# Yeast Flatulence or Eructation ($CO_2$):

## What are the effects and how to control It


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## Yeast Flatulence or Eructation ($CO_2$):

## Why this study?

- Tremendous growth in small brewing operations
- Safety and Health – An after thought?
- Little or no data on $CO_2$ exposures in breweries
- Little data on effects of $CO_2$ at levels < 10,000 PPM
- Curious on the impact of combined risk on health

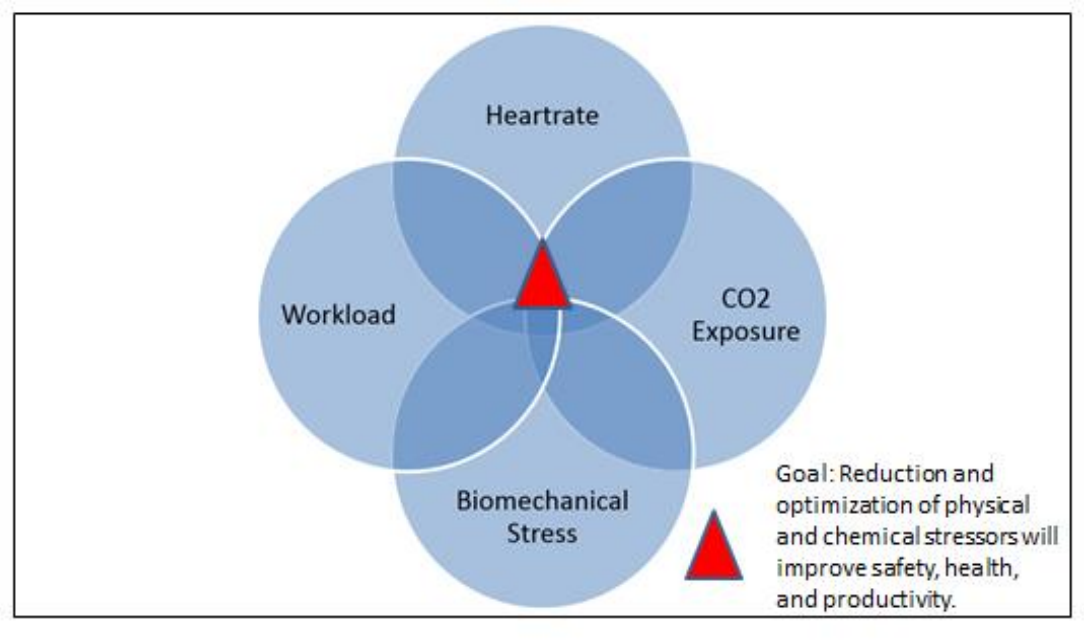
## Yeast Flatulence or Eructation ($CO_2$):

## What are the takeaways of this presentation

- What is Combined Risk
- What $CO_2$ levels are found in different sized breweries
- What variables can impact those $CO_2$ levels
- What effect do lower $CO_2$ levels have on heart rate
- What are effective control measures to reduce combined exposure

# Combined Risk Exposure

## Yeast Flatulence or Eructation ($CO_2$):

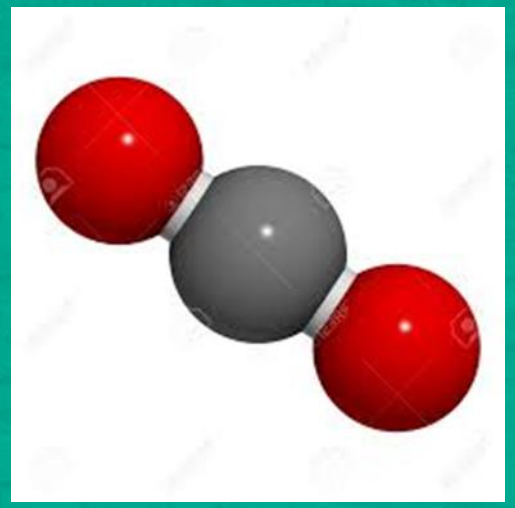



## What is Combined Exposure Risk?

- Multiple exposures causing the same health effect
- The increase in combined risk is greater than one exposure at a time
- Could be additive, multiplicative, or synergistic
- Could be occupational, environmental, or community exposures.

## Risk #1

## Carbon Dioxide



### What do we know about $CO_2$

- Odorless – acidic smell at high concentrations (carbonic acid formation)
- Colorless
- Slightly pungent acid taste
- Non-flammable
- Density – 1.98 kgs/$m^3$ -1.67X greater than air
- Concentration in ambient air ~400 PPM
- Produced by biological methods or combustion
- Variety of uses – photosynthesis to refrigeration

## Risk #1

## Carbon Dioxide

Current Exposure levels to $CO_2$

- OSHA / ACGIH 8 hour – 5000 PPM
- ACGIH TLV STEL* – 30,000 PPM
- NIOSH IDLH – 40,000 PPM

* 15 minute exposure limit

## Known Health Effects of $CO_2$

| Concentration of $CO_2$ (PPM) | Health Effect |
|---|---|
| 3,000 to 5,000 PPM | Slight Increase in Respiration |
| 5,000 PPM | 5% Increase in Respiration |
| 10,000 PPM | Fatigue, Anxiety, Loss of Energy |
| 20,000 PPM | 50% Increase in Respiration, Severe Headache |
| 50,000 PPM | Violent panting and fatigue to the point of exhaustion merely from respiration & severe headache. Prolonged exposure at this level could result in irreversible health effects |
| 90,000 PPM | Death in 5 Minutes |

## Risk #1
## Carbon Dioxide

## Low level CO2 Effects from Literature

- Increased respiration rate
- Increased heart rate
- Headache
- Cognitive impairment
- Increased fatigue

## Risk #2

## Biomechanical Stress

### Health effects of Ergonomic Stressors

- Overexertion injuries
- Musculoskeletal disorders
- Increased physical exertion
- Increased heart rate
- Increased fatigue

## Risk #3

## Workload

### Health Effects of Workload

- Increased stress
- Headaches
- Increased heart rate
- Increased fatigue

# Methodology

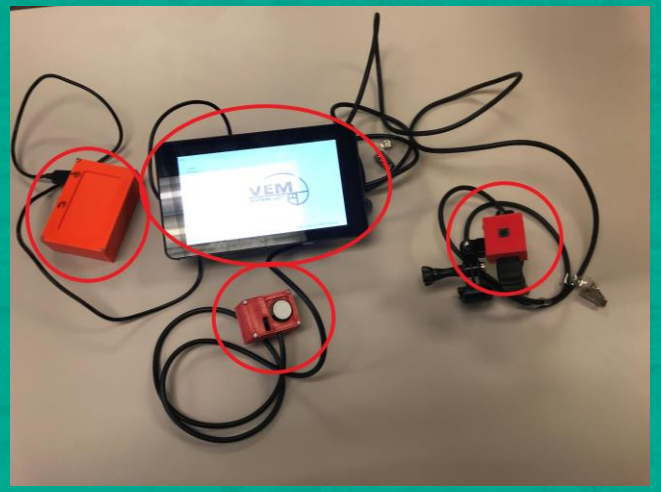
## Methodology: General

## Data Gathering: Who and Where

- Small, Medium, and Large “Craft” Breweries
  - Walk around at different days and times
- Three jobs tasks evaluated
  - Cellar
  - Canning/Packaging
  - Barrel Filling

## Methodology:

## CO2 and Heart Rate Data Collection

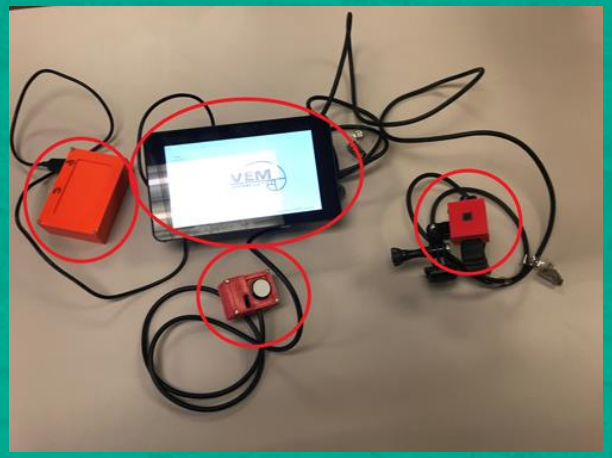


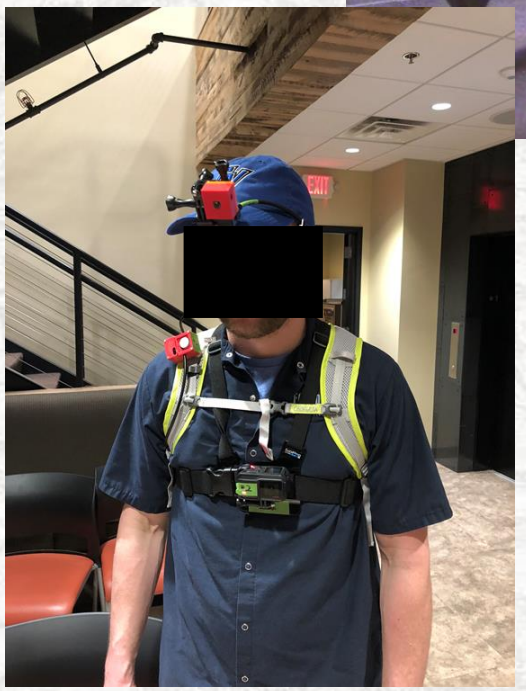
## Video Exposure Monitoring (VEM™)

- Video Feed
  - VEM system wired camera
  - Garman VIRB
- $CO_2$ Sensor
  - CO2 Meter - MinIR 5% CO2 Smart LED Sensor (NDIR)
- Heartrate Sensor
  - Garmin wrist fitness tracker
- Raspberry PI computer
- Proprietary software

