REINHOLD ENVIRONMENTAL ®

2024 Reinhold/PCUG Round Table Presentation

Hosted by LG&E/KU and Co-hosted by Southern Co. and TVA

in The Marriott Resort Lexington Griffin Gate Hotel, Lexington, KY on June 24-25, 2024

Reinhold Conference
June 24th, 2024

SURVEY SAYS: DSI CHALLENGES AND OPERATIONAL BEST PRACTICES FROM USER SURVEYS

Dr. Ian Saratovsky
Gerald Hunt

2010 or 2024?

“Those who don’t know history are destined to repeat it.”

- **Why – On a weekly basis hear from DSI system users still struggling with issues that have been discussed nearly 2 decades ago.**

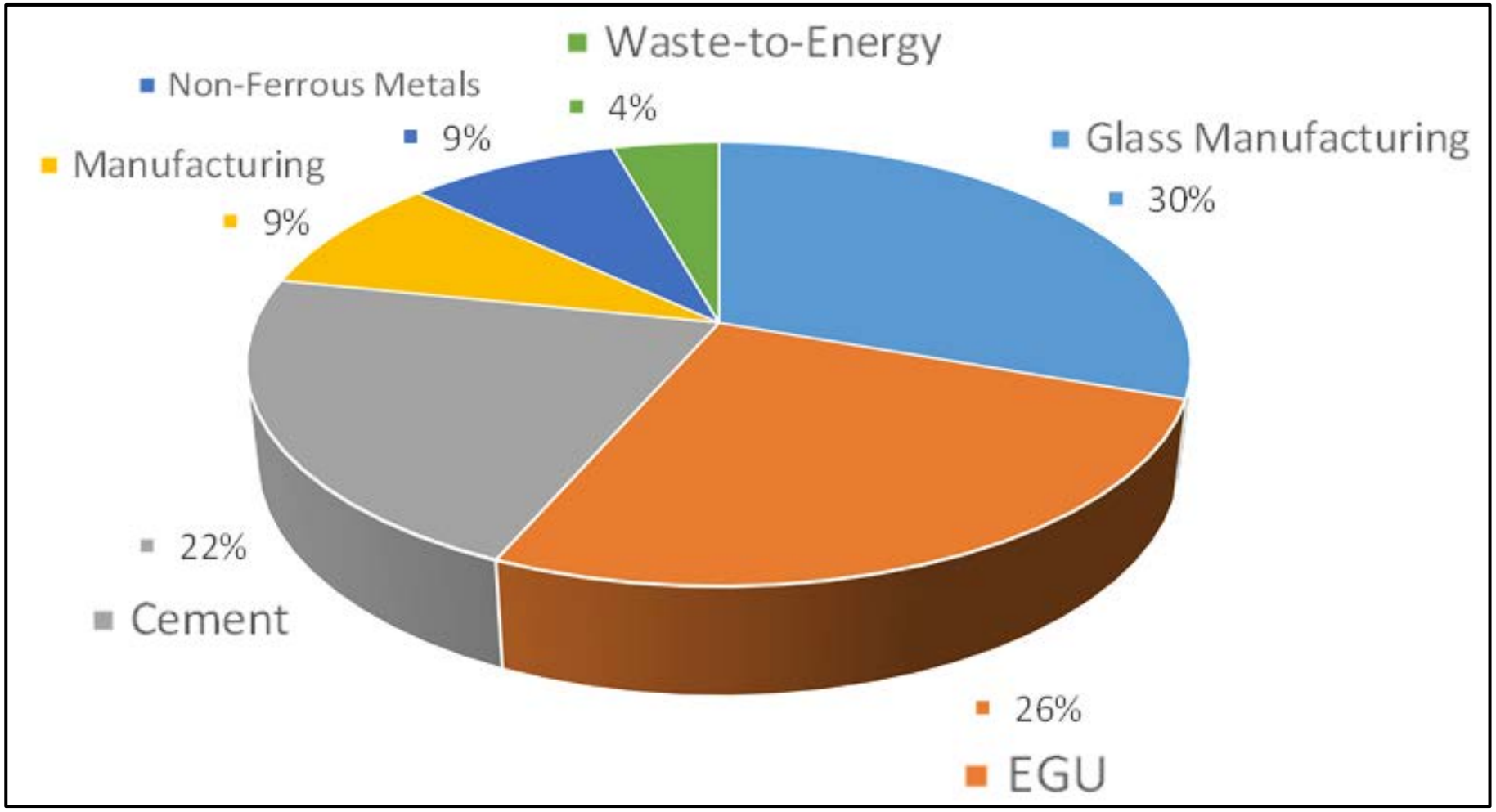
- What – Sent survey to a multitude of DSI end users and put together summary of results received from 23 participants.

- When – Survey conducted over the past 5 weeks so data is up to date and current.

- Who – DSI end users from EGU as well as multitude of industrial sectors. No duplicate answers from same site and some users reflect responses from multiple sites.

#1 – Industries Surveyed

Who are DSI end users taking this survey?



#1 – Industries Surveyed

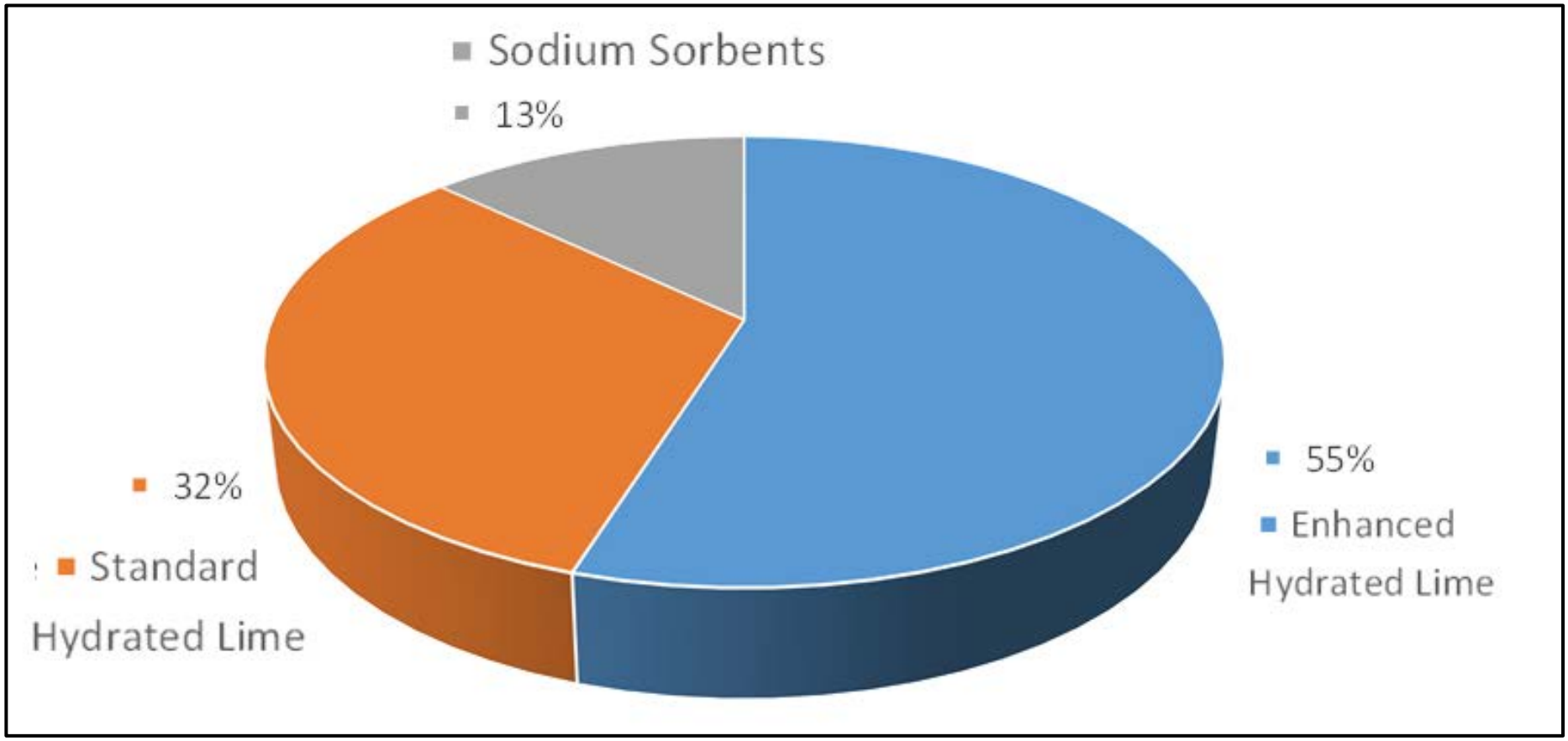
Who are DSI end users taking this survey?

- For the sake of this presentation let's assume the data generated from the survey represents trend of the industry
- Approximately ¼ of the survey takers were the EGUs
  - Likely consistent with current day US operating experience
  - EGUs represent more knowledgeable DSI end users due to multiple decades of operating experience
- Assume ~300 total DSI systems in US operating today

- ❑ Coal fired power plant (SO_2, SO_3, HCl)
- ❑ Cement (SO_2, HCl)
- ❑ Biomass (SO_2, HCl)
- ❑ Glass (SO_2, HCl)
- ❑ Pulp & Paper (SO_2, HCl)
- ❑ Universities (HCl)
- ❑ Calcined Pet Coke (SO_2, SO_3)
- ❑ Fiberglass (SO_2)
- ❑ Chemicals (HCl, Hg)
- ❑ Brick and Tile (SO_2, HCl, HF)
- ❑ Aluminum Smelters (SO_2, HCl, HF, Hg, D/F)
- ❑ Carbon Black (SO_3)

#2 – DSI Sorbent Used

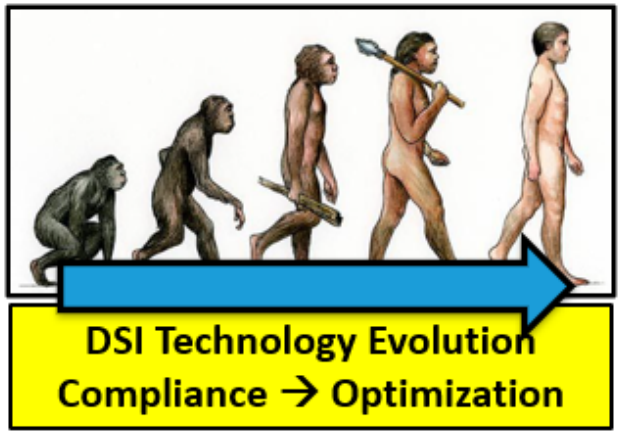
What DSI sorbents used in industry?



