_2

Improve models for physical properties estimation

Investigate & quantify the issue of hydrate formation

(Re-)Engagement of vendors

Membranes for dehydration of supercritical CO_2

Development of acid resistant solid desiccants

Conclusions & Recommendations

- Examined the characteristics of the various dehydration processes & their CCS integration
- A number of suitable technologies already exists
- Due to lack of vendor support information on costs and operation is preliminary, fragmentary & uncertain
- Follow up research & activities in this area needed
- (Re-)Engagement of vendors, also in IEAGHG networks

Thank you, any Questions?

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