## Methodology:

## CO2 and Heart Rate Data Collection



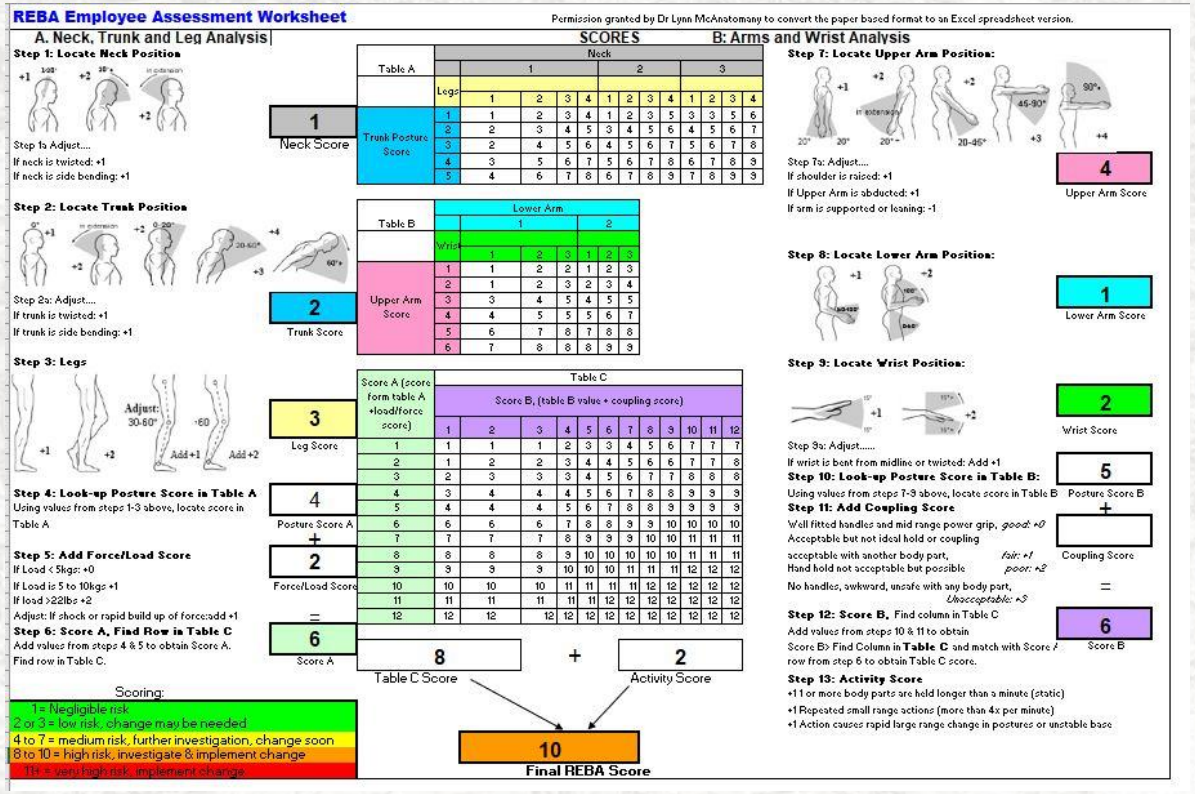


## Methodology:

## Biomechanical Stress

# Biomechanical Risk Factor

- Rapid Entire Body Assessment - REBA

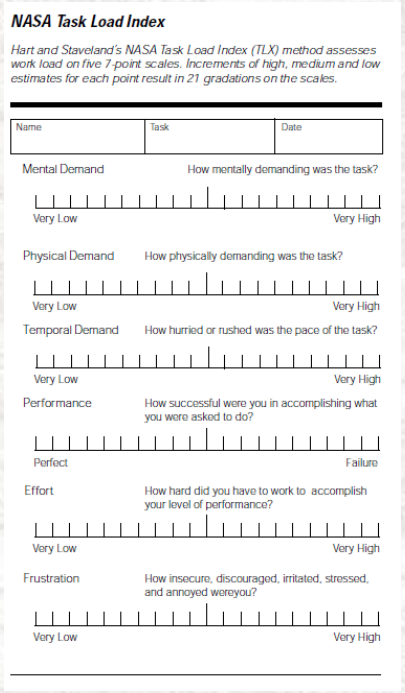


## Methodology: Workload

# NASA – Task Load Index (TLX)

| | |
|---|---|
| Mental demand | How much mental activity was required? Was the task easy or demanding, simple or complex? |
| | |
| Physical Demand | How much physical activity was required? Was the task easy or demanding? |
| | |
| Temporal Demand | How much time pressure did you feel due to the pace of the task? Was the pace slow or rapid? |
| | |
| Overall Performance | How successful were you in performaing the task and how satisfied were you with your performance? |
| | |
| Frustration Level | How irritated, stressed, or annoyed were you versus relaxed, content or complacent during this task? |
| | |
| Effort | How hard did you have to work (mentally and physically) t oaccomplish your level of performance? |

- Six Subscales
- Collected via I-Pad



**NASA Task Load Index**

*Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.*

Name | Task | Date

Mental Demand — How mentally demanding was the task?
Very Low — Very High

Physical Demand — How physically demanding was the task?
Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?
Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?
Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?
Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?
Very Low — Very High

# Results

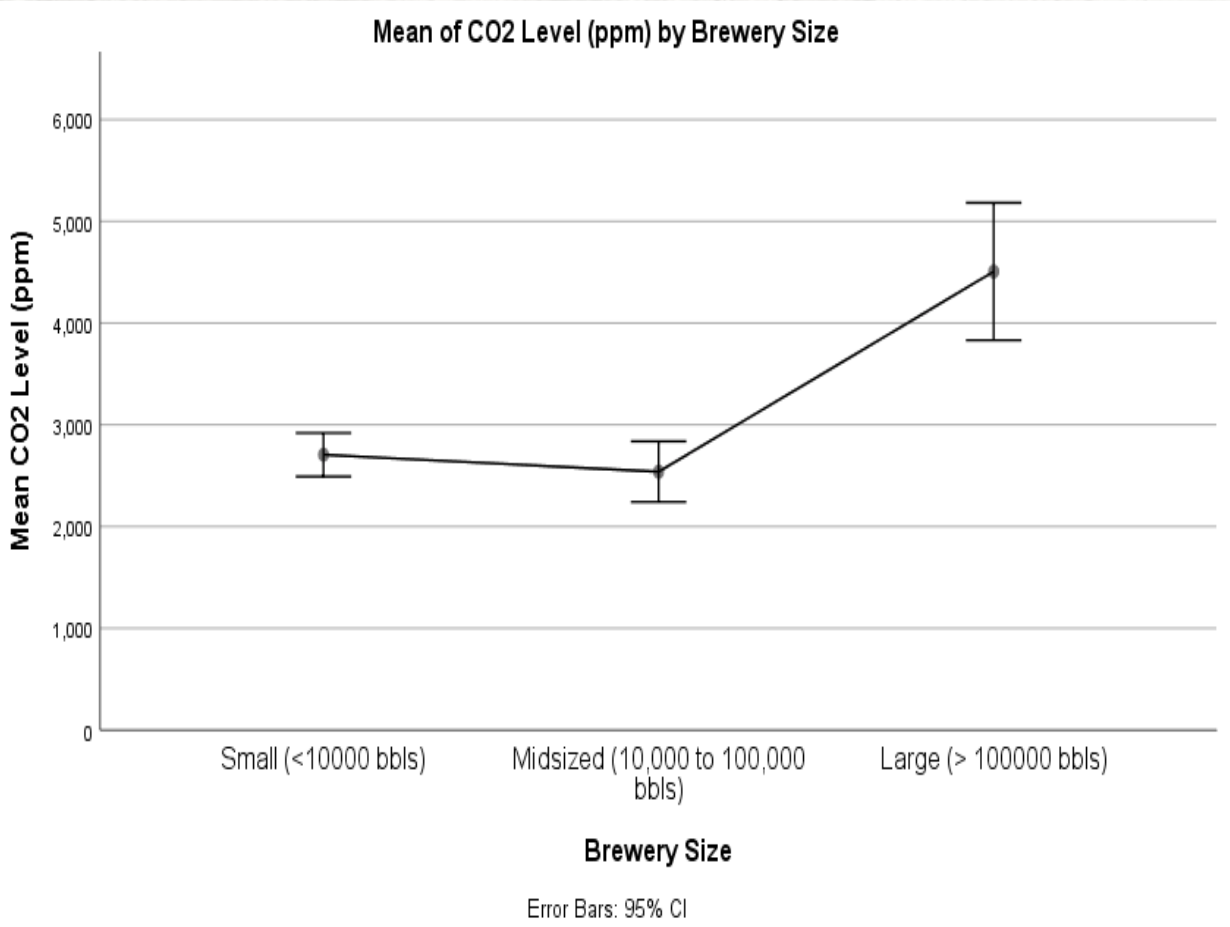
# Phase 1 – What Are the $CO_2$ Levels Found in Different Sized Breweries

# Brewery Demographics

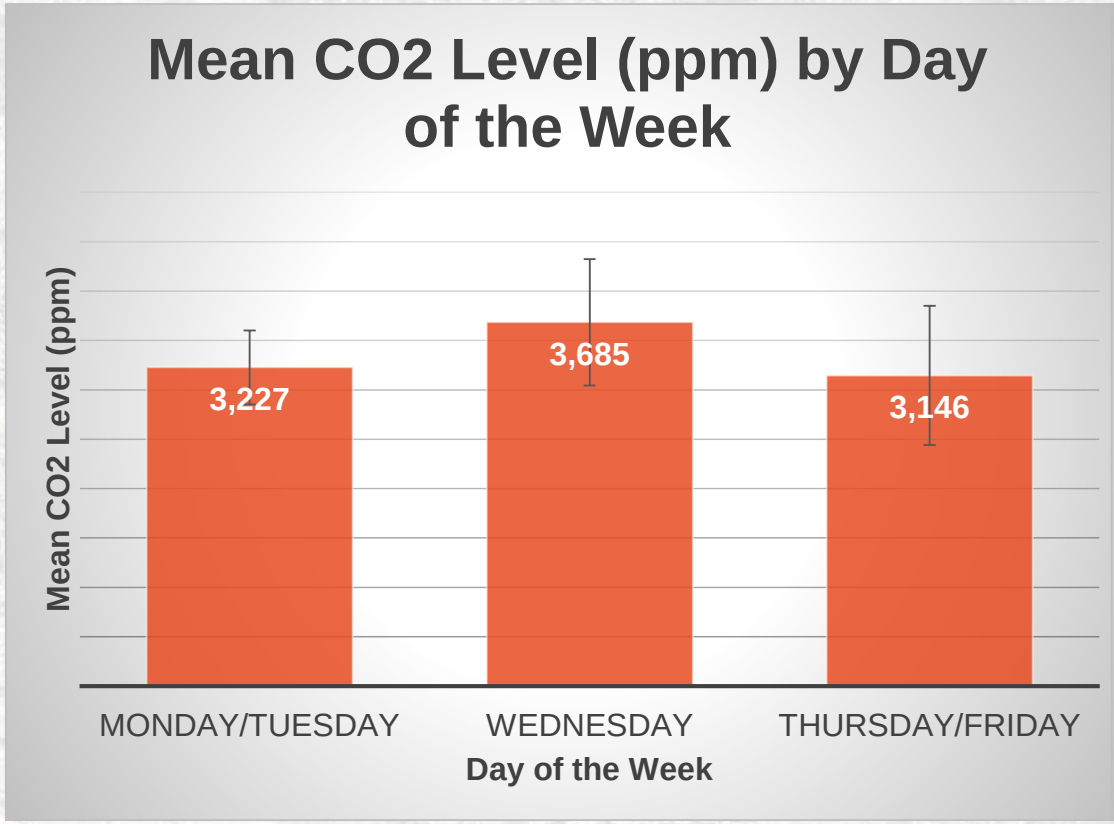
| Brewery | A (Small) | B (Medium) | C (Large) |
|---|---|---|---|
| **Annual Production Volume** | 5000 Barrels (bbls) | 13,000 bbls | 680,000 bbls |
| **Brewery Physical Size** | 5200 $ft^2$ | 11,000 $ft^2$ | 133,500 $ft^2$ |
| **Amount Active Fermentation during sampling periods** | 180-250 bbls | 600 – 660 bbls | 600 – 2800 bbls* |
| **Speed of Packaging Lines** | 32 cans/minute | 50 bottles per minute<br>40 cans per minute | 120-750 can/minute<br>450 bottles/minute |

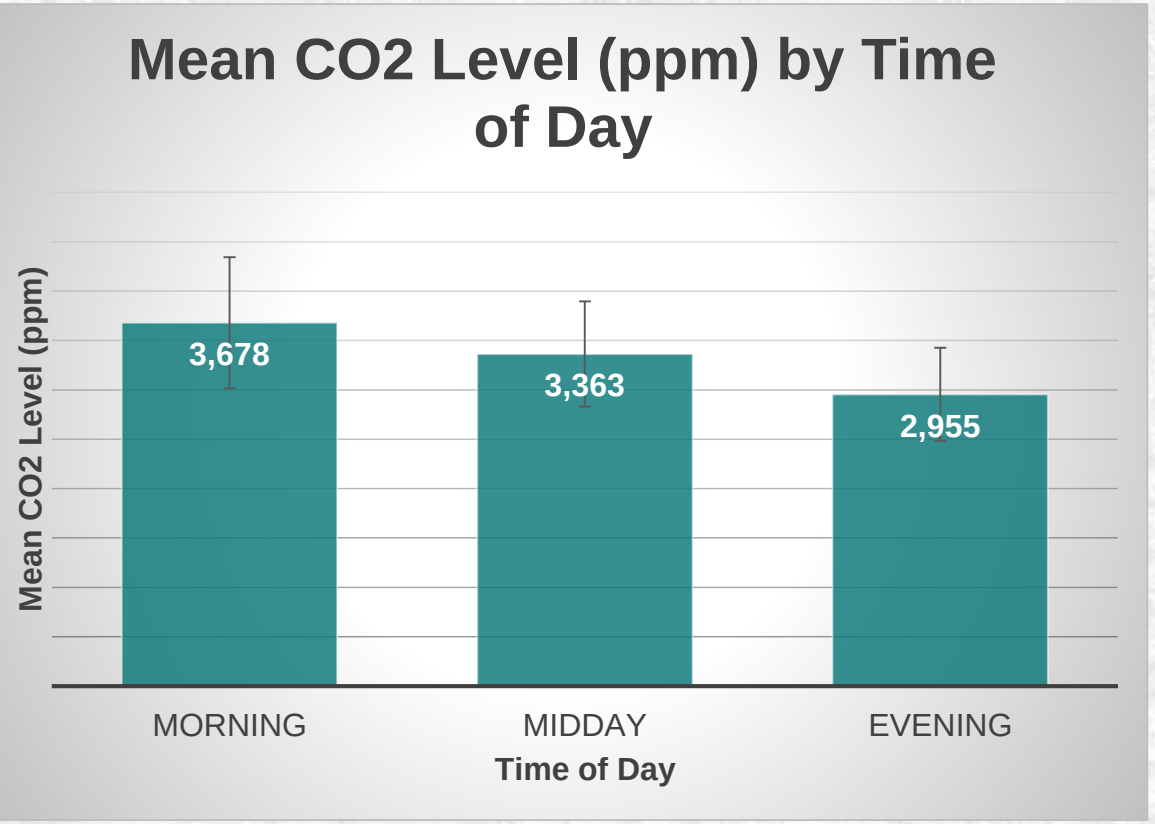
# Overall $CO_2$ Level In Craft Breweries by Size

| Brewery Size | Arithmetic Mean (ppm) | Standard Deviation (ppm) | 95th Percentile Point Estimate (ppm) | $UTL_{95\%,95\%}$ (ppm) |
|---|---|---|---|---|
| Small | 2710 | 652 | 3952 | 4470 |
| Medium | 2540 | 880 | 4509 | 5510 |
| Large | 4510 | 2250 | 8756 | 10800 |

