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# UNDERSTANDING THE SCIENCE BEHIND MITIGATING THE TRANSMISSION OF COVID-19

~~SESSION 1: TRANSMISSION PATHS~~

~~SESSION 2: AIRBORNE MITIGATION STRATEGIES~~

SESSION 3: ESTIMATING EFFECTIVENESS OF RISK MITIGATION STRATEGIES

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AHK CONSULTING, INC. | DIRECTOR OF EDUCATION FOR AAEE

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# ESTIMATING RISK

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THANK YOU TO OUR SPONSORS FOR THIS SERIES



# WHAT WE'RE GOING TO COVER



**SESSION 1**  
Transmission Paths



**SESSION 2**  
Airborne Mitigation



**SESSION 3**  
Estimating Risk



## REVIEW OF SESSION 2

- Increasing outside air ventilation rates can effectively reduce the recirculation risk – but it can be difficult to implement and comes with an energy penalty.
- MERV 13 filters are between 85-100% effective at removing potentially infected particles from recirculated air.
- HEPA filters approach 100% effectiveness but often require too much pressure drop for a retrofit application.
- UVc lighting can effectively reduce active virus particles in a moving airstream.



## SESSION 3: ESTIMATING RISK

During the COVID-19 pandemic, engineers have often been asked to inform building owners what strategies should be employed to reduce the risk of infection of building occupants. This has been a difficult task because we have not been able to accurately quantify the reduction in infection risk that will result from a particular strategy. This session uses the Wells-Riley equation and our best-known estimates for the quanta generation rate of SARS-COV-2, estimated through empirical methods such as Monte Carlo simulations, to help quantify the risk reduction of various transmission mitigation strategies.

1. Differentiate between empirical and theoretical equations.
2. Understand how quanta generation rate can be back-calculated from epidemiological case studies.
3. Compare the relative virulence of common airborne diseases as described by their known quanta generation rates.
4. Quantify the estimated risk of infection for four different scenarios: K-12 classroom, open floorplan office space, grocery store, and conference room.
5. Discuss the relative risk reduction of several mitigation strategies, including masks, filtration, and increased outside air ventilation based on presented results.

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# ESTIMATING RISK:

# CALCULATING PROBABILITY OF INFECTION

## WHAT IS WELLS-RILEY?

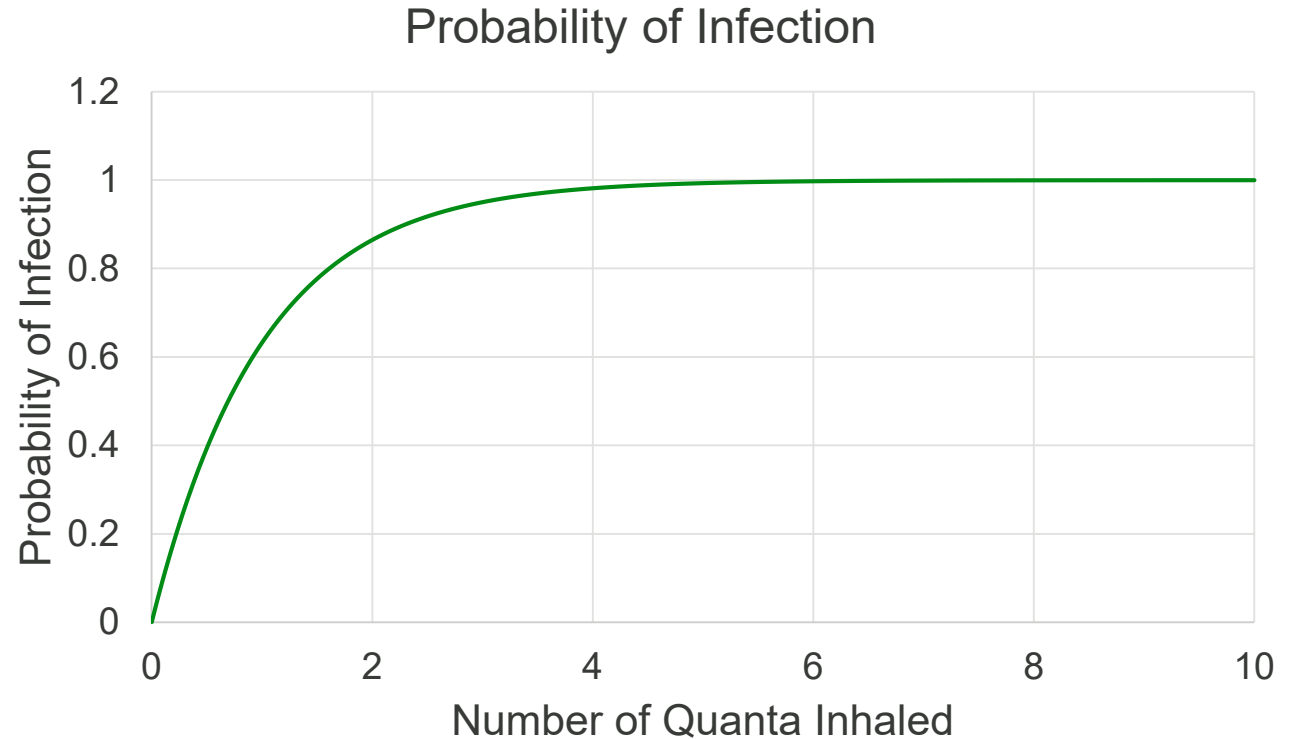
- Used to determine the probability of infection of an airborne disease
- Estimates airborne particle (aerosol) transmission only
- Already used for diseases like
  - Rhinovirus (common cold)
  - SARS
  - Measles
  - Tuberculosis



## THE WELLS-RILEY EQUATION

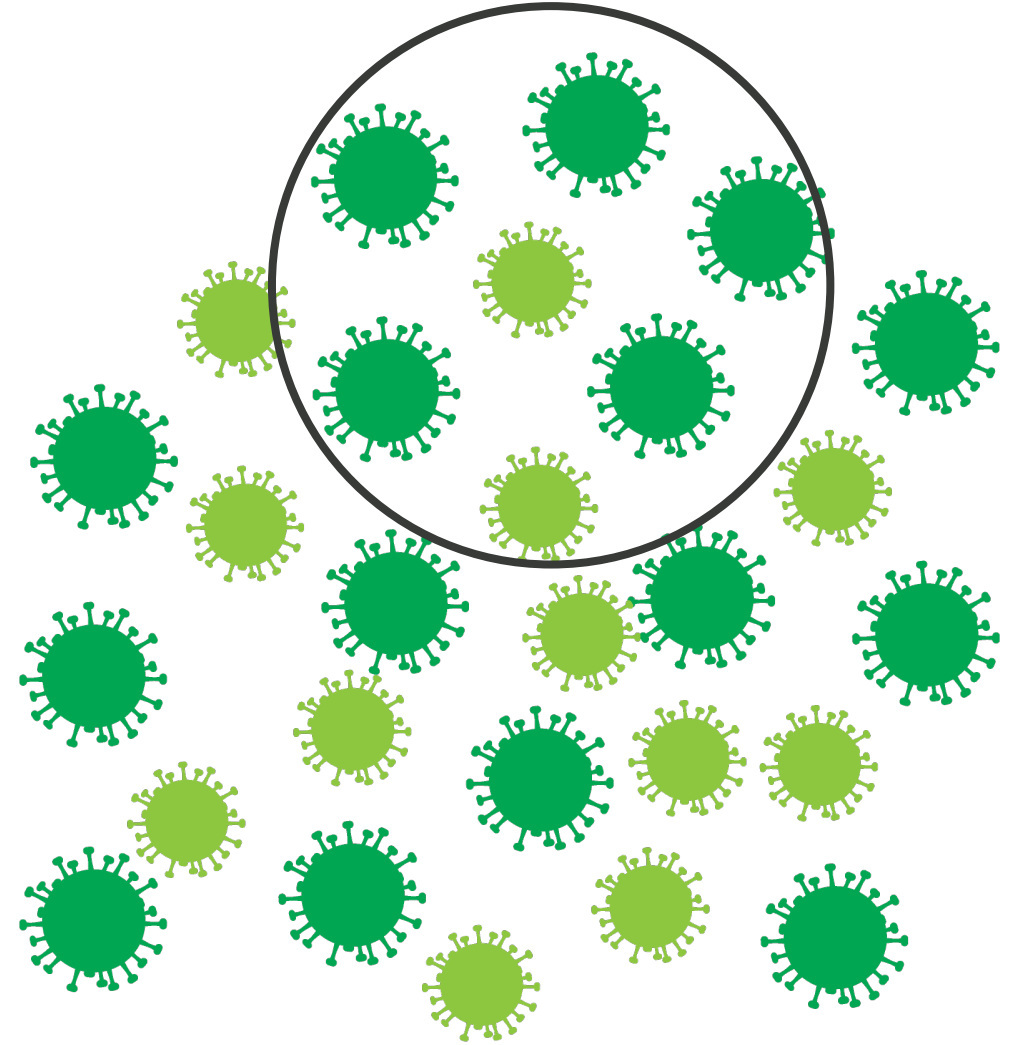
$$p = \frac{\text{positive cases}}{\text{susceptible people}} = 1 - e^{-n}$$

- $p$  = Probability of infection
- $n$  = The "number of quanta inhaled by a susceptible person"



## QUANTUM OF INFECTION (QUANTA)

- Hypothetical infectious dose of a pathogen
- One inhaled quanta represents ~63% chance of infection



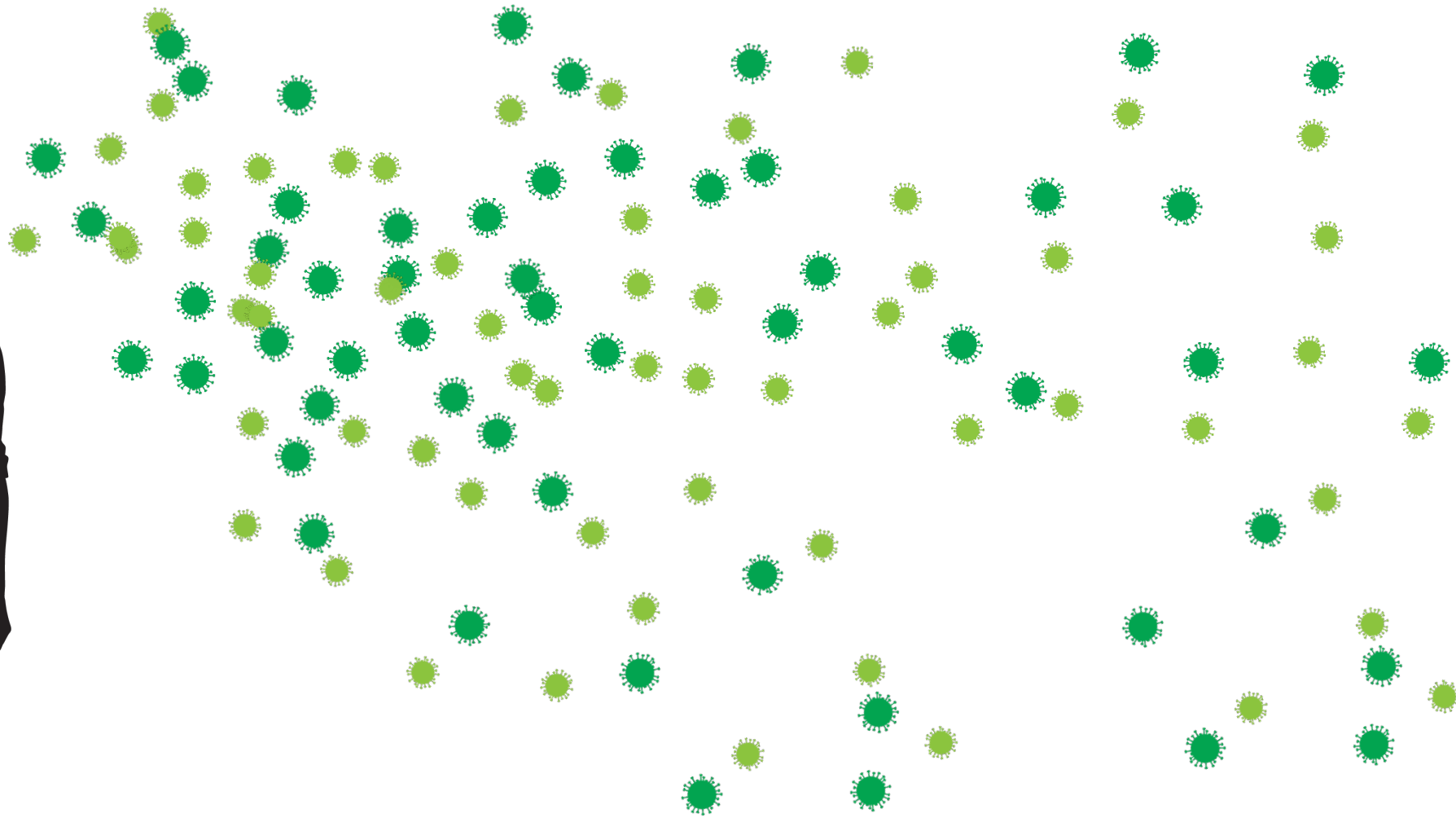
Infection Disease	Reported Value of Quanta Generation Rates (q)
Rhinovirus (Common Cold)	~1-10 per hour
Tuberculosis	~1-50 per hour
SARS (SARS-CoV-1)	~10-300 per hour
Influenza	~15-500 per hour
Measles	~570-5600 per hour
COVID-19 (SARS-CoV-2)	???

## QUANTA GENERATION RATES OF COMMON PATHOGENS

## WHAT IS MEANT BY *EMPIRICAL*?

- Information acquired by observation or experimentation rather than theory
  - Careful, scientific study of the real-world
- Steps to find quanta generation rate:
  - Find confirmed spread event
  - Determine number of infected
  - Quantify environmental factors
  - Back calculate quanta generation rate that correlates with observed infection rate





$$p = 1 - e^{-n}$$

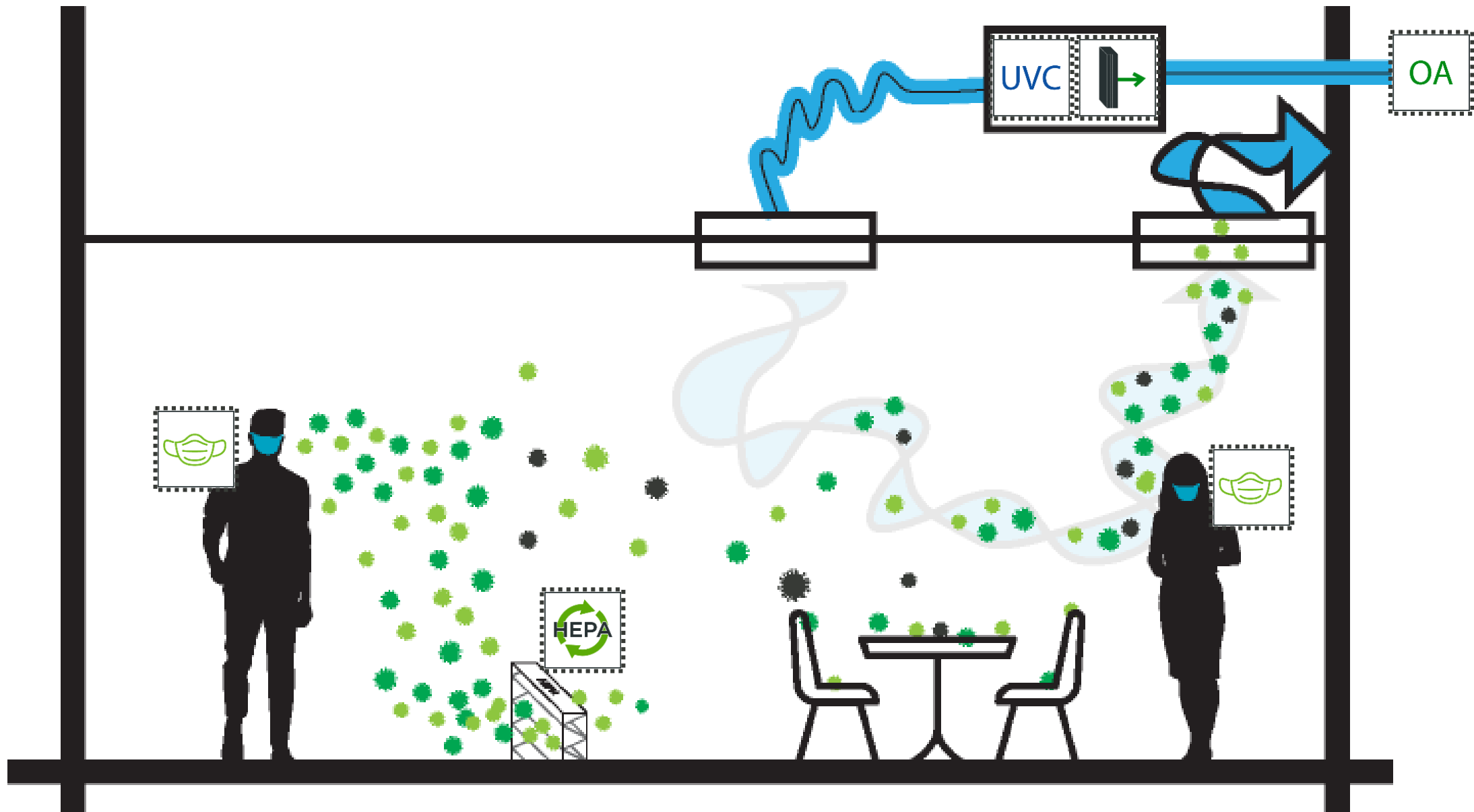
**HOW DO WE DETERMINE HOW MUCH QUANTA IS INHALED?**

Determine quanta emitted into space by an infectious person.

Calculate the average concentration of quanta in the air.

Determine how much quanta is inhaled by a susceptible person.

Determine the probability of infection based on quanta inhaled.





## ASSUMPTIONS

Only focuses on airborne transmission. Does not account for large droplet or fomite transfer.