#2 – DSI Sorbent Used

Take-aways from survey

- Majority of DSI end users are using a hydrated lime sorbents
  - Potential bias towards hydrated lime
  - Estimate that ≤ 25% of DSI end users in US using sodium sorbents
  - Drivers – sorbent development, new DSI data, disposal, etc.
- More DSI end users likely using enhanced hydrated lime product over standard hydrated lime product
  - Enhanced hydrated lime products been available in US for over a decade
- Sorbent selection reflection of process DSI user follows.
  - Emission compliance
  - Establishes comfort with solution
  - Optimization

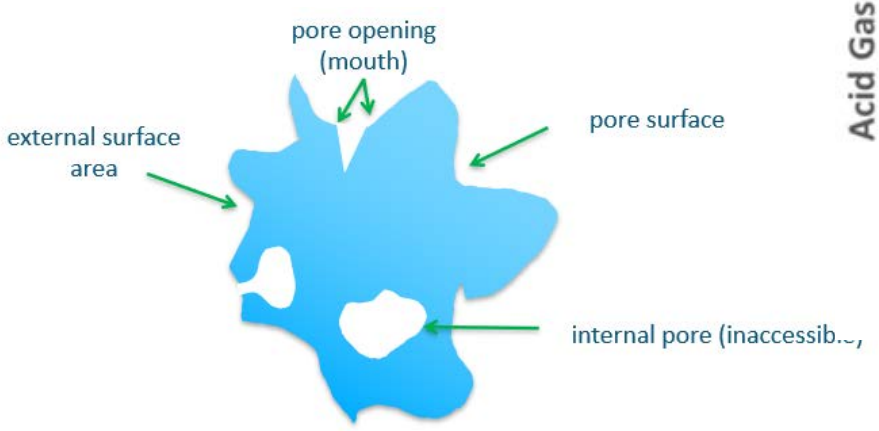


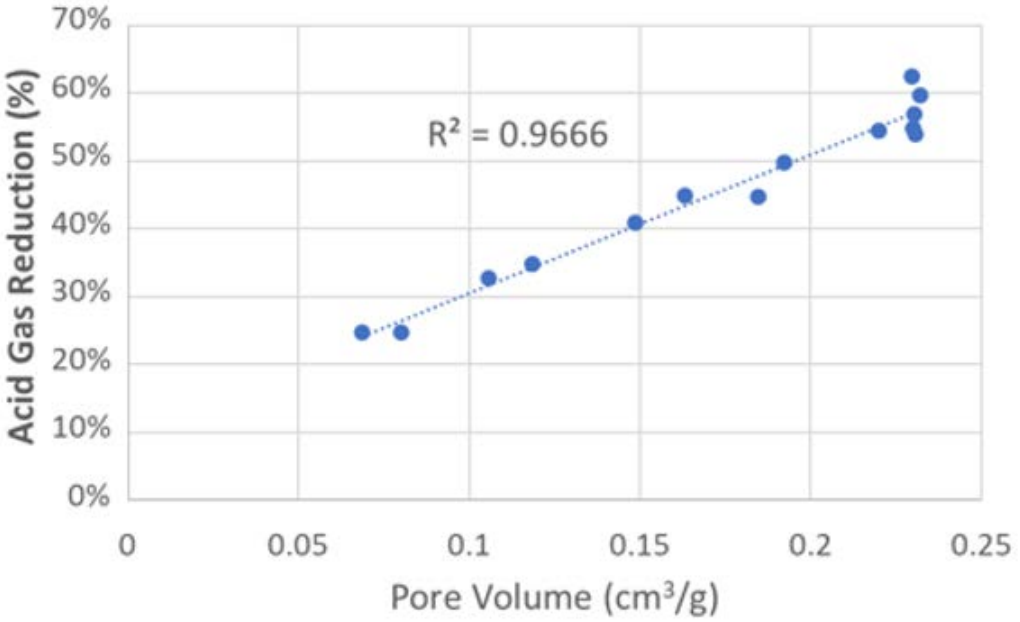
#2 – DSI Sorbent Used

Hydrated lime '101' – what property matters most?

Is sorbent pore volume important? **Yes**

But is it the <u>most</u> important property? **Yes**





Internal Surface Area + External Surface Area = <u>Total</u> Surface Area

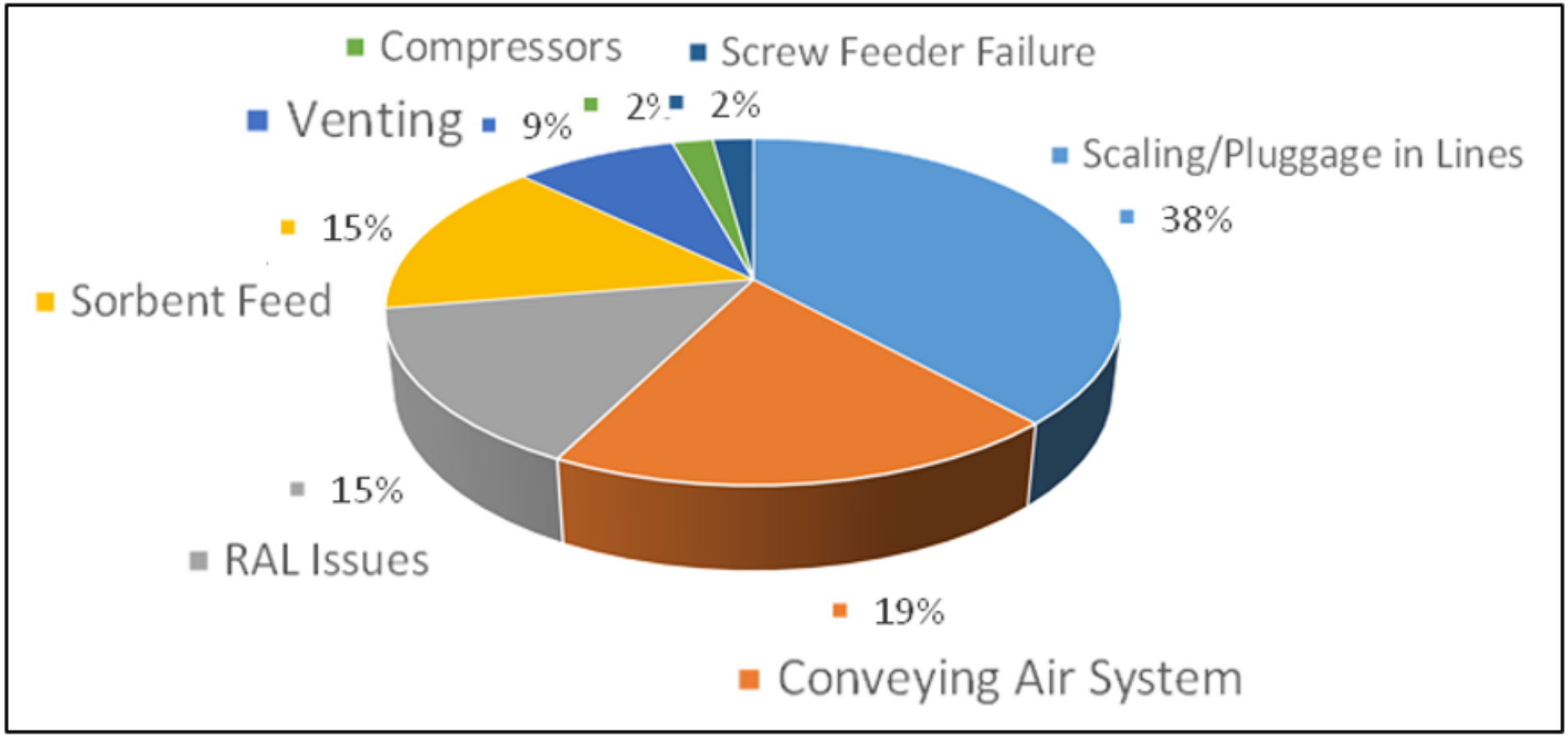
Driven by Pore Volume Driven by Particle Size

Total Cost of Ownership (TCO) = Annual Sorbent Spend + Annual Disposal Cost

Unit Cost x Annual Sorbent Usage

#3 – System Design Impacting Reliability

What impacts system reliability?



#3 – System Design Impacting Reliability

Take-aways from survey

- Carbonate scaling is most common issue impacting reliability
- Range in responses yet potential connection around conveying air system design / operation
  - Carbonate scaling
  - Conveying air system
  - RAL issues
  - Sorbent feed
  - Venting
- DSI conveying air system and hose/piping design can impact all of these issues
  - Conveying velocity
  - Conveying air relative humidity
  - Conveying air temperature
  - Elbow design and materials of construction

#3 – System Design Impacting Reliability

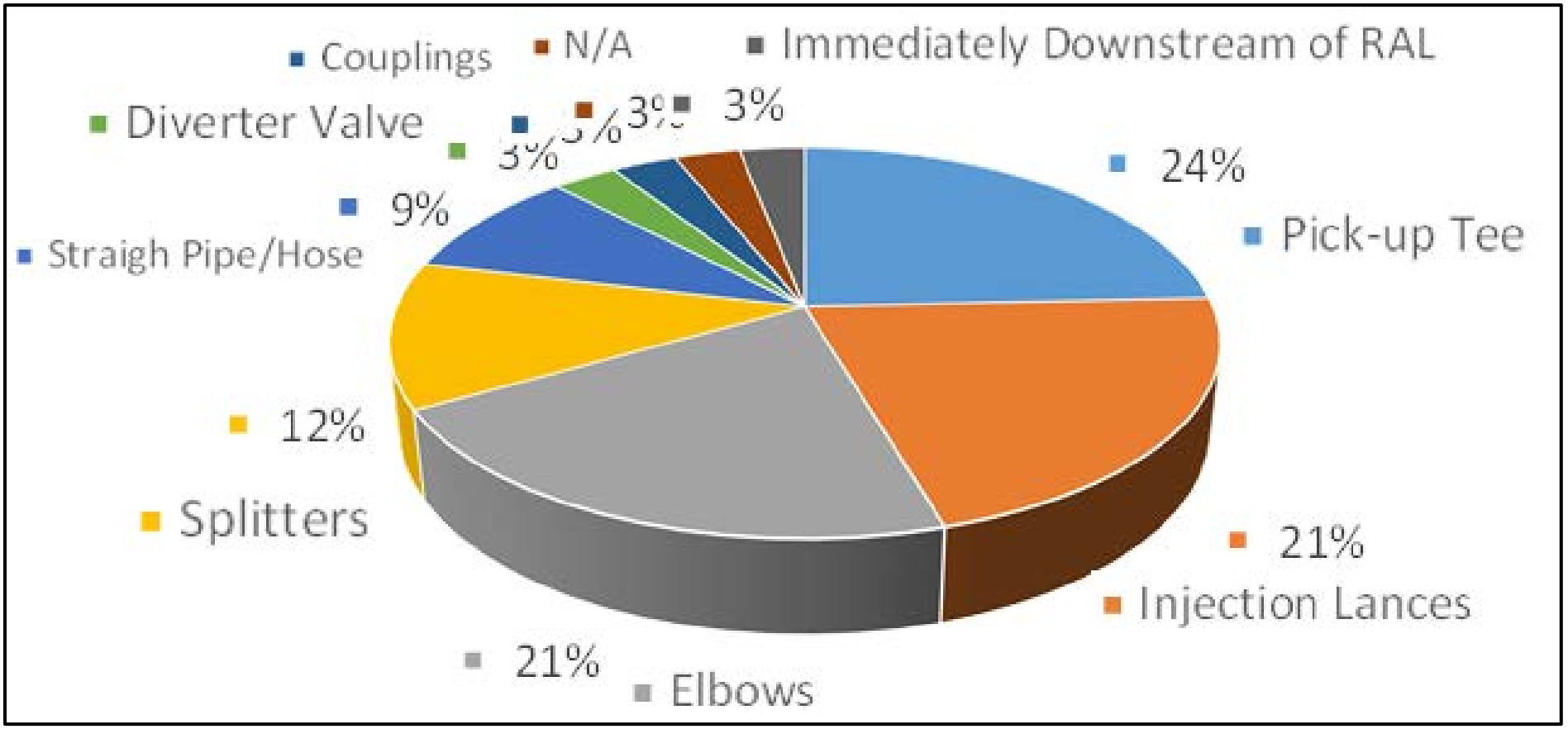
Pneumatic Conveying of Hydrated Lime is a Chemical Process

- Single speed blowers necessitate excess conveying velocity
  - Typical conveying design velocity of 3,300 ft/min +/-10%

- Variable frequency drives (VFD) provide flexibility as ambient conditions change
  - Volumetric air flow (ACFM) will vary as temperature varies
  - Think ideal gas law (PV = nRT)

#4 – Scaling Locations

Where is carbonate scaling forming?