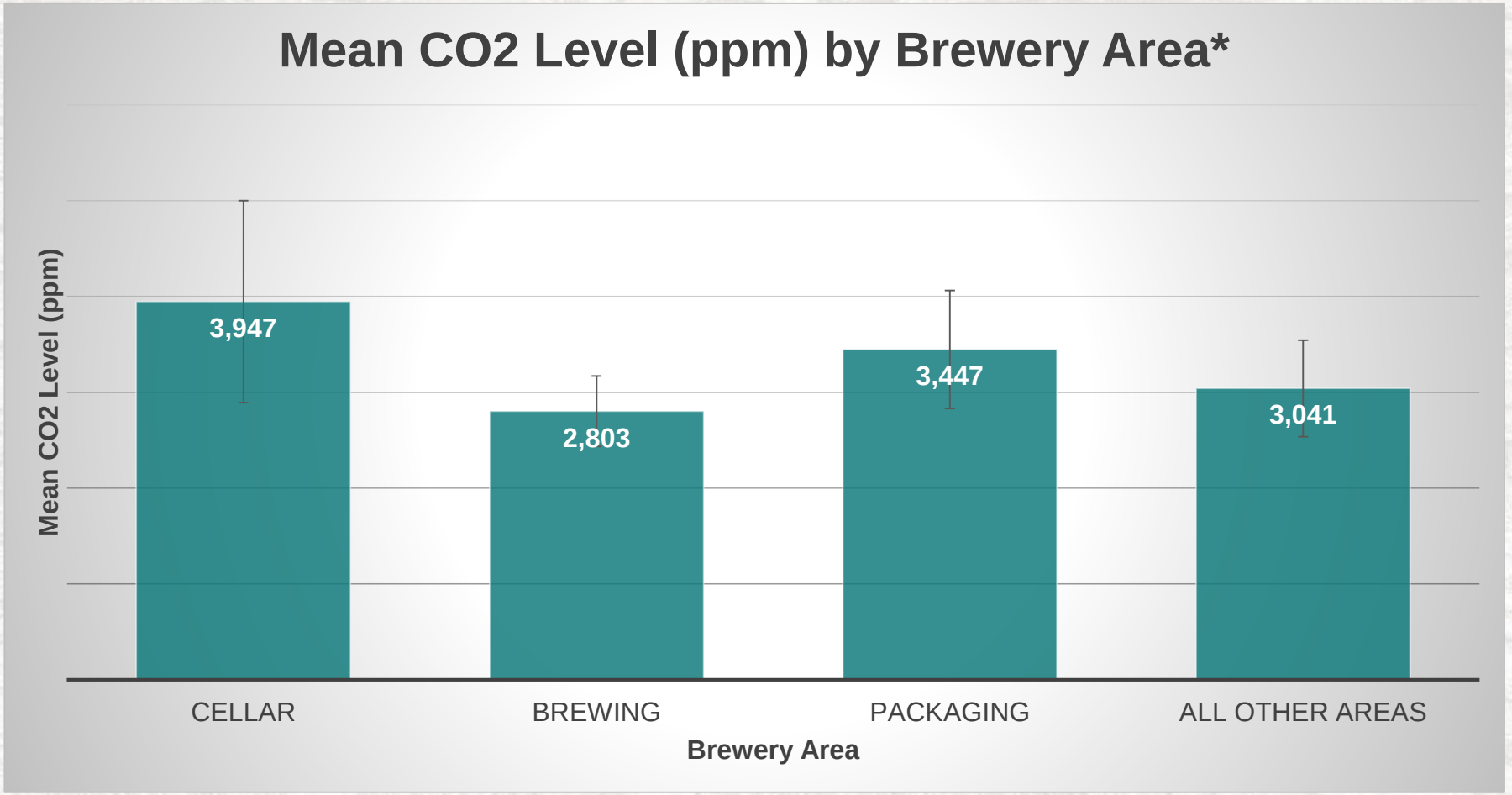


# Overall $CO_2$ Levels by Day and Time

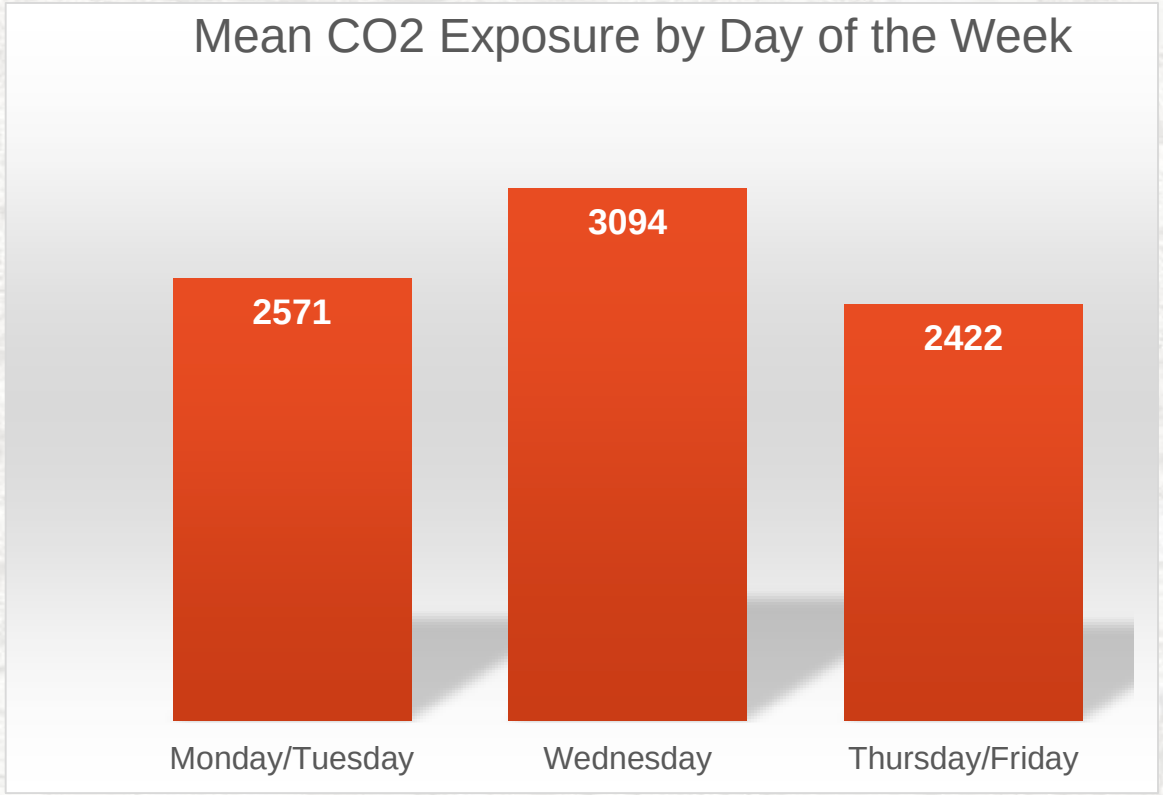


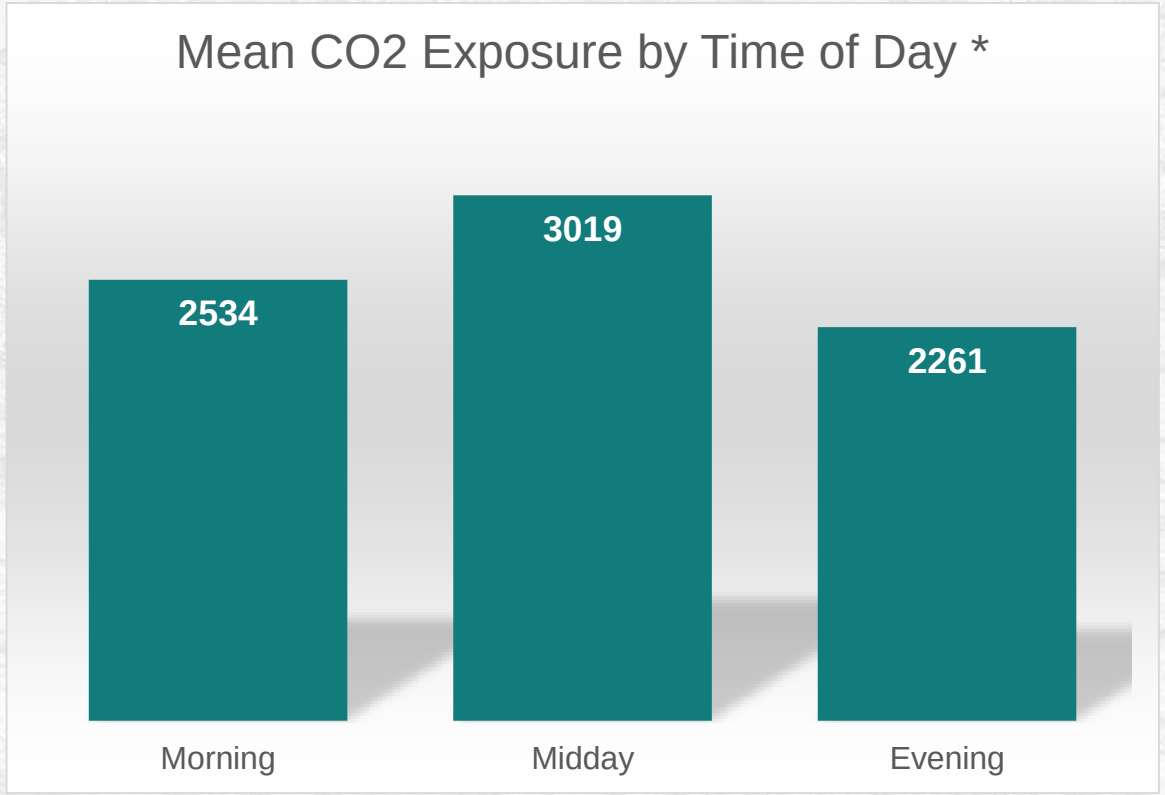



# Overall CO2 Levels By Brewery Area

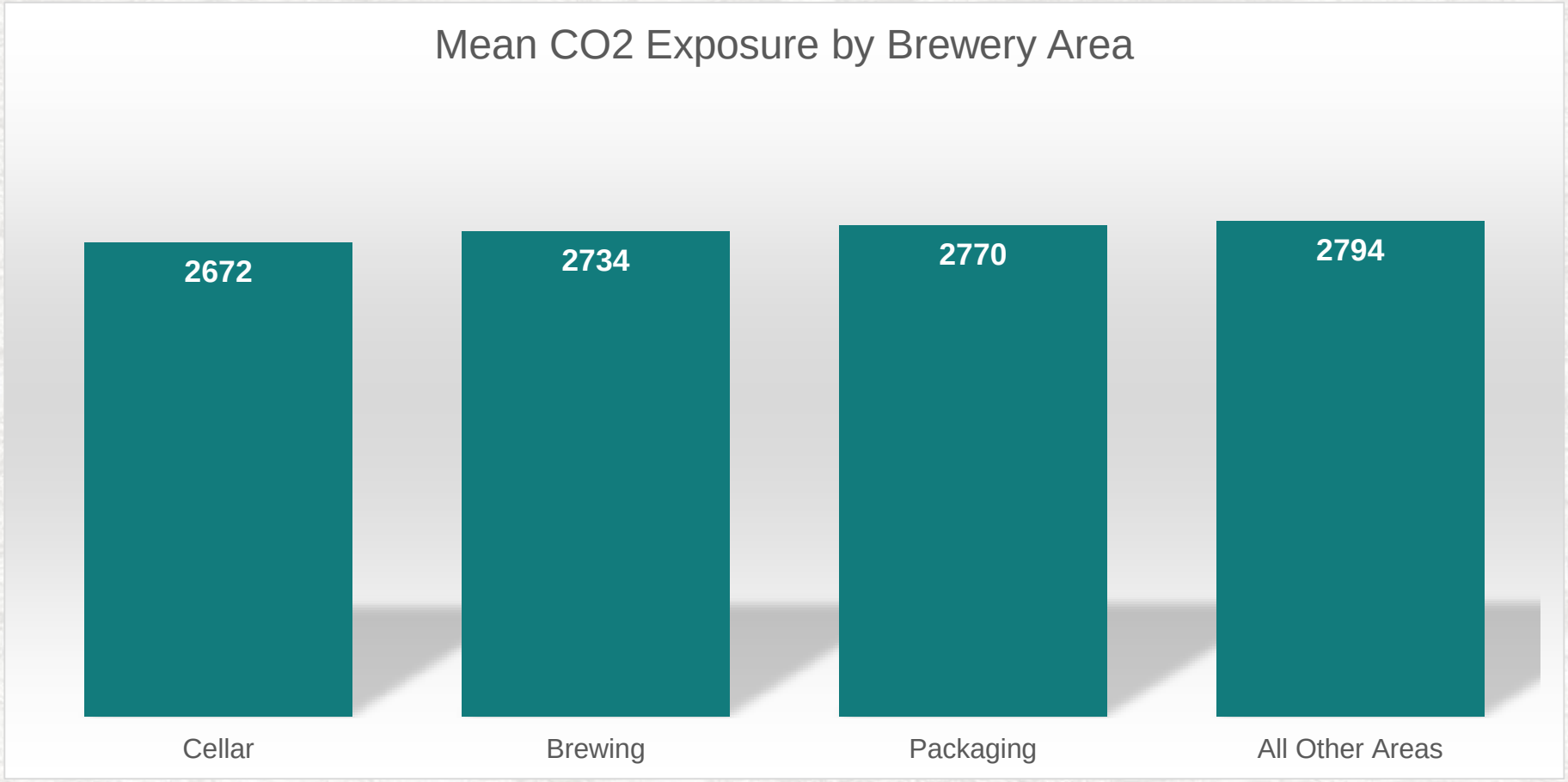