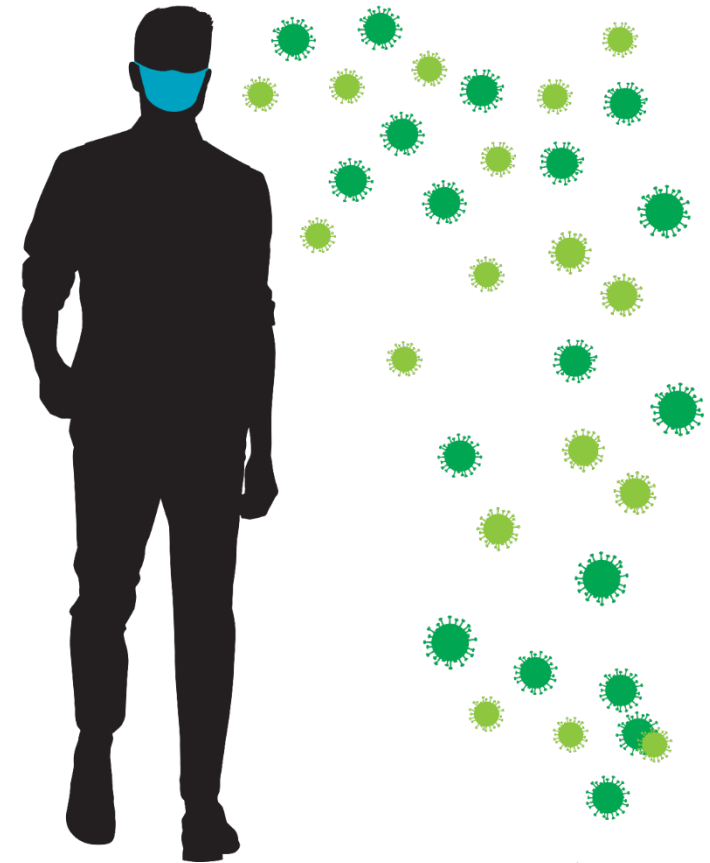
Assumes a fully mixed room – doesn't increase risk based on proximity to the infected person (even though that's reality).



## STEP 1 – QUANTA EMITTED

$$E = q \cdot N_{infected} \cdot (1 - \eta_{masks,e} \cdot x_{masks,e})$$

- $E$  = Emission rate (quanta emitted per hour)
- $q$  = quanta generation rate
- $N_{infected}$  = Number of infectious persons
- $\eta_{masks,e}$  = efficacy of the masks being worn by the infected (filtration efficiency)
- $x_{masks,e}$  = fraction of infected people wearing masks (1 if single infected wearing mask)



Determine quanta emitted into space by an infectious person.

Calculate the average concentration of quanta in the air.

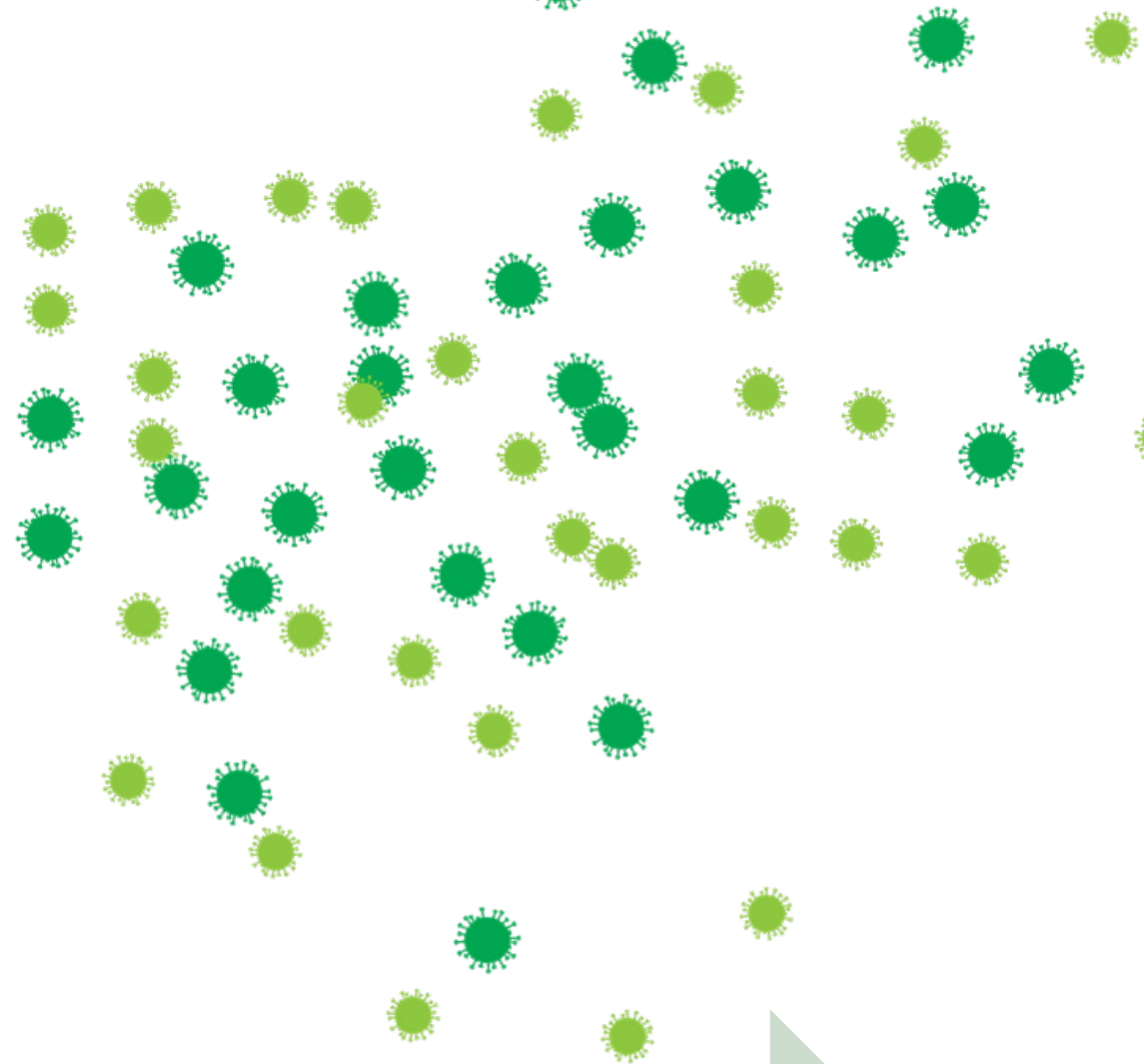
Determine how much quanta is inhaled by a susceptible person.

Determine the probability of infection based on quanta inhaled.

## STEP 2 – AVERAGE CONCENTRATION

$$C_{avg} = \frac{E}{\lambda V} \cdot \left[ 1 - \frac{1}{\lambda D} (1 - e^{-\lambda D}) \right]$$

- $C_{avg}$  = Average concentration of quanta in air
- $E$  = Emission rate (quanta emitted per hour)
- $V$  = volume of space
- $D$  = duration of event
- $\lambda$  = sum of first order loss rates (mitigation factors)

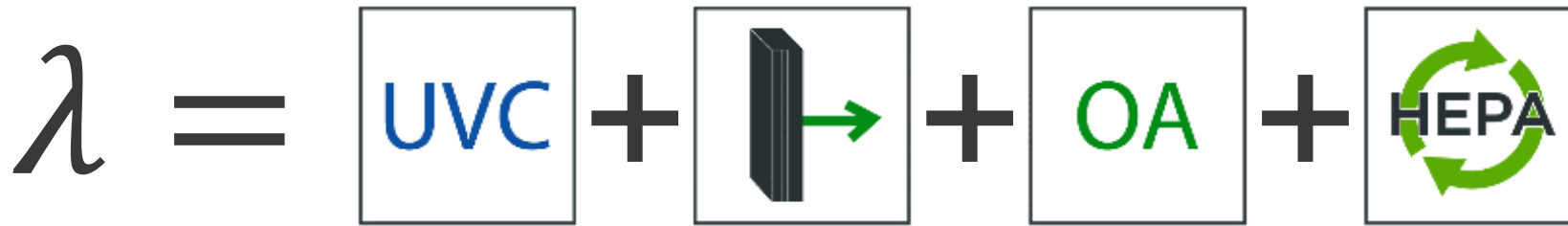


Determine quanta emitted into space by an infectious person.

Calculate the average concentration of quanta in the air.

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Determine the probability of infection based on quanta inhaled.

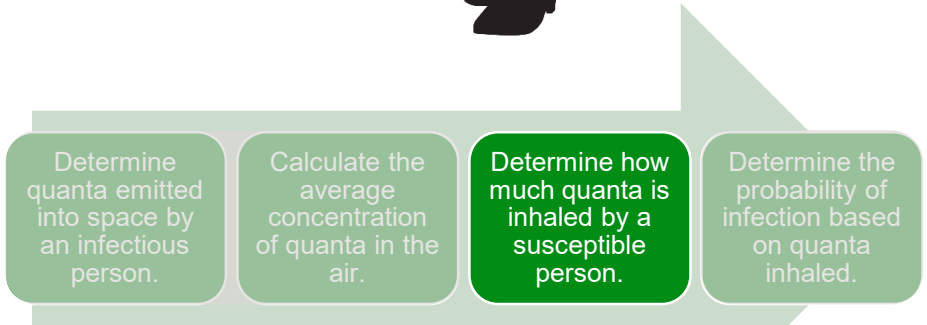
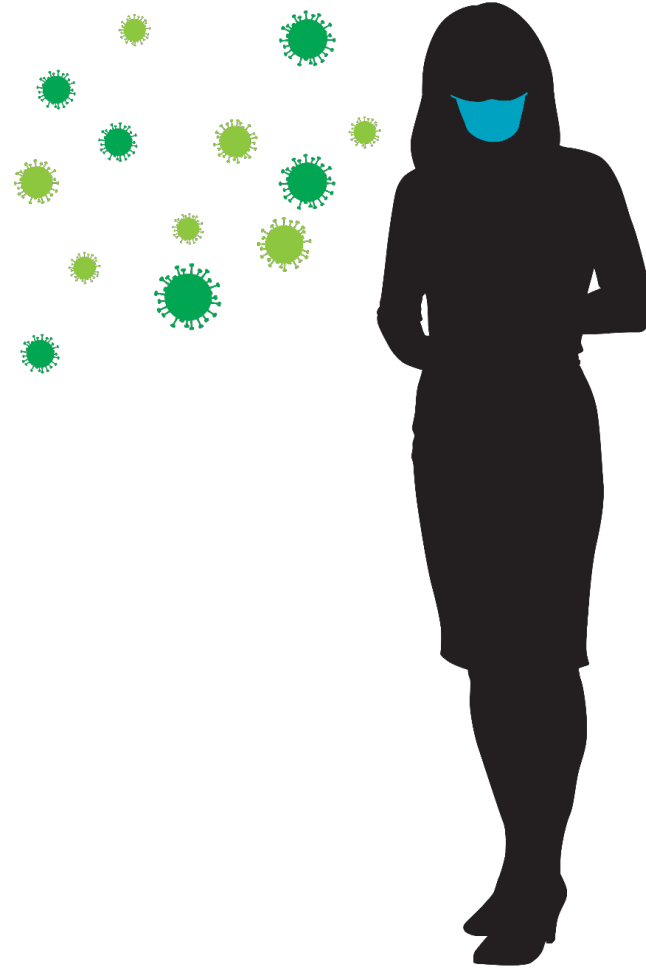


**FINDING FIRST ORDER LOSS RATES**

## STEP 3 – QUANTA INHALED

$$n = C_{avg} \cdot p \cdot D \cdot [1 - (x_{mask,i} \cdot \eta_{mask,i})]$$

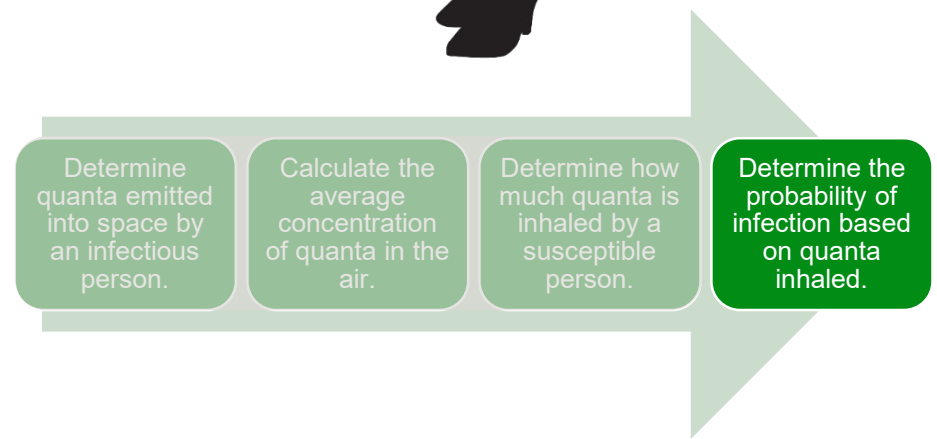
- $n$  = number of quanta inhaled
- $C_{avg}$  = Average concentration of quanta in air
- $p$  = pulmonary rate susceptible people
- $D$  = duration of exposure
- $x_{mask,i}$  = number of susceptible people wearing masks
- $\eta_{mask,i}$  = capture efficiency of worn mask



## STEP 4 – PROBABILITY OF INFECTION

$$p = 1 - e^{-n}$$

- $p$  = probability of infection
- $n$  = number of quanta inhaled



Determine quanta emitted into space by an infectious person.

Calculate the average concentration of quanta in the air.

Determine how much quanta is inhaled by a susceptible person.

Determine the probability of infection based on quanta inhaled.



## Jose L. Jimenez

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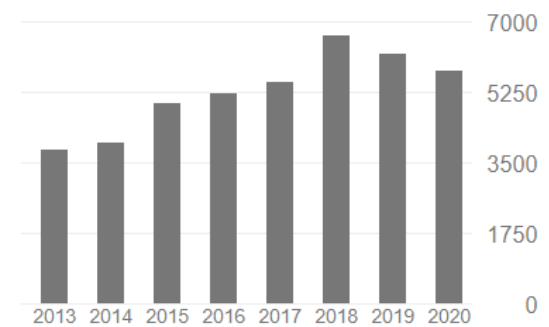
[Atmospheric Chemistry](#) [Mass Spectrometry](#) [Aerosols](#) [Air Quality](#) [Air Pollution](#)

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TITLE	CITED BY	YEAR
<p><a href="#">The formation, properties and impact of secondary organic aerosol: current and emerging issues</a></p> <p>M Hallquist, JC Wenger, U Baltensperger, Y Rudich, D Simpson, ... Atmospheric chemistry and physics 9 (14), 5155-5236</p>	2834	2009
<p><a href="#">Evolution of organic aerosols in the atmosphere</a></p> <p>JL Jimenez, MR Canagaratna, NM Donahue, ASH Prevot, Q Zhang, ... Science 326 (5959), 1525-1529</p>	2056	2009
<p><a href="#">Ubiquity and dominance of oxygenated species in organic aerosols in anthropogenically-influenced Northern Hemisphere midlatitudes</a></p> <p>Q Zhang, JL Jimenez, MR Canagaratna, JD Allan, H Coe, I Ulbrich, ... Geophysical research letters 34 (13)</p>	1672	2007
<p><a href="#">Field-deployable, high-resolution, time-of-flight aerosol mass spectrometer</a></p> <p>PF DeCarlo, JR Kimmel, A Trimborn, MJ Northway, JT Jayne, AC Aiken, ... Analytical chemistry 78 (24), 8281-8289</p>	1600	2006
<p><a href="#">Chemical and microphysical characterization of ambient aerosols with the aerodyne aerosol mass spectrometer</a></p> <p>MR Canagaratna, JT Jayne, JL Jimenez, JD Allan, MR Alfarra, Q Zhang, ... Mass spectrometry reviews 26 (2), 185-222</p>	1399	2007

Cited by [VIEW ALL](#)

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Citations	58844	34436
h-index	122	94
i10-index	453	406



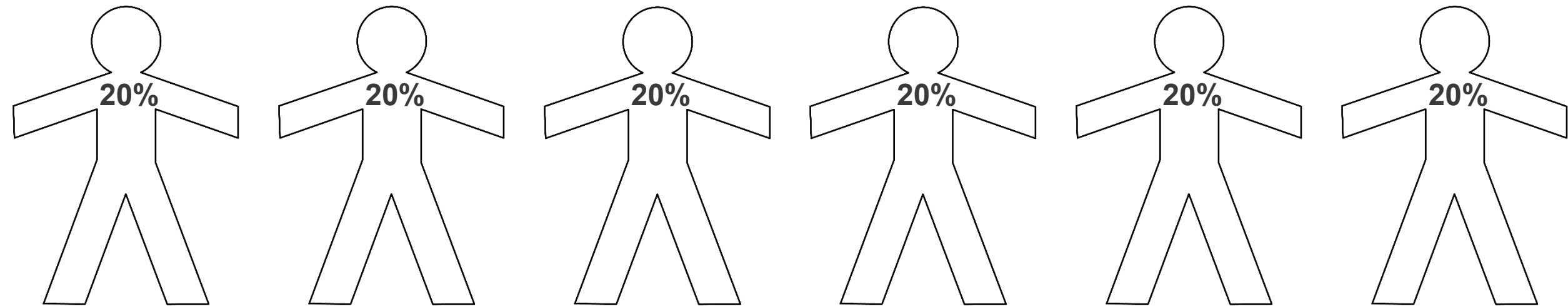
Co-authors [VIEW ALL](#)