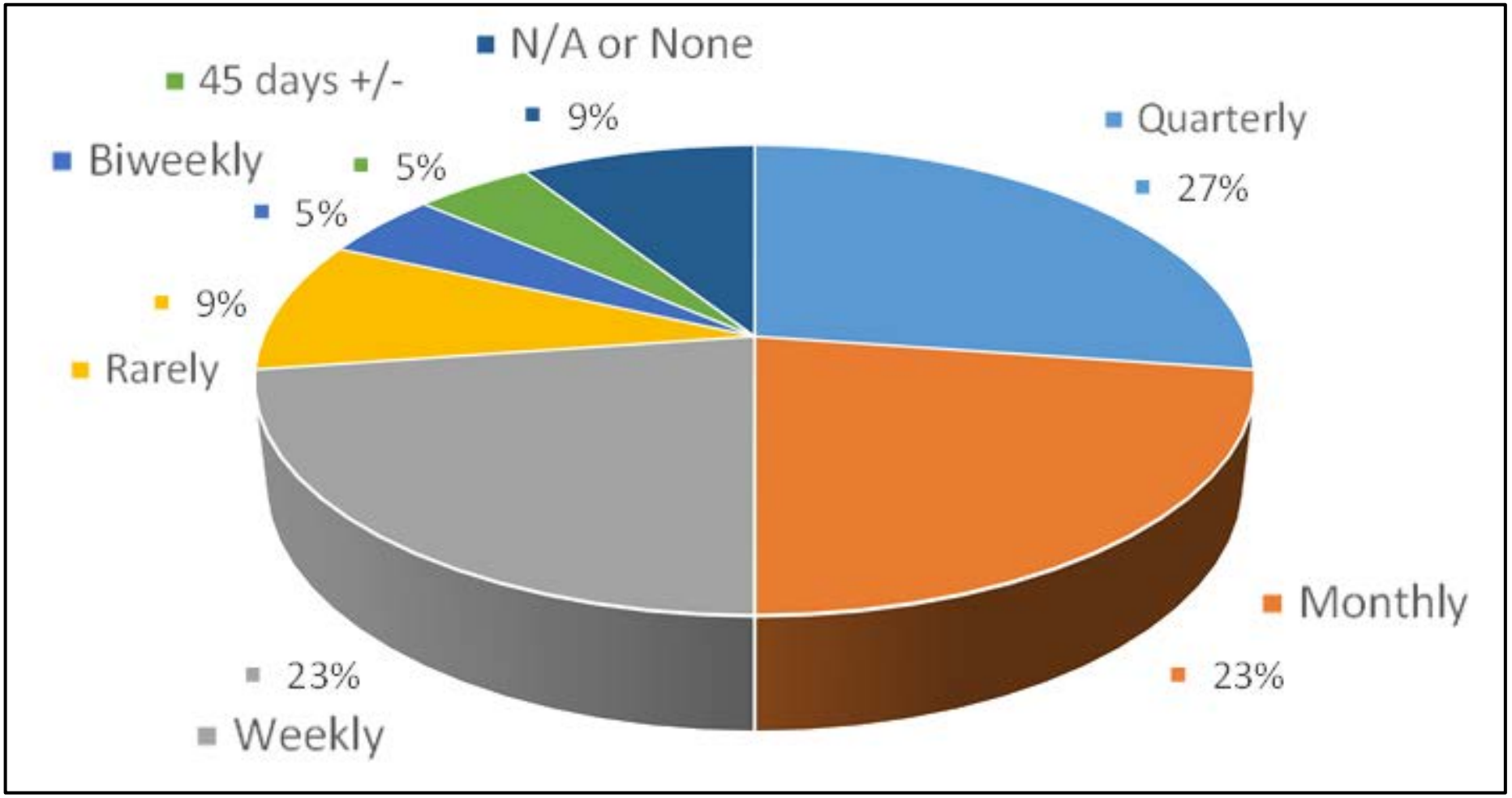
#4 – Scaling Locations

Take-aways from survey

- Nearly equal issues with pick-up tee, elbows and injection lances
- Diversity in results that indicates consistent carbonate scaling issues throughout the conveying system from ‘tip-to-tail’
- Common to see DSI systems retrofit with hose elbows even some new systems incorporate in design with reliability improvements
- Any experiences from audience regarding injection lances, pick-up tee, splitter that improved reliability?

#5 – Carbonate Frequency

How often does carbonate scaling occur requiring maintenance?



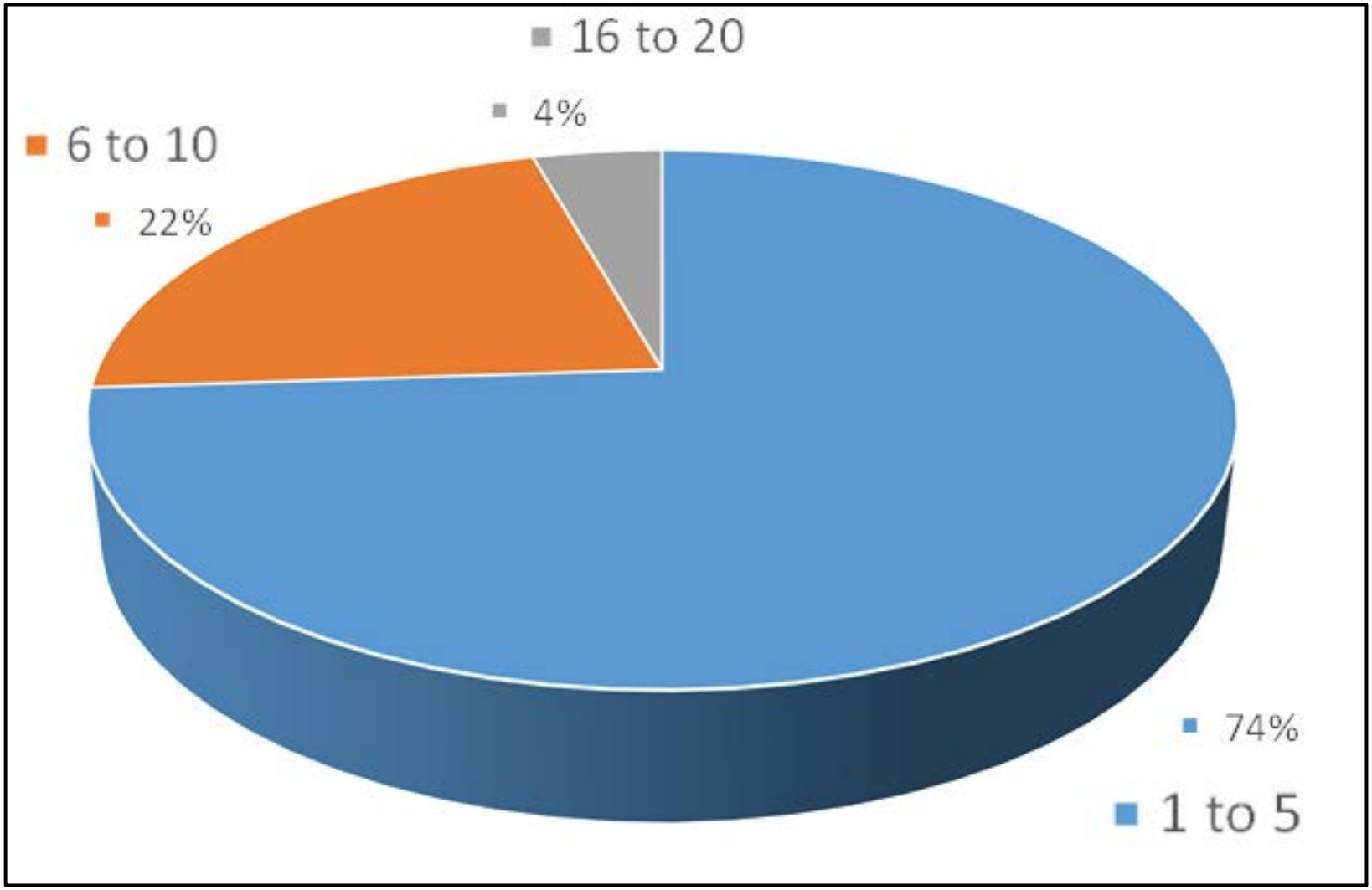
#5 – Carbonate Frequency

Take-aways from survey

- About ½ DSI end users have carbonate scaling issues at least once per month that require operator attention
  - Extrapolate this trend to the industry then could expect that ~150 sites having issues with this kind of frequency!
- Less than 10% have no issues (or responded with “N/A”)
- Why hasn’t this issue been solved (or at least improved)?
  - Lack of initial project capital funds?
  - Lack of knowledge on issue?
  - Inability to get capital funds once operations experiences issue?

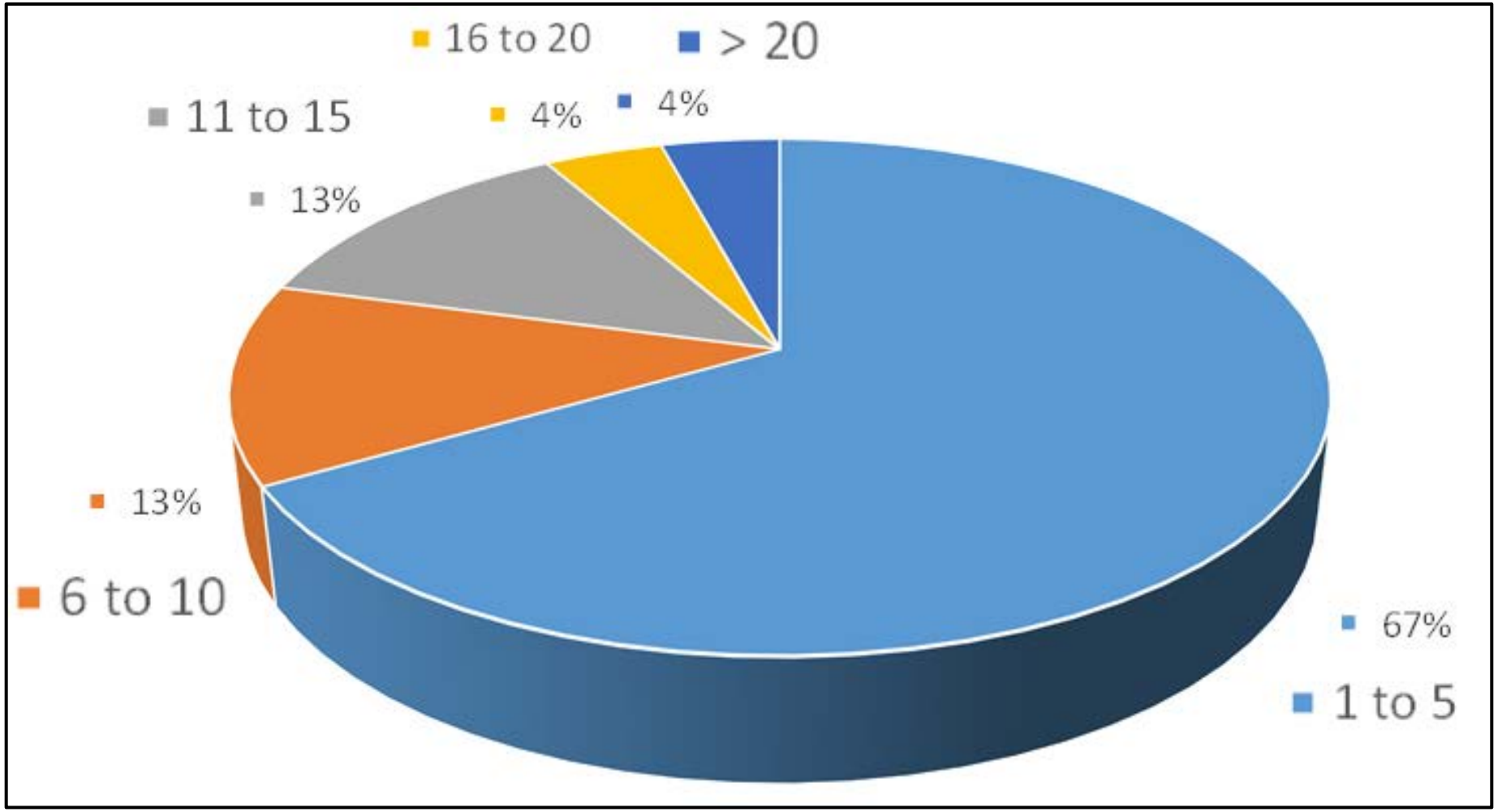
#6 – DSI Preventative Maintenance

How many man-hours per week?