# Small Brewery $CO_2$ Levels by Day and Time

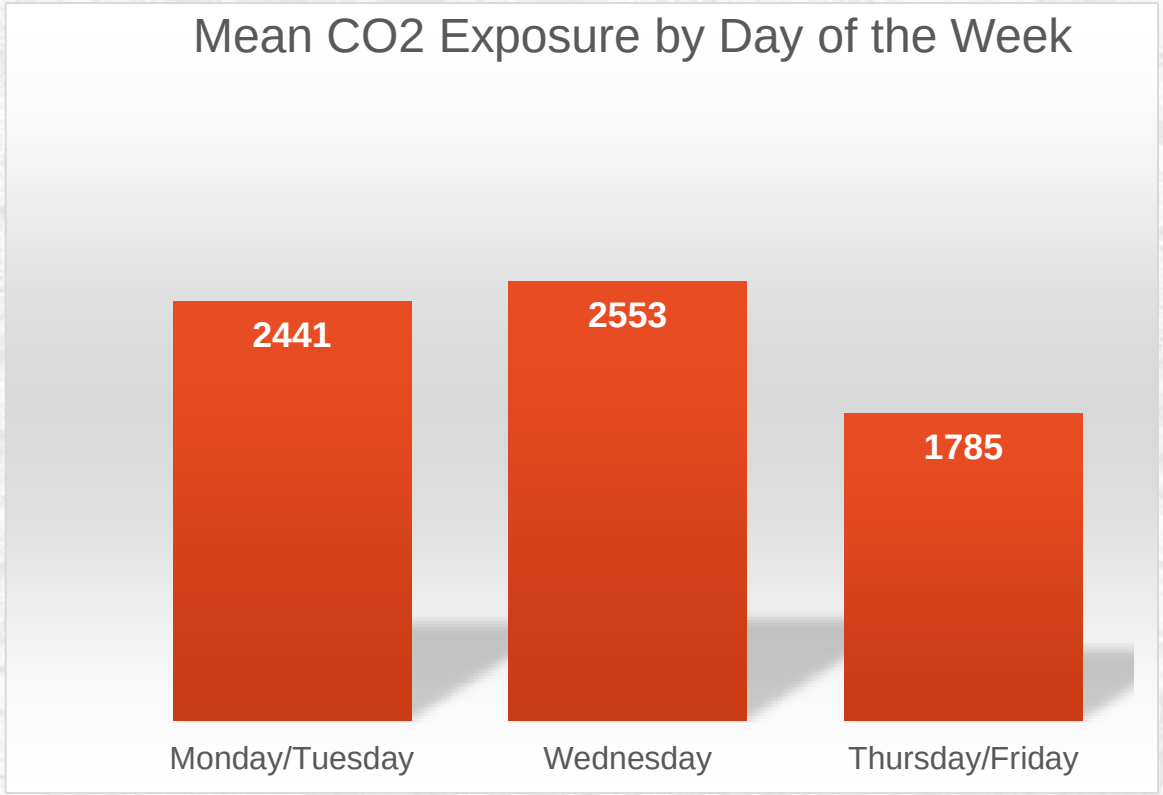


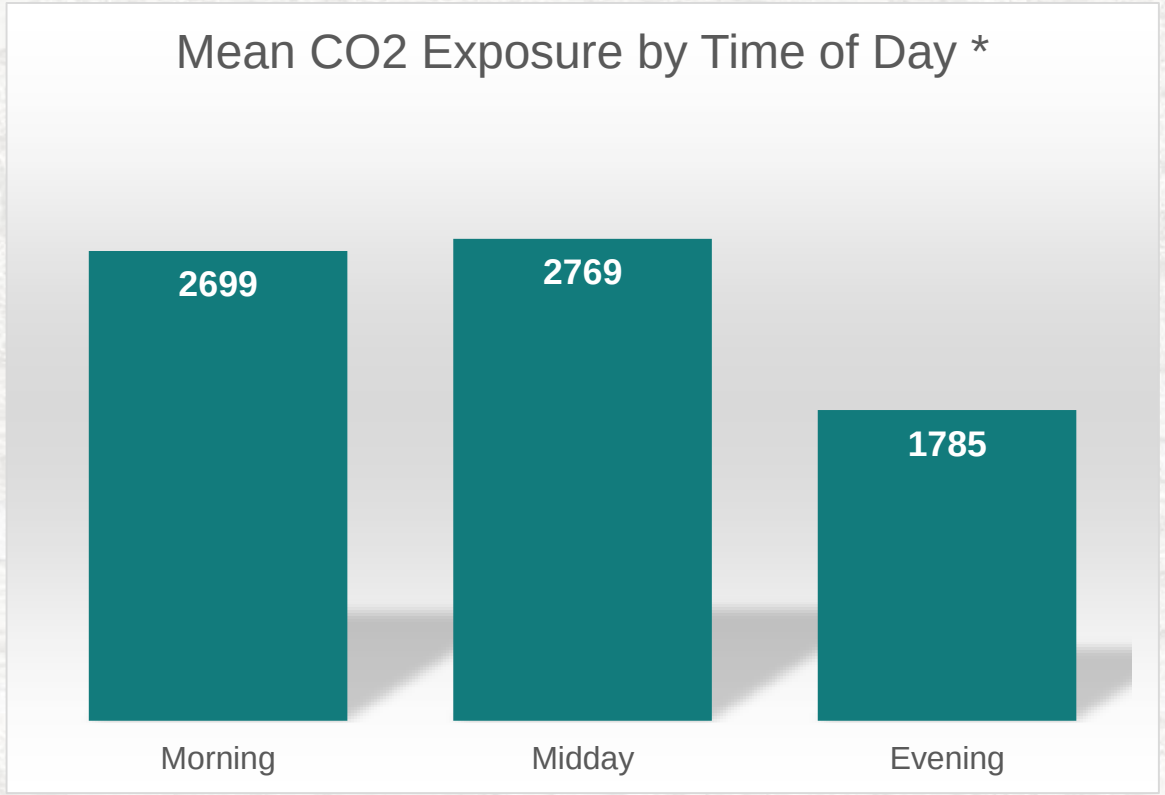



# Small Brewery CO2 Levels By Brewery Area

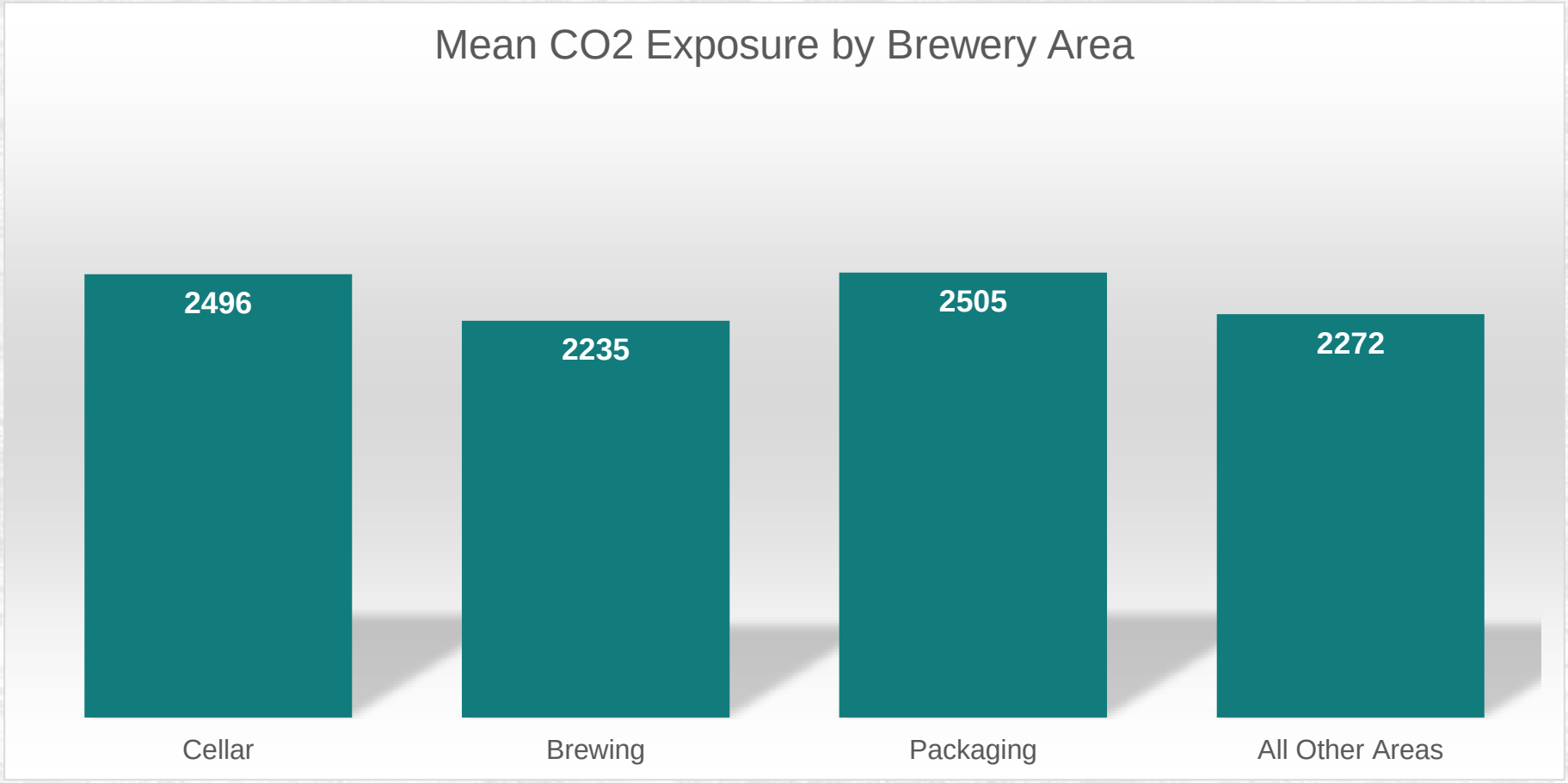


# Medium Brewery $CO_2$ Levels by Day and Time

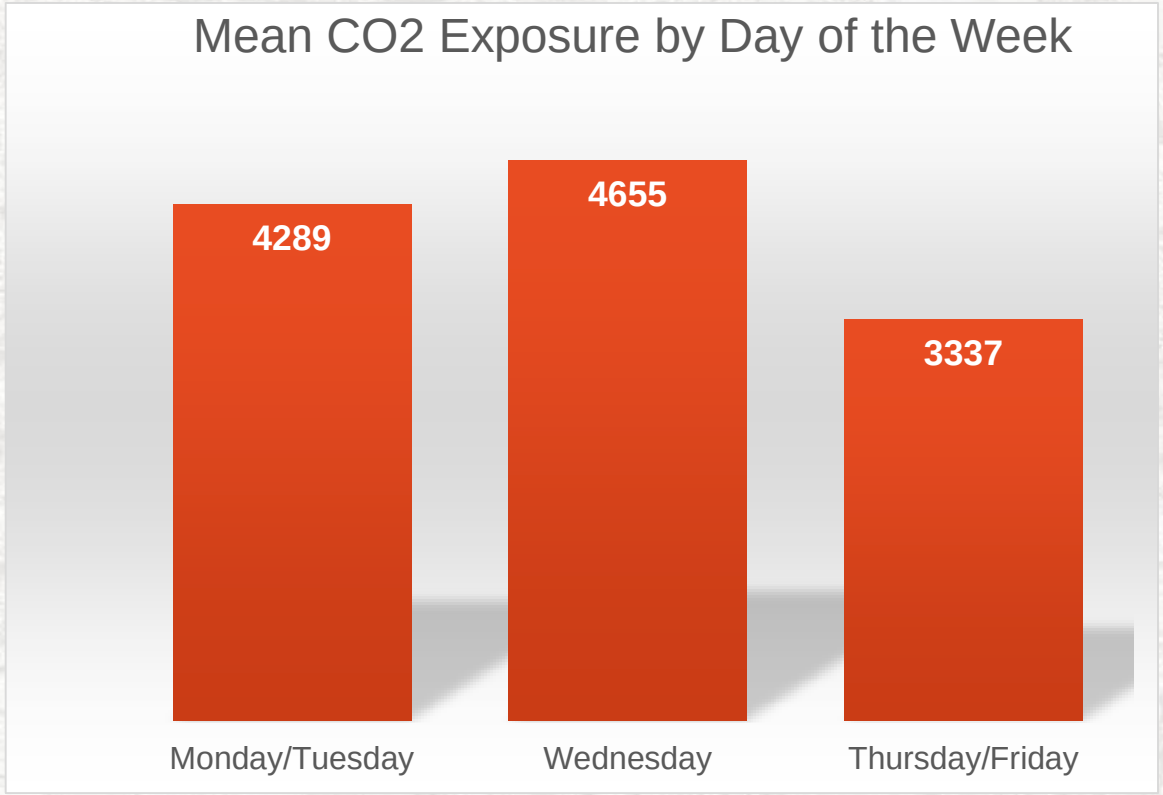


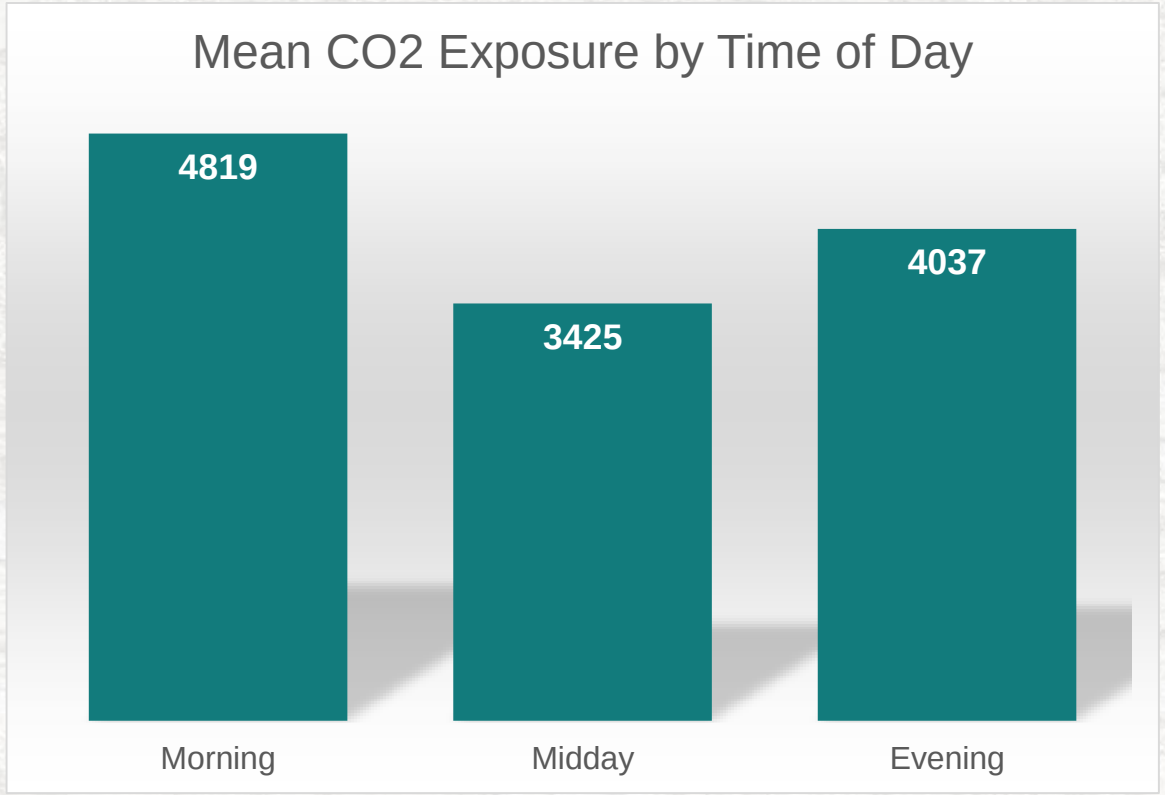