- Douglas A. Day  
CIRES, University of Colorado, B...
- Pedro Campuzano-Jost

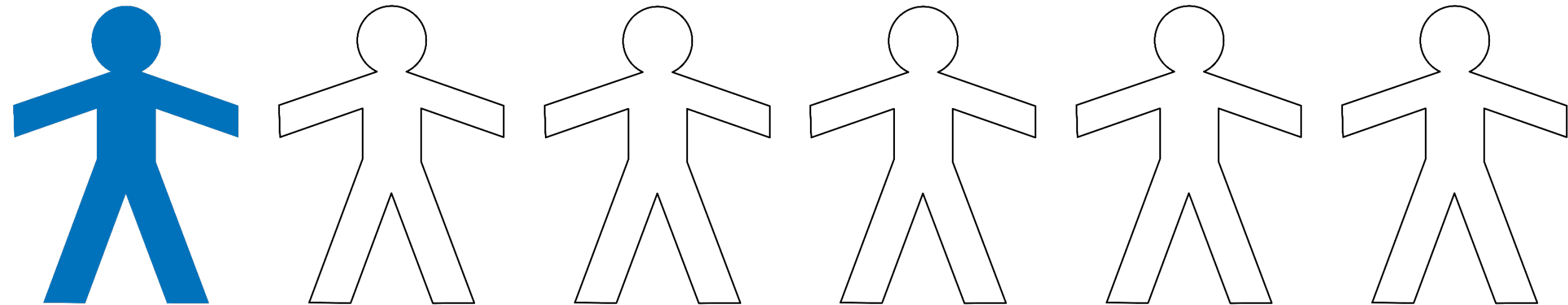
**CREDIT TO PROF. JIMENEZ | UNIVERSITY OF COLORADO – BOULDER**



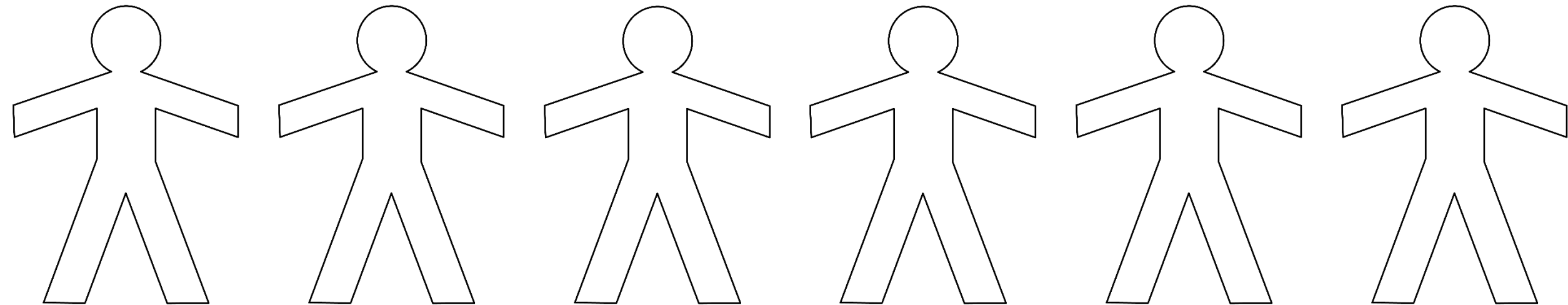
# **UNDERSTANDING INFECTION RISK**



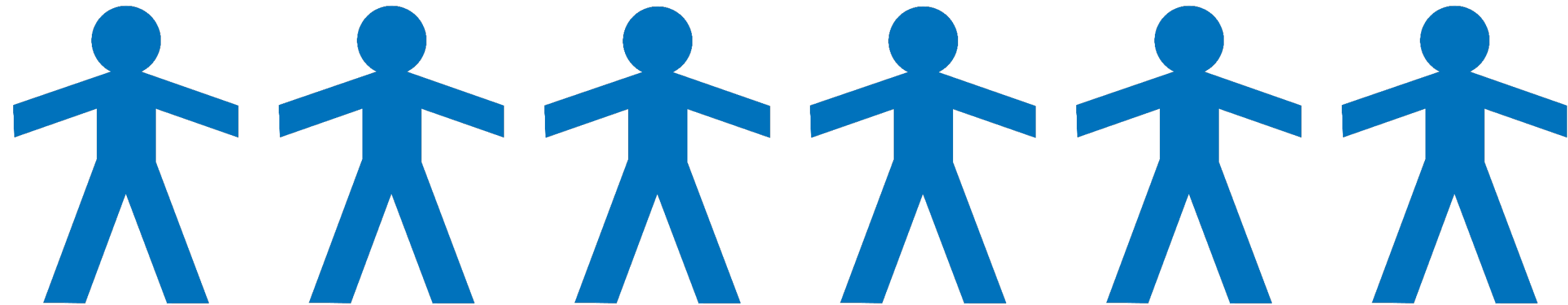
**UNPACKING PROBABILITY OF INFECTION**



**UNPACKING PROBABILITY OF INFECTION**



**UNPACKING PROBABILITY OF INFECTION**



**UNPACKING PROBABILITY OF INFECTION**




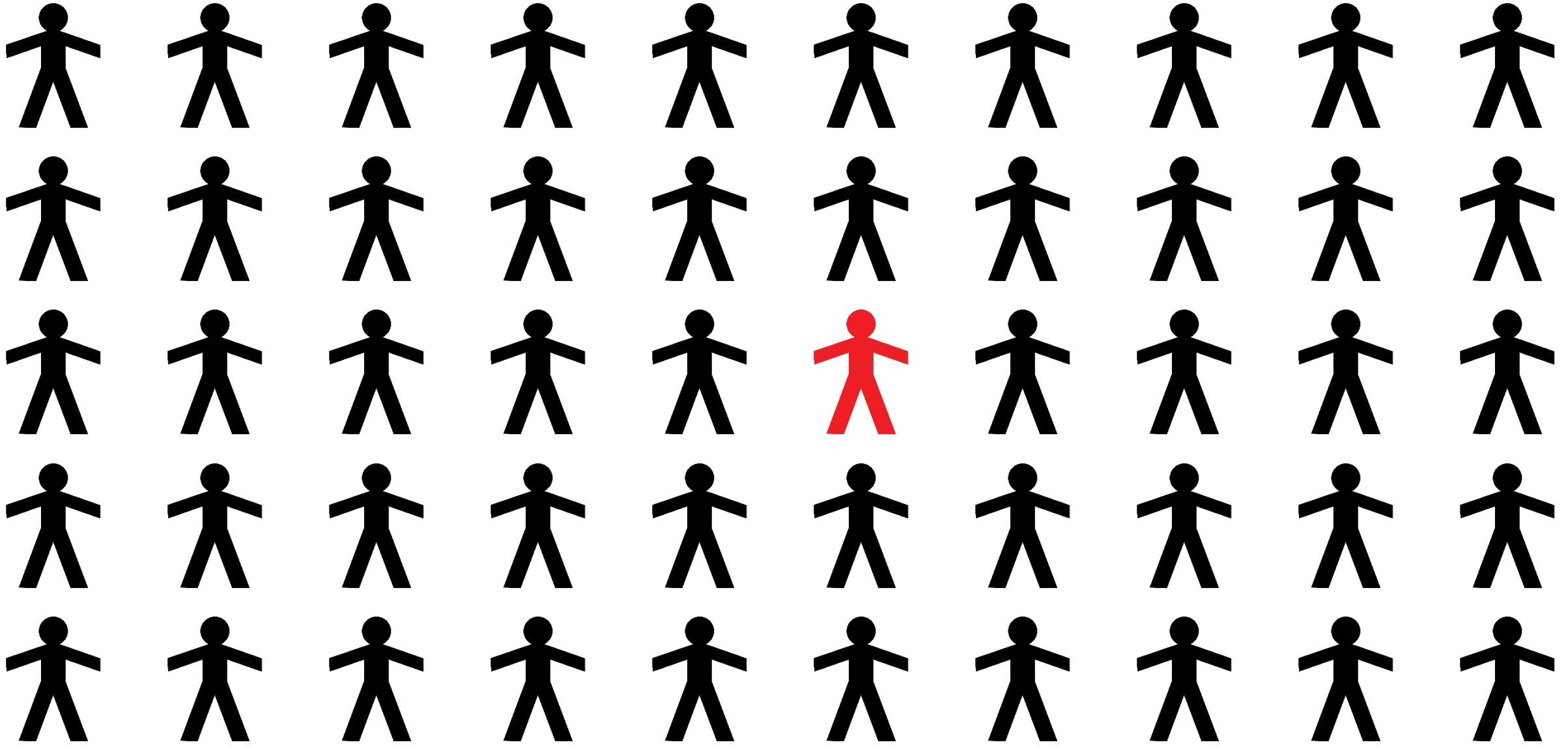
**GAMBLER'S FALLACY**



# INFECTION RISK SCENARIOS

Single event discrete  
Single event absolute  
Multiple event absolute