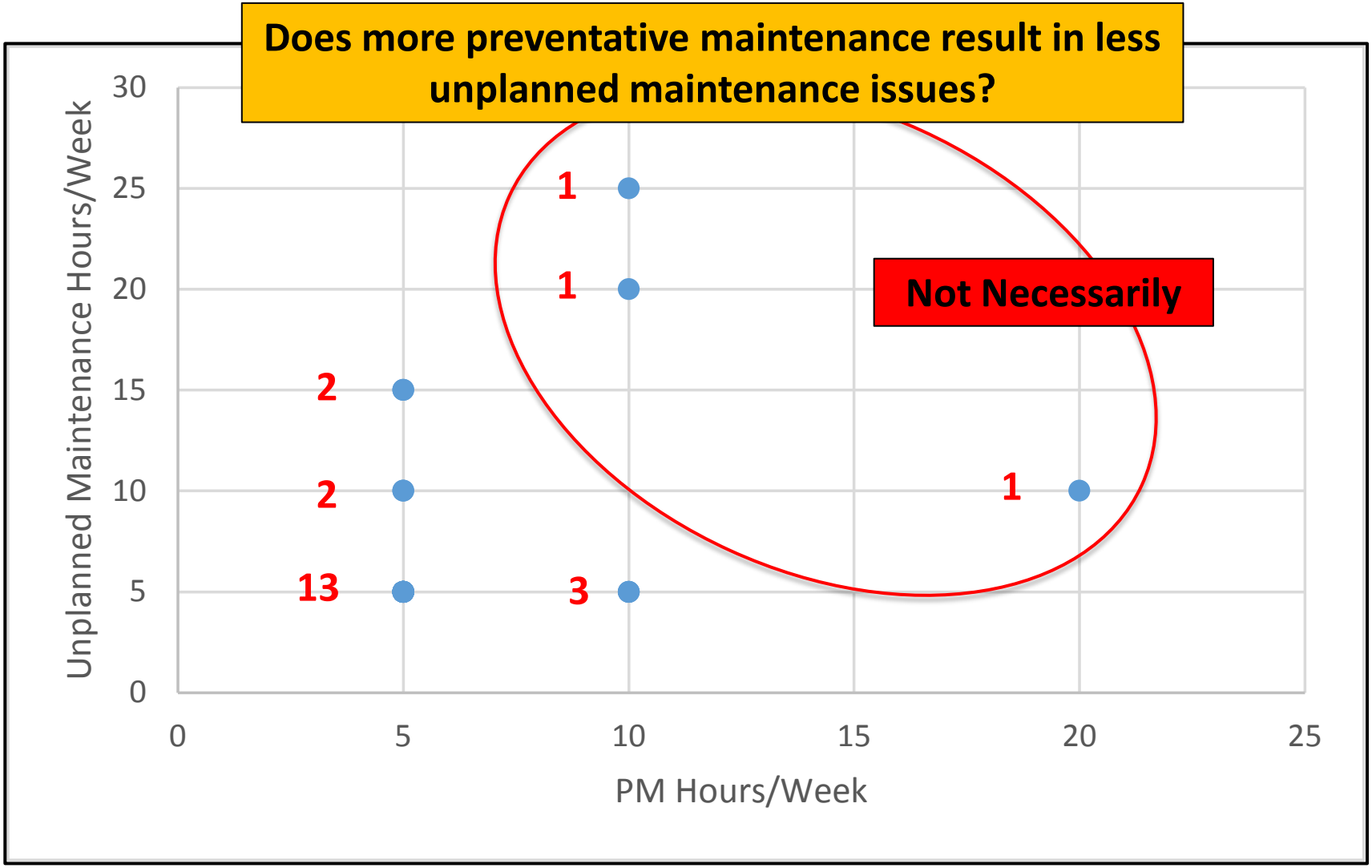
#7 – DSI Unplanned Maintenance

How many man-hours per week?



#6 & #7 – DSI Maintenance

Take-aways from survey



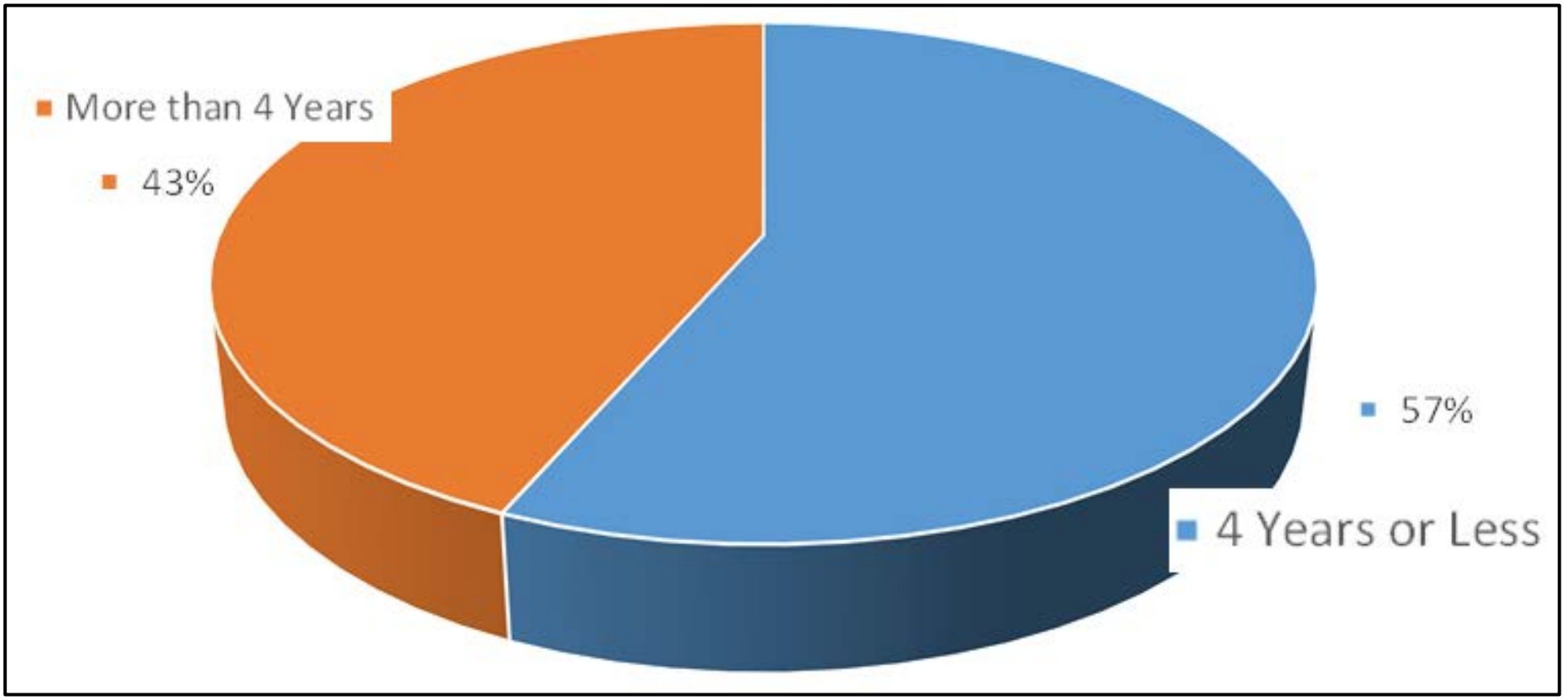
#6 & #7 – DSI Maintenance

Take-aways from survey

- No DSI system is “maintenance free”
- Best case is that a site spends 2-10 man-hours/week on both preventative maintenance and unplanned maintenance
  - Potentially up to 25% of a full-time employee equivalent week spend on DSI systems
- Worst case is that over 10% of sites spending > 30 man-hours/week on both preventative maintenance and unplanned maintenance
  - Extrapolate from 300 DSI systems operating
  - 30+ sites spending nearly a single full-time employee equivalent on DSI system maintenance activities
- Challenges
  - Many site resources more constrained (time is more valuable)
  - Primary focus is on production, air pollution control systems typically secondary
  - Feedback is sites see increasing personnel turnover

#8 – DSI End User Experience

How much DSI operating experience does typical end user have?



#8 – DSI End User Experience

Take-aways from survey

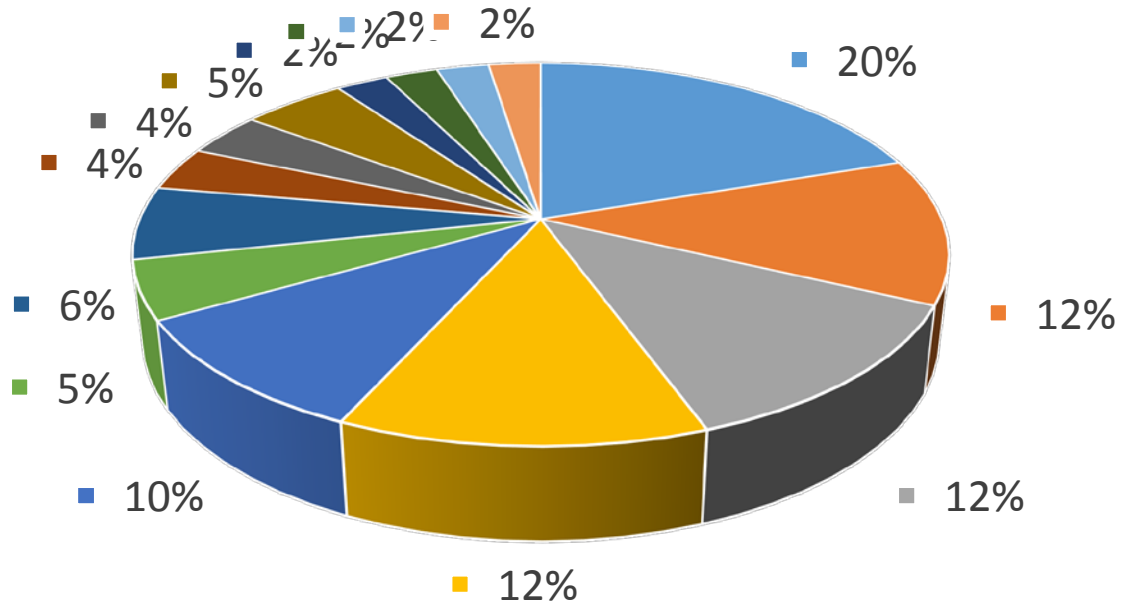
- > 50% of DSI end users have less than 4 years of experience

- ~10% of those surveyed responded with < 1 year of experience
  - Do we really believe that nearly 30 sites with DSI systems have someone with < 1 year of experience in charge of DSI system?
  - How does this impact system on-going reliability?
  - How does this impact end user optimization success?

- How to address these challenges?
  - Site specific transfer of knowledge/experience, training, etc.
  - Industry associations, conferences, etc.
  - “Looking for partners, not vendors”

#9 – DSI Spare Parts Inventory

What are end users keeping on-site?