# Medium Brewery CO2 Levels By Brewery Area



# Large Brewery $CO_2$ Levels by Day and Time



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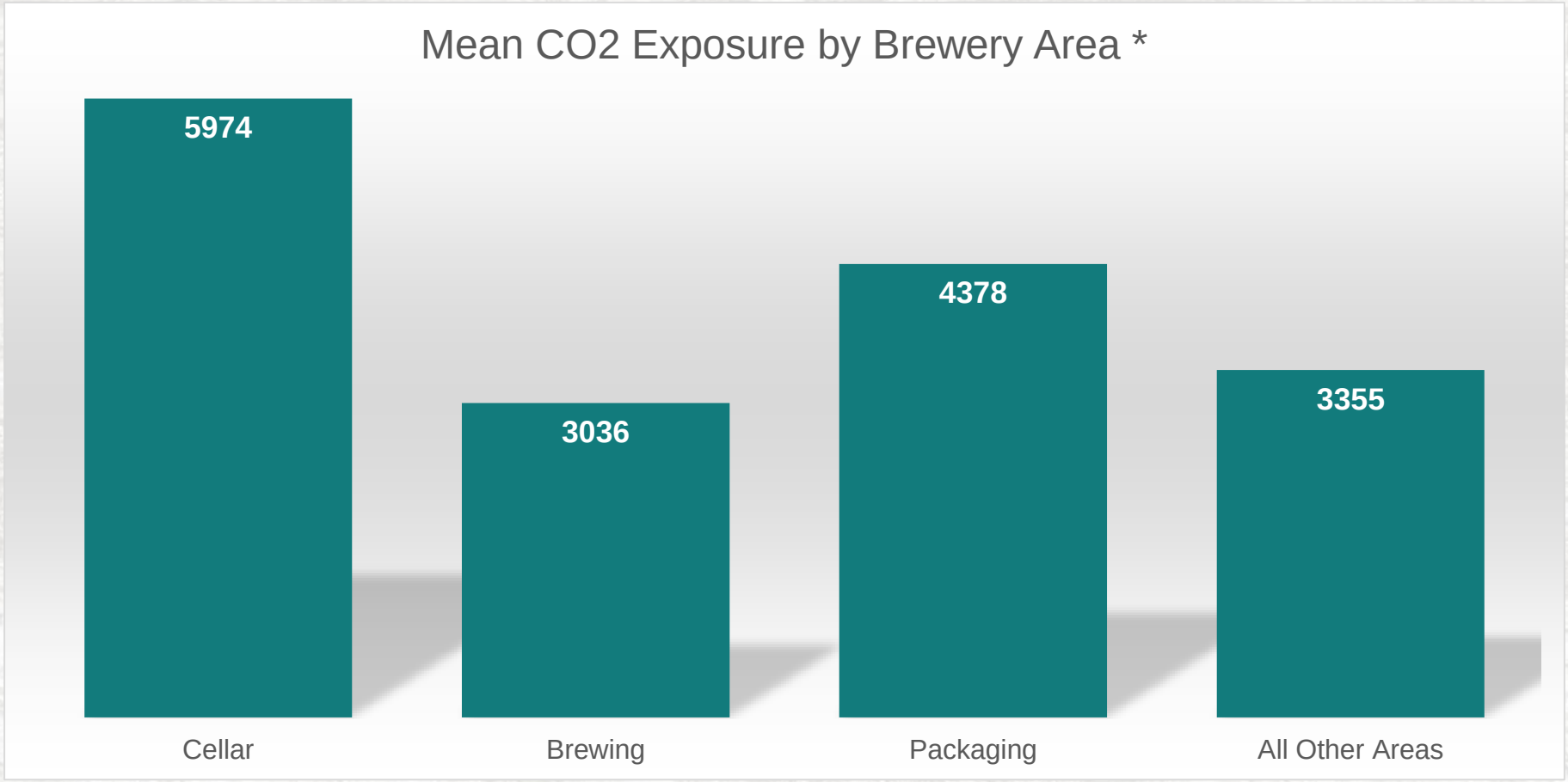
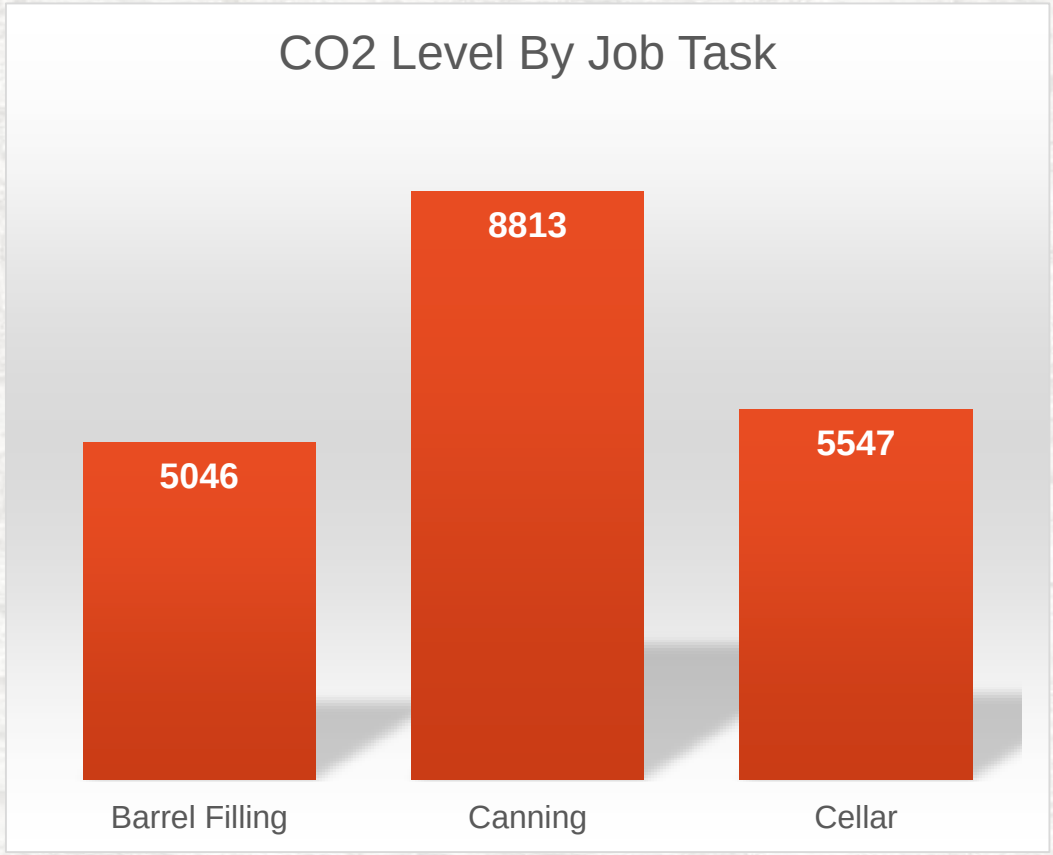
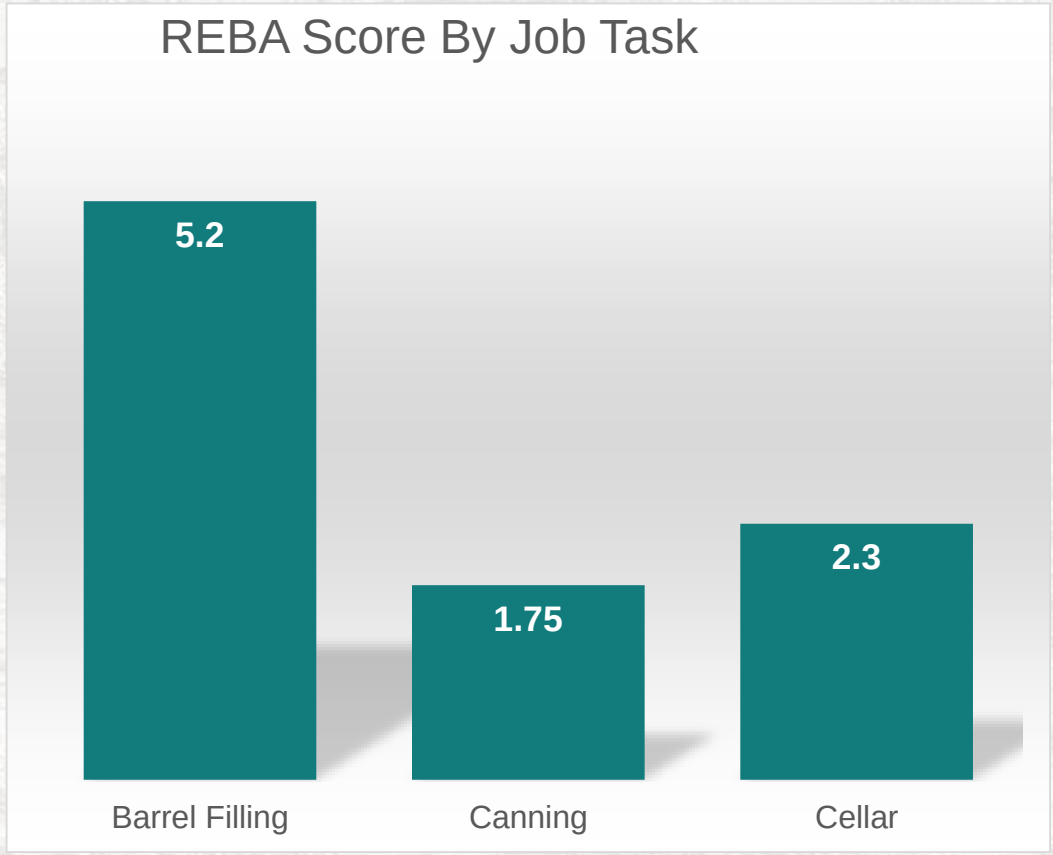


