AWITC 2013

Myth busting
"Dry ice creates an protective layer"

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Content

- Typical operational practices
- Theory – the issues at stake
- Experimental observations
- Operational implications

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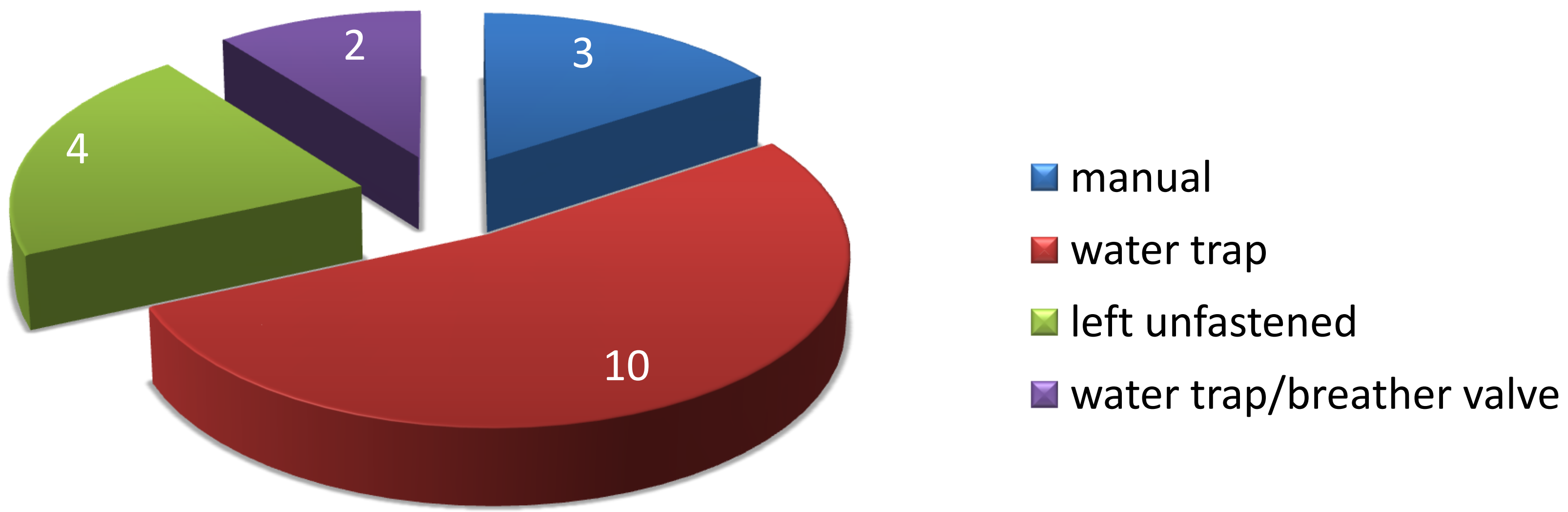
Busting the myth