- Hoses
- RAL Wear Components
- Complete RAL
- Blower VFD, Filter, Belts
- Injection Lances
- Circuit Boards
- Dehumidifier Parts
- Not Sure / None
- Silo Fluidizers
- Bin Vent Filters/Bags
- Splitters
- Level Switch, Transmitters
- Valves, Actuators
- Screw Feeder, Flexible Trough

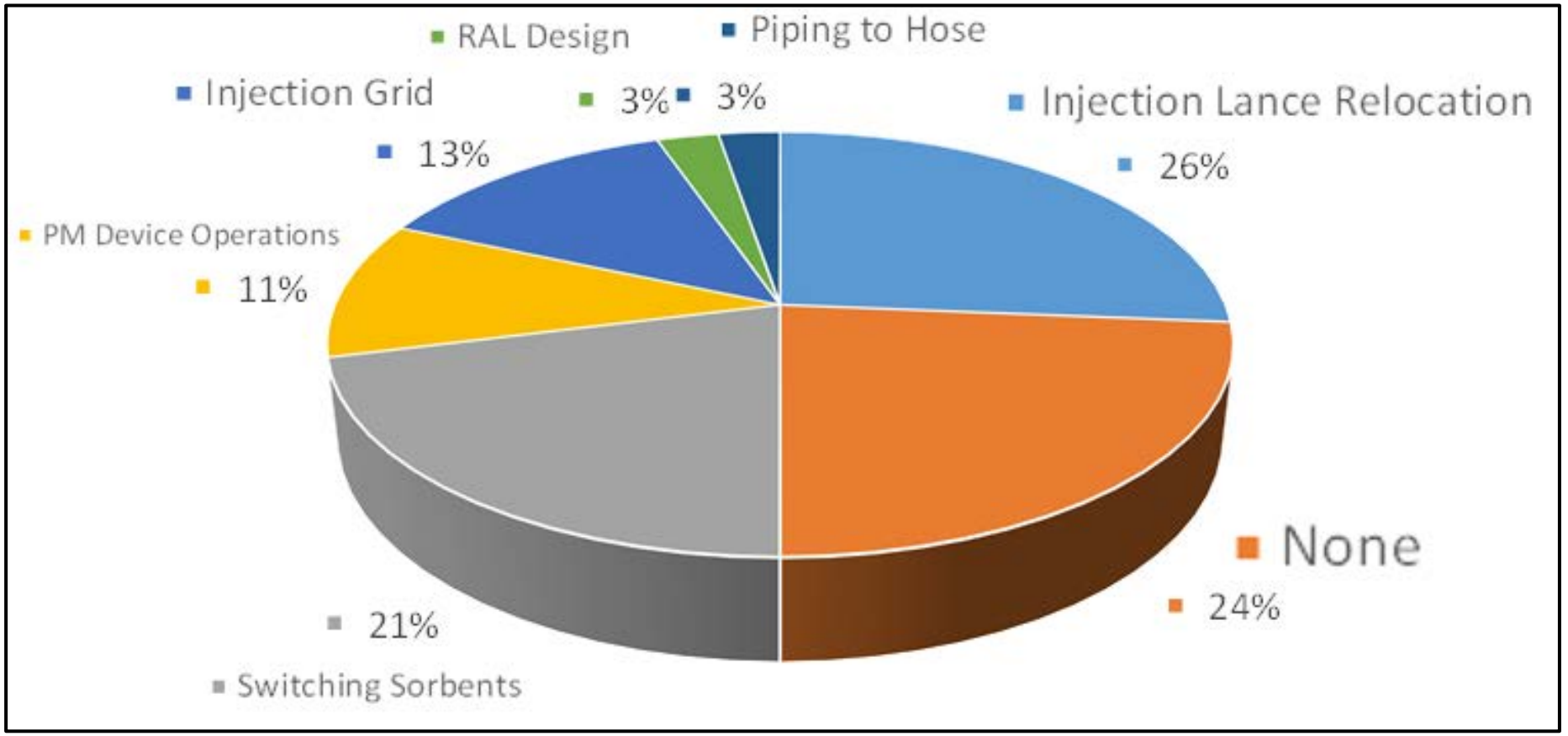
#9 – DSI Spare Parts Inventory

Take-aways from survey

- 20% of DSI end users keep spare hose on-site
- ~25% of DSI end users keeping spare RAL and/or spare RAL wear parts on-site
- ~10% each hoses and blower components
- Every other item is ≤ 5%
  - How to know what is ‘right’ components to keep as spare parts?
  - How have lead times been impacted since COVID?
- One response – “Almost no spare parts”

#10 – DSI Optimization

What aspects of DSI solution have end users tried to improve?



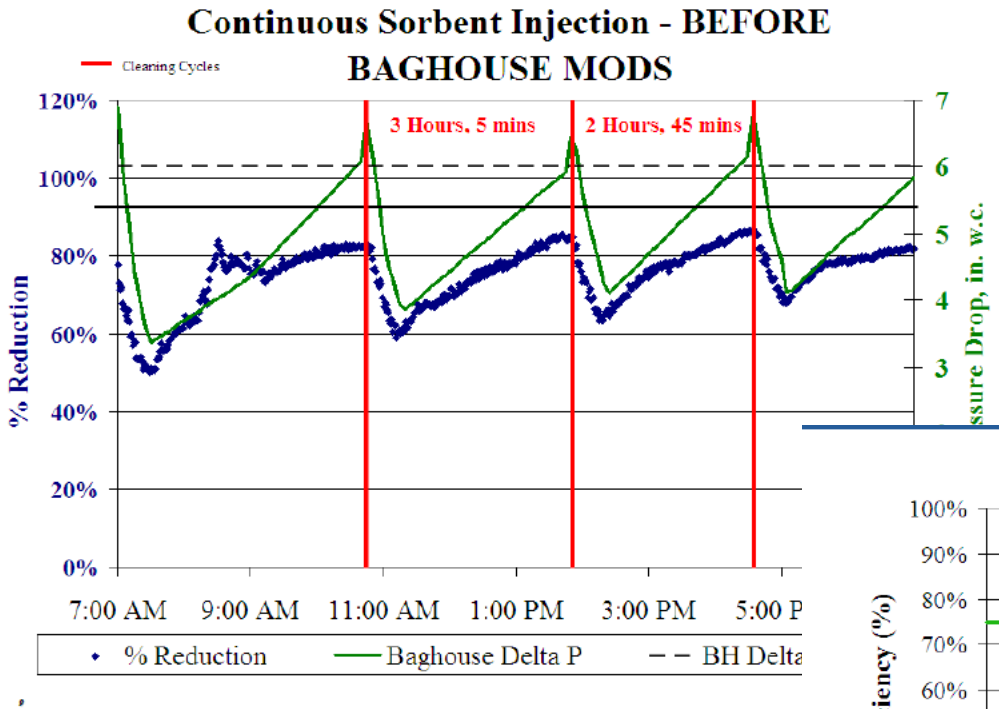
#10 – DSI Optimization

Take-aways from survey

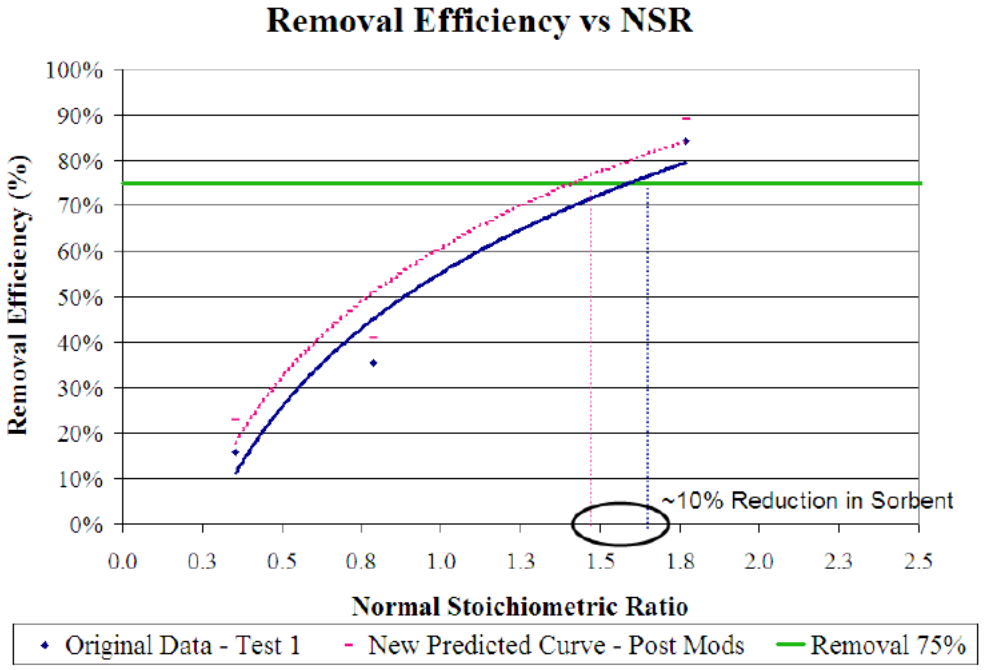
- **25% have not even tried any kind of optimization**
  - Extrapolates to 75+ DSI end users have not attempted any optimization
- 20% of those surveyed have optimized with sorbents
  - Relatively easy as little/no capital required for this optimization
  - Total cost of ownership (TCO) focus
- ~25% of spare parts were based around RAL yet only 3% of those surveyed have explored optimizing the RAL design
  - Different RAL designs, materials of construction, etc.
  - Why is this not explored further by DSI end users?
- ~¼ of DSI end users optimized injection location
  - What is driving this as most popular optimization?
- Only 10% have tried to optimize PM device operations
  - PM device is existing asset
  - Why is this not evaluated more?

#10 – DSI Optimization

Case study optimization baghouse operation



Site ↓ Usage by 10% Solely from Changing Baghouse Operation

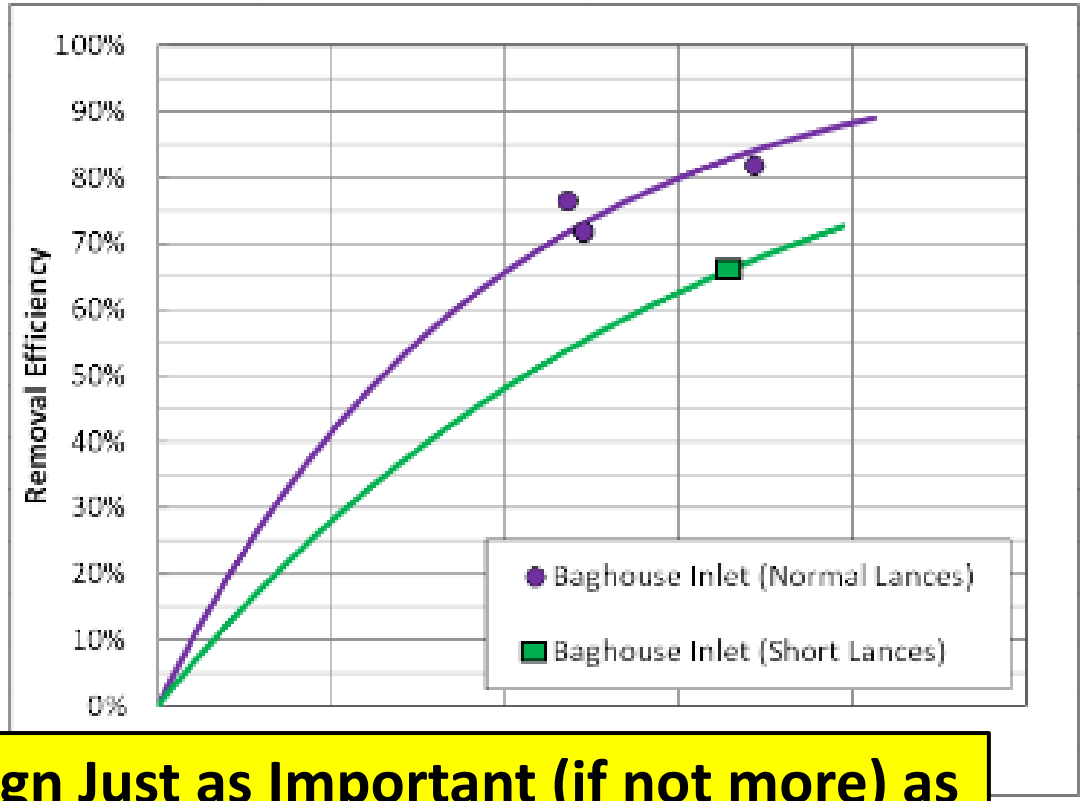


"Implementation of Baghouse Cleaning Changes to Improve Sorbent Injection System." 2014 MEGA Symposium; J. Rooney, A. Carstens, J. Daghlian, B. Simko.