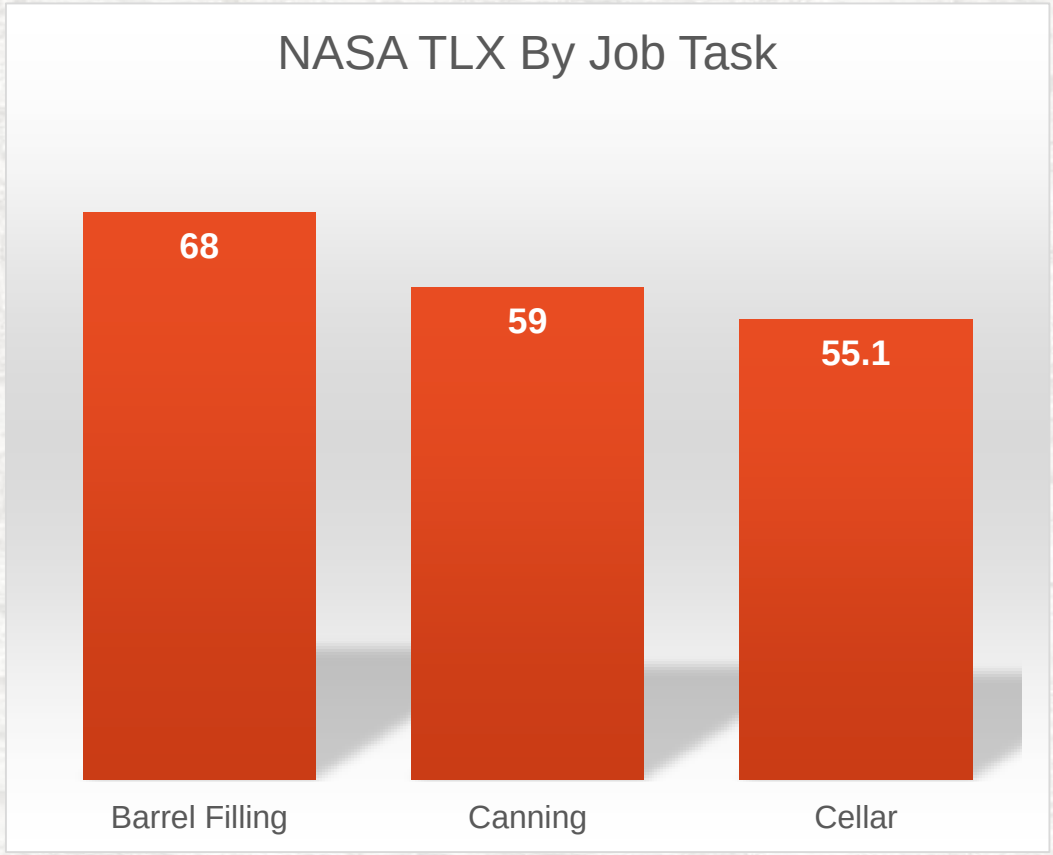
# Phase 2 – Do Lower Levels of CO2 Effect a Brewer's Heart Rate

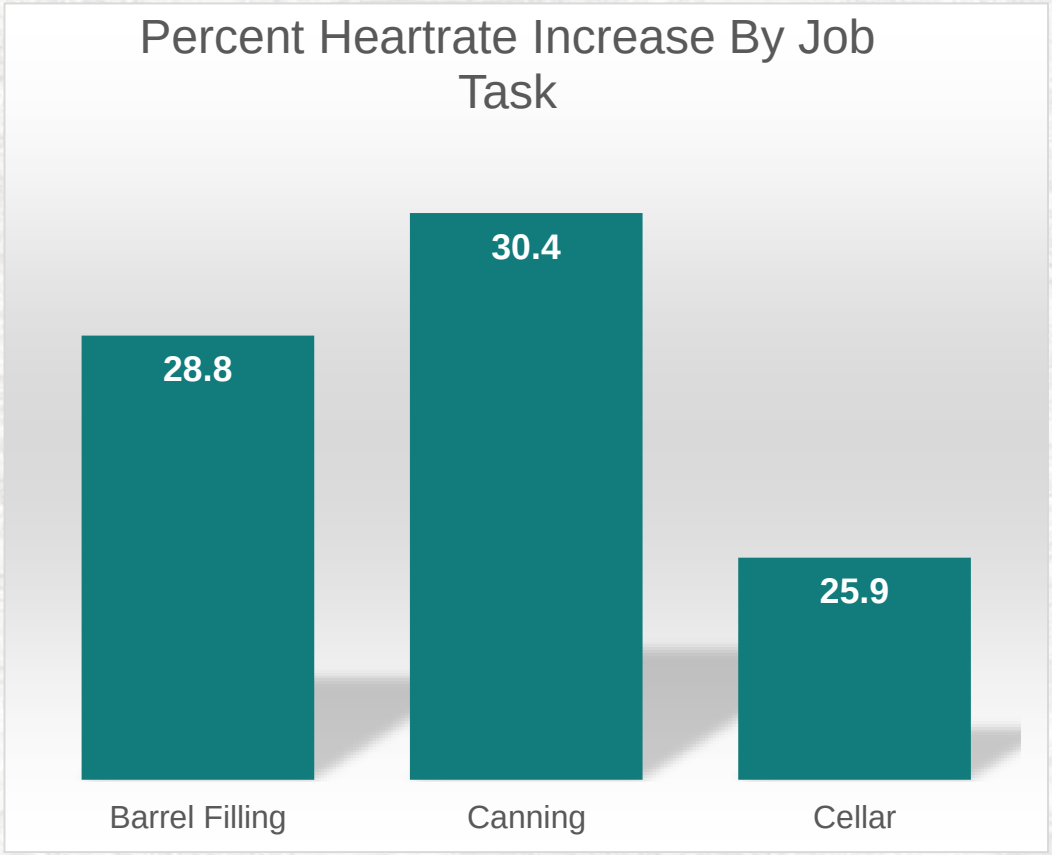
# Brewery Mean CO2 Levels and REBA Score by Job Task