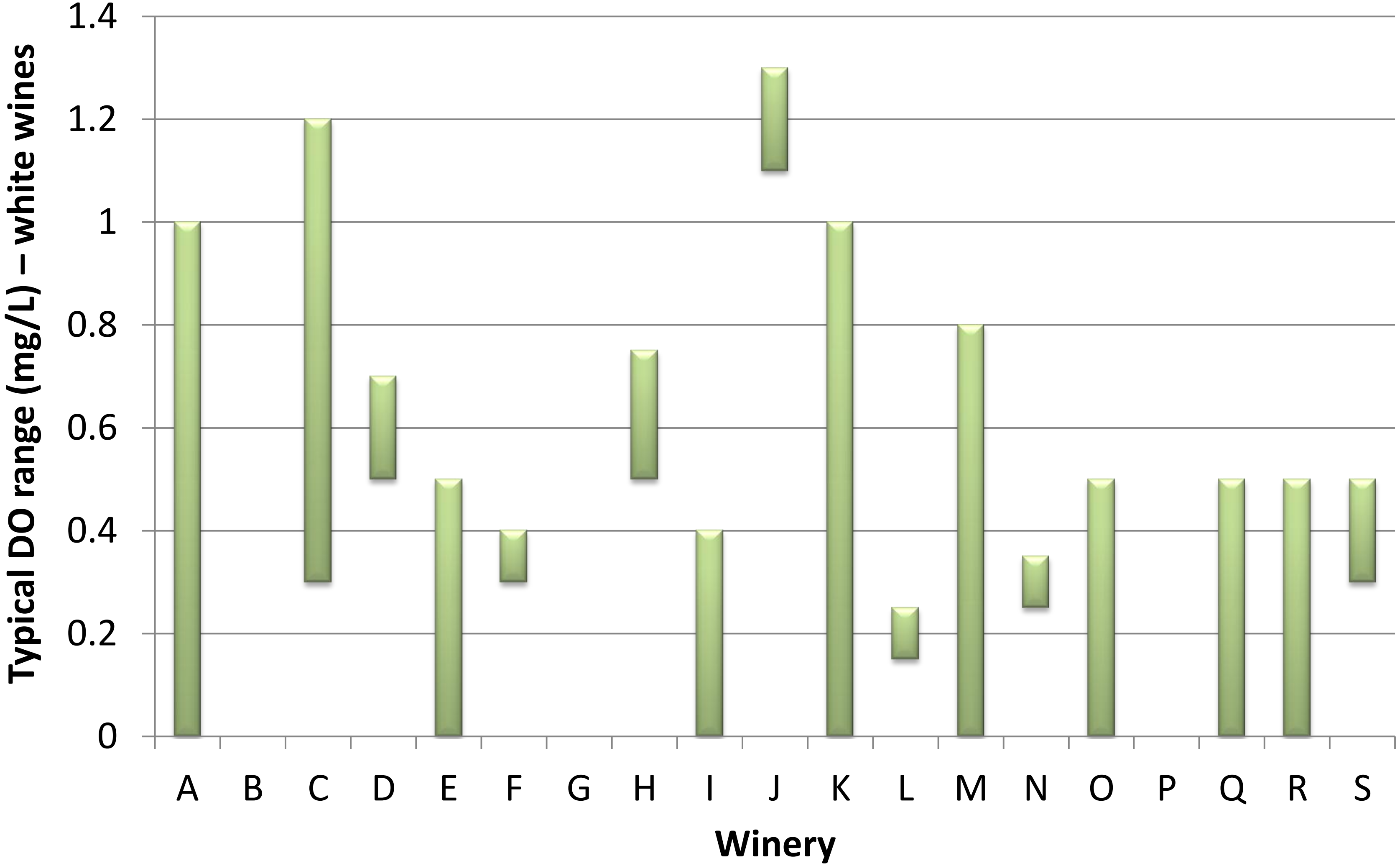
“Dry ice forms a protective layer”

- Ullage management and oxygen exclusion is multifaceted
  - Tank evacuation
  - Tank blanketing
  - Wine sparging

