# DYNAMIS SP 3:

## Product gas handling ($CO_2$ and $H_2$)

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# Objectives of the work

- WP 3.1. $CO_2$ conditioning and transport
  - $CO_2$ quality: to recommend on the purity of $CO_2$ from a transport perspective
- WP 3.2 $H_2$ conditioning for export
  - $H_2$: to assess export quality of $H_2$ -> fuel cell vehicles
- Input to other SPs:
  - Recommendations on $CO_2$ quality and $H_2$ export quality serve as input to pre-engineering studies (SP5)

# Main results $H_2$ quality for PEM

| Compound | Concentration limit |
|---|---|
| Hydrogen fuel index (minimum, %) | 99.95 |
| Non-hydrogen constituents (maximum content)<br>Dimensions in micromoles per mole unless otherwise stated | |
| Total gases | 500 |
| Water ($H_2O$) | 5 |
| Total hydrocarbons<br>C2+<br>Methane | <br>2<br>100 |
| Oxygen ($O_2$) | 5 |
| Helium (He), Nitrogen ($N_2$), Argon (Ar) | Sum: 500 |
| Carbon dioxide ($CO_2$) | 1 |
| Carbon monoxide (CO) | 0.5 |
| Total sulfur compounds | 0.01 |
| Ammonia ($NH_3$) | 0.1 |

# Main conclusions

- Existing limits for inert compounds 100-500 ppmv are most challenging for $H_2$ production in HYPOGEN plant -> relaxation of limit for inert compounds to 2,000-10,000 ppmv is suggested
- Experimental data for long term impact of inert compounds on PEM cells in the range of 5,000-10,000 ppmv are urgently needed
- DYNAMIS recommends 0.5 ppmv CO, instead of 10 ppmv
- Expected developments by 2012 in high temperature PEM cells allow for a CO concentration limit of about 0.1%

# $CO_2$ quality recommendations

- Aim: come up with recommendations on $CO_2$ quality to be used for Hypogen
- Philosophy: What maximum concentrations of impurities can be allowed in the $CO_2$ (from a technical, legal or health & safety perspective)?
- Approach: starting point are $CO_2$ quality recommendations as assessed by ENCAP

# Dynamis $CO_2$ quality recommendation

| Compound | Concentration limit | Remarks |
|---|---|---|
| $H_2S$ | 200 ppm | Health and safety considerations |
| CO | 2000 ppm | Health and safety considerations |
| $SO_x$ | 100 ppm | Health and safety considerations |
| $NO_x$ | 100 ppm | Health and safety considerations |
| $H_2O$ | 500 ppm | Technical limit |
| $O_2$ | Aquifer <4 vol% (all non cond. gases), EOR >100 ppm | Technical limit; storage issue |
| $CH_4$ | Aquifer < 4 vol%, EOR <2 vol% (all non cond. gases) | Like ENCAP |
| $N_2$, Ar, $H_2$ | <4 vol% (all non cond. gases) | Like ENCAP |
| $CO_2$ | > 95% | Result of other compounds in $CO_2$ |

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# Safety and toxicity limits

## Hydrogen sulphide - $H_2S$

- Limit of 200 ppm is set by health and safety requirements
- The amount of $H_2S$ in $CO_2$ needs to be controlled, because:
  - its toxicity; $H_2S$ is immediately dangerous to life at 100 ppm (NIOSH), compared to 40,000 ppm for $CO_2$
  - internal corrosion issues; in presence of water, $H_2S$ forms sulfuric acid

# Safety and toxicity limits

- Approach to define the limit for $H_2S$ (and CO, $SO_x$ and $NO_x$) from a health and safety perspective:

  *$H_2S$ reaches equal level of toxicity as $CO_2$ in case of a leak/rupture*

| Compound | Short Term Exposure Limit (STEL) | Maximum (not corrected) | Safety factor | Recommended level |
|---|---|---|---|---|
| | ppm | ppm | ppm | ppm |
| $CO_2$ (reference) | 10,000 | 1,000,000 | - | - |
| $H_2S$ | 10 | 1000 | 5 | 200 |
| CO | 100 | 10,000 | 5 | 2,000 |
| SOx | 5 | 500 | 5 | 100 |
| NOx | 5 | 500 | 5 | 100 |

# Technical limits

**Water in $CO_2$**

- Limit of 500 ppm $H_2O$ is set by technical requirements
- The water concentration in $CO_2$ need to be controlled to prevent for:

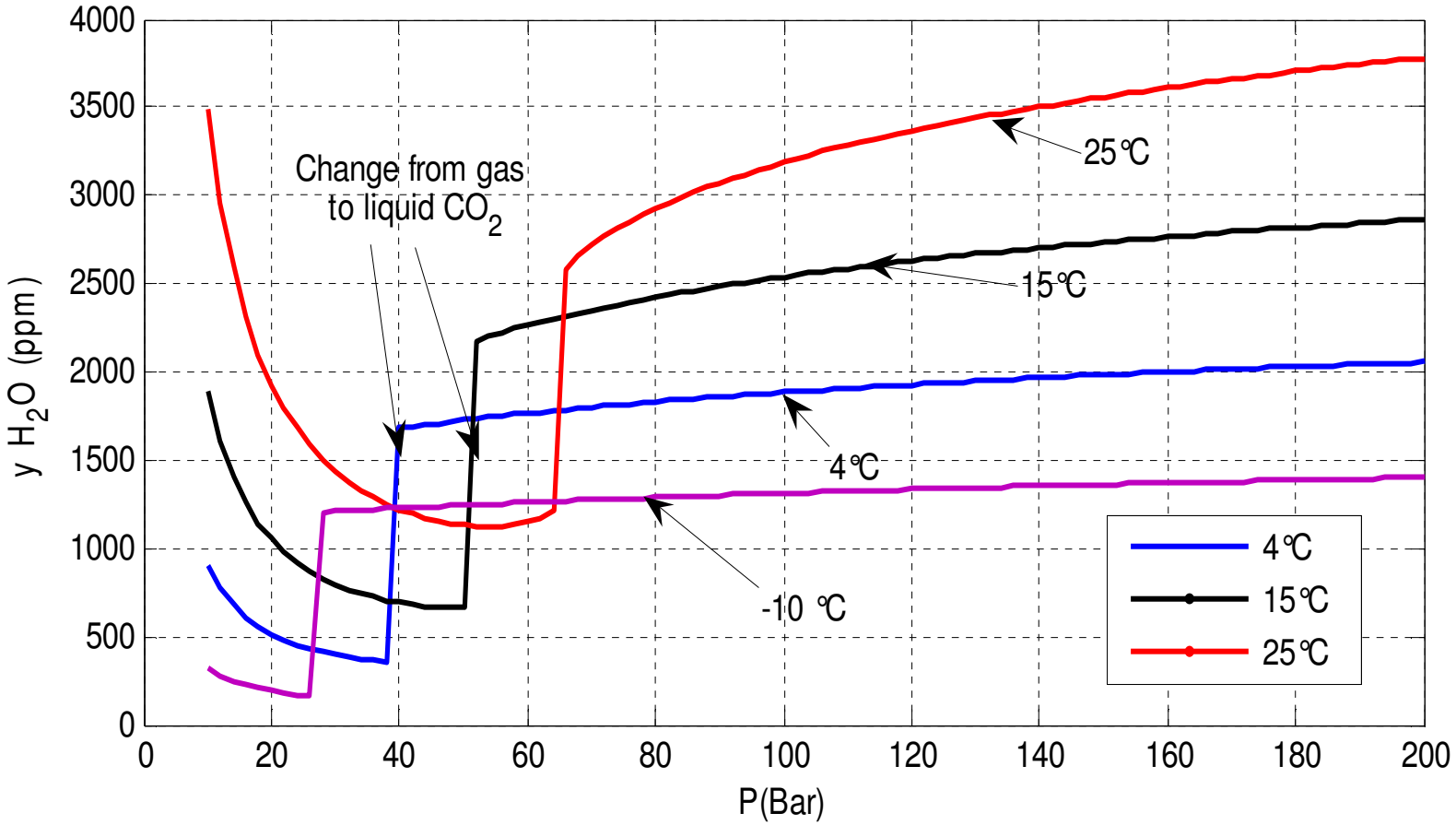
Hydrate formation:

  - $H_2S$ hydrates form at temperatures up to 32°C, $CO_2$ hydrates form up to 10°C

Corrosion:

  - Corrosion effects come from $CO_2$ in combination with $H_2S$ and/or $O_2$ that form corrosive substances in the presence of water

# Water solubility in pure $CO_2$




Source: Austegaard and Barrio, 2006

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# Technical limits

**Non-condensable gases in $CO_2$**

- The total volume of non-condensable gases ($N_2$, $H_2$, $CH_4$, $O_2$, Ar) is set to 4%.

- Reasons to limit the concentration of non-condensables in $CO_2$:
  - Transport capacity
  - Two-phase flow
  - Compression work
  - High energy content and market value of $H_2$

  - Storage: Minimum Miscibility Pressure (MMP)

# Main conclusions

- For all pre-combustion schemes modelled only the water concentration was above the limit proposed in the Dynamis quality recommendation:
  - Without drying step water concentration typically is 700-1000 ppm
- Concentrations of other impurities are well below the limits as proposed in the Dynamis quality recommendation