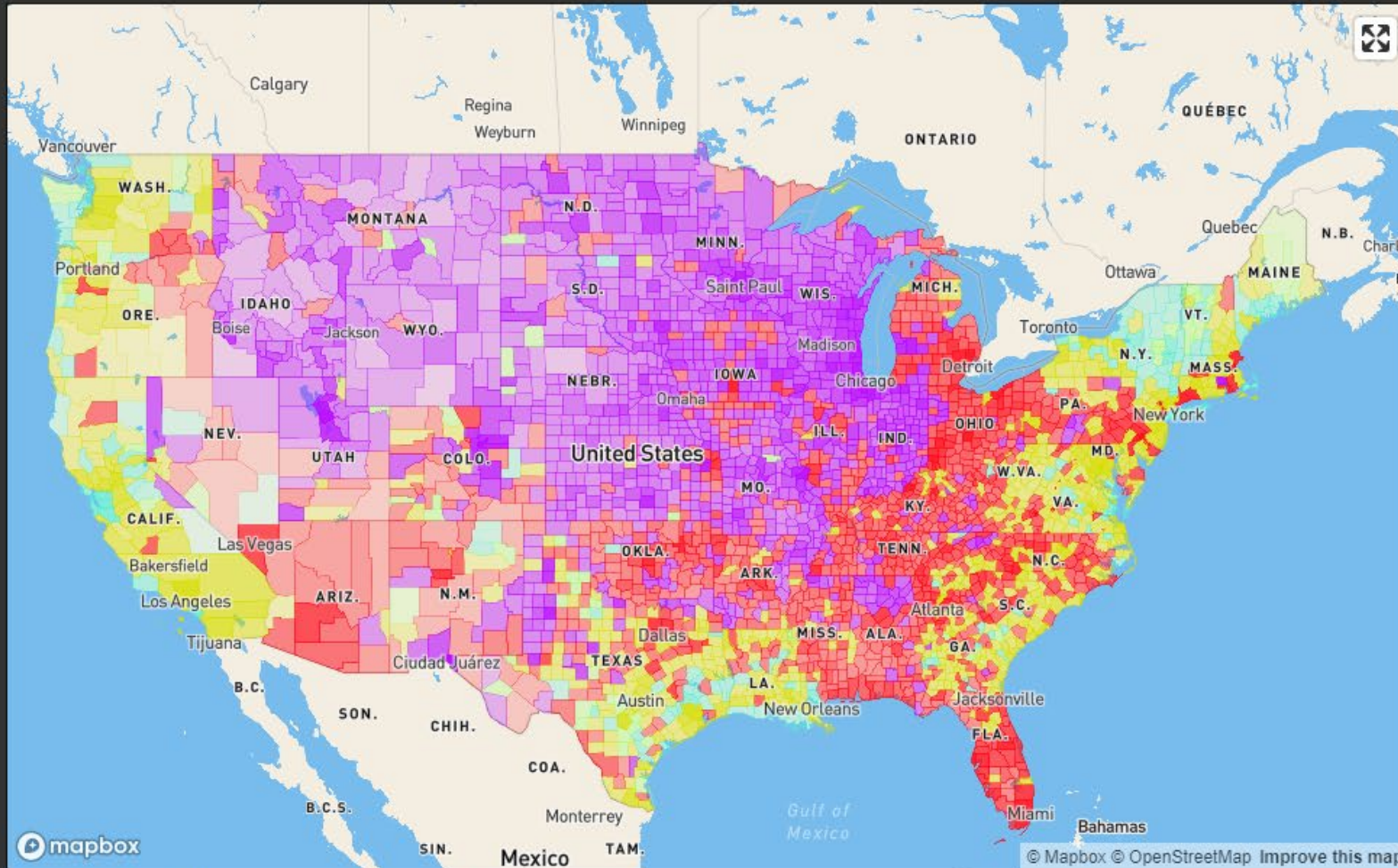
**SINGLE EVENT DISCRETE**



**SINGLE EVENT ABSOLUTE**



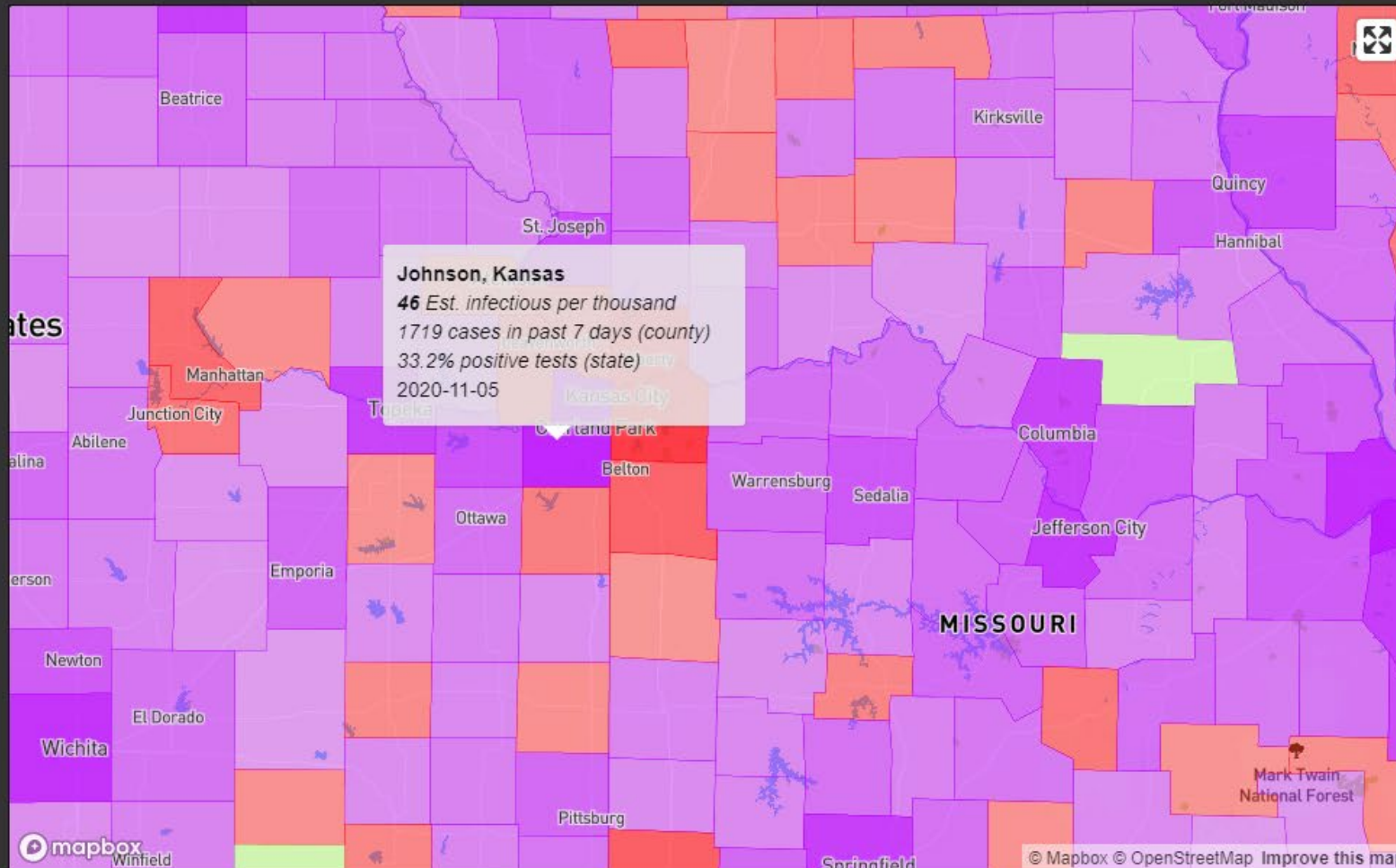
# COVID-19 now



Estimated infectious cases per thousand



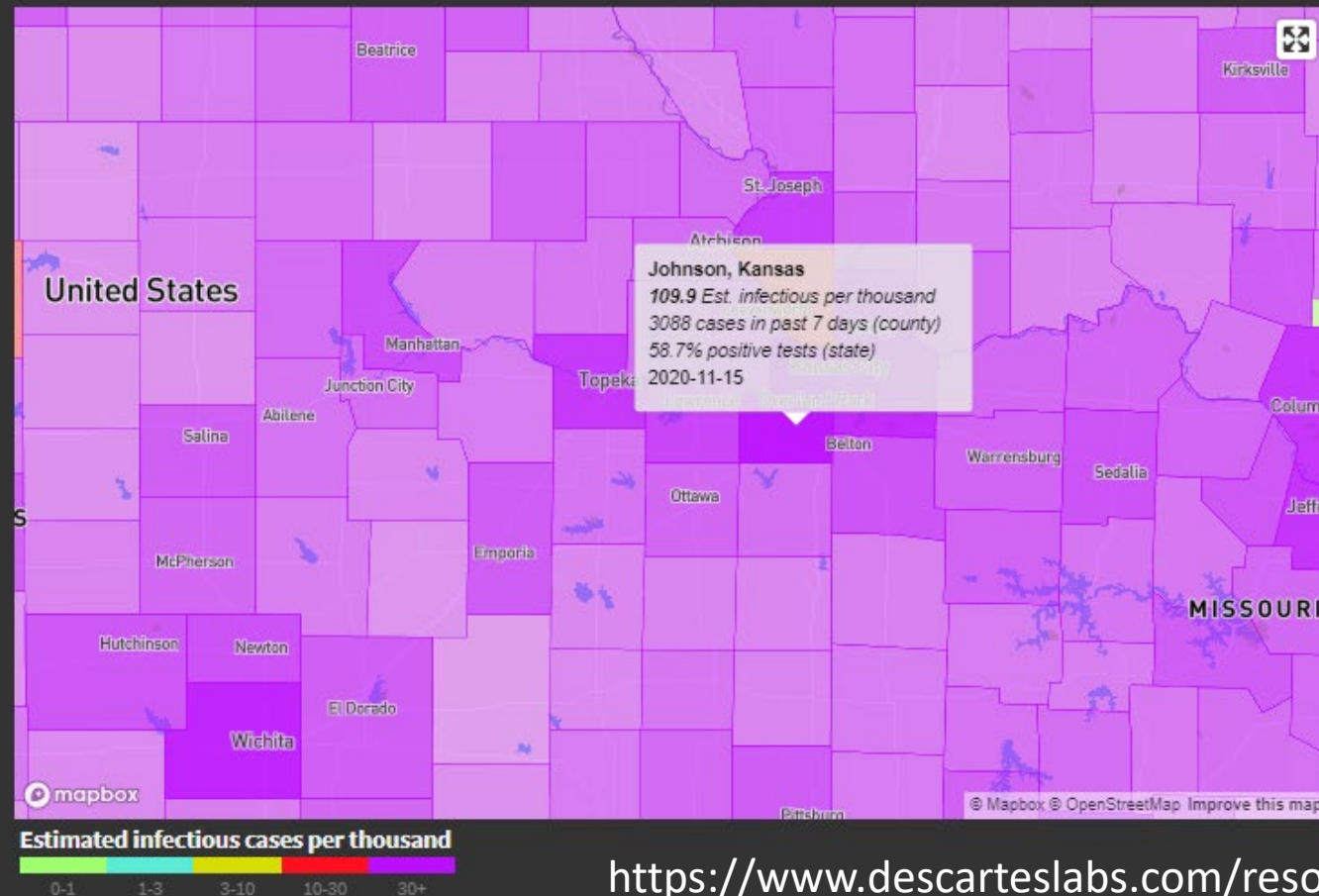
# COVID-19 now



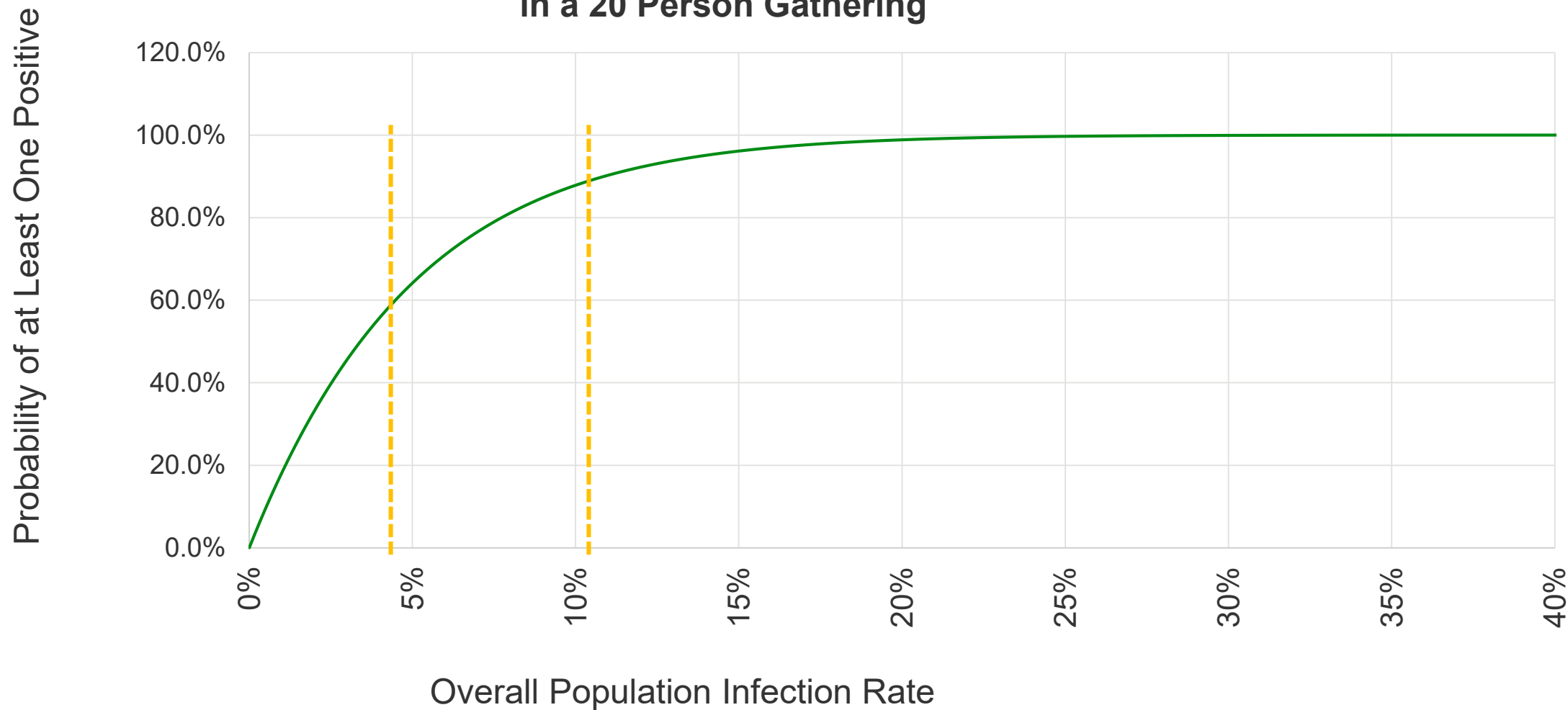
Estimated infectious cases per thousand



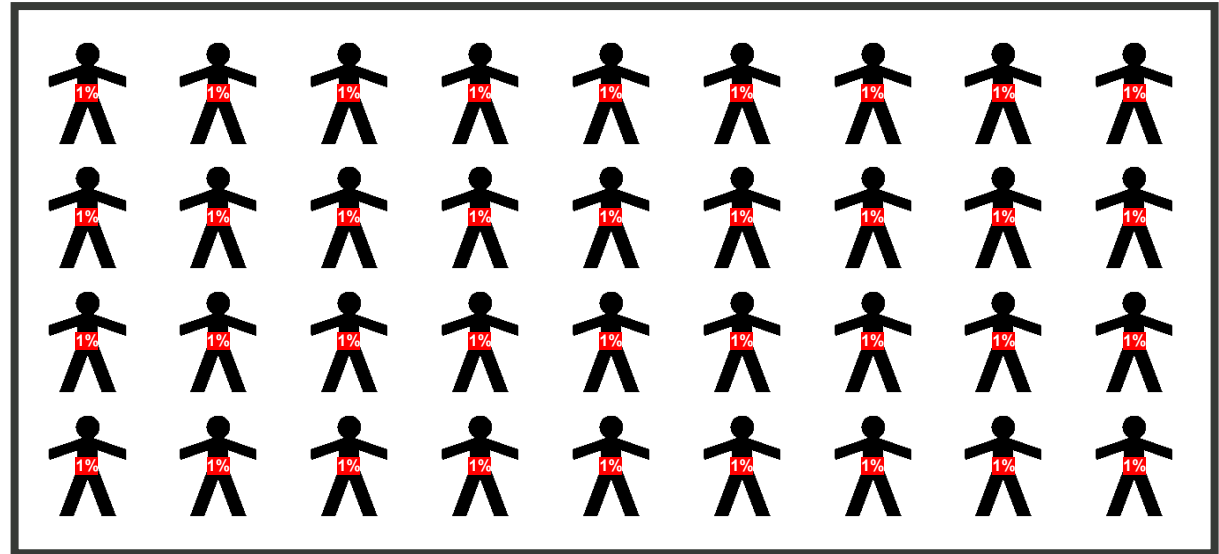
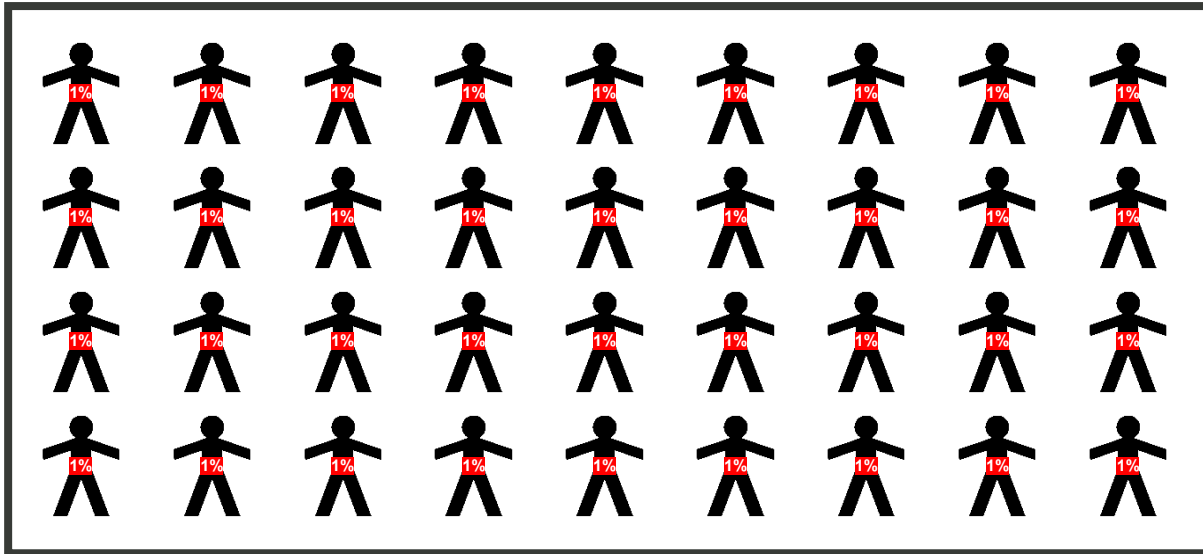
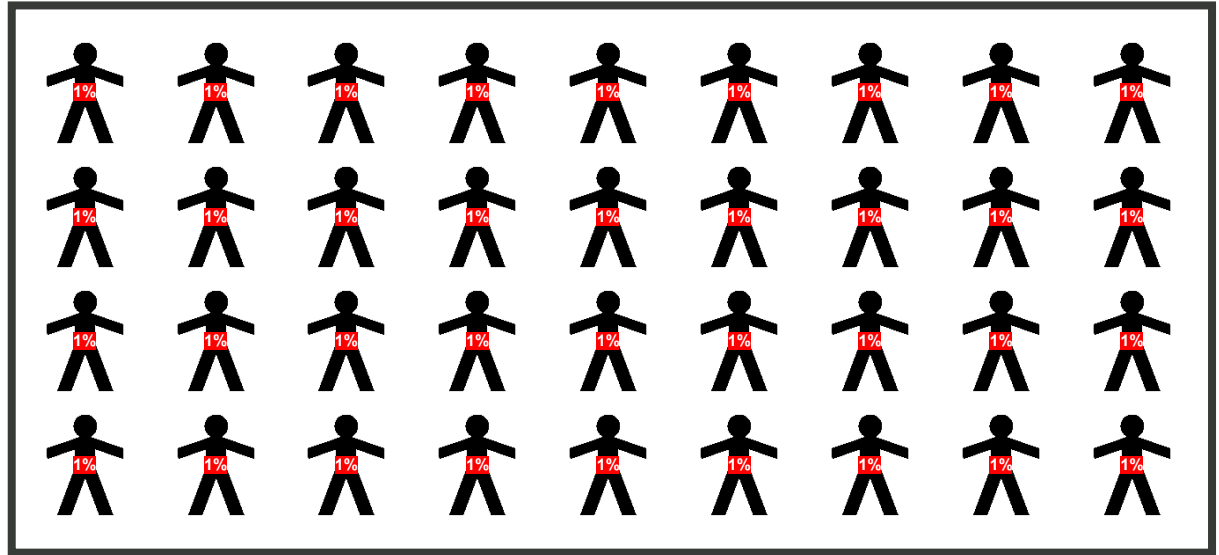
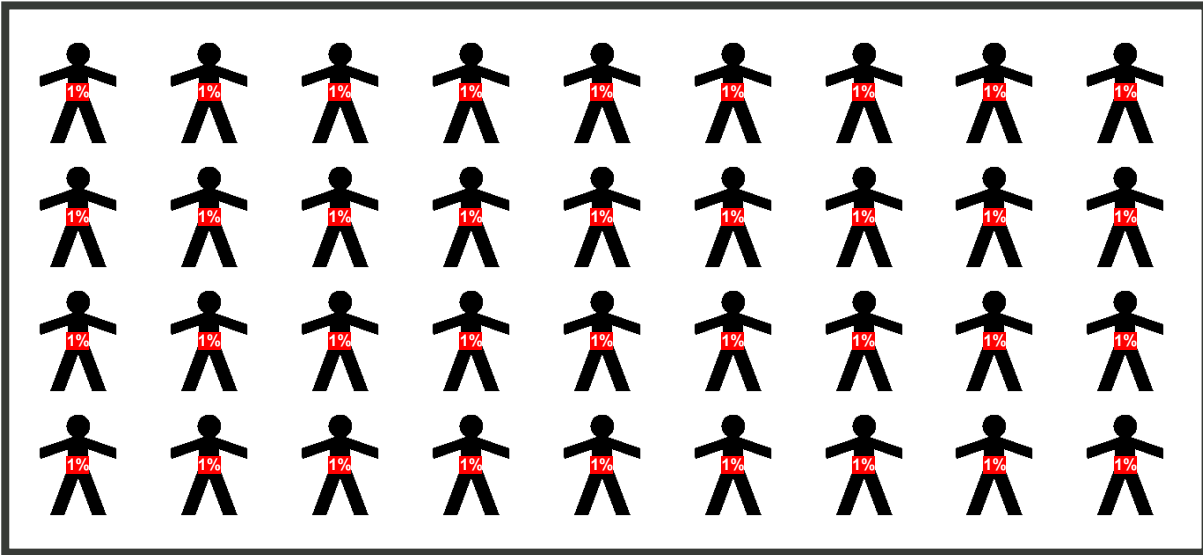
# COVID-19 now



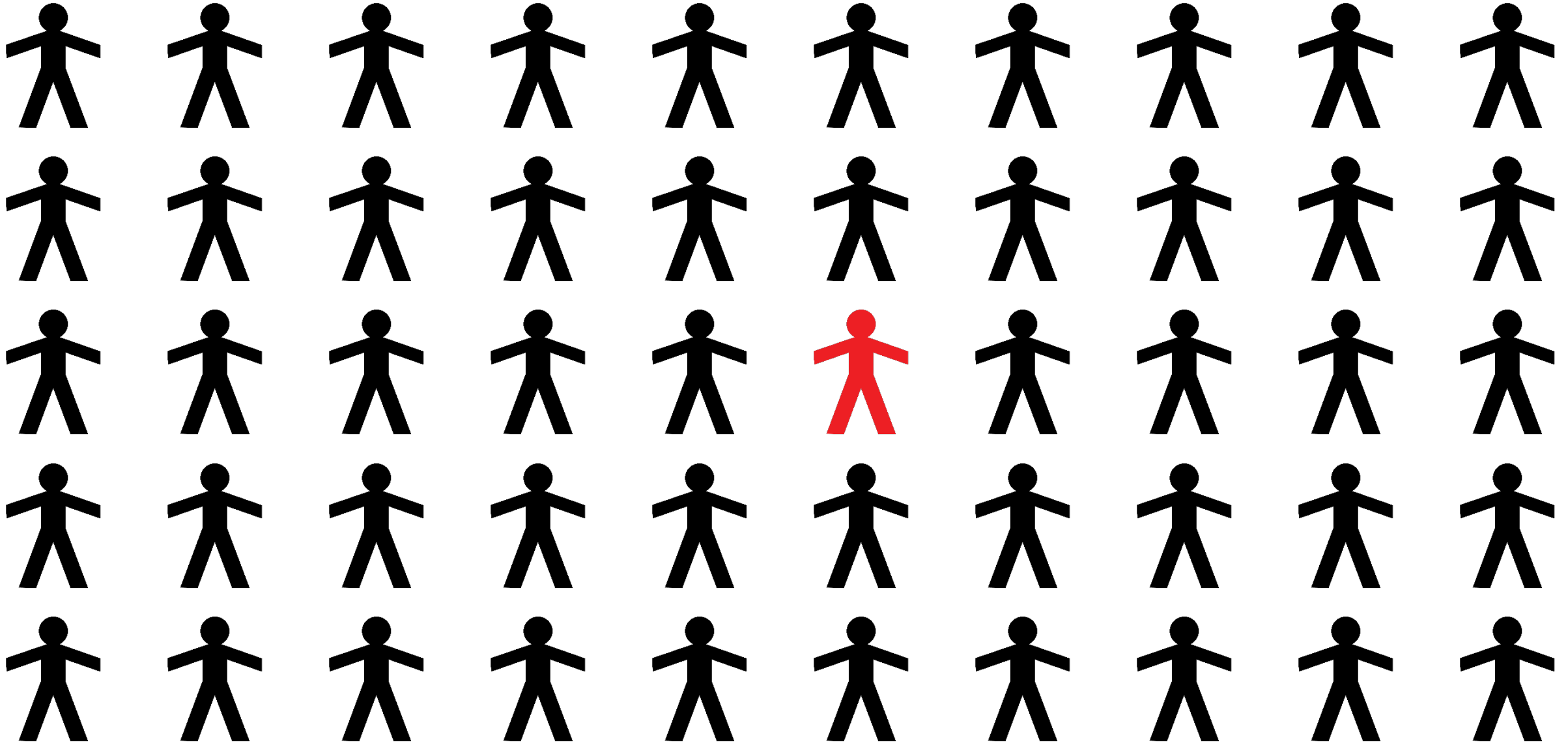
## Probability of "At Least One" in a 20 Person Gathering