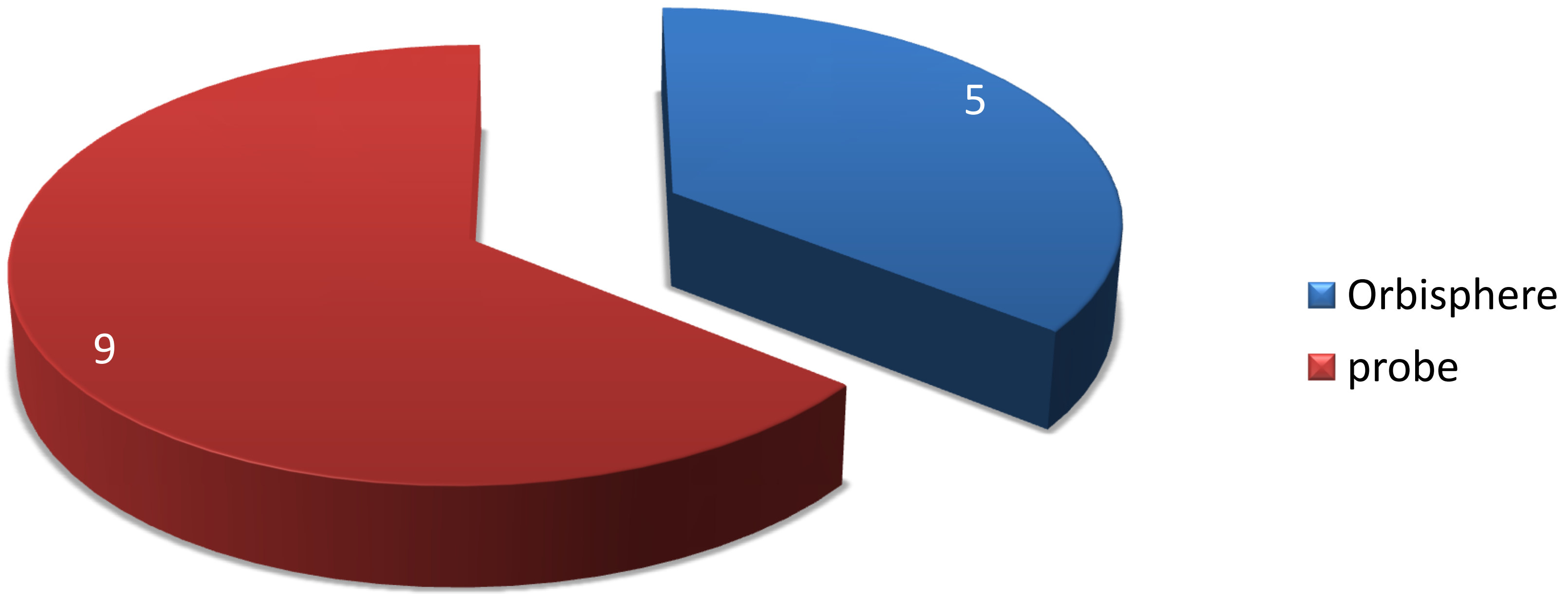
Method of venting on storage tanks



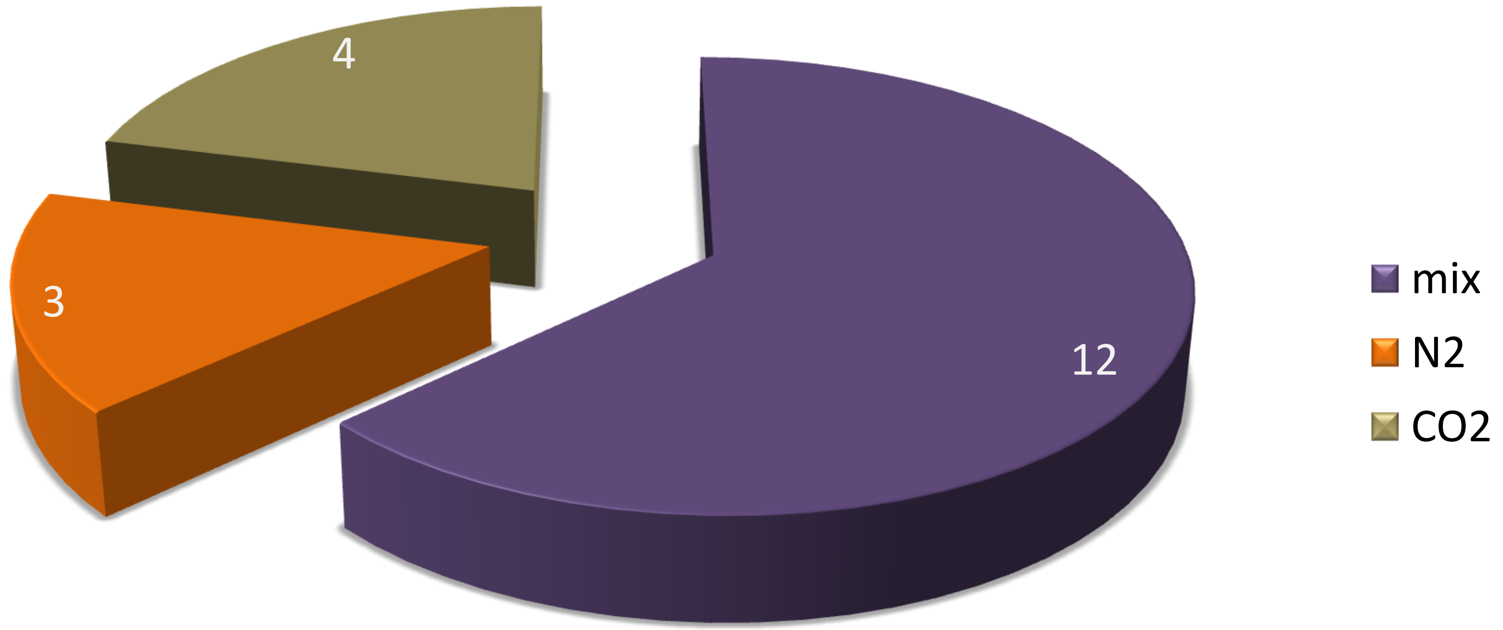
Typical levels of DO in white wines



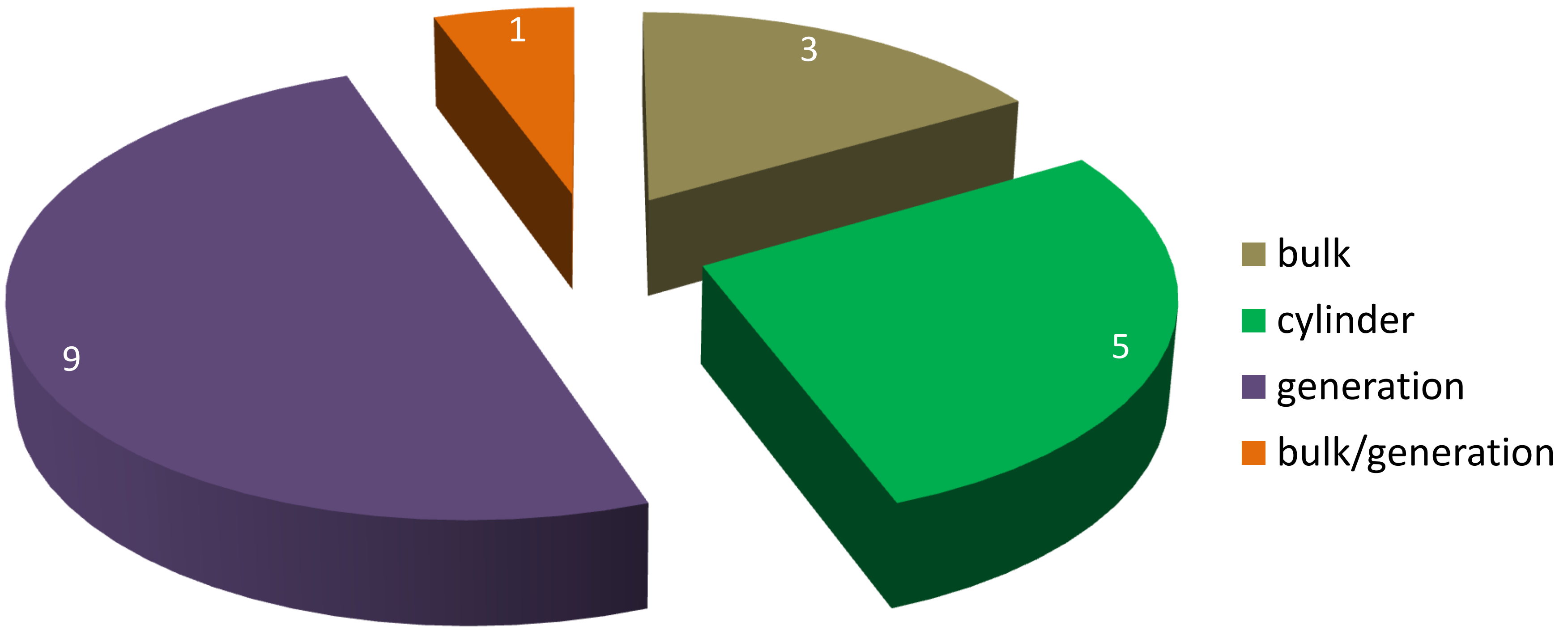
Method of DO measurement



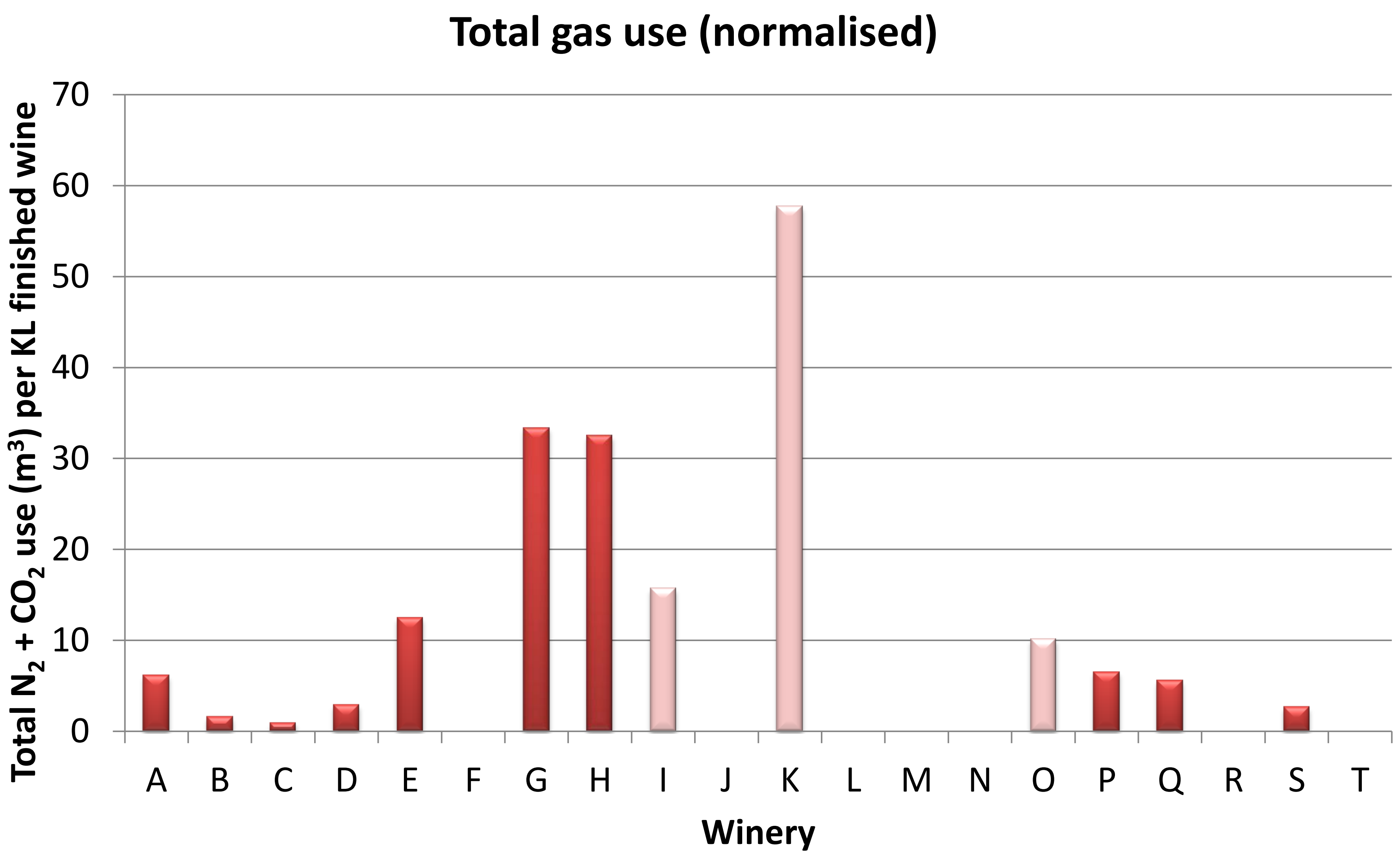
Gas types used



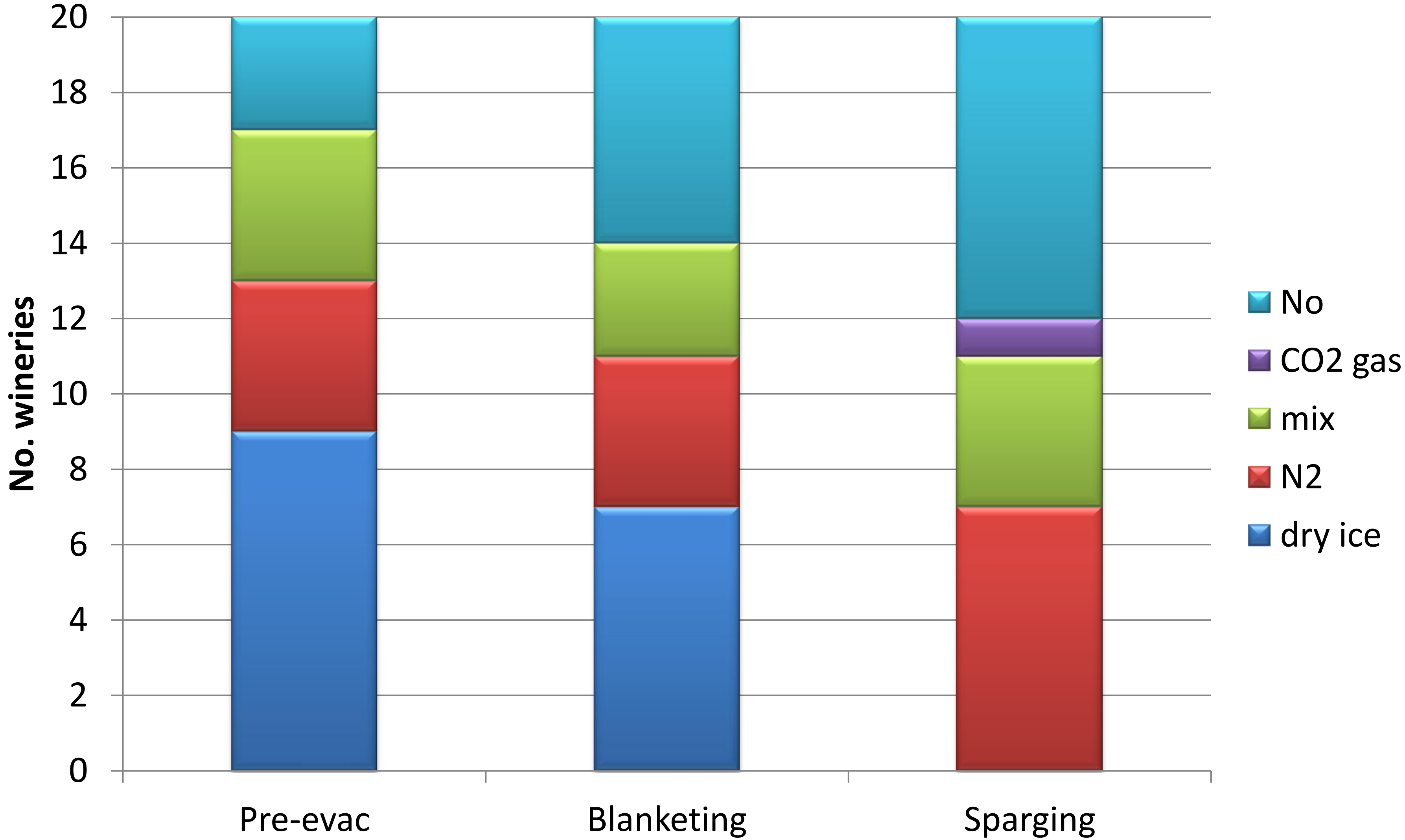
Source of nitrogen used on site



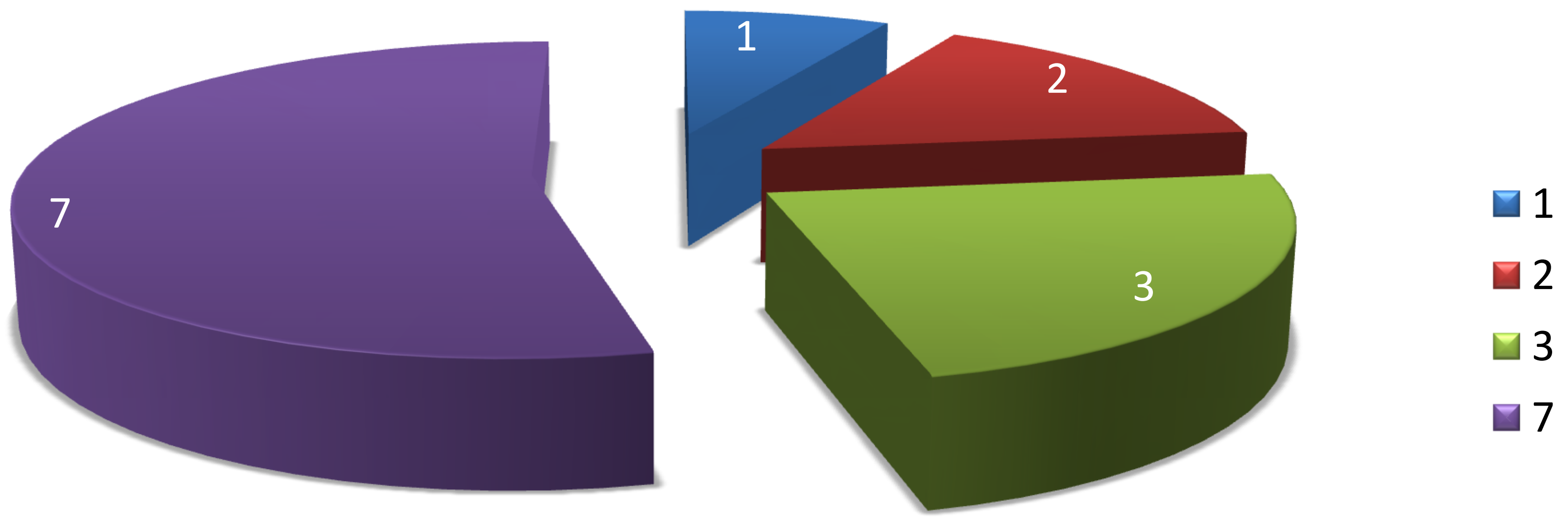
Overall gas usage



Type of gas application used during tank filling



Frequency of dry ice application for stored wines – no. per week



Operational practices

- Minimise ullages
  - Not always possible
    - Infrastructure
    - Operational requirement
  - Thermal expansion
    - Refrigeration cycles
    - Seasonal fluctuation

- Manage ullages
  - Dry ice addition
  - Gas cover

Managing Ullages

- Dry ice addition
  - Typically ½ - 1 bucket (2- 8kg)
  - Maybe 3 times per week
  - Largely independent of ullage volume (and tank sealing mechanisms)

  - Time consuming
  - Expensive
  - Potentially ineffective

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Managing Ullages

- Continual gas cover
  - 24/7 gas application
  - Typical flowrate around 10 L/min
  - Applied using diffuser
  - Creating positive pressure to prevent ingress of oxygen
  - Gas selection important to maintaining dissolved CO_2 levels

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Managing Ullages

- Periodic gas flushing
  - Typically a manual system enabled during racking or filling
  - Periodic application during storage
  - Potentially automated to ensure sufficient protection from oxygen without excessive gas utilisation

Managing Ullages

- Primary Goal
  - Protect wine from oxygen penetration
- Secondary Goals
  - Manage dissolved gases
    - Particularly CO_2 and O_2

- Do some gases for a LAYER?

