CLEANROOM ENERGY REDUCTION:

POSSIBILITIES FOR NOW & IN THE NEAR FUTURE

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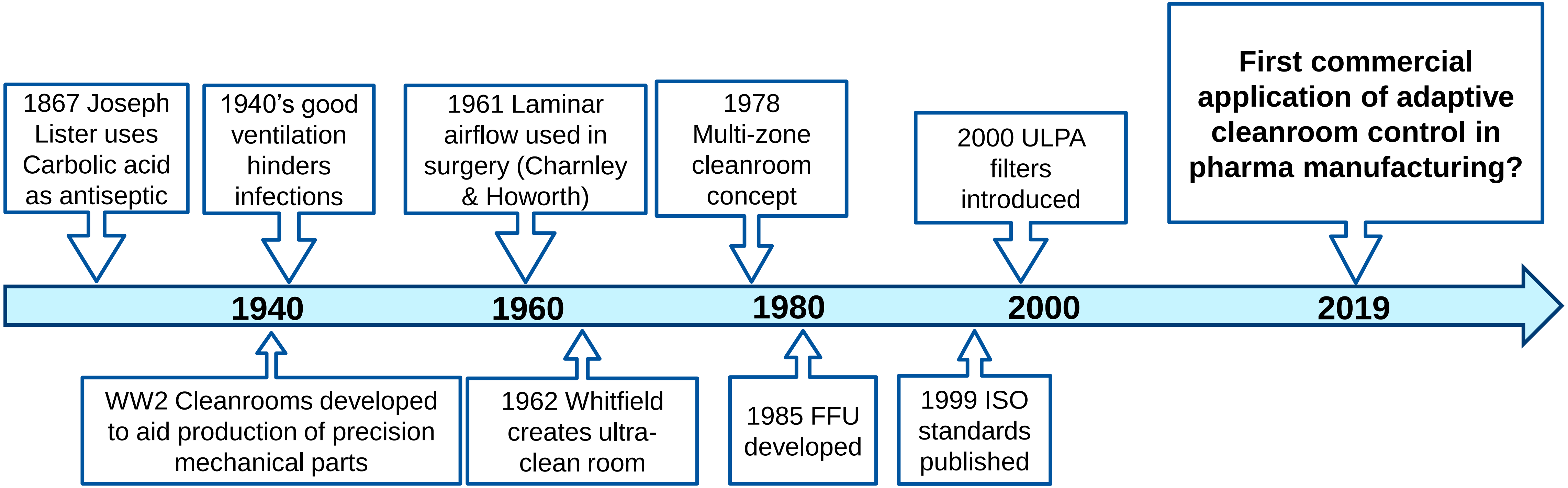
ISPE Boston Area Chapter Product Show

18th September 2019

AGENDA

1. Introduction
2. Cleanroom development history vs What we know today
3. 3 great energy reduction strategies – guaranteed to work in cleanrooms
4. Future opportunities
5. Summary

A BRIEF HISTORY

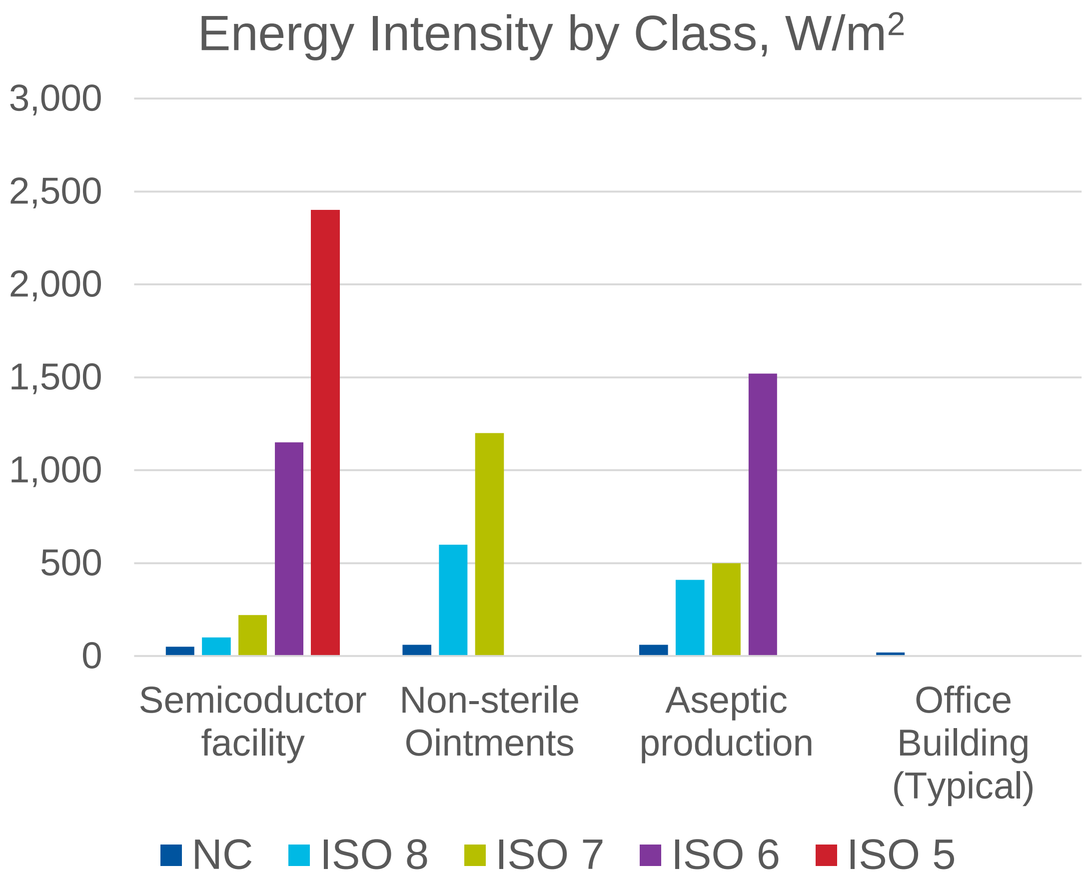


The standard industry model for cleanroom design & operation has not changed for around **50 years**.