**PROBABILITY OF AT LEAST ONE**



**MULTIPLE EVENTS ABSOLUTE**

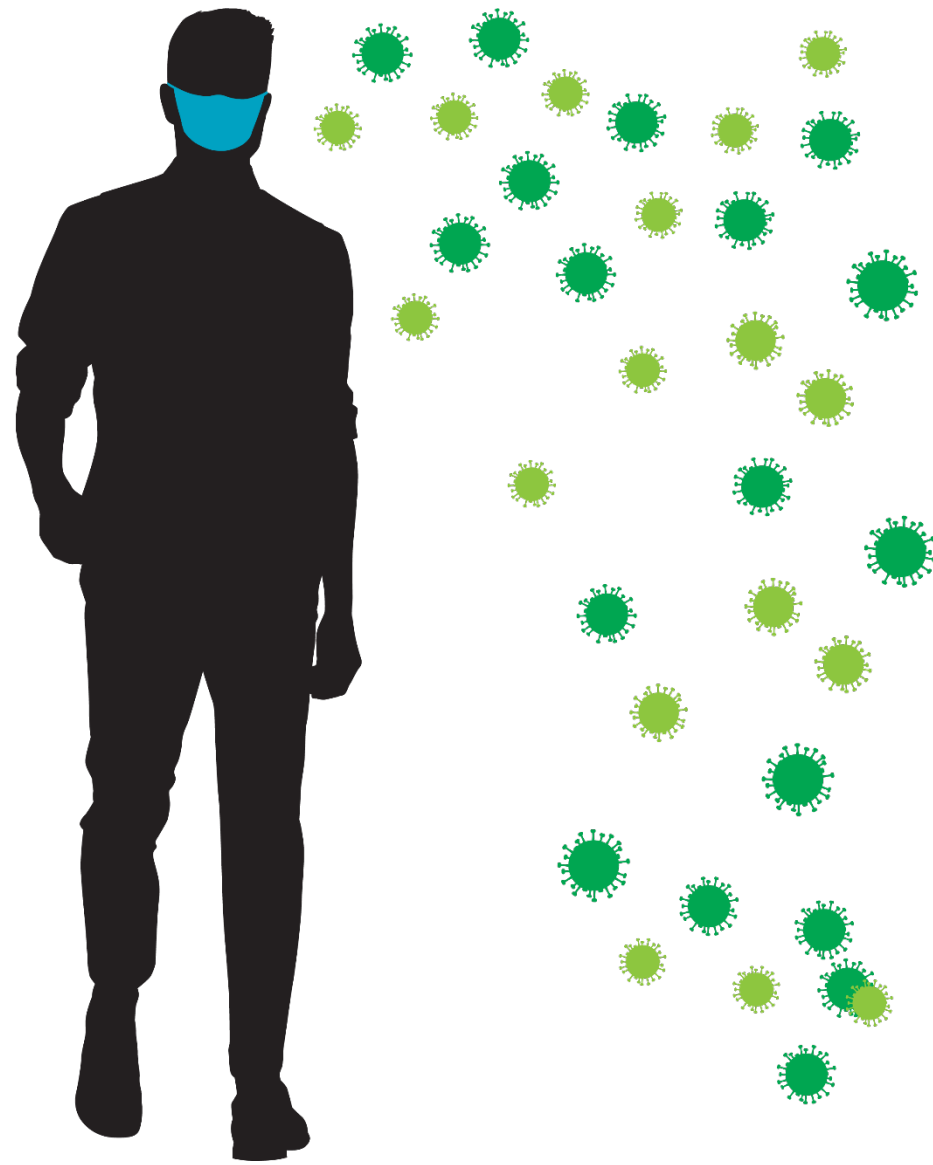


**SINGLE EVENT DISCRETE**

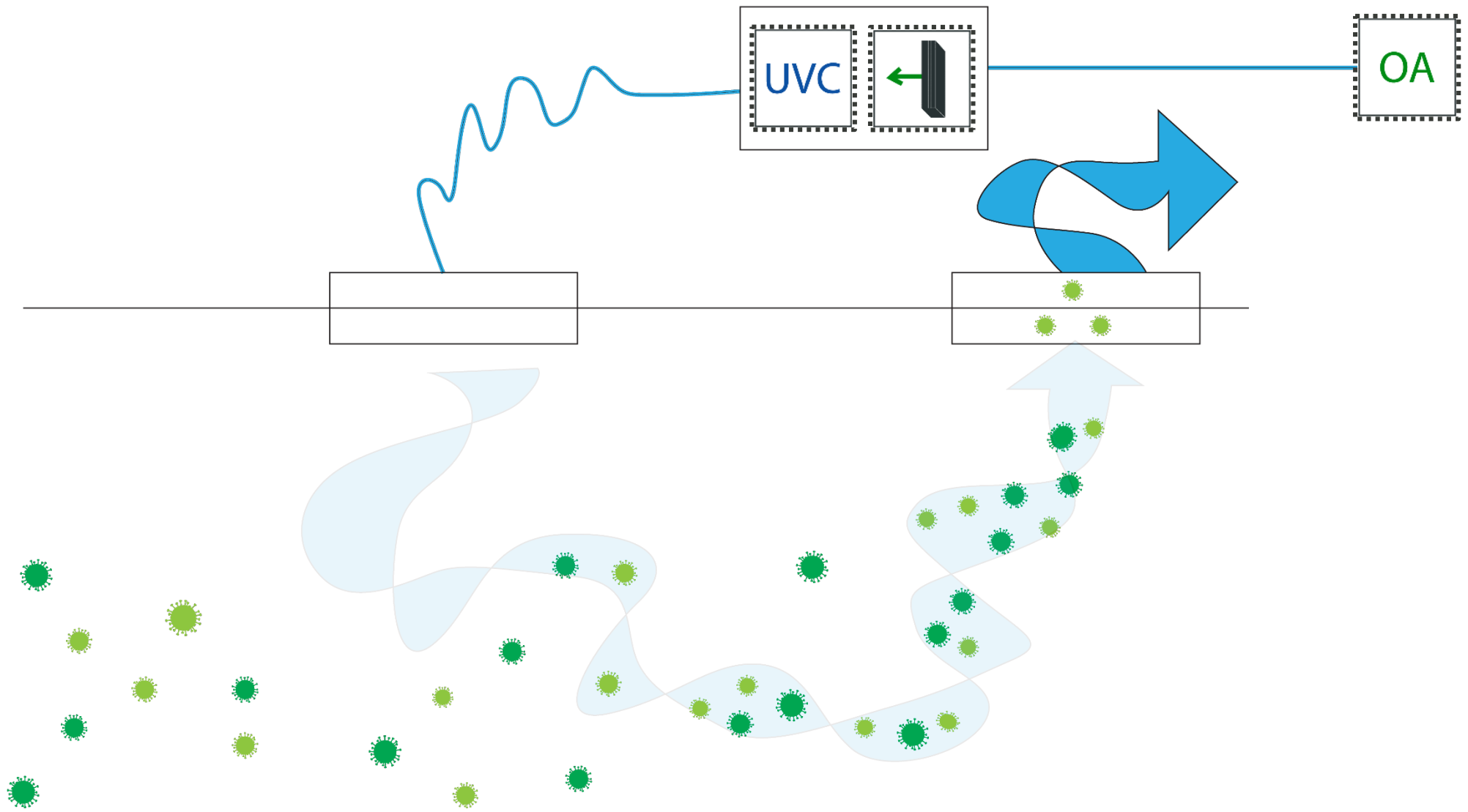


# MITIGATION STRATEGIES

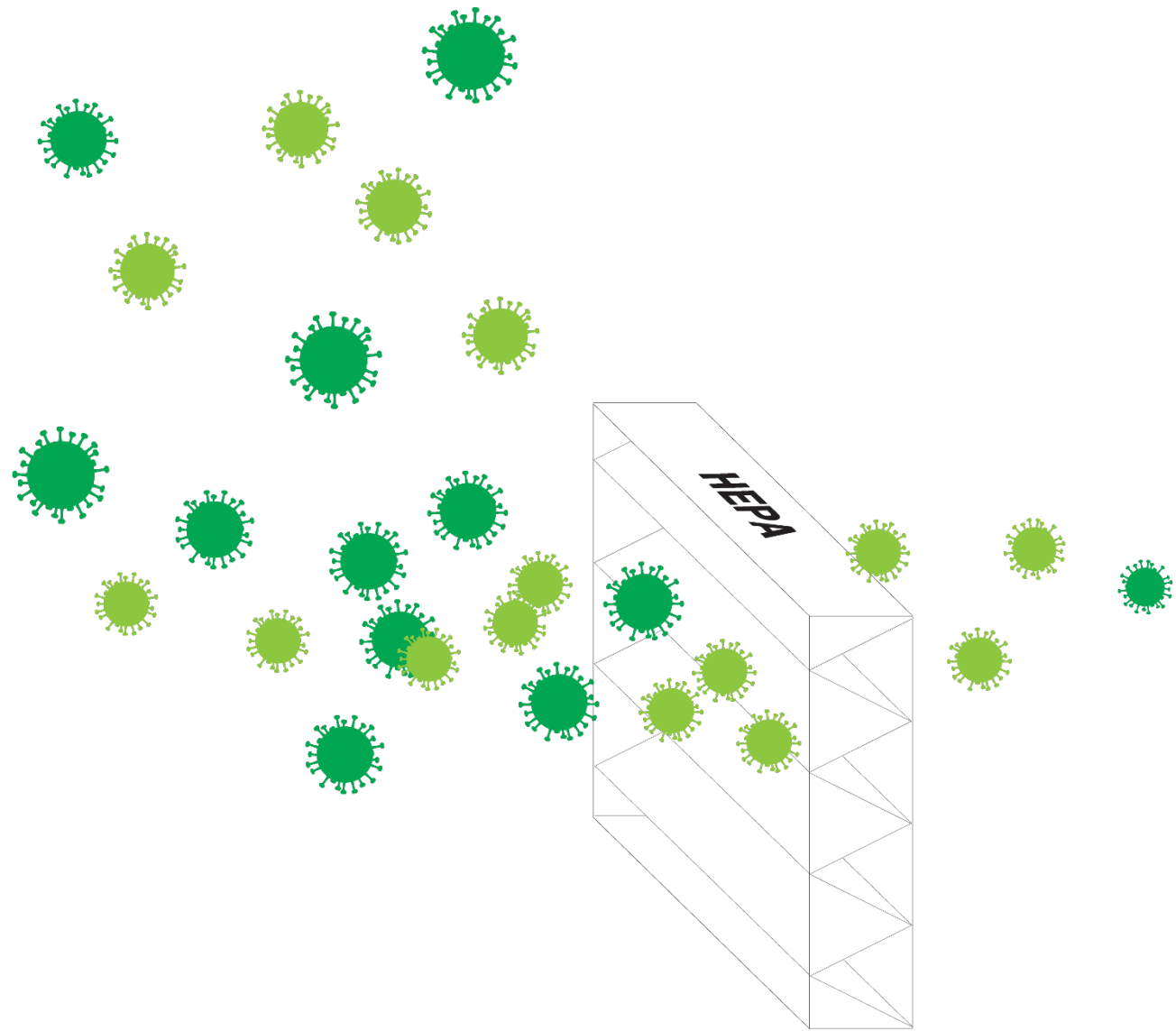




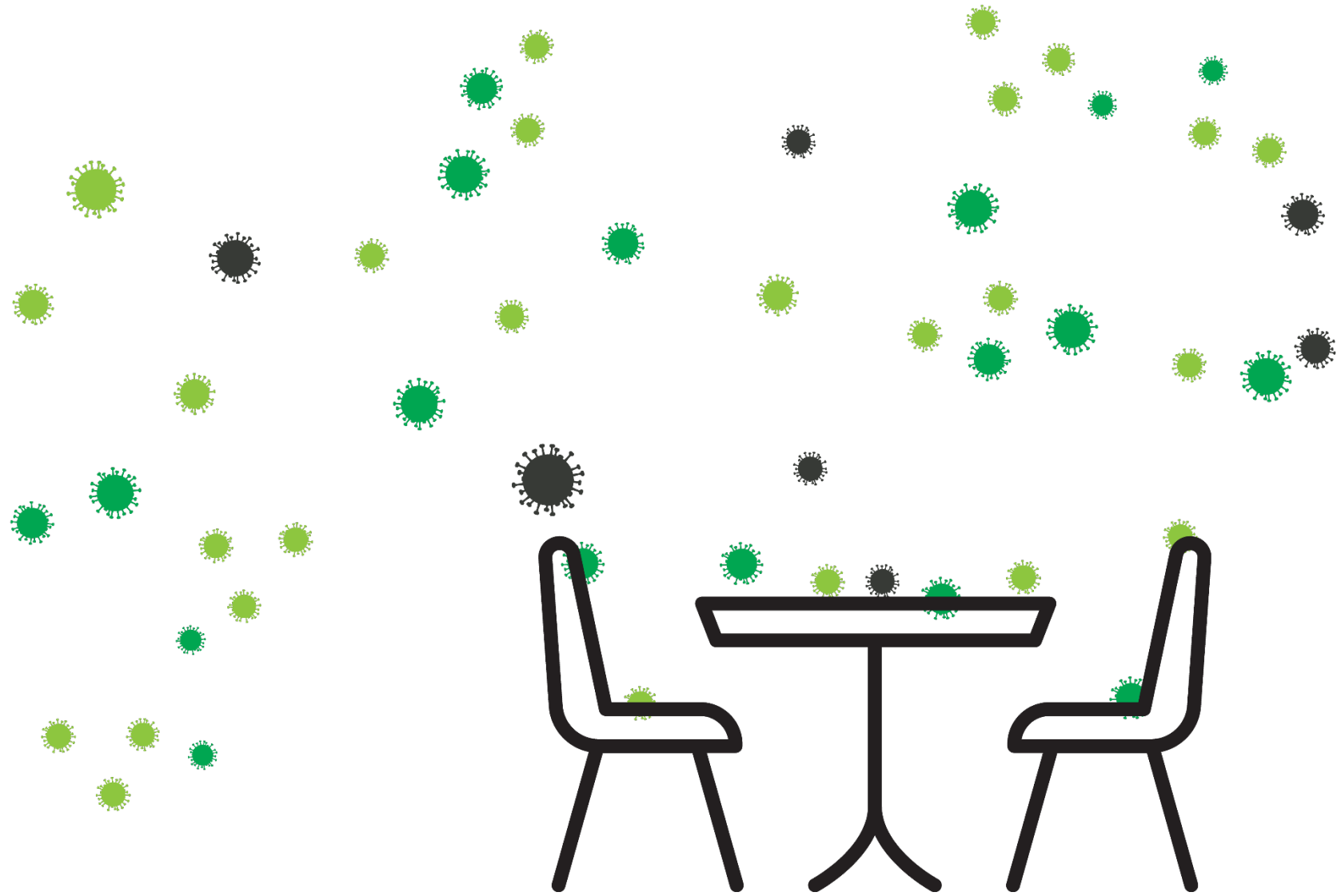
**MITIGATION FOR QUANTA GENERATED**



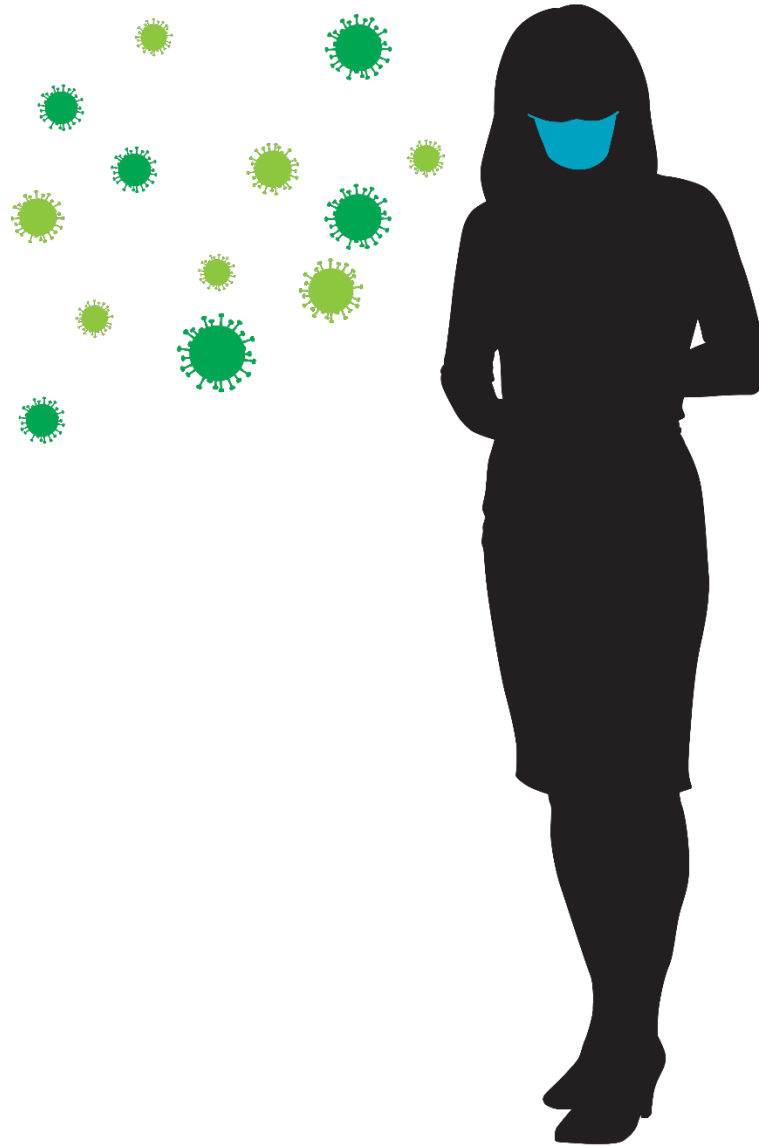
## MECHANICAL/HVAC MEASURES



## IN-ROOM MEASURES



**BIOLOGY AND PHYSICS**



**MITIGATION FOR QUANTA INHALED**



# KEY TAKEAWAYS



## KEY TAKEAWAYS

- The Wells-Riley equation gives us a tool for tracking infectious quanta from generation to inhalation
- The Quanta Generation Rate is a theoretical value that describes the relative virulence of a pathogen
- The Quanta Generation Rate of SARS-COV-2 is unknown

**QUIZ TIME**

**+**

**5 MINUTE BREAK**

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# ESTIMATING RISK:

# FINDING QUANTA GENERATION RATE

## RECAP: IMPORTANCE OF QUANTA

- Quanta generation rate is a **critical variable** for the probability of infection equation
- Determines the virulence of the disease

Infectious Disease	Reported Value of Quanta Generation Rates (q)
Rhinovirus (Common Cold)	~1-10 per hour
Tuberculosis	~1-50 per hour
SARS (SARS-CoV-1)	~10-300 per hour
Influenza	~15-500 per hour
Measles	~570-5600 per hour
COVID-19 (SARS-CoV-2)	???