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Gas Species – Some Details

	Nitrogen	Carbon dioxide	Argon
Mol. Weight	28	44	40
Boiling Point	-196	-78	-186
Specific Volume (m3 per kg at 15°)	0.84	0.53	0.59
Specific Gravity (rel. air)	0.97	1.53	1.38
Solubility (v/v)	0.017	1.01	0.038

Gas diffusion

Diffusion is the spread of particles through random motion from an area of high concentration to an area of low concentration

Fick's Law

$$J = -D.\frac{d\text{Ø}}{dx}$$

J = rate of gas exchange

D = diffusion coefficient

Ø = concentration

X = position (length of interface)

Fick's Law - What's really important

- Forces faster/greater than diffusion
- Physical constraints – distance, layering, space filling, gas density
- Generation of new gases – gases super saturated in solution
- Diffusivity of the gas species (CO_2 in air 0.13 v N_2 in air 0.17)

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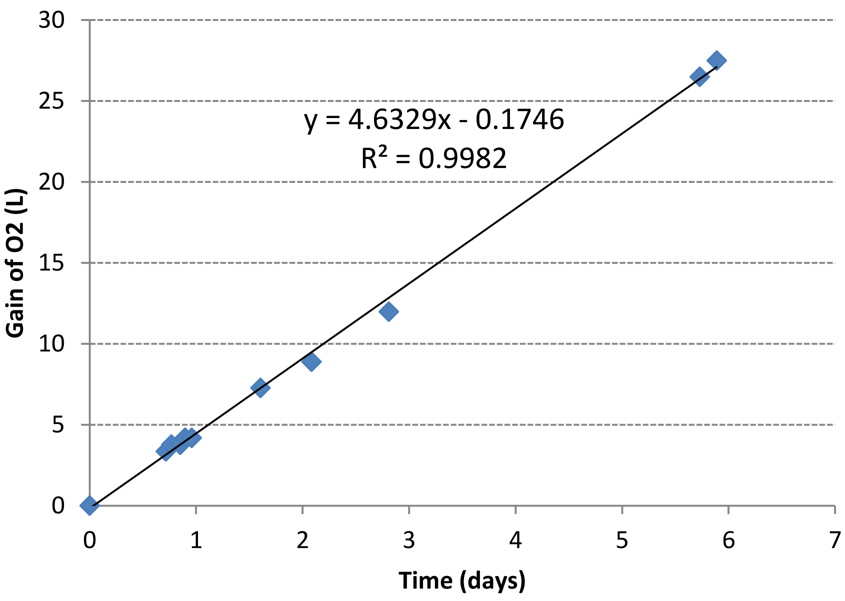
Stages of diffusion

In a typical storage tank, diffusion will occur:

- through tank seal / entry point
- through headspace
- solution into wine
- through wine until reaction.

Tank OTR

- How much oxygen enters a tank?
  - AWRI measurement on 760 L tank, with standard lid and breather valve.
  - Tank inerted with dry ice to < 0.2 % O_2



- Over 4 L of oxygen ingress per day!!

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Tank OTR

- 4 L ~ 5g = 5000 mg O_2
  - On a 1000 L tank, theoretical exposure equals 5 mg/L/day
  - On a 10kL tank, theoretical exposure equals 0.5 mg/L/day
  - On a 200kL tank, theoretical exposure equals 0.025 mg/L/day
- Whilst theoretical exposure is unlikely to be realised, tank OTR is significant!

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Thermal expansion

- Typical expansion coefficient for wine is ~ 0.2 ml/L/Deg C
- Given a refrigeration deadband of 3 degrees, each refrigeration cycle has the potential to draw in this equivalent volume of air.
- This corresponds to approximately 0.15 mg/L oxygen
- This can occur daily with refrigeration events

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Implications

What oxygen level is acceptable?