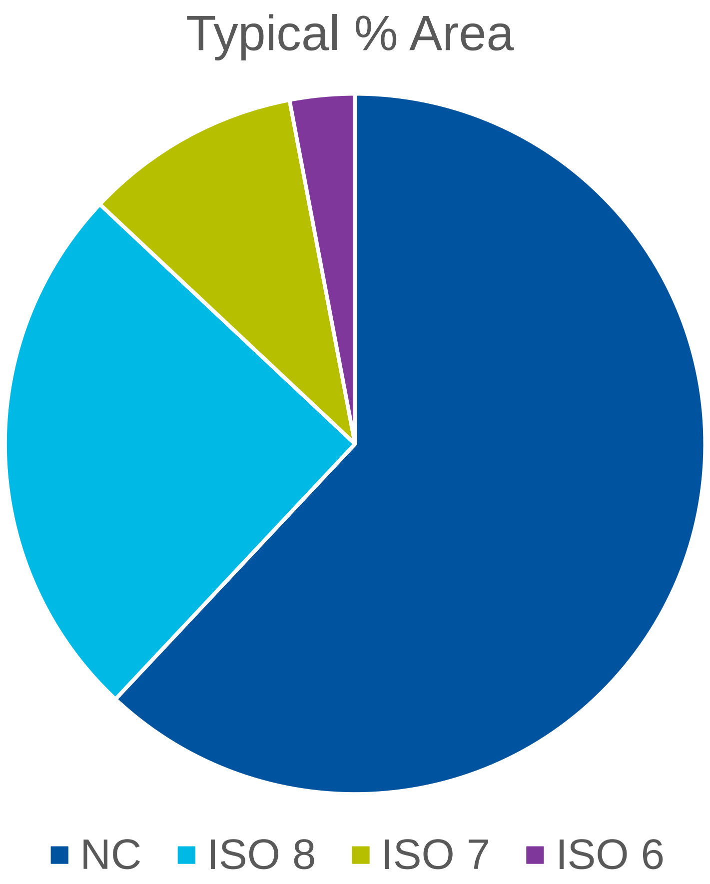
WHAT WE KNOW ABOUT CLEANROOMS TODAY

- **Critical for product protection**
- **Performance (cleanliness) is dependent on many factors influencing:**
  - **Contamination infiltration –** ***from less clean areas***
  - **Contamination generation –** ***people, process & equipment***
  - **Contamination removal effectiveness –** ***design, filtration***
- **Air Change Rates are not a reliable indicator of cleanroom performance.**
- **HVAC systems are designed, constructed, commissioned & validated for "worst case" scenarios.**
- **Very energy intensive spaces (up to 80% of energy consumption is HVAC) – no correlation to production output/volume**

ENERGY INTENSITY VS AREA

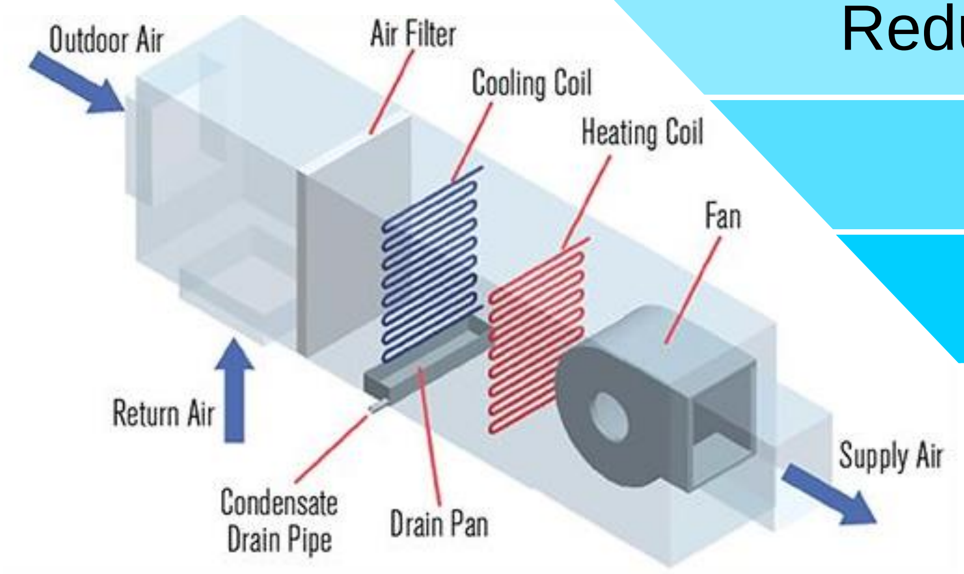


Data Source: Cleanroom Technology article "Saving energy in cleanrooms" by Alexander Fedotov (Invar-project), published 04 Aug 2014.



Data Source: eeco2 approximation

PHARMACEUTICAL HVAC ENERGY REDUCTION STRATEGIES:



- Reduce quantity of air
- Reduce amount of conditioning
- Condition efficiently
- Maintain efficiency
- Improve robustness & compliance

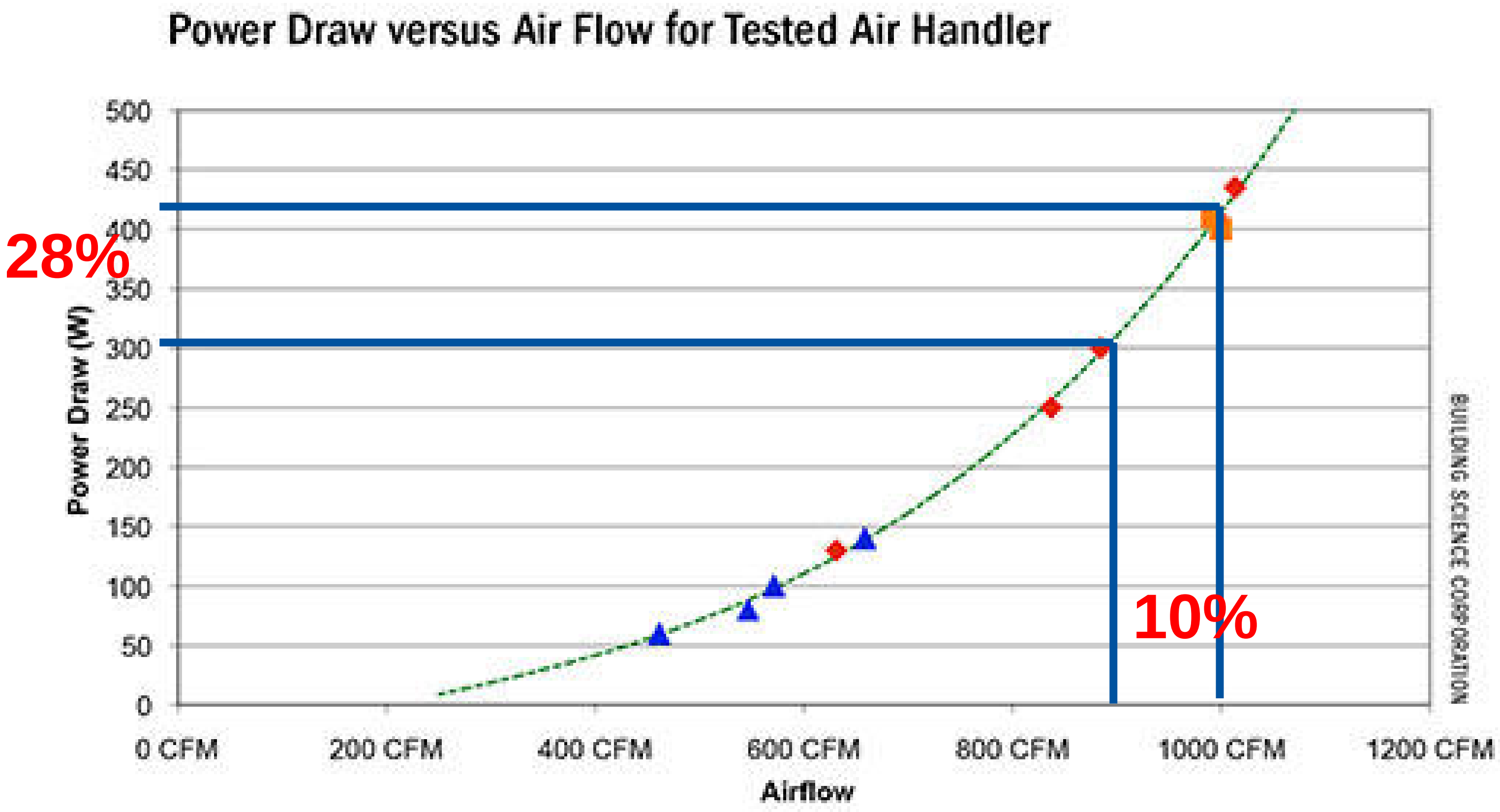
ENERGY REDUCTION: *TODAY*

WHAT YOU CAN DO TODAY IN YOUR FACILITIES:

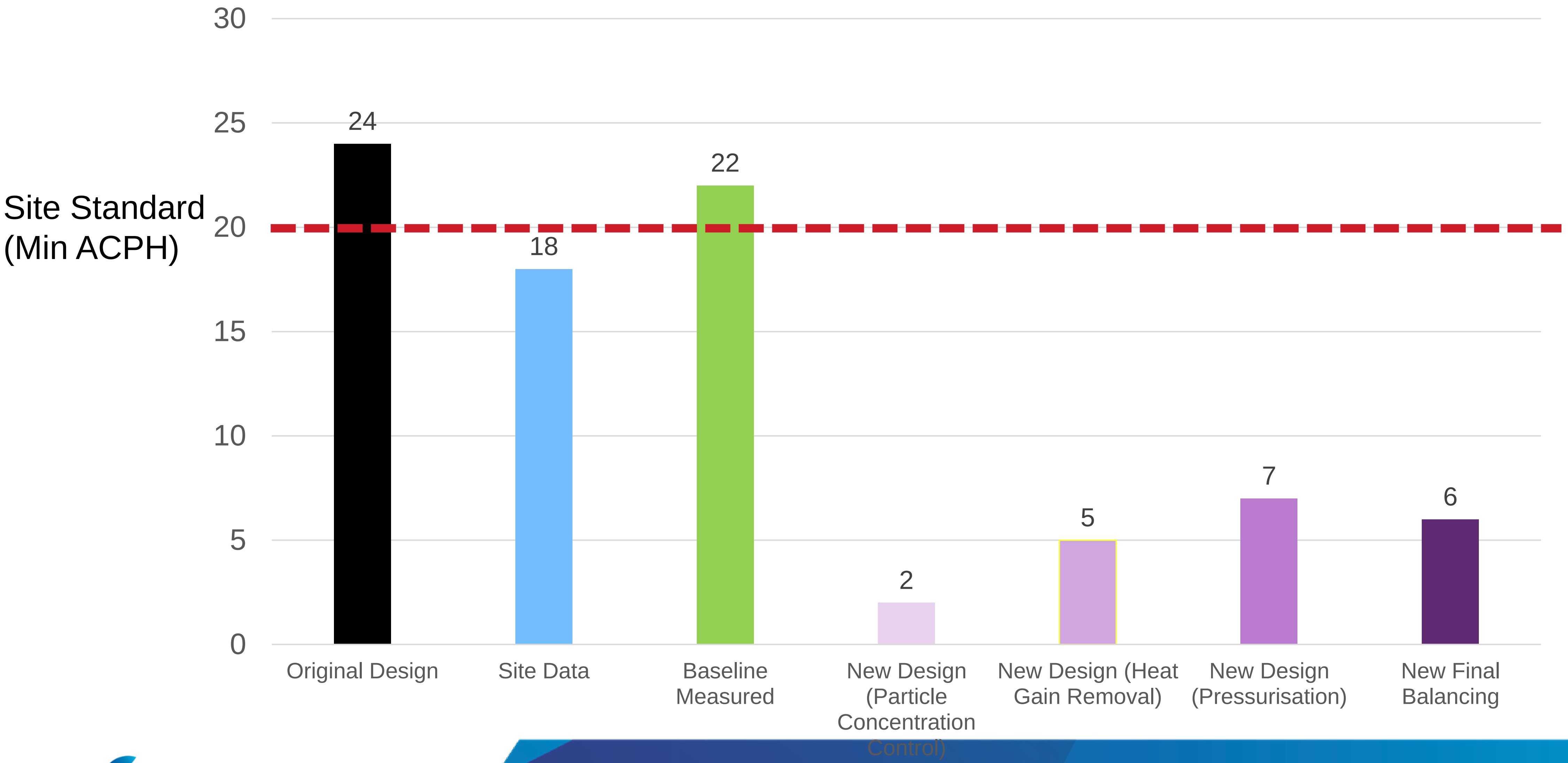
- AIR CHANGE RATE REDUCTION
- SETBACK
- CONTROLS OPTIMISATION

FAN AFFINITY LAWS: WHY AIRFLOW IS SIGNIFICANT FOR ENERGY REDUCTION

- From the fan affinity laws, fan power is related to airflow by a “cube” law.
- A small reduction of airflow (10% in this case), gives a 28% reduction in the fan power consumed.
- That’s why air change rate reduction is such an effective energy reduction strategy.



1. HOW MUCH AIR DO WE NEED?



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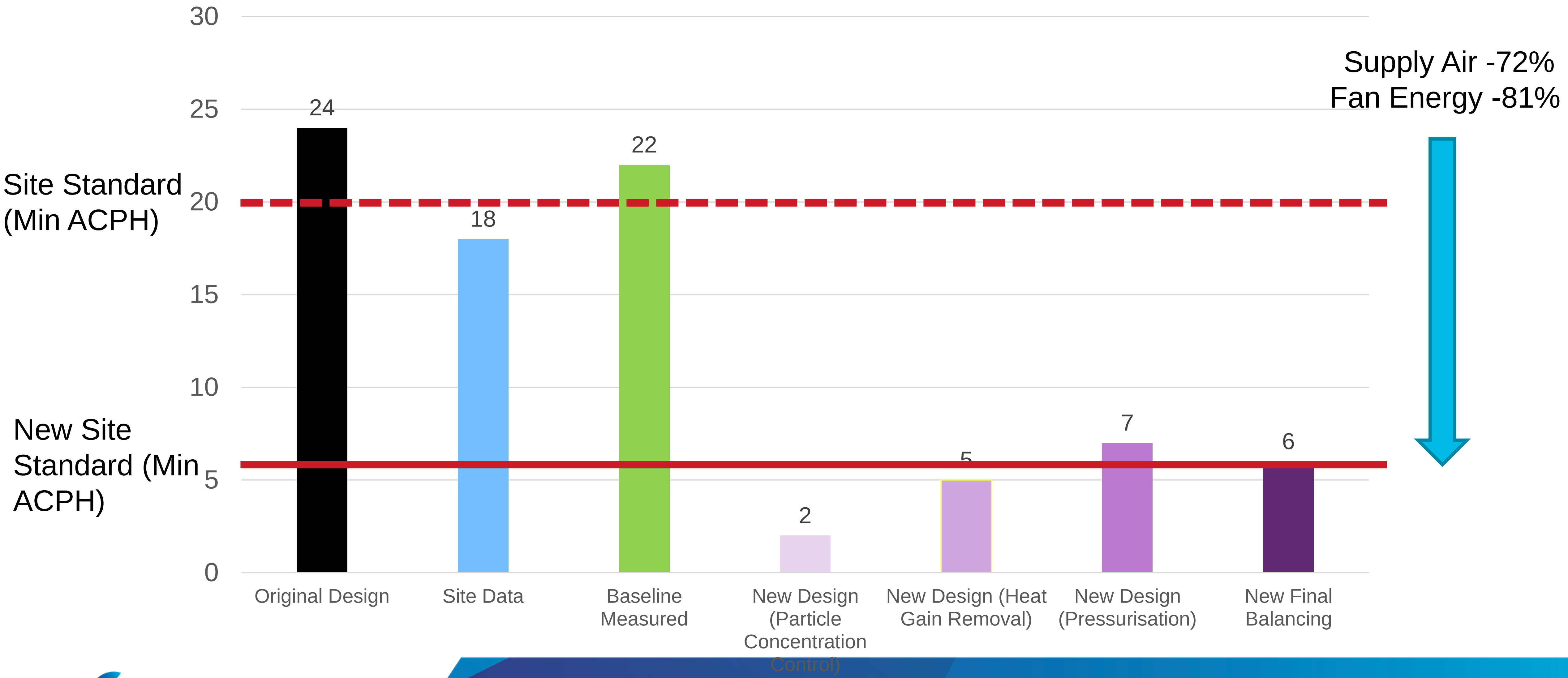