- Quanta is unknown for COVID-19; so, how do we find it?

The background features a dark blue gradient with a large, faint, circular pattern in shades of blue and purple. A solid green horizontal band runs across the middle of the image, containing the text.

# EMPIRICAL ANALYSIS

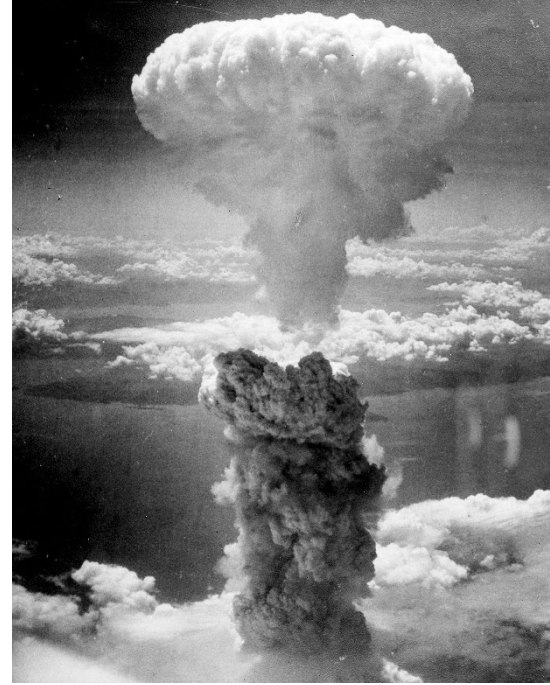
# MONTE CARLO EXPLAINED

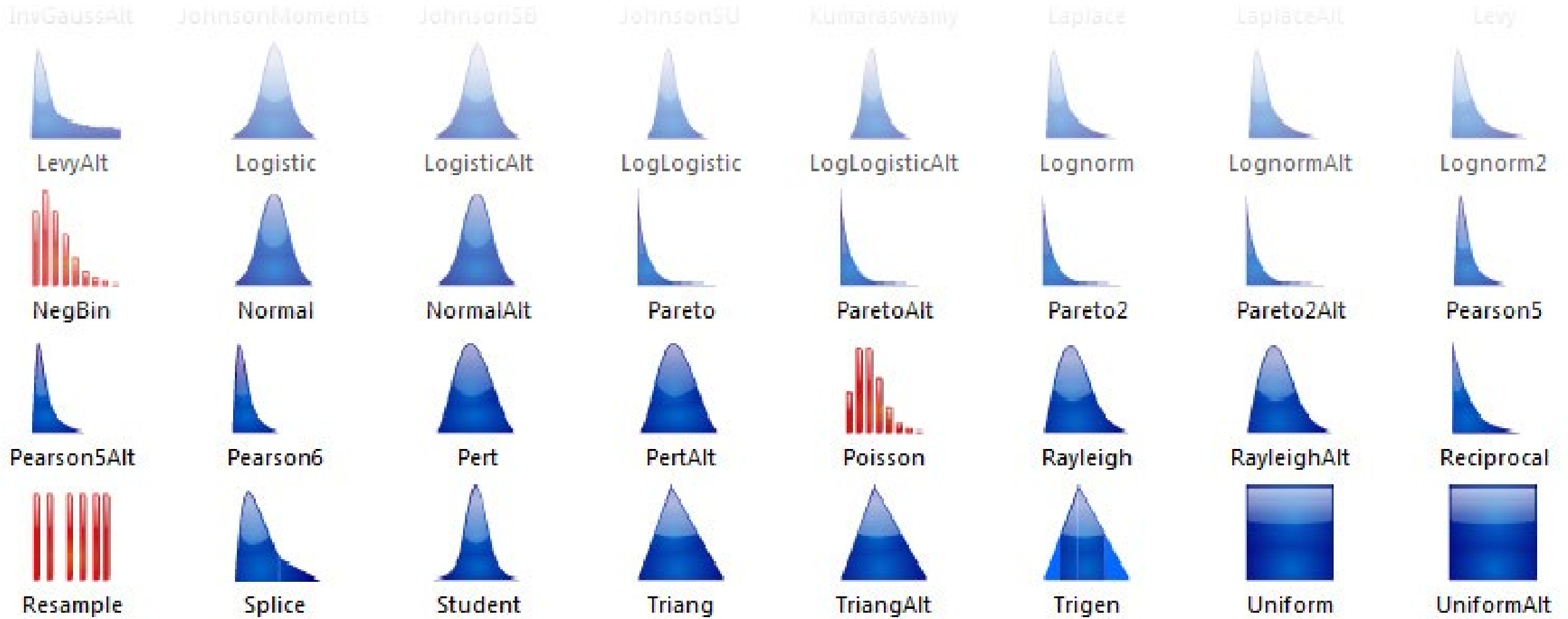
## ORIGIN

- Developed by Stanislaw Ulam – a mathematician on the Manhattan Project
- Named for the famed gambling destination in Monaco due to the role of chance and random outcomes

## HOW IT WORKS

- Statistical probability analysis
- Allows a range of values and expected distribution to be applied to unknown variables
  - Everything from the riskiest outcome to the most conservative option and all the possibilities in between





## MONTE CARLO EXPLAINED

SOURCE: [https://www.palisade.com/risk/monte\\_carlo\\_simulation.asp](https://www.palisade.com/risk/monte_carlo_simulation.asp)

## HOW IS MONTE CARLO USED

- Wind energy yield analysis
- Autonomous robotics
- Telecommunications network scenarios
- Climate change forecasting
- Computer graphics – light path tracing in video games
- Applied statistics
- Insurance companies
- Business pursuits





# **QUANTIFYING COVID-19: EMPIRICAL CASE STUDIES**



## WHAT WAS OUR STRATEGY?

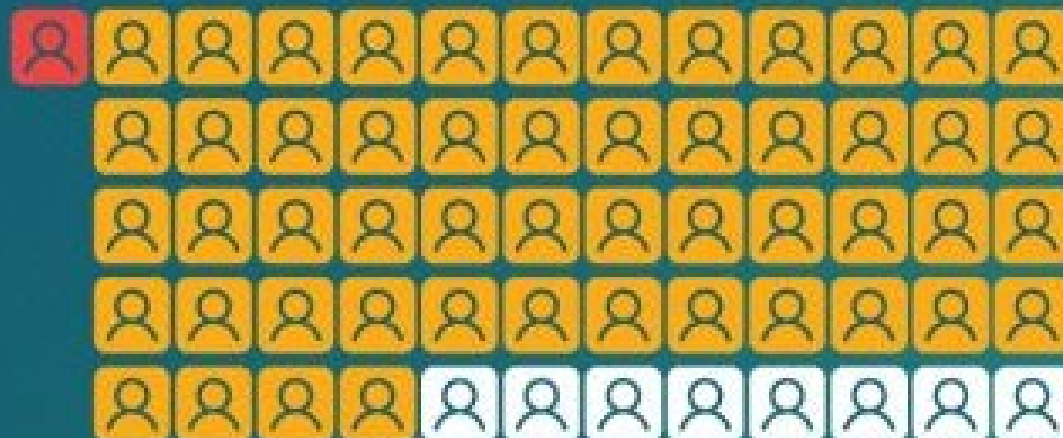
### SIMULATE ACTUAL CASES USING THE WELLS-RILEY AND MILLER EQUATIONS

- Determine the % of people infected in each event
- Enter in all known data about the event
- Identify unknown inputs and apply industry best practices to estimate their value
- Apply probability functions to these values to quantify uncertainty
- Back calculate for the quanta generation using Monte Carlo



# **CASE STUDY 1: WASHINGTON STATE CHOIR PRACTICE**

# After choir practice with one symptomatic person, 87% of group developed COVID-19



● Index case

● 32 confirmed and 20 probable cases

● unaffected person

**COVID-19 spreads easily**






- Avoid groups
- Stay at least 6 feet apart
- Wear face coverings

CDC.GOV

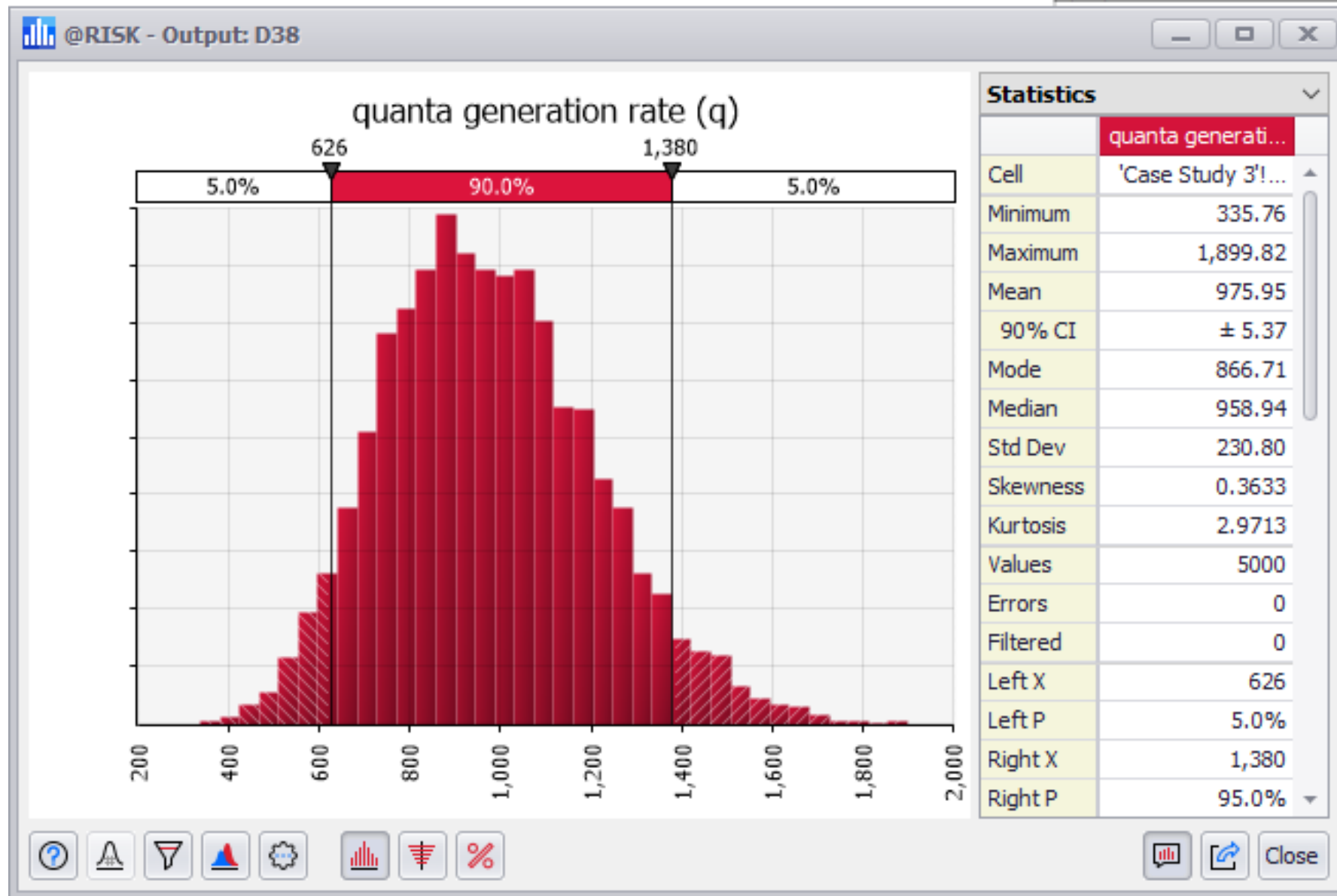
[bit.ly/MMWR51220](https://bit.ly/MMWR51220)

MMWR

**THE STORY**

Parameter	Value	Probability Distribution
Number of People	61	Constant (known)
Number Infected	32 – 53	Pert 
Exposure Time	2.5 hour	Constant (known)
Volume of Space	810 m <sup>3</sup>	Constant (known)
Design Primary Air	1.0 CFM/SF	Constant (known)
OA Fraction	0.08 – 0.27	Uniform 
Filter	MERV 11	Constant (known)
Deposition Rate	0.3 – 1.5	Uniform 
Inactivation Rate	0 – 0.63	Uniform 
Breathing Rate	21.4 – 31.7 L/min	Uniform 

## SIMULATION SETUP










**THE RESULTS - WASHINGTON STATE CHOIR PRACTICE**



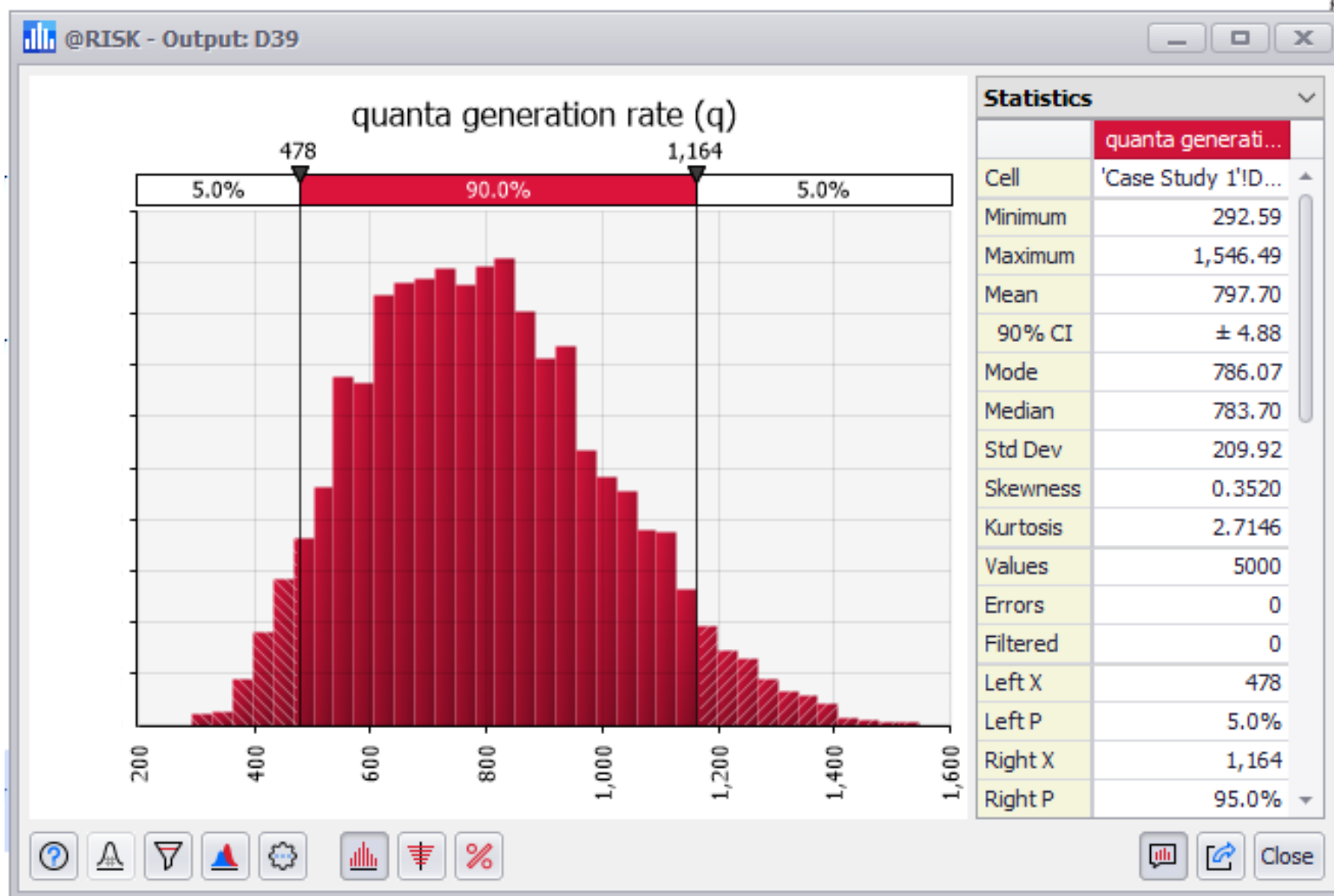
# **CASE STUDY 2: CALL CENTER IN SOUTH KOREA**



## THE STORY

Parameter	Value	Probability Distribution
Number of People	173	Constant (known)
Number Infected	79 (57.7%)	Constant (known)
Exposure Time	8 – 10 hour	Uniform 
Volume of Space	1667 – 2084 m <sup>3</sup>	Uniform 
Design Primary Air	0.5 – 1.5 CFM/SF	Uniform 
OA Fraction	0.05 – 0.3	Uniform 
Filter	MERV 7	Constant (known)
Deposition Rate	0.3 – 1.5	Uniform 
Inactivation Rate	0 – 0.63	Uniform 
Breathing Rate	10.5 – 14.4 L/min	Uniform 