#10 – DSI Optimization

Case study optimizing injection grid

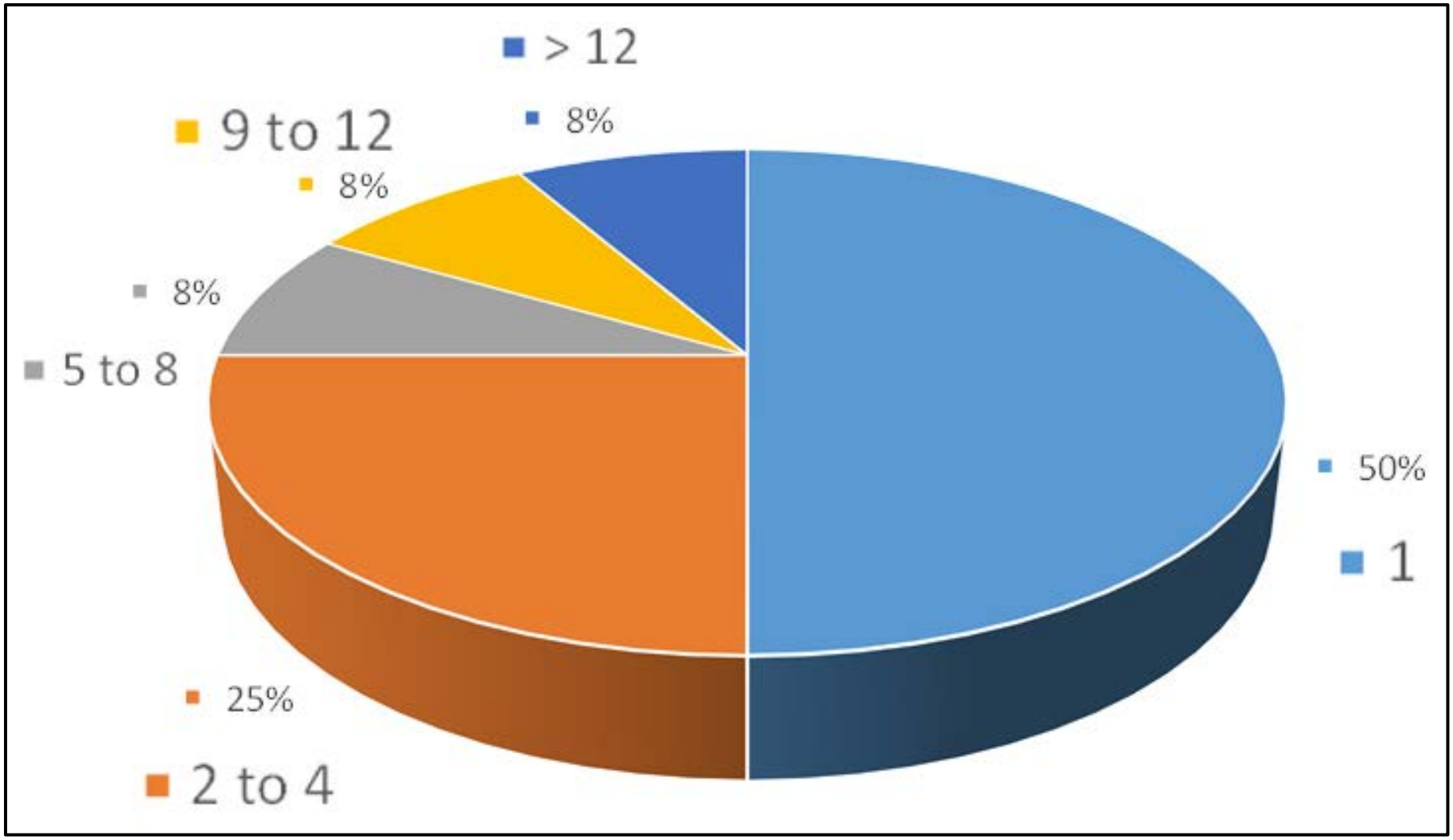
- Industrial end user with baghouse filter and relatively small duct with four (4) DSI lances
- End user was on the cusp of non-compliance
- Worked with end user to adjust injection lance depths to illustrate how critical dispersion is to DSI performance
- Not only helped achieve compliance but optimizing injection grid reduced operating cost



DSI Injection Grid Design Just as Important (if not more) as Sorbent Injected

#11 – Injection Lance Quantity

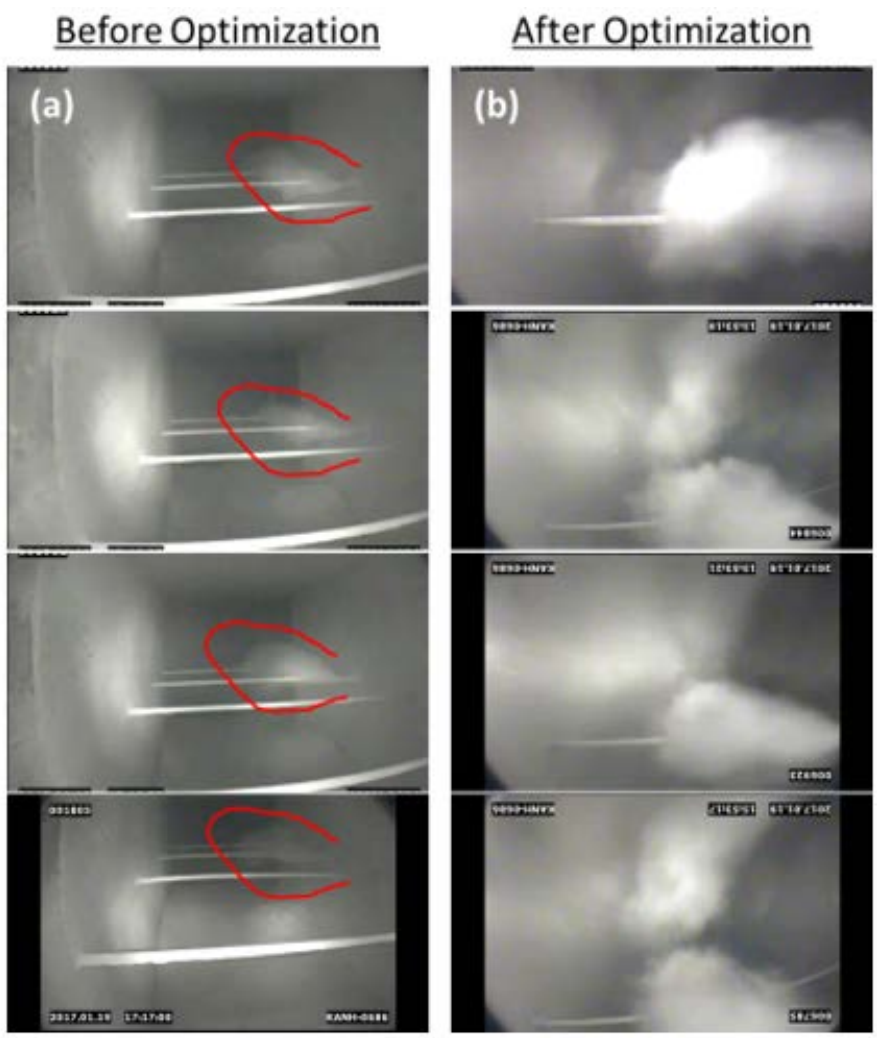
How many lances does typical DSI end user have installed?



#11 – Injection Lance Quantity

Take-aways from survey

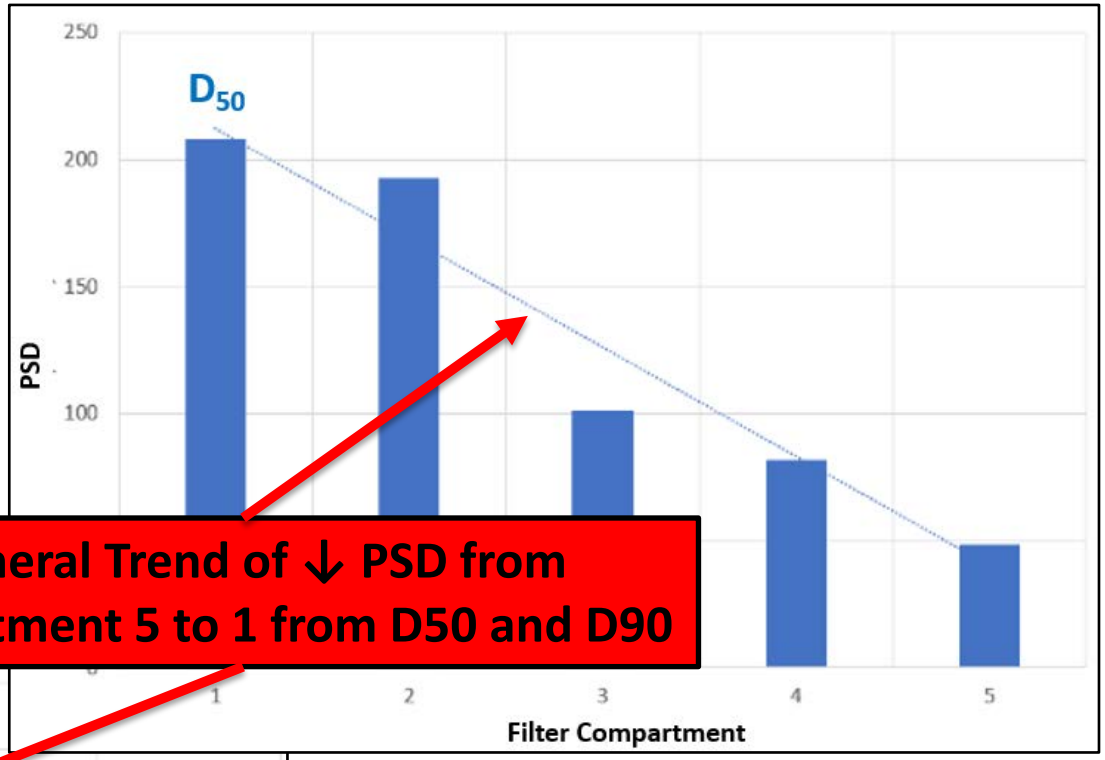
- 50% of DSI end users only have single injection lance
  - Why is this so high?
- Only 25% of DSI end users have more than 4 injection lances
  - Likely represents the EGU sector
  - But does EGU sector still have room to improve?
  - Why do end users over-estimate sorbent capability to disperse within duct?
  - What tools can help further optimize? CFD Modeling? Duct Camera? Residue Analysis?