1. HOW MUCH AIR DO WE NEED?

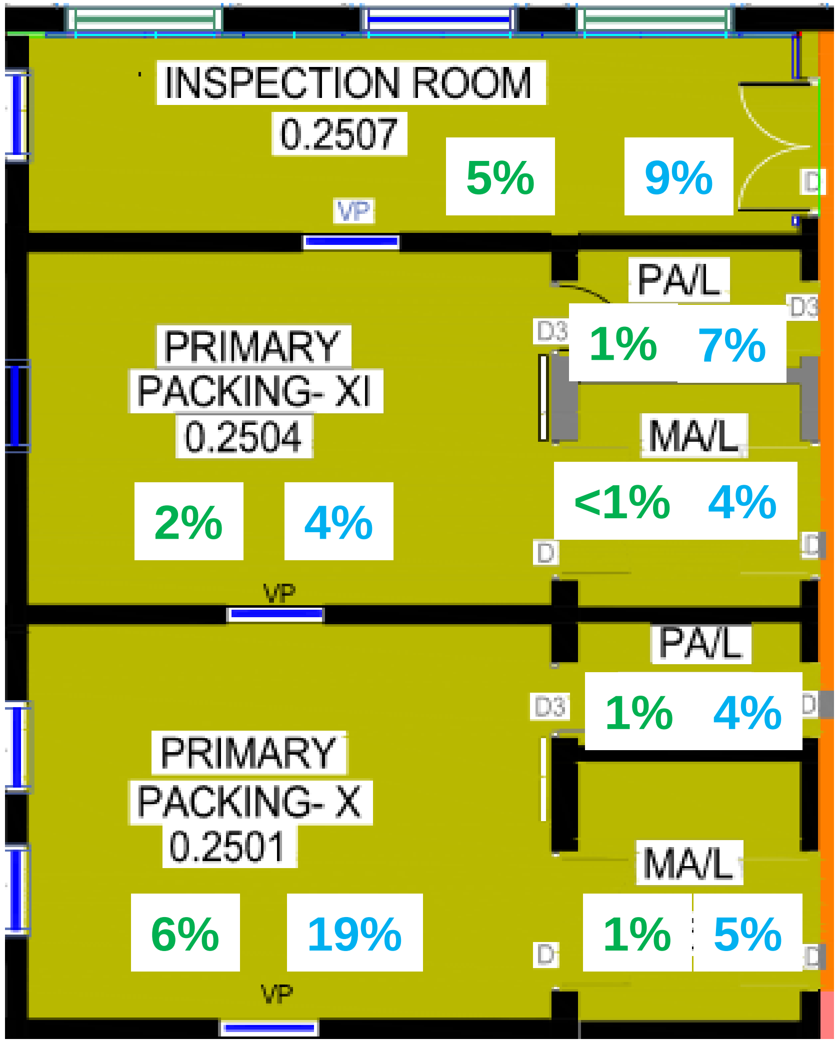
≥0.5 micron shows very small increase

≥5.0 micron shows larger increase but greatly under compliance limits

Improved diffusers selected for revised airflow and improved mixing will mitigate the 5.0 micron increases

Trial demonstrates ACPH's can be reduced…

…without impact on quality compliance



% of class limit

0.5µm 5.0µm

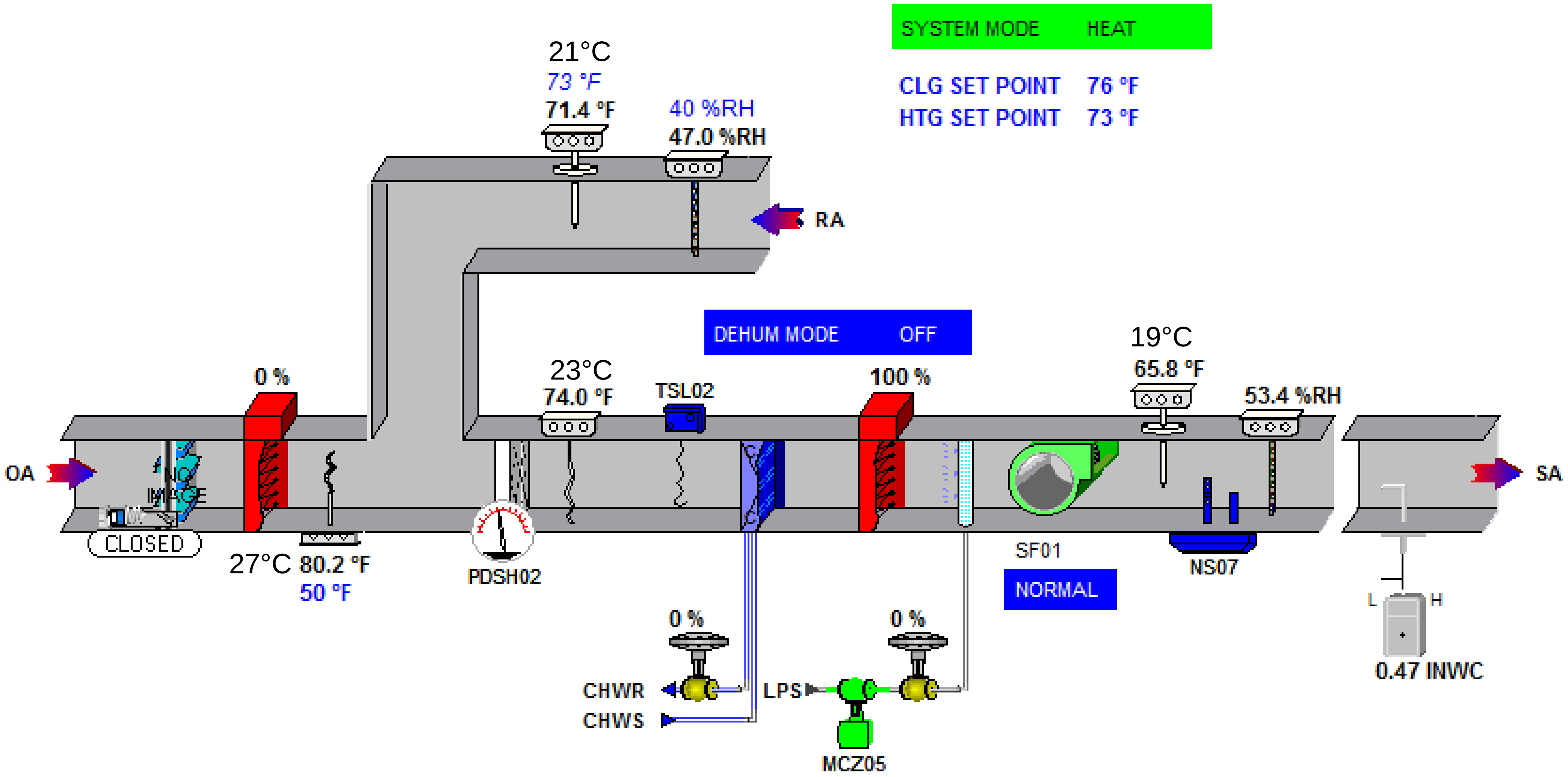
2. SET BACK (TURN-DOWN) – NON PRODUCTION TIME