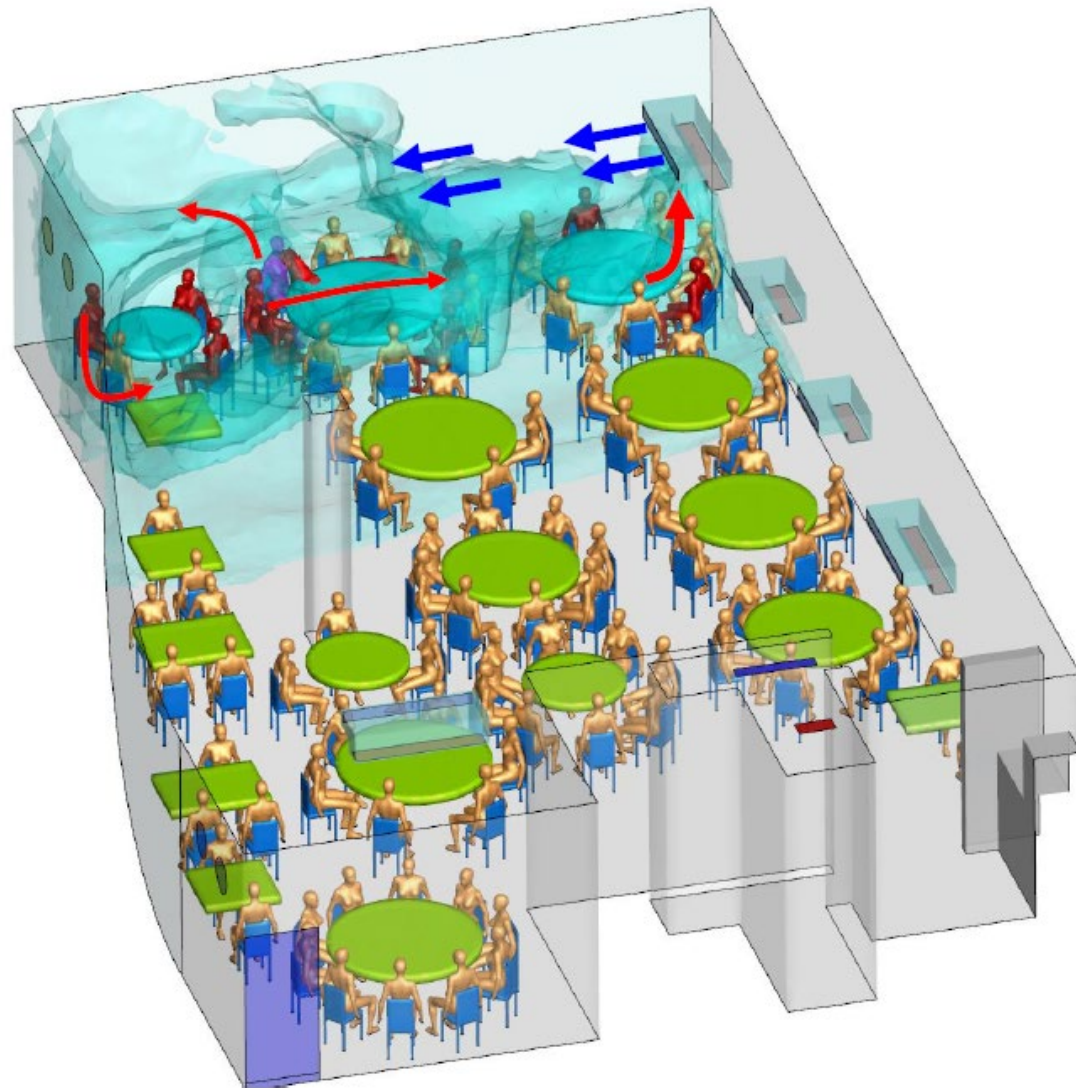
## SIMULATION SETUP



**THE RESULTS - CALL CENTER IN SOUTH KOREA**








# **CASE STUDY 3: RESTAURANT IN GUANGZHOU, CHINA**

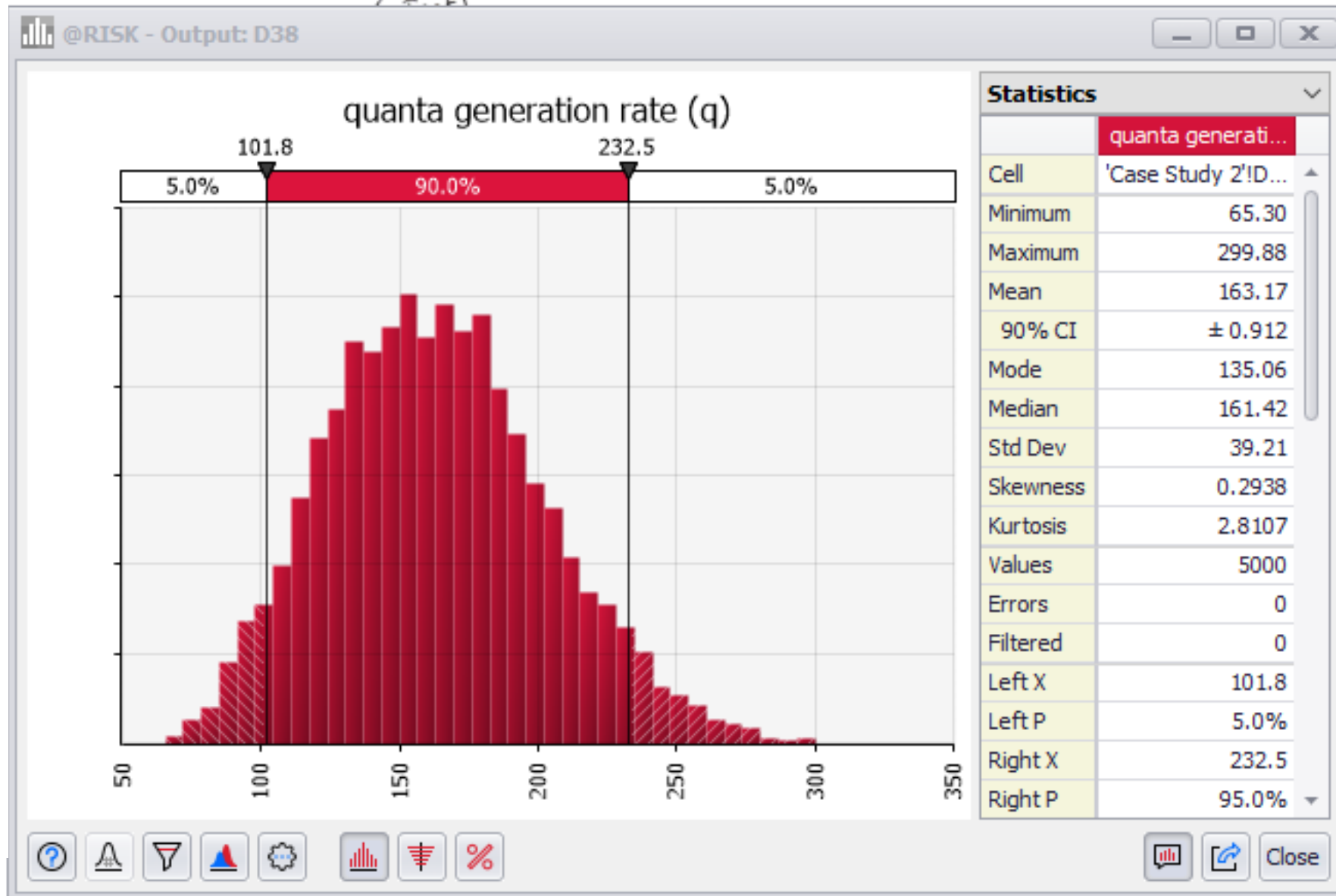


## THE STORY

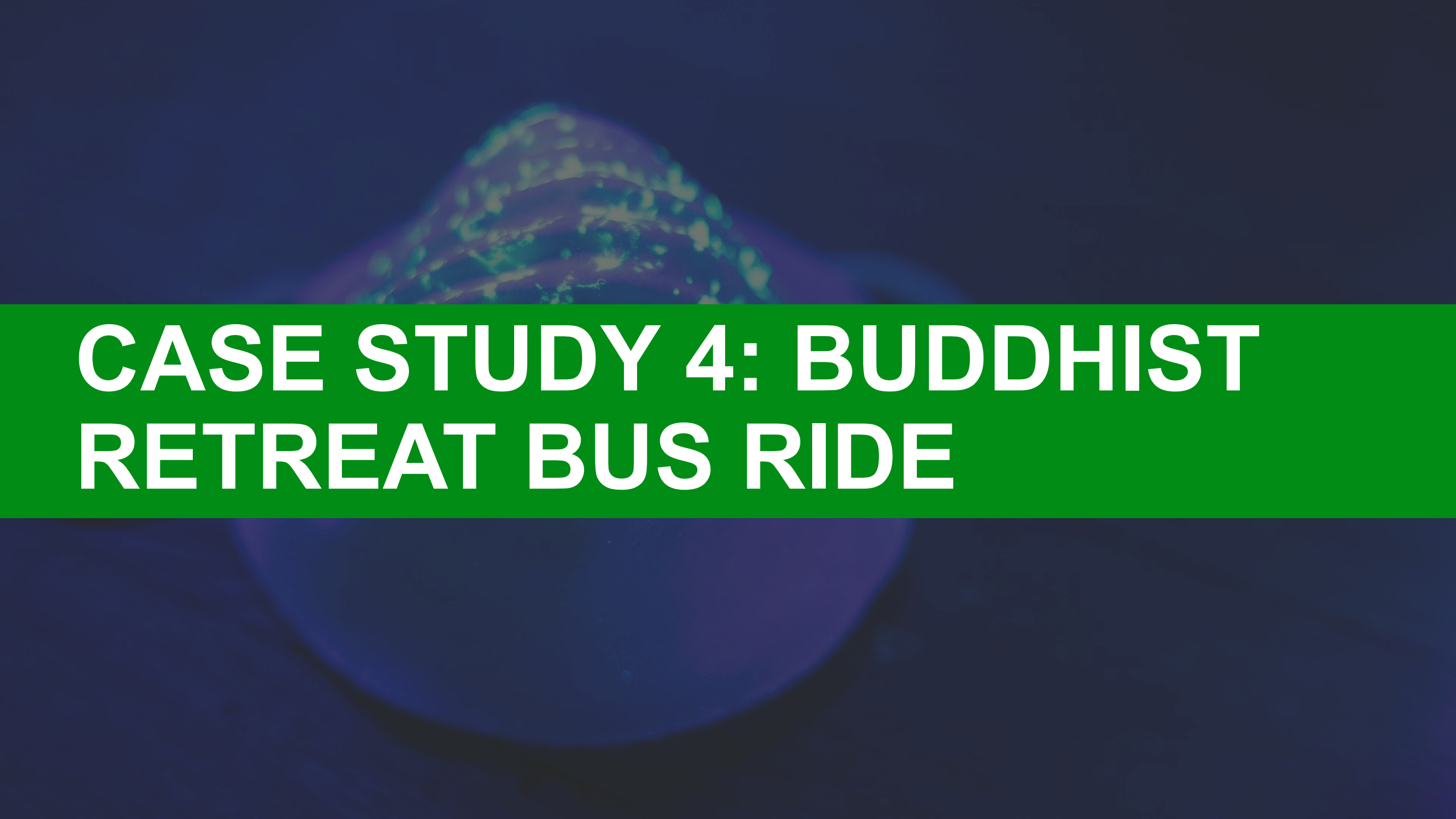
**SOURCE:** El Pais | [https://english.elpais.com/spanish\\_news/2020-06-17/an-analysis-of-three-covid-19-outbreaks-how-they-happened-and-how-they-can-be-avoided.html](https://english.elpais.com/spanish_news/2020-06-17/an-analysis-of-three-covid-19-outbreaks-how-they-happened-and-how-they-can-be-avoided.html)

Parameter	Value	Probability Distribution
Number of People	21	Constant (known)
Number Infected	10 (47.6%)	Constant (known)
Exposure Time	0.9 – 1.25 hour	Uniform 
Volume of Space	38 m <sup>3</sup>	Constant (known)
Design Primary Air	1.0 – 2.0 CFM/SF	Uniform 
OA Delivered	0.77 ACH	Constant (known)
Filter	MERV 4	Constant (known)
Deposition Rate	0.3 – 1.5	Uniform 
Inactivation Rate	0 – 0.63	Uniform 
Breathing Rate	4.2 – 5.8 L/min	Uniform 

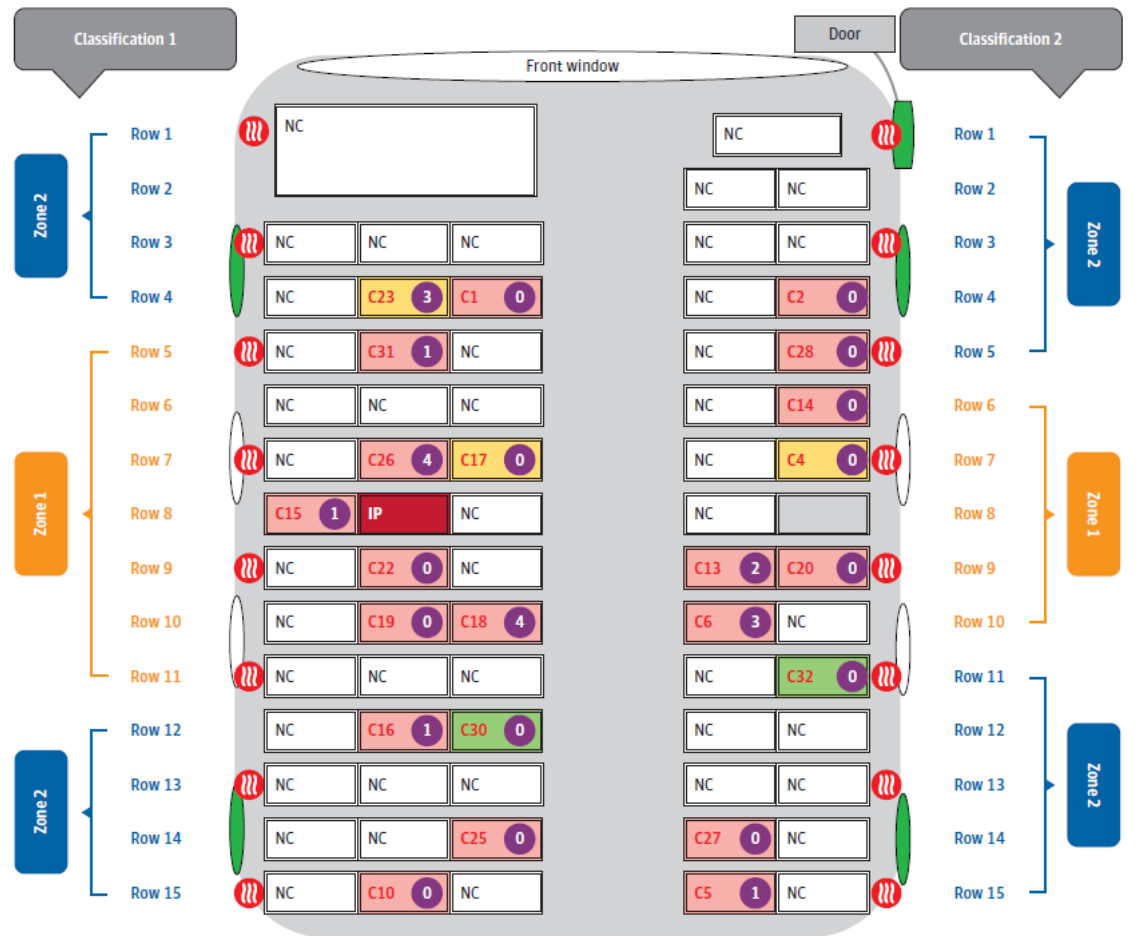
## SIMULATION SETUP



**THE RESULTS - RESTAURANT IN GUANGZHOU, CHINA**



# **CASE STUDY 4: BUDDHIST RETREAT BUS RIDE**







	Noncase		Asymptomatic case		Mild case		Moderate case		The index patient (a moderate case)		No. of tertiary cases infected		Air vents (warm air)
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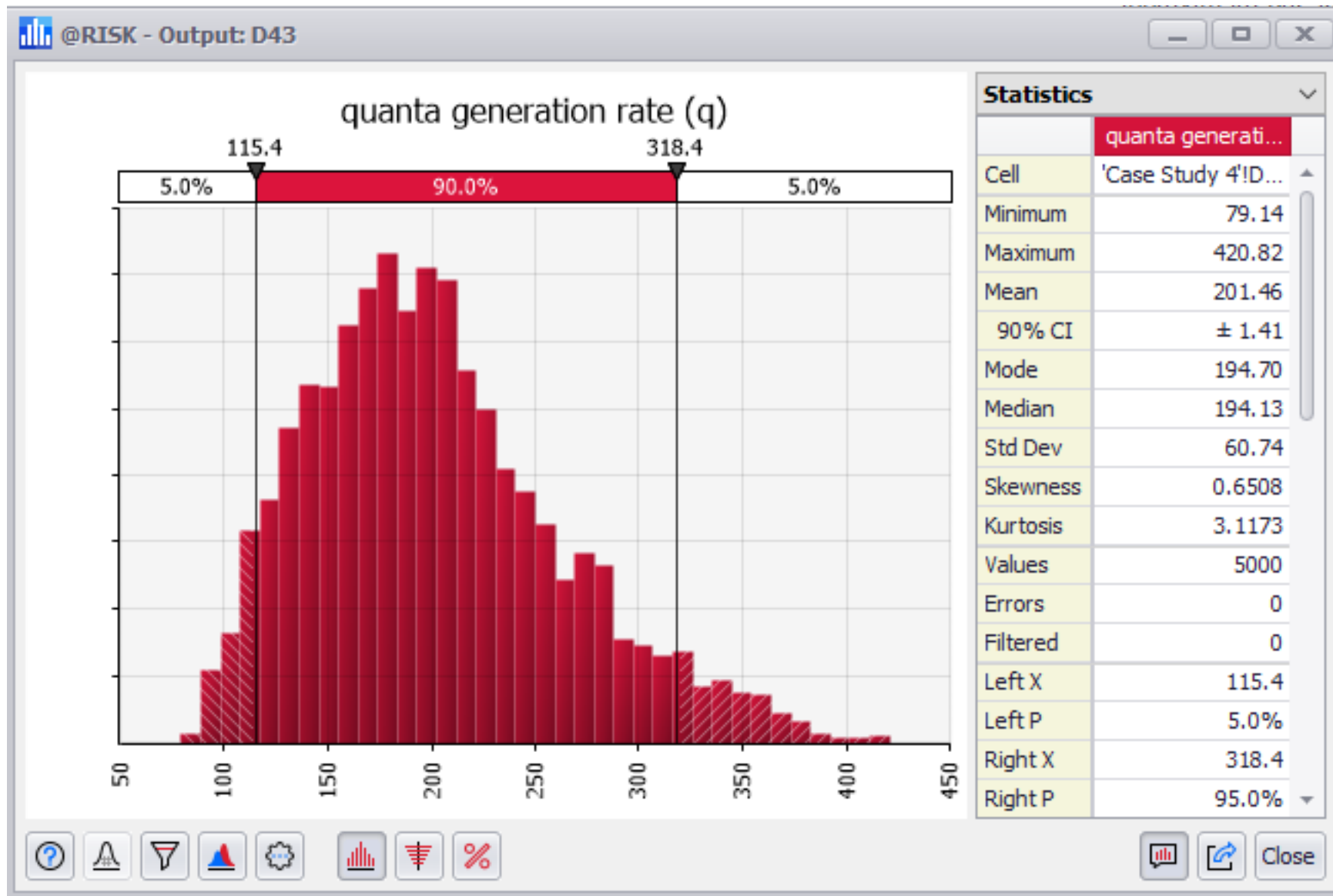
Classification 1<sup>17</sup> and 2.<sup>18</sup> Two different approaches to define high-risk and low-risk COVID-19 zones are indicated: zone 1 (high-risk zone) and zone 2 (low-risk zones). Severity levels of cases were indicated. Windows are indicated

with ovals, and there are 4 green side windows and that could be opened for fresh air. C indicates case; NC, noncase.