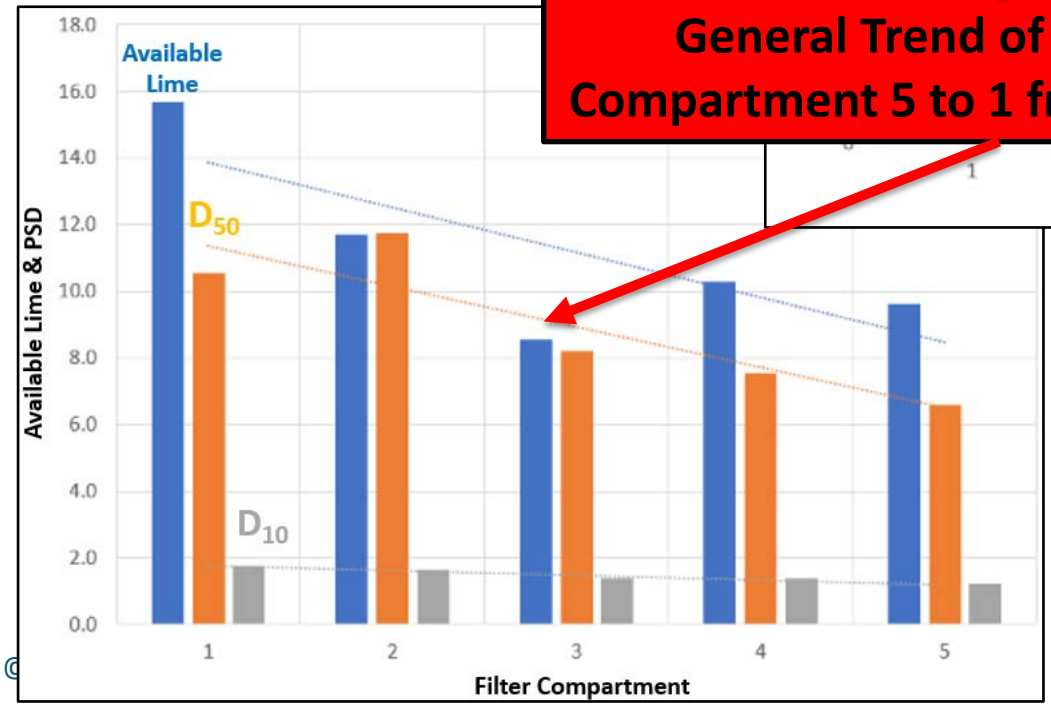
#11 – Injection Lance Quantity

Sorbent Dispersion and PSD

- DSI user seeking to optimize operations
- Residue analyzed and found interesting trends comparing filter compartments



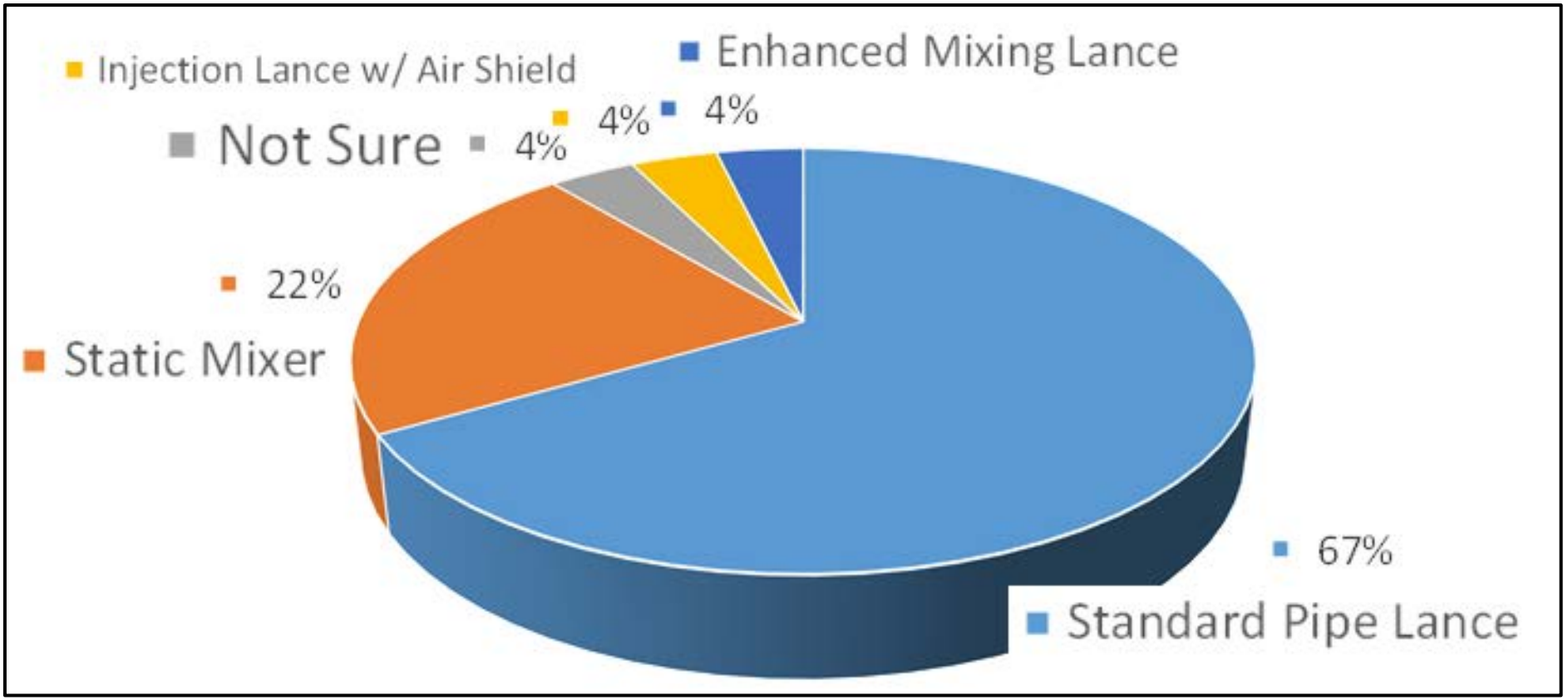
General Trend of ↓ PSD from Compartment 5 to 1 from D50 and D90



- Clear trend in PSD from nearest to furthest compartment
- Sorbent dispersion optimization potential

#12 – Injection Grid Design

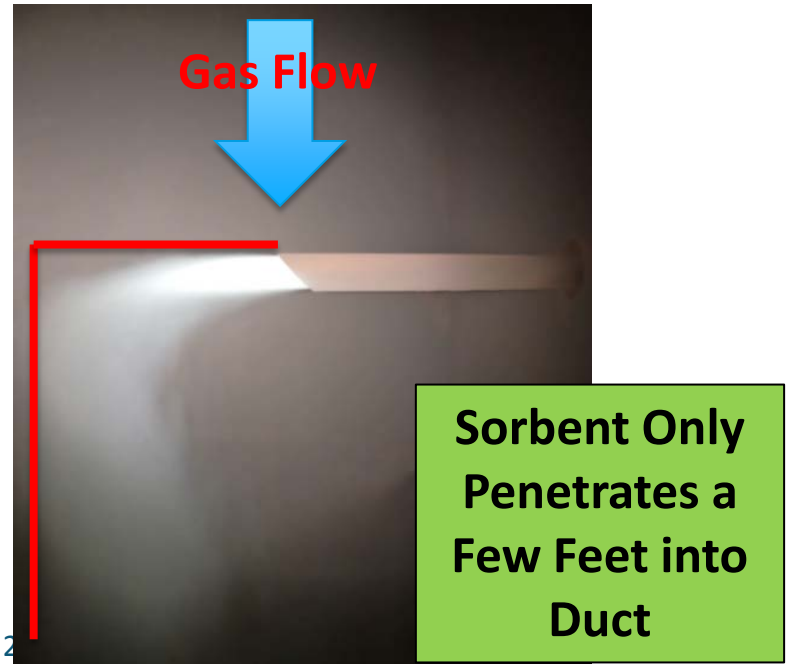
What kind of injection grid does DSI end user have?



#12 – Injection Grid Design

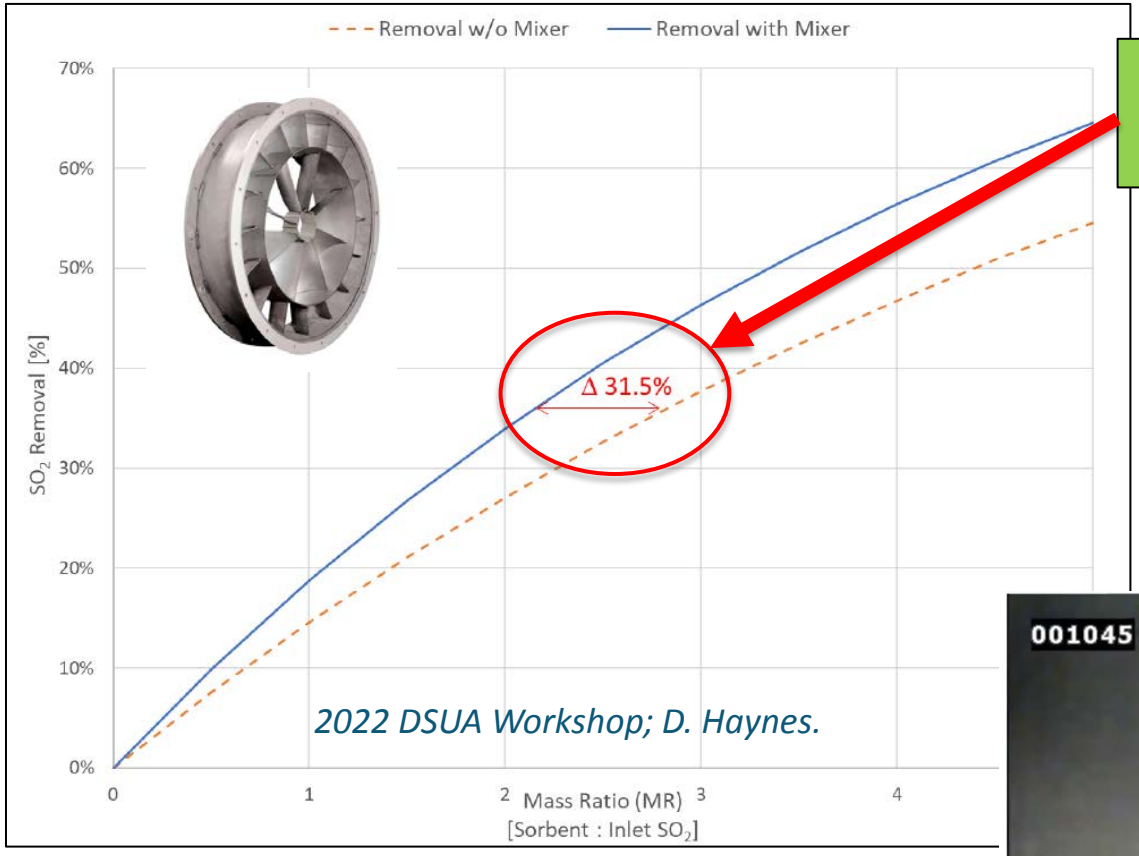
Take-aways from survey

- 67% of DSI end users still using standard injection lance design
  - ✓ Potential for further optimization in DSI performance and operating cost
- Only ¼ of DSI end users using some version of enhanced dispersion solution
- Use of tool such as duct camera may help DSI end users see challenges in achieving 'good' dispersion