- No people = no contamination source
- No production = no risk to product
- When no production turn down air supply rate (+ relax temp/humidity setpoints)

It's a good idea to:

- Keep people out of area whilst in setback mode
- Provide visual indication for setback mode – to alert operators
- Qualify return to normal operation (particles + micro)
- Might require CV boxes on fresh air to maintain pressure

3. BAS CONTROLS – FOR EFFICIENCY



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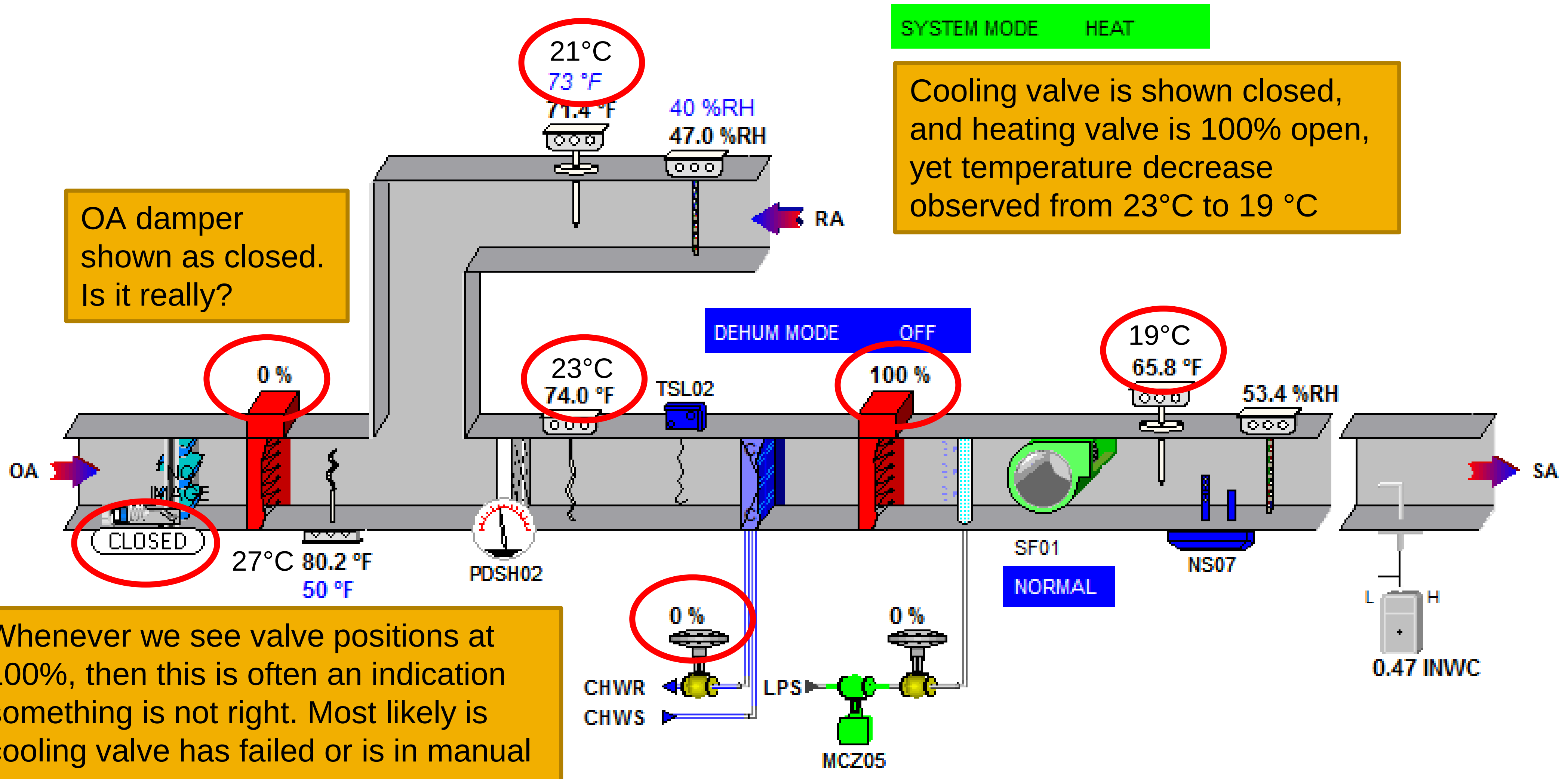


Cooling valve is shown closed, and heating valve is 100% open, yet temperature decrease observed from 23°C to 19 °C

OA damper shown as closed. Is it really?

Whenever we see valve positions at 100%, then this is often an indication something is not right. Most likely is cooling valve has failed or is in manual bypass.

……AND FINALLY: ISO 14644-16

Cleanrooms and associated controlled environments —

Part 16:
Energy efficiency in cleanrooms and clean air devices

Salles propres et environnements maîtrisés apparentés —

Partie 16: Efficacité énergétique dans les salles propres et les dispositifs à air épuré

ISO/TC **209**

Secretariat: ANSI

Voting begins on:
2019-03-04

Voting terminates on:
2019-04-29

Part 16 – currently at final review stage (FDIS)

- **Expected publication around Q4 2019**
- **What's in it?**
  - Process to follow
  - Debunks air change rate myth
  - Lots of examples of what to do
  - Helpful calculations
  - Benchmarking techniques