- Generally accepted to be < 0.5 % to prevent growth of aerobic bacteria

Wine quality impact evidence is largely anecdotal – but real

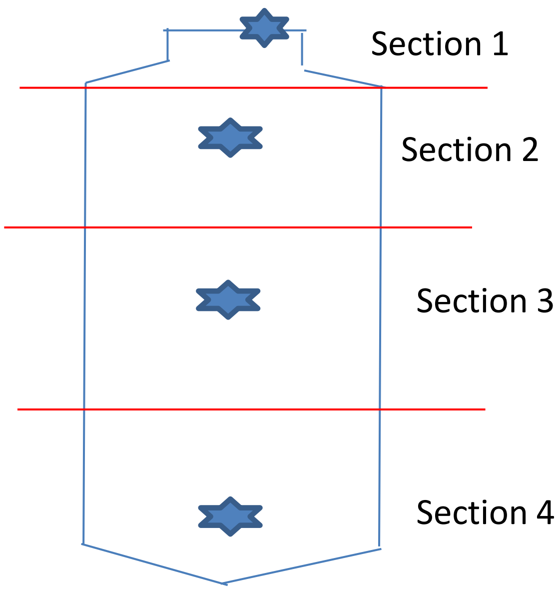
Oxidation damage must be decoupling volatile loss and natural ageing

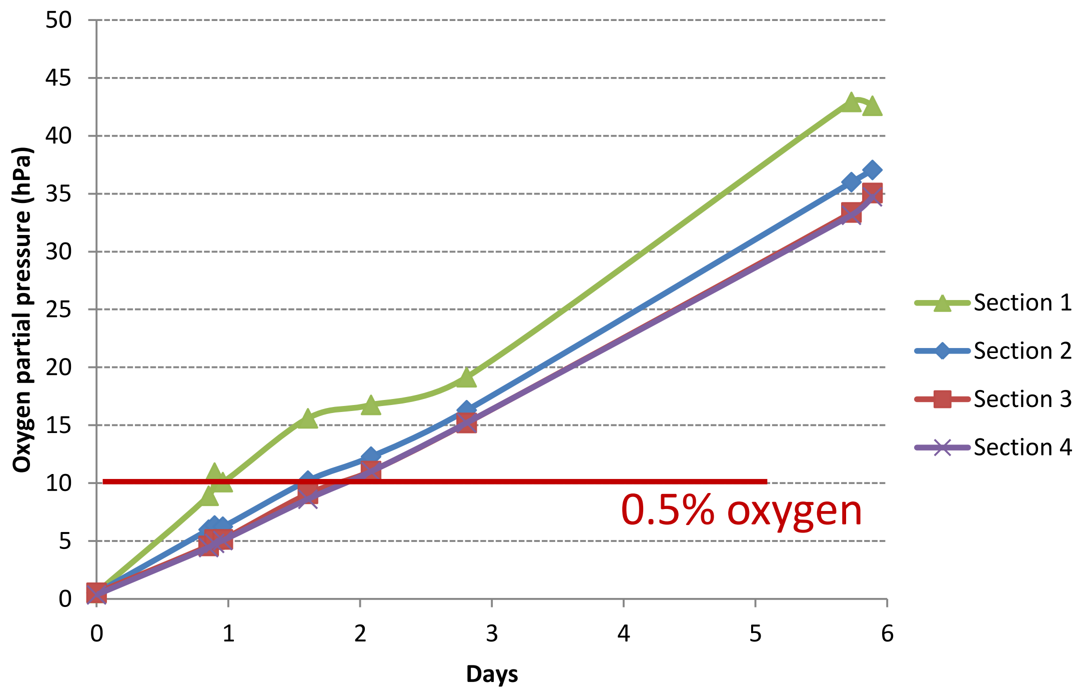
Gas cover

- Carbon dioxide
  - CO_2 offers superior evacuation performance due to higher density through displacement of oxygen
  - Gaseous application through diffuser is best
  - Solubility in wine is high
  - Dissolution into wine can create a vacuum
  - Protection is short lived. CO_2 cover is not impermeable to oxygen.
  - Continuous application/ replenishment is required
  - Operation costs of manual dry ice application are high

Gas cover

Diffusion of O_2 through CO_2





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Gas cover

- Nitrogen
  - Cost advantage over CO_2
  - Comparable density to O_2 , therefore diffuses with oxygen.
  - Large volumetric usage required to therefore displace oxygen.
  - Previous studies report a 3 – 5 volume to volume ratio is required.
  - Significantly shorter protection times than CO_2

Gas cover

- Mixed gas
  - Benefit of CO_2 whilst partially offsetting the higher costs
  - Reduced operation expenses associated with adjusting DCO_2 levels.
  - N_2/CO_2 ratios of 60/40 up to 80/20 sufficient to maintain desired DCO_2 levels.
- Automation has the potential to optimise the efficiency and the gas cost of the system

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Improving Ullage Management

- Minimising wine movements
  - Software systems (optimisation)
  - Evaluate the cost/benefit of packaging run scheduling
  - Implications on other aspects of wine production
- Tank design and tank sealing/breather systems
  - Maintain water traps and lid seals
  - Opportunities exist for further development of tank sealing mechanisms
- Design and evaluation of best mechanism to introduce mixed gas to tanks
  - Floating distribution systems