#12 – Injection Grid Design

Case studies with static mixers



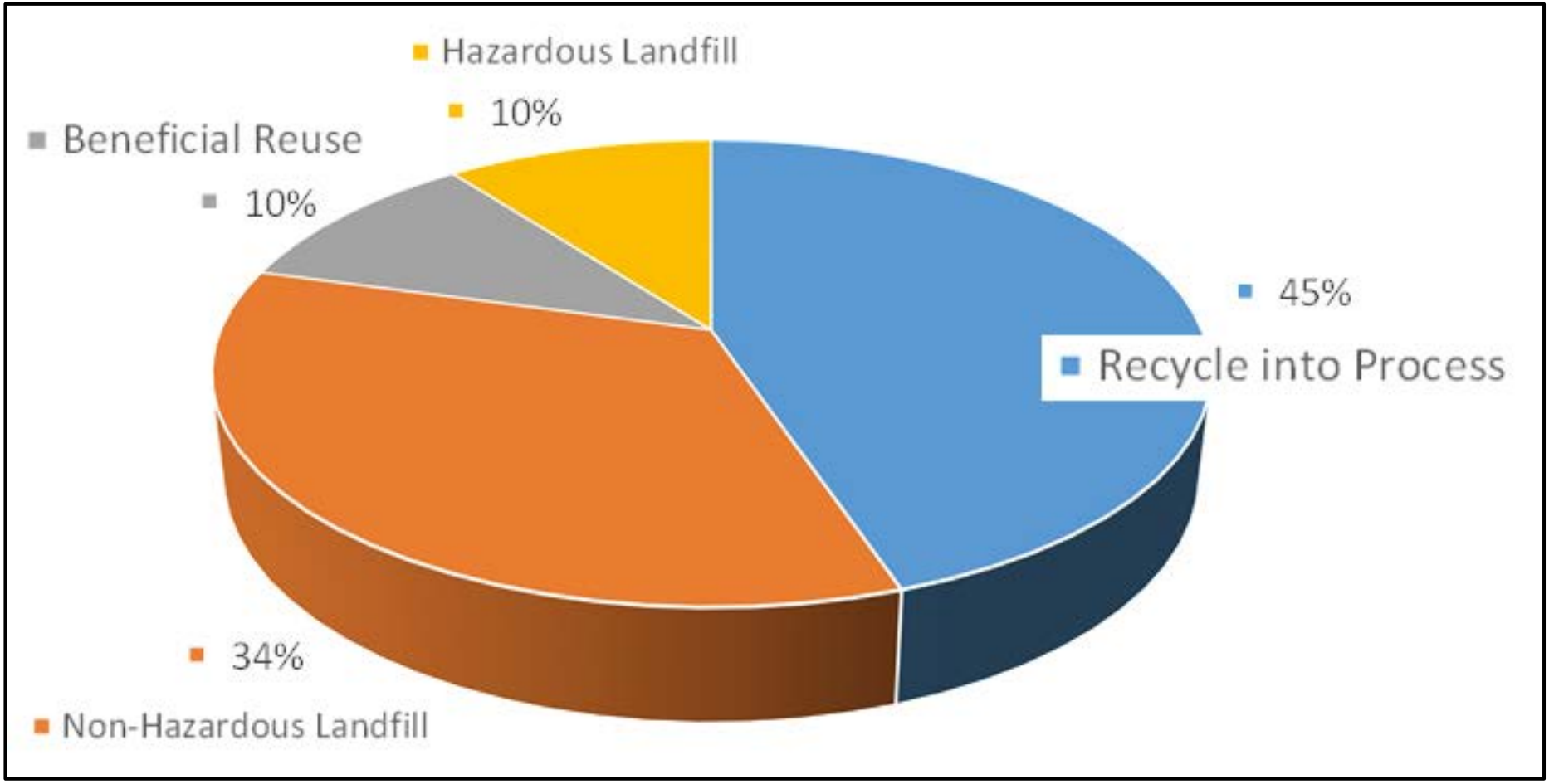
Sorbent ↓ from Static Mixer

DSI into Delta Wing (Sorbent Dispersed into Cloud, Not a Stream)

[DSUA Webinar - 2021 Ep 7 | August - American Electric Power & Lechler (youtube.com)]

#13 – Byproduct Fate

What do DSI end users do with byproduct generated?

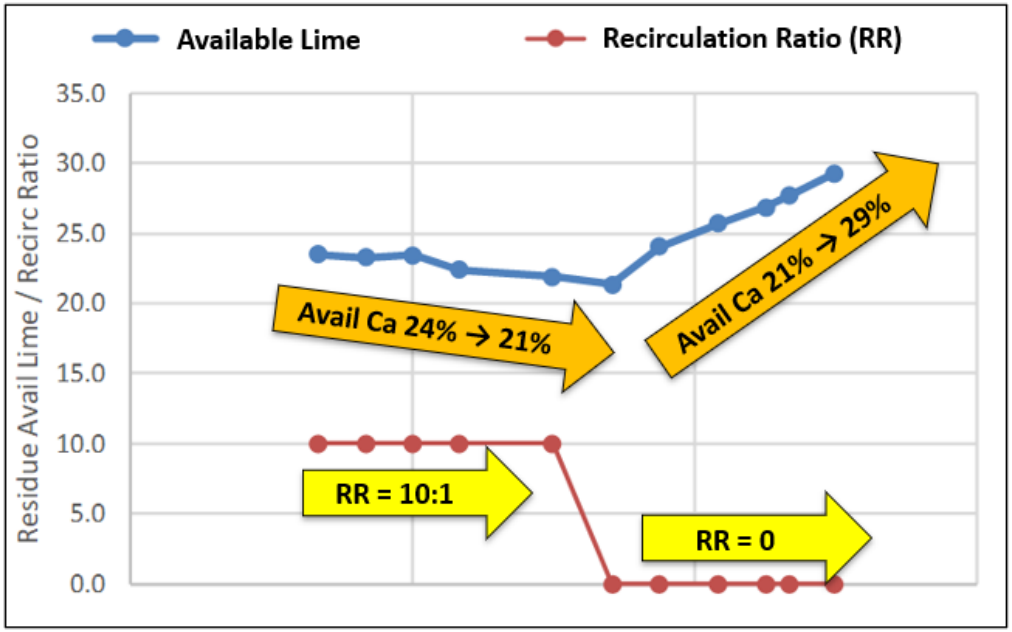


#13 – Byproduct Fate

Take-aways from survey

- Nearly ½ of DSI end users able to recycle back into their process
  - Are EGUs successful recycling back into process or just industrials?
- Only 10% of DSI end users found a beneficial use for their byproduct
  - Represents further opportunity to optimize TCO
- Value in routinely collecting byproduct samples and analyzing chemistry
  - Data to explore beneficial reuse opportunities
  - Objective DSI performance data

Test Program Showed Inverse Relationship Between Residue Recirculation Ratio and Residue Available Lime

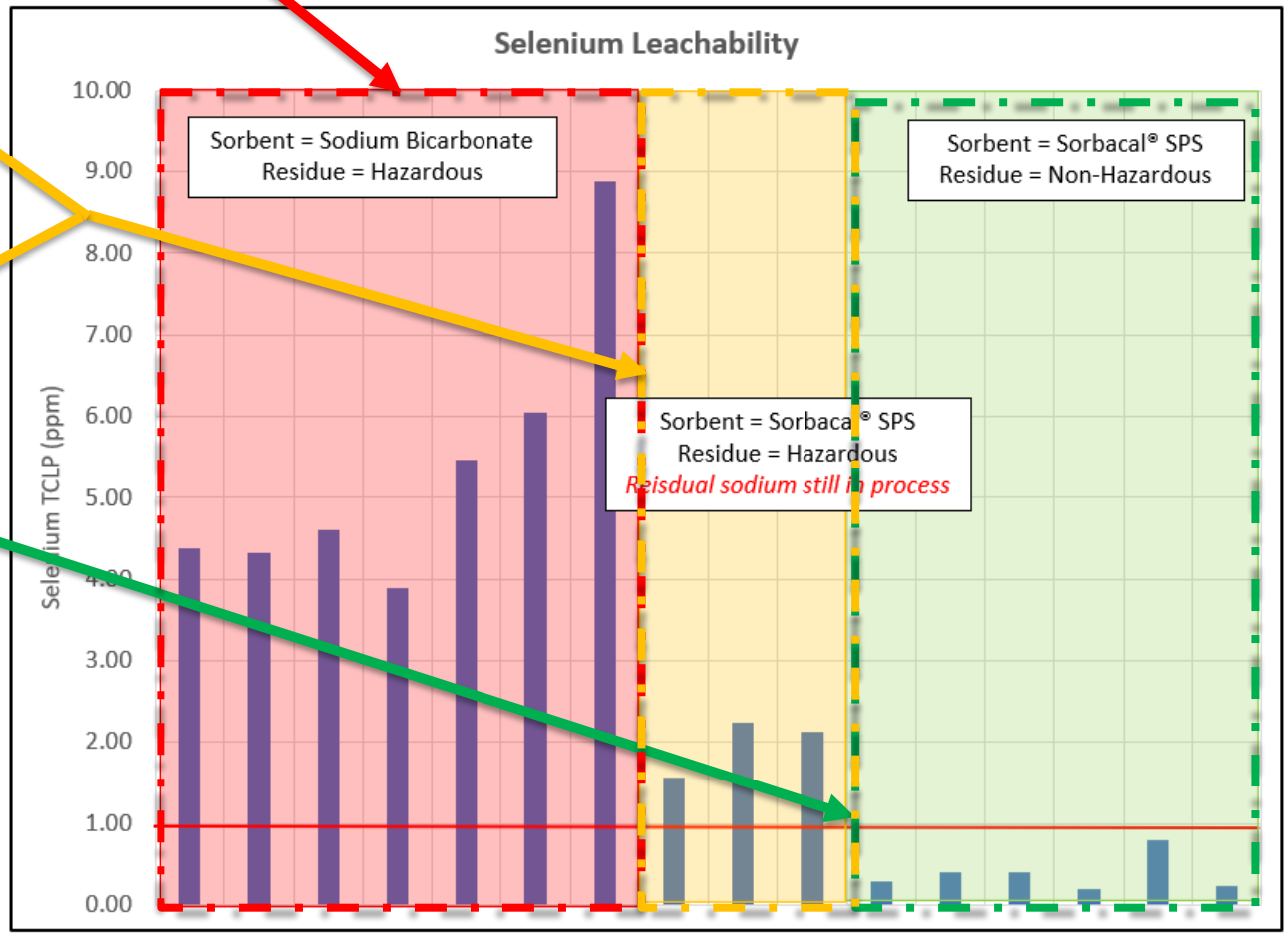


#13 – Byproduct Fate

Hazardous vs. Non-Hazardous

- DSI user making hazardous residue when injecting sodium bicarbonate due to selenium leaching via TCLP

- Switched to Sorbacal® SPS
- Sustained injection to achieve steady state
- Once steady state achieved selenium leaching was below RCRA limit
- User re-classified residue as non-hazardous



Thank you for your time!

Lhoist North America

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"I would like to thank Lhoist for the technical support that has helped us to significantly improve our process and reduced our malfunctions leading to violations of our air permit"

"Support throughout this process was nothing short of life saving. I am sincerely grateful for advice that helped to achieve the steady state of operation that we have today."

"Have been accessible for any questions or concerns that have arisen with our scrubber and have become one of my first calls when it comes to flue gas physiochemical dynamics and acid gas treatment"

"I have never had a materials vendor relationship remotely as fruitful as this and the appreciation and customer loyalty it has created here is equally unprecedented."

"When we first began working with Lhoist, we were struggling to run for one whole day between system cleanings. Currently, we are achieving one month of continuous run time between maintenance cleanings."

"I am certain we would not be operating the way we are today without Lhoist's technical expertise and endless support with troubleshooting, design consideration and operational guidance."

Improve equipment reliability, reduce O&M hours, reduce violations, reduce operating costs…