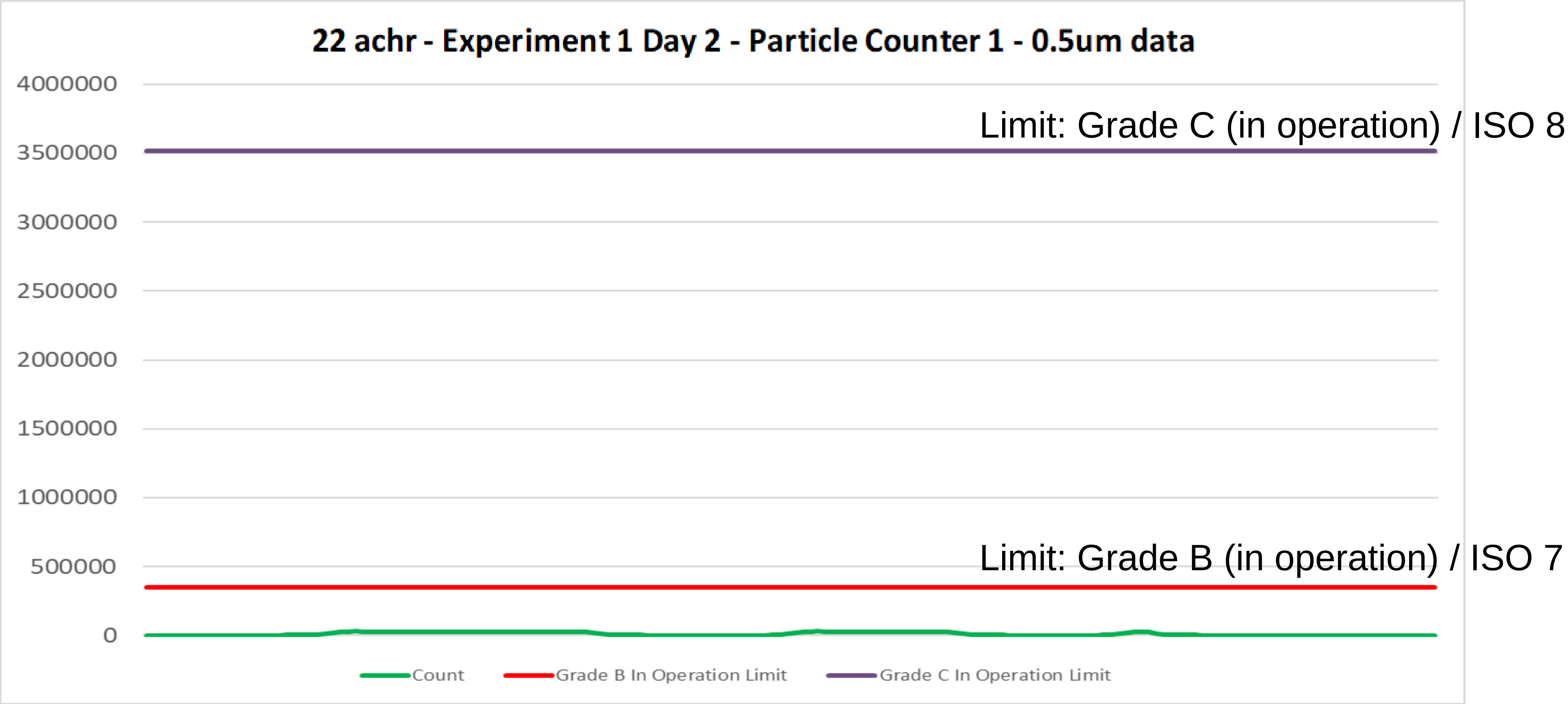
Design cleanroom with efficiency in mind & use performance data in use to 'tune' cleanroom HVAC to the real need.