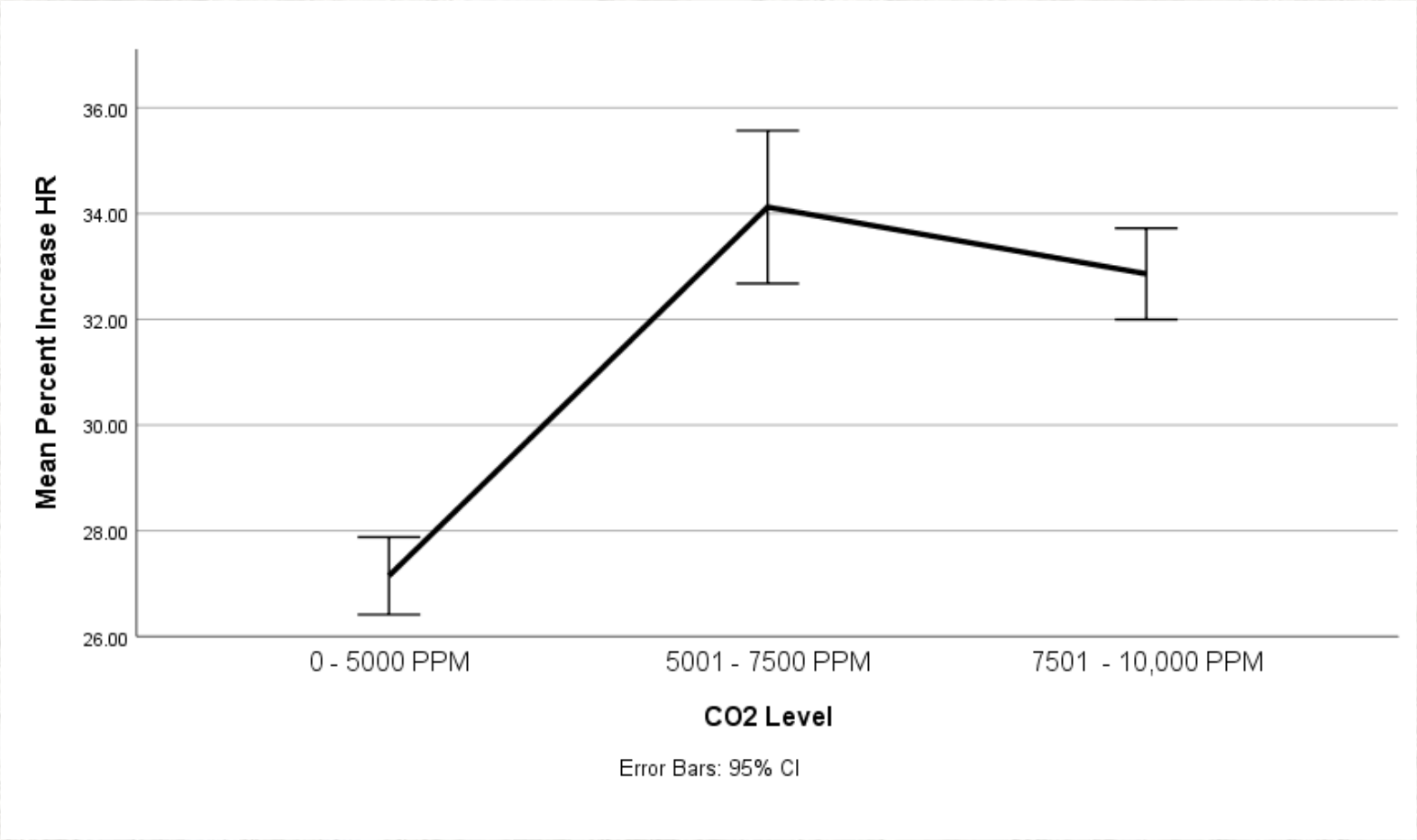



# Brewery Mean CO2 Levels and REBA Score by Job Task

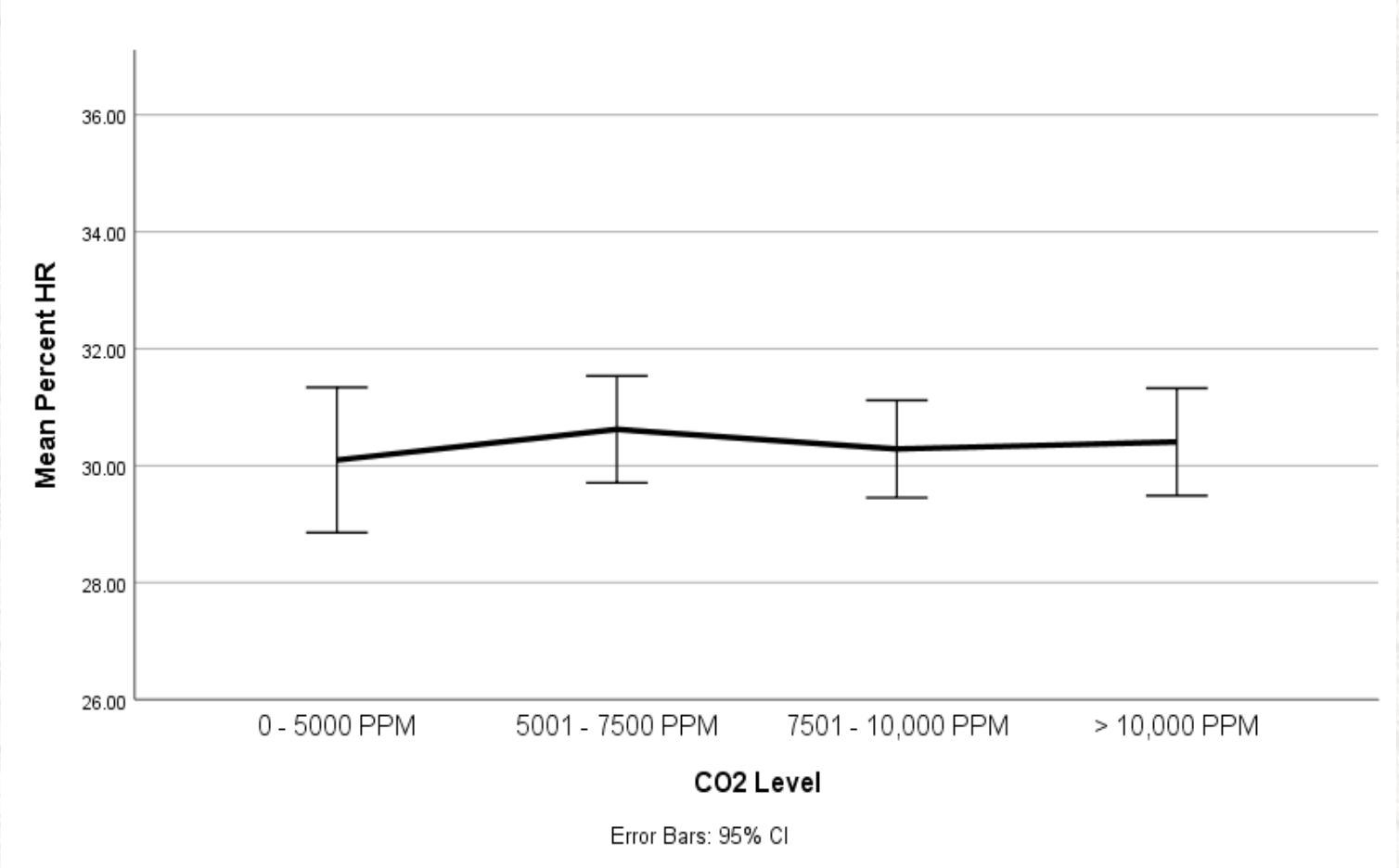


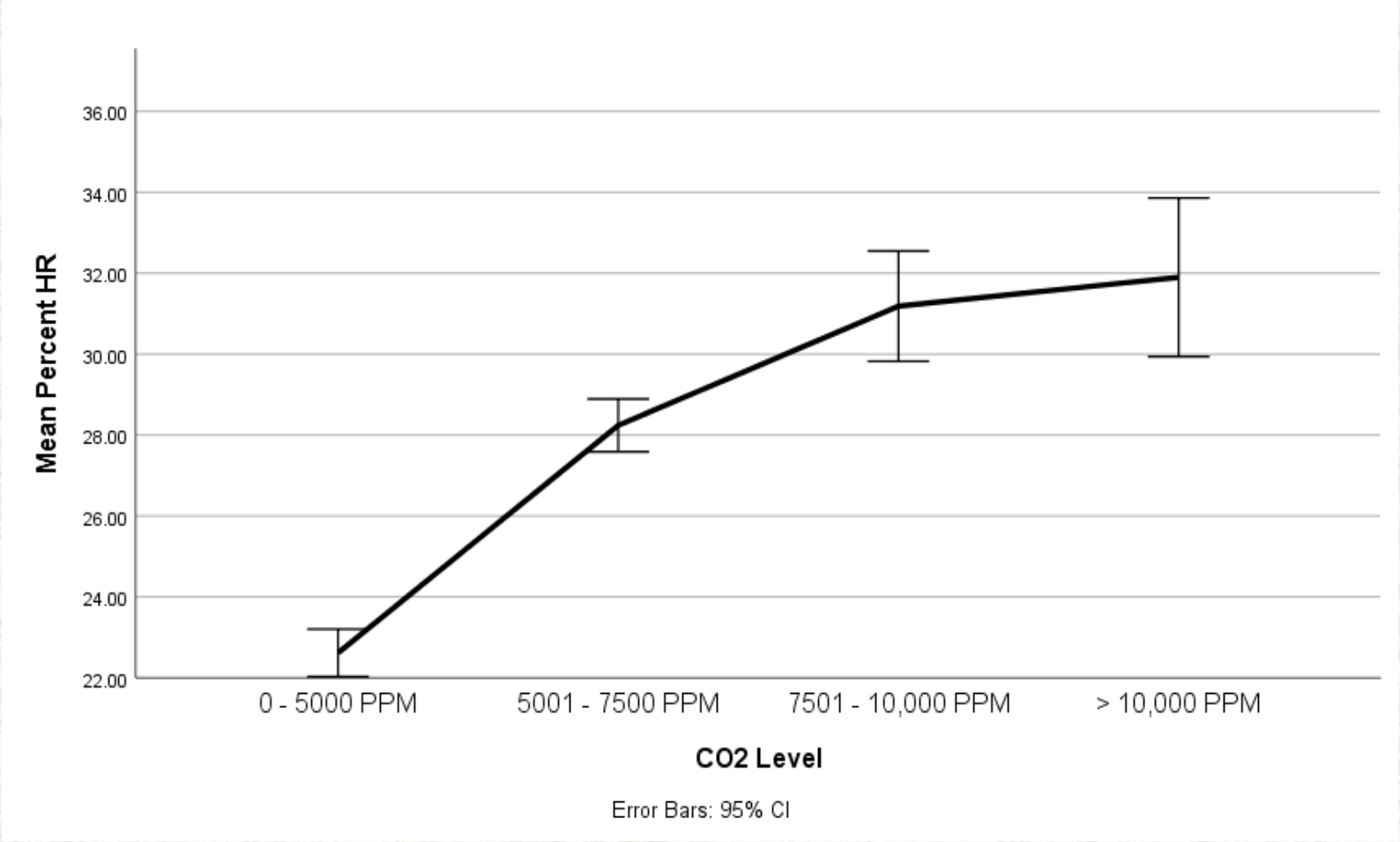
# Barrel Filling Mean Percent Heart Rate increase By CO2 Concentration



# Canning Mean Percent Heart Rate increase By CO2 Concentration



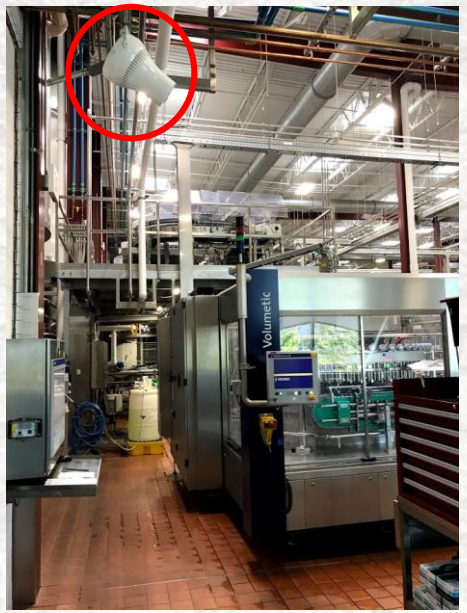
# Cellar Mean Percent Heart Rate increase By CO2 Concentration