ENERGY REDUCTION: *FUTURE*

ADAPTIVE (DEMAND BASED) CONTROL -

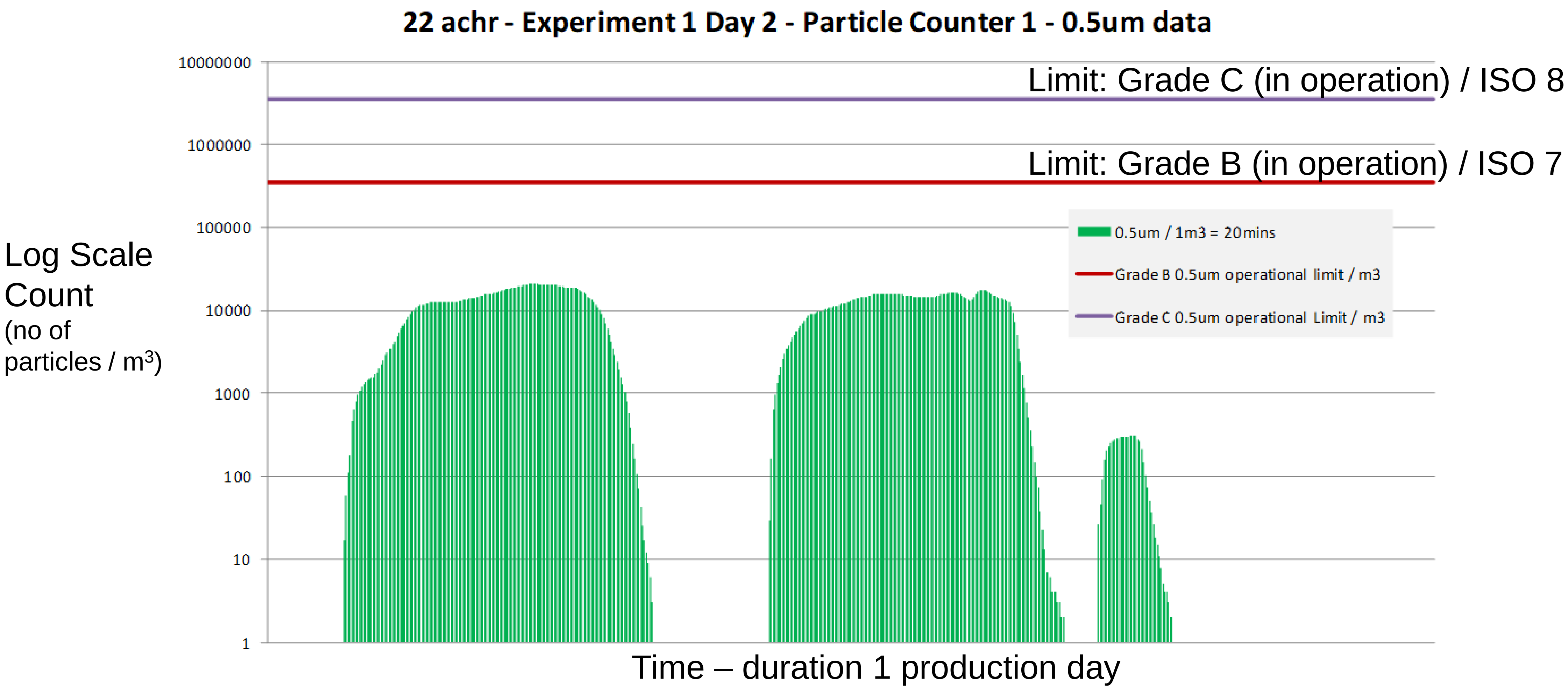
FUTURE CLEANROOM OPERATIONS WILL BE SUPER-EFFICIENT

PARTICLE CONCENTRATION

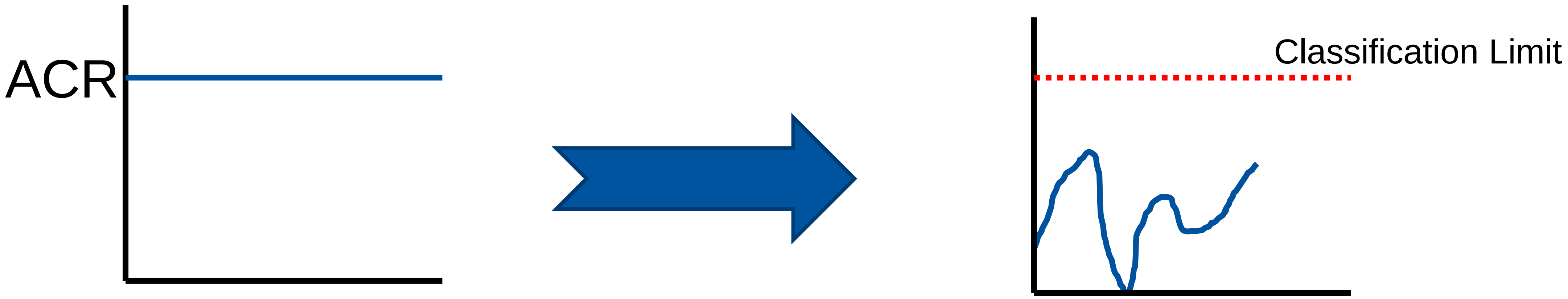


Time – duration 1 production day

PARTICLE CONCENTRATION



CURRENT PRACTICE



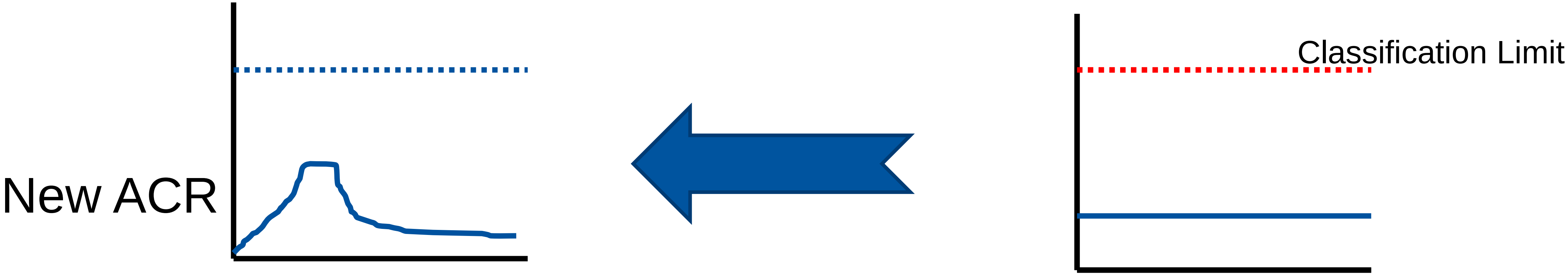
Fixed Air Supply Rate (ACR)

Variable Contamination Levels (#particles/m3)

WHAT DOES IT MEAN?

- We don’t know the actual contamination level at any particular time or location
- Most of the time particle generation rates are low, therefore air flow is much higher than needed
- Fan energy accounts for 35-50% of the annual energy consumption of a cleanroom
- As energy costs increase, cost of production increases

HYPOTHESIS:
CAN WE CONTROL TO A FIXED CONTAMINATION LEVEL?



Variable Air Supply Rate (ACR)

Fixed Contamination Levels (#particles/m3)


GRADE B
GRADE C
CLEANROOM
TEST FACILITY
AIRFLOW

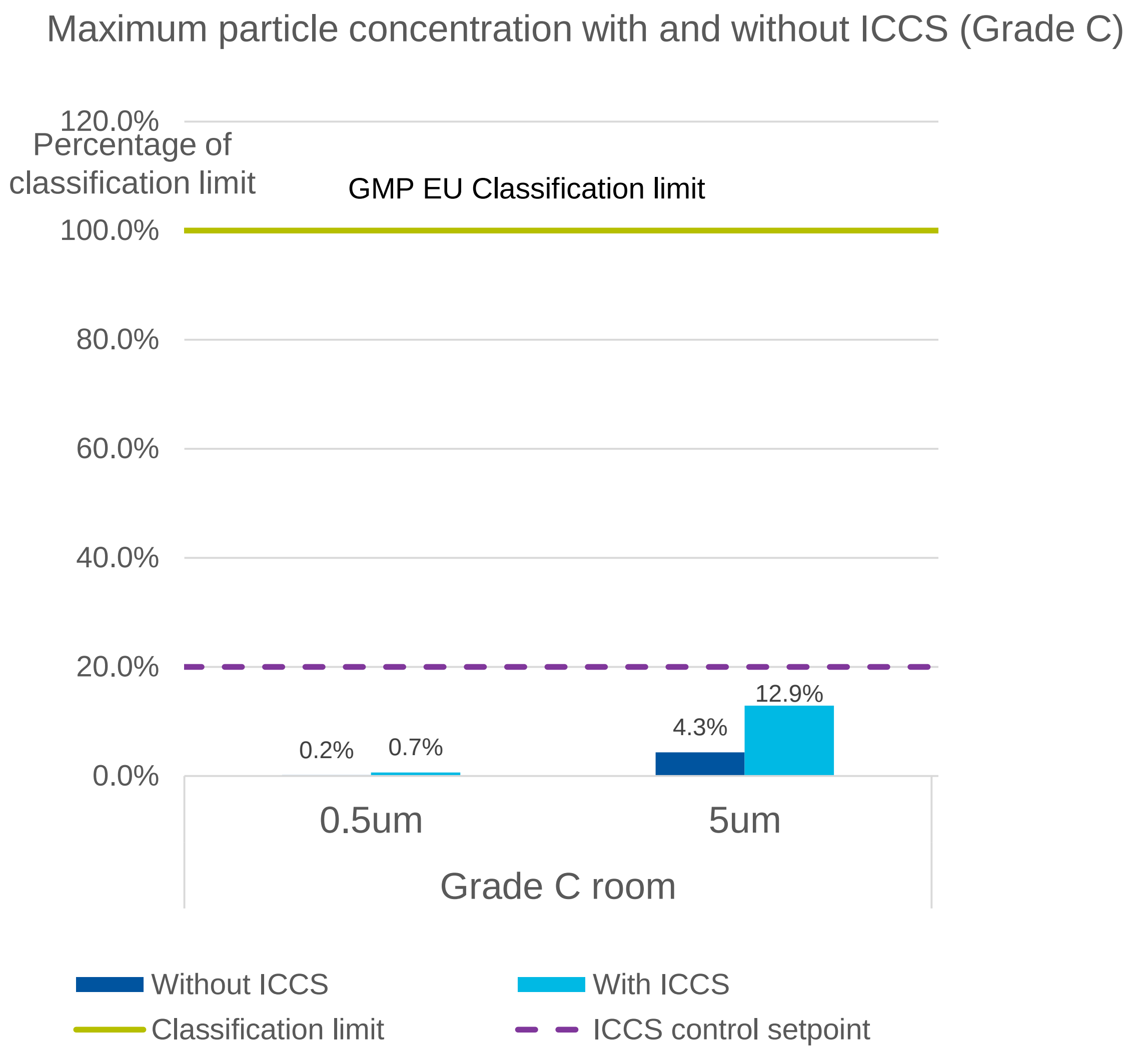
RESULTS – STATIC VS. DYNAMIC CONTROL

- **Static air change rate (without ICCS): PI controllers implemented in the BMS maintain the ACR for cleanrooms to steady state**

- **Dynamic particulate control (with ICCS): particle counter based MPC implemented in the PLC platform control the particle concentration dynamically.**

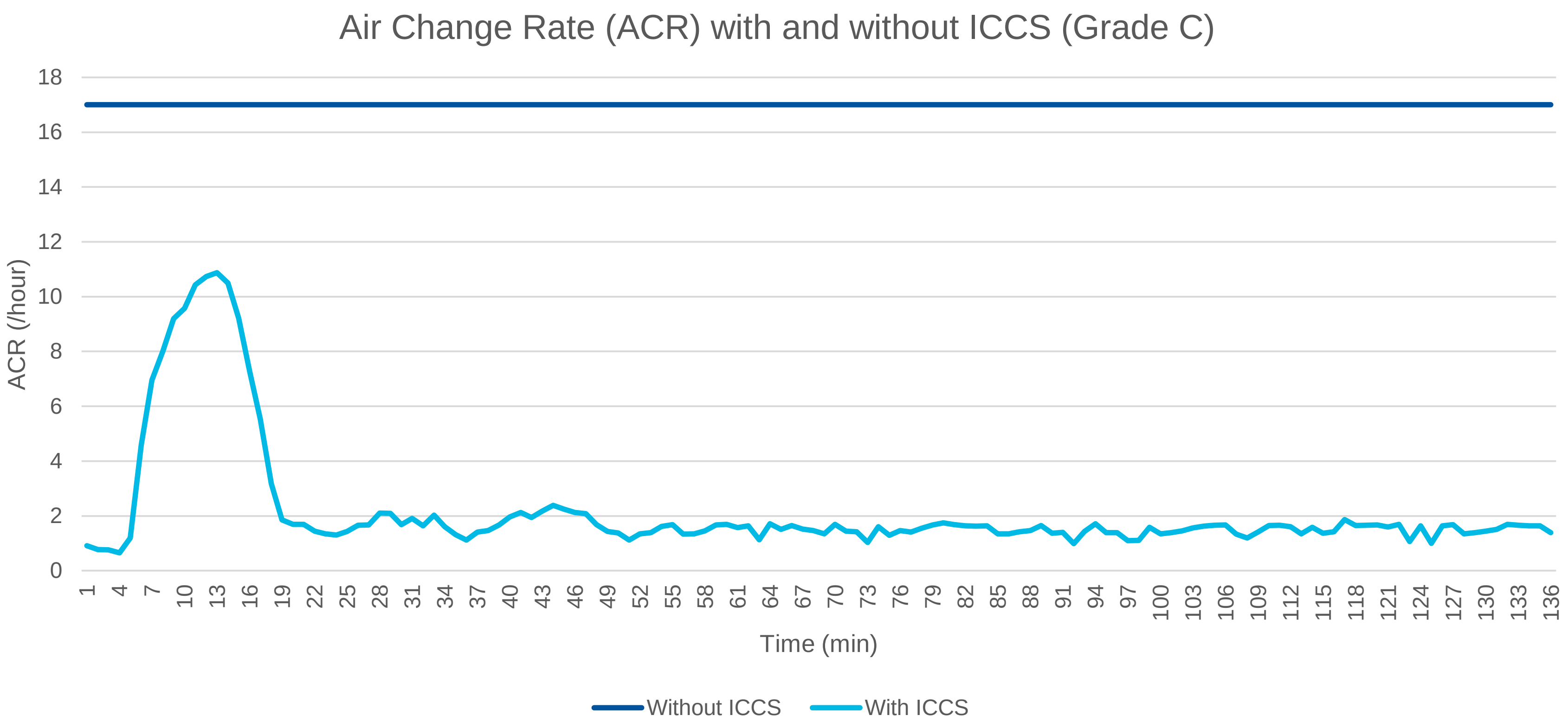
- **ICCS control setpoint: 20% of classification limit**

- **People with cleanroom gowning**



RESULTS – ACR IN TEST CLEANROOMS

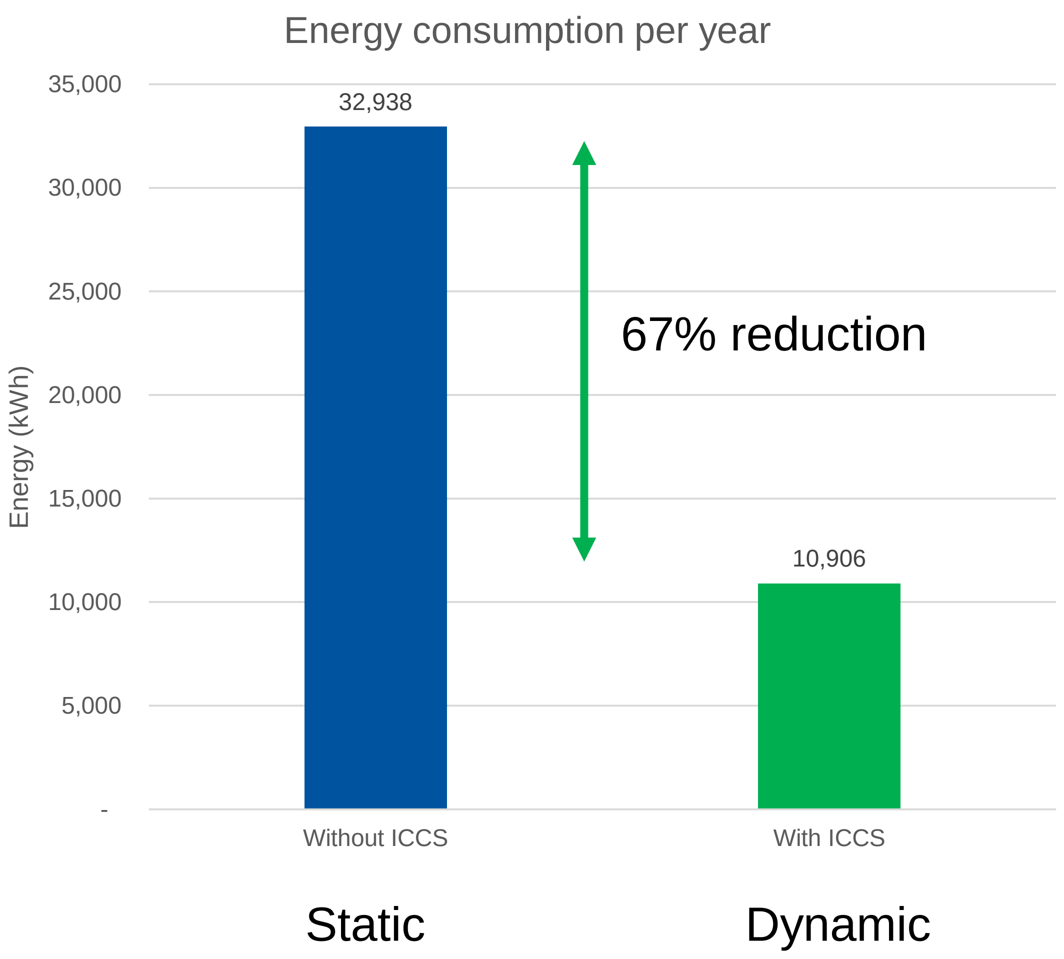
Grade C room



RESULTS - ENERGY

- Particulate count maintained under **20%** of class limit

- **67%** energy reduction compared with static system.



SUMMARY

1. Cleanroom energy consumption can be reduced with no significant impact to performance;
2. Higher classes are more energy intensive – but lower classes consume more energy;
3. Performance of the cleanroom is critical - Air Change Rate is not;
4. Applicable reduction strategies should be considered on a case by case basis;
5. Adaptive (demand based) control of cleanroom HVAC has huge potential for cleanroom energy reduction globally.

THANK YOU

Any Questions?

Find out more at:
www.eeco2.com