# Phase 3 – Control Evaluation

# Controls Implemented for Each Job Task Evaluated

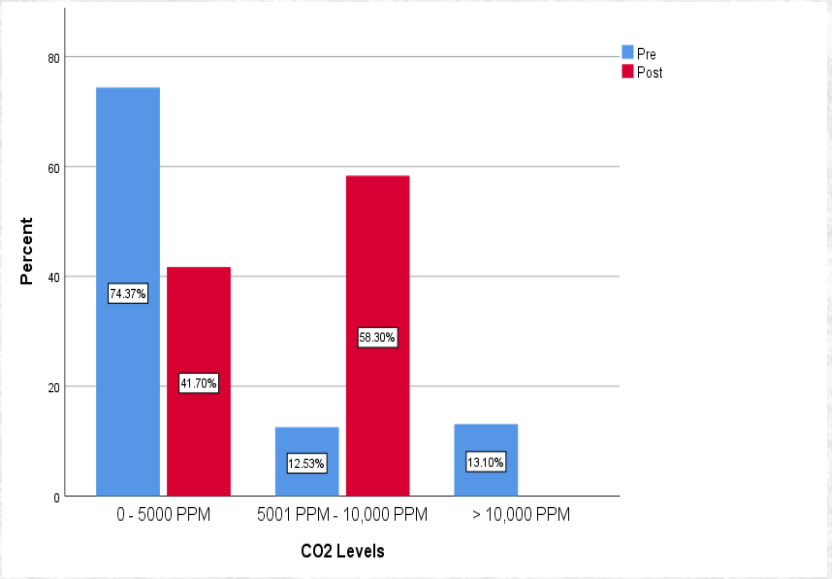

New Barrel Filler

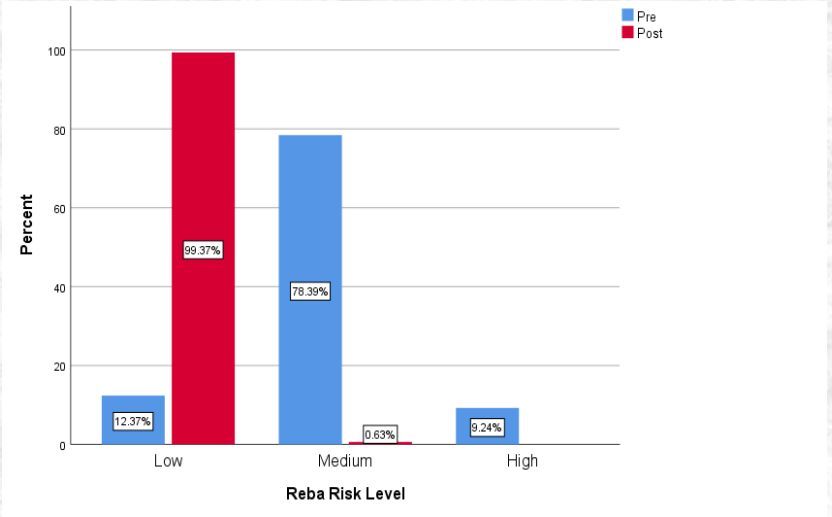



Canning Line
Dilution Ventilation

Cellar Extraction
Ventilation

# Barrel Filling Control Evaluation

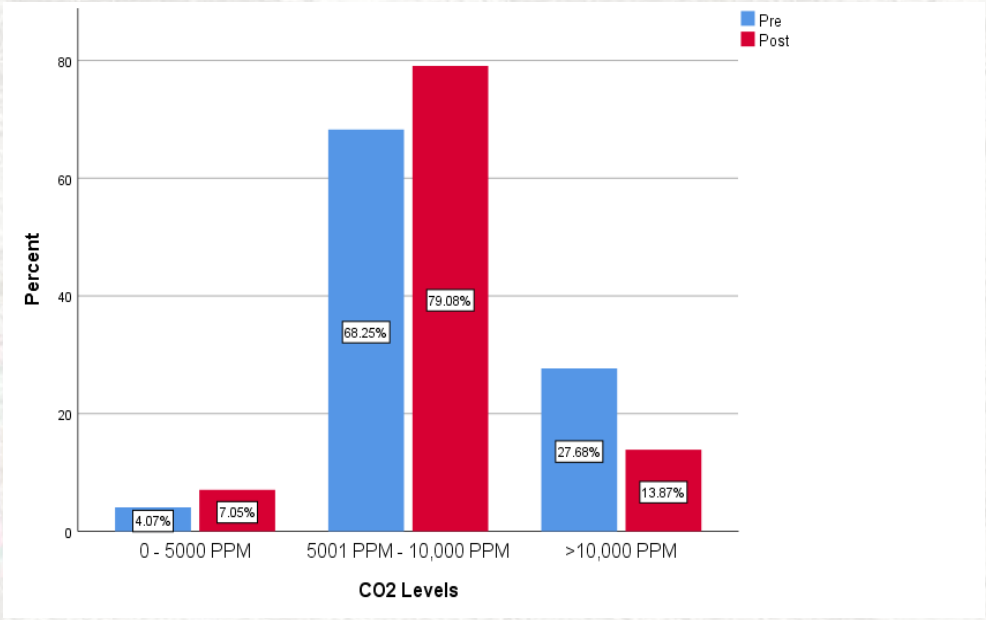


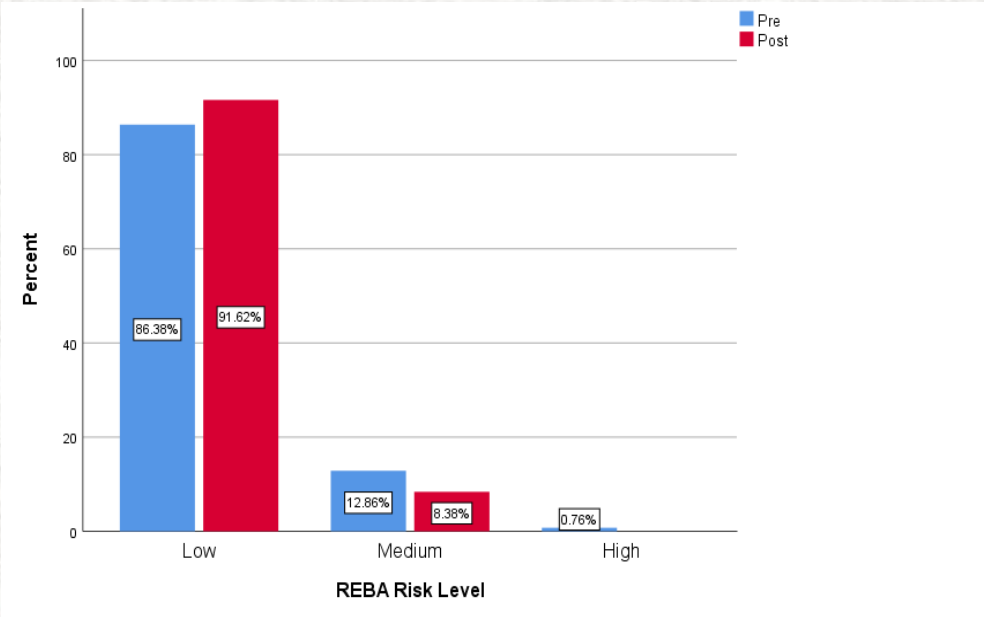



# Barrel Filling Control Evaluation

| | Pre Control n=250 | Post-Control n=1162 | | | |
|---|---|---|---|---|---|
| **Variable** | Mean | Mean | t | p | r |
| **$CO_2$ Concentration** | 3927 | 5808 | -22.51 | < 0.001 | 0.79 |
| **Heart Rate** | 98.73 | 88.36 | 10.58 | < 0.001 | 0.29 |
| **Percent Heart Rate Increase** | 32.75 | 24.82 | 11.21 | < 0.001 | 0.49 |
| **REBA Score** | 5.057 | 1.687 | 50.17 | < 0.001 | 0.93 |
| **NASA TLX** | 58.33 | 44.33 | N/A | N/A | N/A |

# Canning Filler Control Evaluation

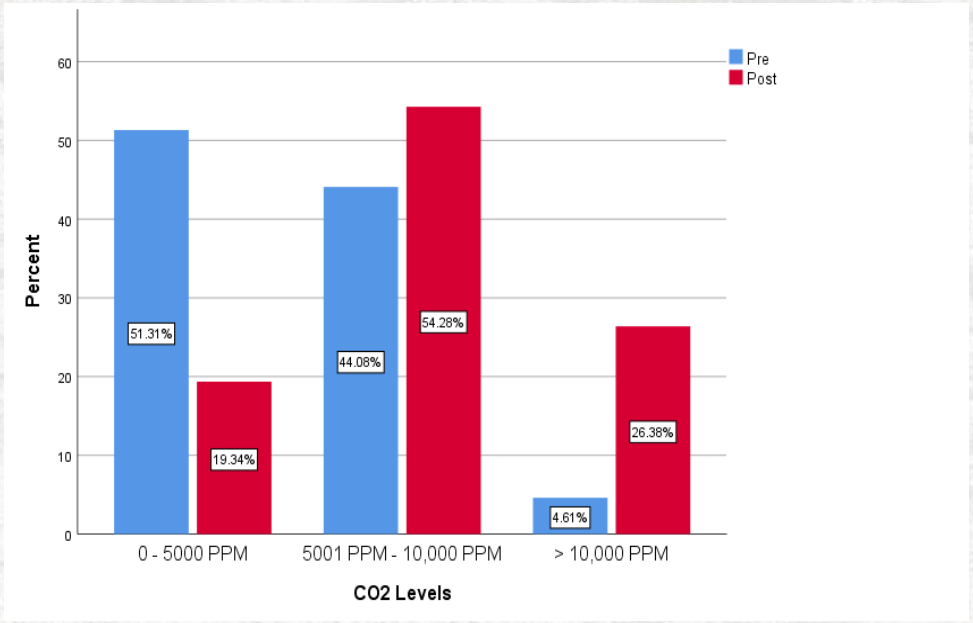



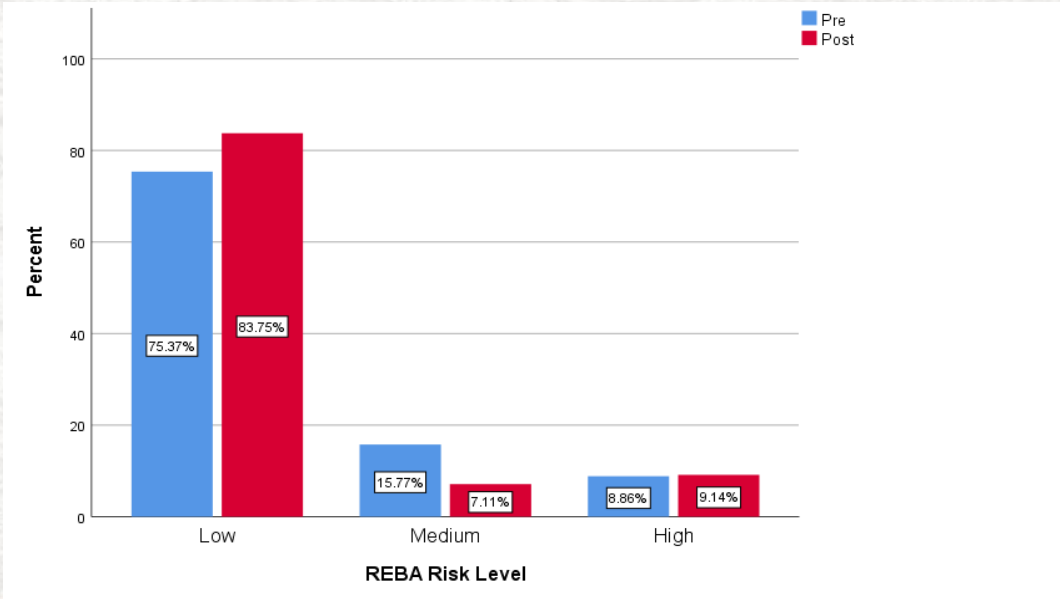



# Canning Filler Control Evaluation


| | Pre Control n = 656 | Post-Control n = 929 | | | |
|---|---|---|---|---|---|
| **Variable** | Mean | Mean | t | p | r |
| **$CO_2$ Concentration** | 9273 | 7493 | 16.03 | < 0.001 | 0.41 |
| **Heart Rate** | 104.0 | 92.42 | 22.33 | < 0.001 | 0.55 |
| **Percent Heart Rate Increase** | 37.72 | 30.17 | 22.18 | 0.005 | 0.52 |
| **REBA Score** | 1.484 | 1.662 | - 2.83 | < 0.001 | 0.07 |
| **NASA TLX** | 50 | 50 | N/A | N/A | N/A |

# Cellar Control Evaluation



# Cellar Control Evaluation

| | Pre Control n = 1338 | Post-Control n = 1520 | | | |
|---|---|---|---|---|---|
| **Variable** | Mean | Mean | t | p | r |
| **$CO_2$ Concentration** | 5780 | 7783 | -11.93 | < 0.001 | 0.27 |
| **Heart Rate** | 90.09 | 86.80 | 8.595 | < 0.001 | 0.16 |
| **Percent Heart Rate Increase** | 28.12 | 25.27 | 9.325 | < 0.001 | 0.17 |
| **REBA Score** | 2.97 | 2.01 | 10.06 | < 0.001 | 0.19 |
| **NASA TLX** | 60.67 | 55.67 | N/A | N/A | N/A |

# Conclusions

## Phase 1 – $CO_2$ Brewery Levels

## Conclusions

- Levels of $CO_2$ in breweries can exceed legal and recommended exposure limits for 8 hours in large and mid-sized breweries.
- The cellar and packaging areas of a brewery are of most concern when addressing $CO_2$ exposures.
- The production cycle on a daily basis affects $CO_2$ levels in small and Mid-Sized Breweries
- The more areas are separated in a brewery the greater the $CO_2$ exposures.
- $CO_2$ exposure levels are dependent on square footage, Fermentation capacity, and production levels.

# Workload, Biomechanical Stressors, and $CO_2$ Exposure Levels Effect on Heart Rate

## Conclusions

- Workload had an impact on the barrel filling task (especially the physical demand subscale).
- Biomechanical stressors had the largest impact on heart rate in the barrel filling task.
- Rising Levels of $CO_2$ had the largest impact on heartrate in the cellar.
- Consistently high levels of $CO_2$ in the canning filler task had the largest impact on heart rate in any of the three job tasks evaluated.
- The exact contribution of each stressor on heart rate is unknown.

## Effectiveness of Controls

## Conclusions

- Ventilation and work station redesign can be effective in reducing heart rates in brewers to reduce fatigue.
- The redesign of tasks with high biomechanical stress makes a large impact on brewer's heart rate and fatigue
- Dilution ventilation is effective in areas where work stations are fixed.
- Dilution ventilation is limited by brewery ambient air concentrations
- Extraction ventilation has limitations in application

# Effectiveness of Controls

## Other Controls to Consider

- Push – Pull Ventilation
- Extraction and High Gravity Fermentations
- Piping $CO_2$ out of Building
- Dedicated line for Fermenter Evacuations
- CO2 recovery systems
- Raise items to move to waist level
- Eliminate reaching above shoulder level and away from your body

# Acknowledgements


- Brewery Vivant – Grand Rapids
- Saugatuck Brewing – Douglas
- Founders Brewing Company – Grand Rapids
- Cody Green – Founders
- Dr. Jim McGlothlin and Kyle Fischer – VEM Systems Developers

# Questions

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