# THE STORY

Parameter	Value	Probability Distribution
Number of People	68	Constant (known)
Number Infected	24 (35.8%)	Constant (known)
Exposure Time	1.67 hr	Constant (known)
Volume of Space	51 m <sup>3</sup>	Constant (known)
Design Primary Air	4.0 – 6.0 CFM/SF	Uniform 
OA Flow	0 CFM	Constant (known)
Filter	MERV 7	Constant (known)
Deposition Rate	0.3 – 1.5	Uniform 
Inactivation Rate	0 – 10	Uniform 
Breathing Rate	4.2 – 5.8 L/min	Uniform 

## SIMULATION SETUP



**THE RESULTS - BUDDHIST RETREAT BUS RIDE**

The background features a stylized globe with a blue and purple color scheme, showing some internal structure or data points. A solid green horizontal band runs across the middle of the image, containing the text.

# RESULTS VISUALIZATION

Case Study	Range	Mean Value
Miller, et. al.	680 – 1190	970
Washington State Choir Practice	626 – 1,380	976
Call Center in South Korea	478 – 1,164	798
Restaurant in Guangzhou, China	102 – 233	163
Buddhist Retreat Bus Ride	115 – 318	201

**THE RESULTS: ESTIMATED QUANTA GENERATION RATES**

Infection Disease	Reported Value of Quanta Generation Rates (q)
Rhinovirus (Common Cold)	~1-10 per hour
Tuberculosis	~1-50 per hour
SARS (SARS-CoV-1)	~10-300 per hour
Influenza	~15-500 per hour
<b>COVID-19 (SARS-CoV-2)</b>	<b>~100-1100 per hour (est. mean of 600)</b>
Measles	~570-5600 per hour

## CONCLUSION

**QUIZ TIME**

**+**

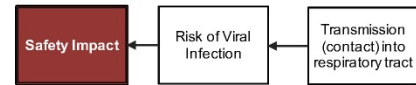
**5 MINUTE BREAK**

---

# ESTIMATING RISK: MITIGATION STRATEGIES

# HOW TO REDUCE THE RISK OF COVID-19 INFECTION THROUGH BUILDING DESIGN.

Transmission of COVID-19 in buildings requires two things — the active virus being present in sufficient quantity to cause infection and the transmission of that active virus into the respiratory tract of the person being infected. In public buildings, it's often difficult to control for the presence of the virus, but good design practices can work together to reduce the overall risk of infection.



## 3 Transmission Paths

Using the Cause Map diagram we are able to highlight the 3 potential transmission paths of a viral infection. Each path has different control opportunities (Solutions) that can reduce the risk of transmission. The 3 paths include:

### Surface Transmission

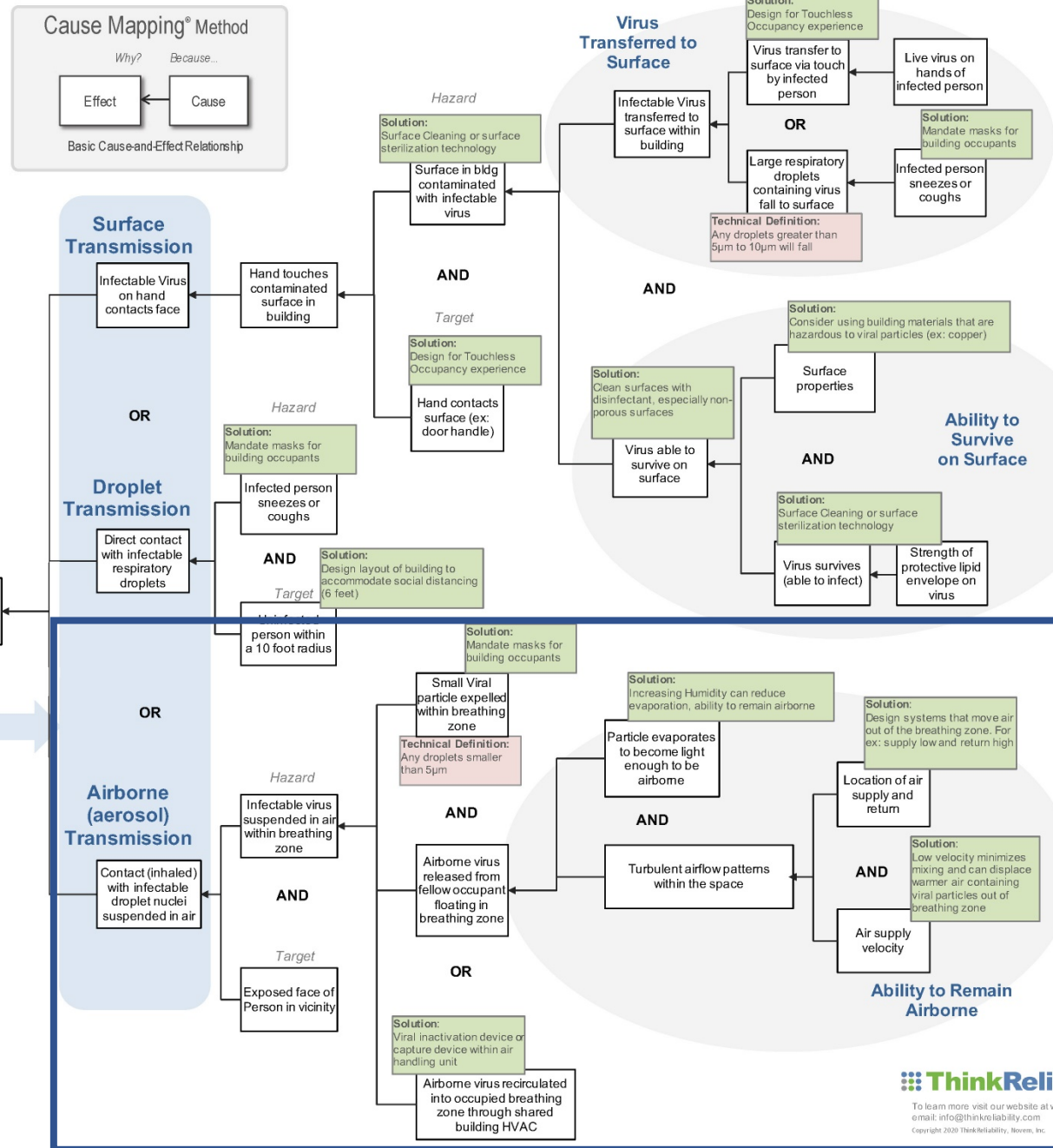
A person touches a contaminated surface and then inadvertently touches their face introducing the virus.

### Droplet Transmission

An infected person is talking, coughing, or sneezing within close contact of others. Large Respiratory droplets (greater than 5µm to 10µm) makes direct contact to infect.

### Airborne (aerosol) Transmission

An infected person is talking, coughing, or sneezing. The small respiratory droplets (less than 5µm to 10µm) remain suspended in air for a period of time and over greater distance.





## MODEL LIMITATIONS

- Assumes fully mixed room. Doesn't predict pockets of increased airborne quanta.
- Concentration is averaged over entire time occupied. Reality it would be worse at the end versus the beginning.
- Q is an estimate – not a known value
  - ~100-1100 with est. mean of 600



**K-12 CLASSROOM**



**OPEN OFFICE**



**CONFERENCE ROOM**



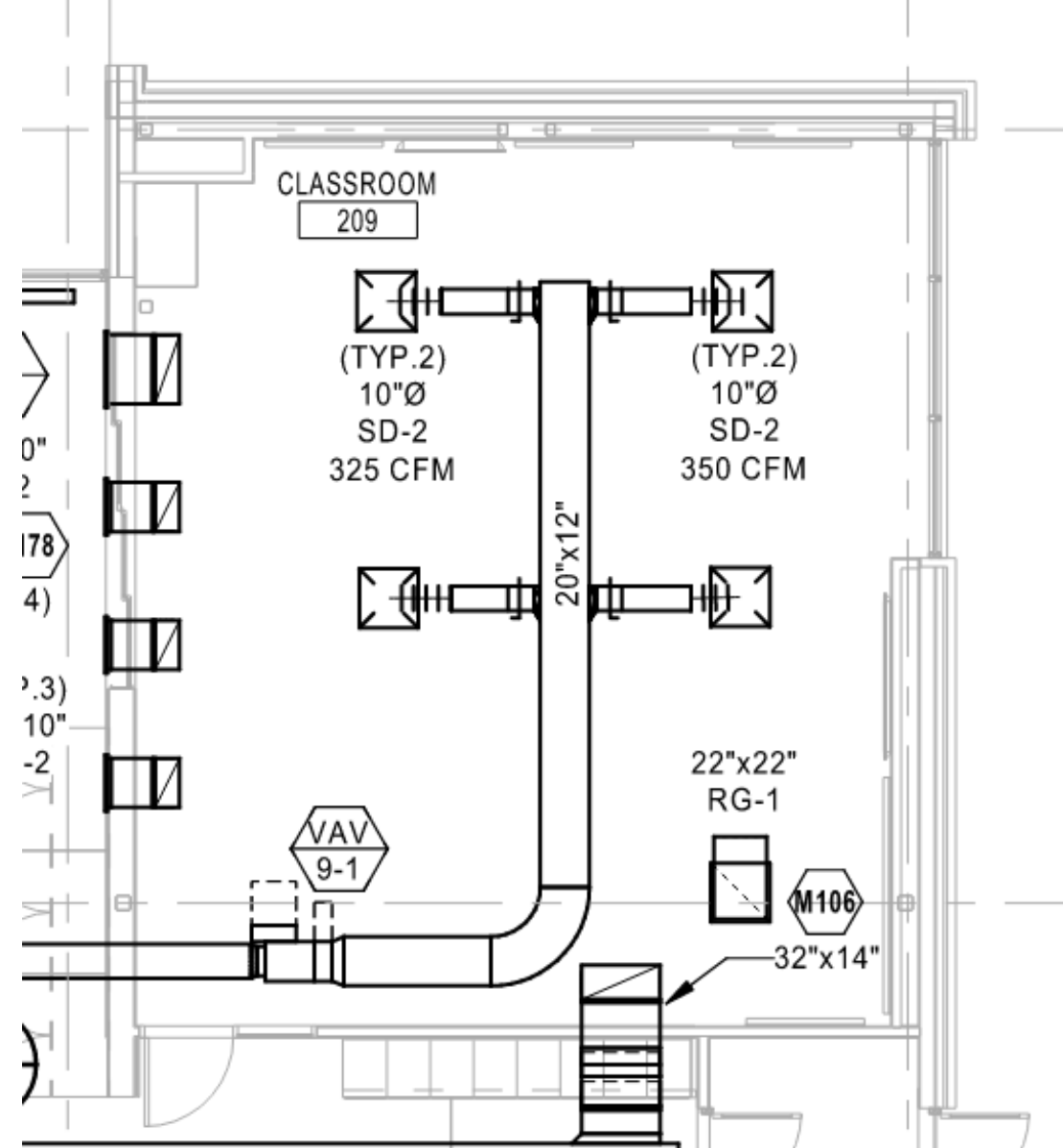
**GROCERY**

## **APPLICATIONS WE'LL LOOK AT**



# K-12 CLASSROOM





**K-12 CLASSROOM**




















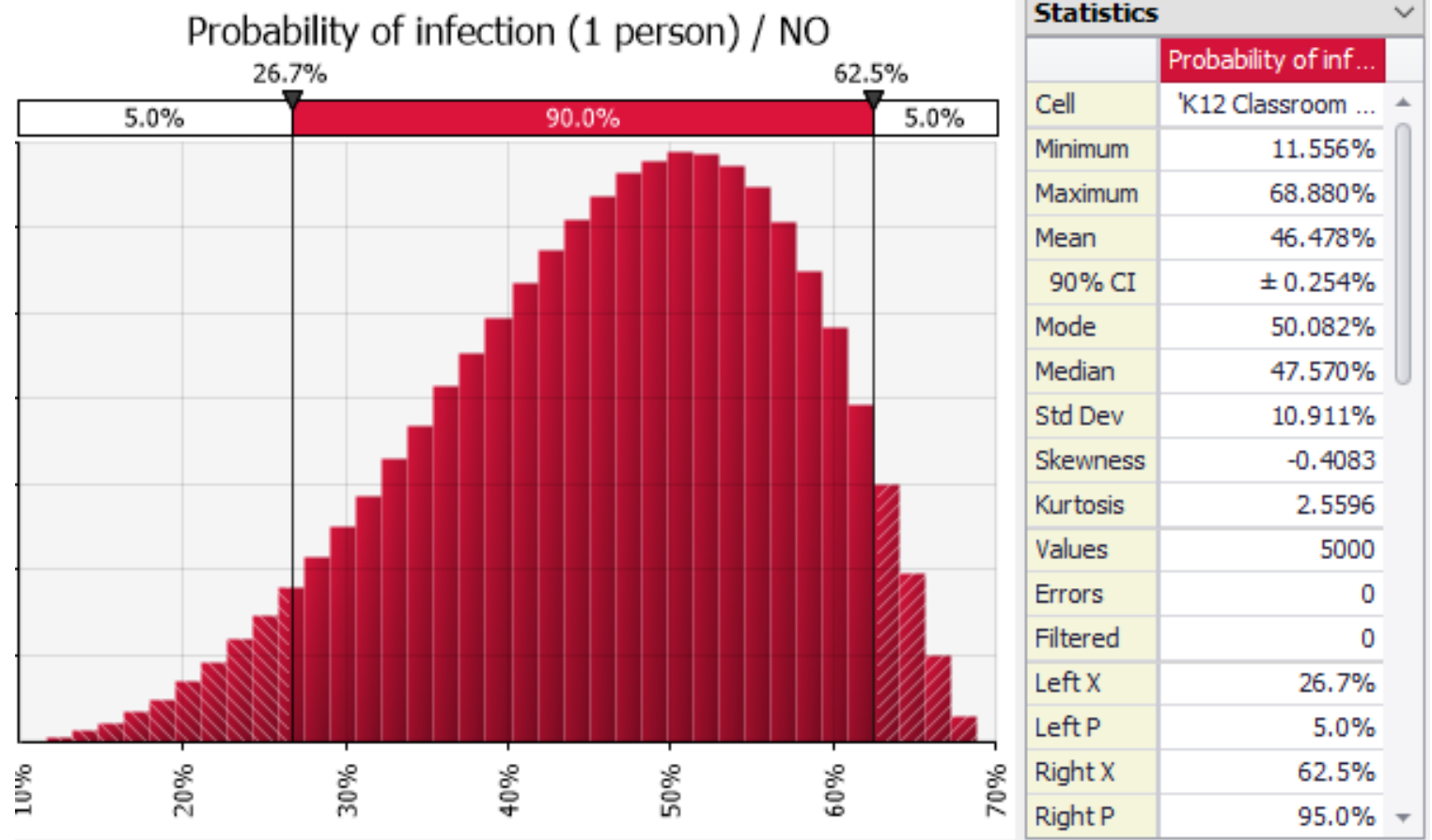
## KNOWN AND INPUTS

### ELEMENTARY SCHOOL, AGES 5 THROUGH 11

- 800 SQFT with 10 ft. ceilings
- Primary Air of 1350 CFM (1.69 CFM/SF). Assumed constant for the simulation.
- Outside Air set based on the parent HVAC unit (35% OA).
- 20 occupants in the classroom
- 1 assumed to be infectious
- Breathing rate of 4.9 L/min. - children 6 to 11 with sedentary activity
- Duration of 5.5 hours
- Q estimate 100-1100 with est. mean of 600

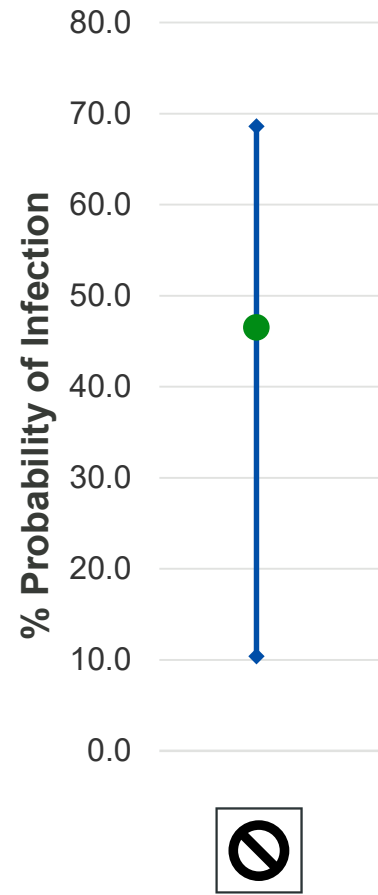
## MODELING STRATEGY

1. Base run with Code OA, MERV 7, no masks, no mitigation 
2. MERV 13 
3. 100% OA 
4. In-duct UVC 
5. MERV 13 + UVC  
6. MERV 13 + UVC + 100% OA   
7. MERV 13 + cloth masks  
8. MERV 13 + tight fitting N95 masks  
9. Tight fitting N95 masks 
10. MERV 13 + cloth masks + in-room HEPA @ 3 ACH   



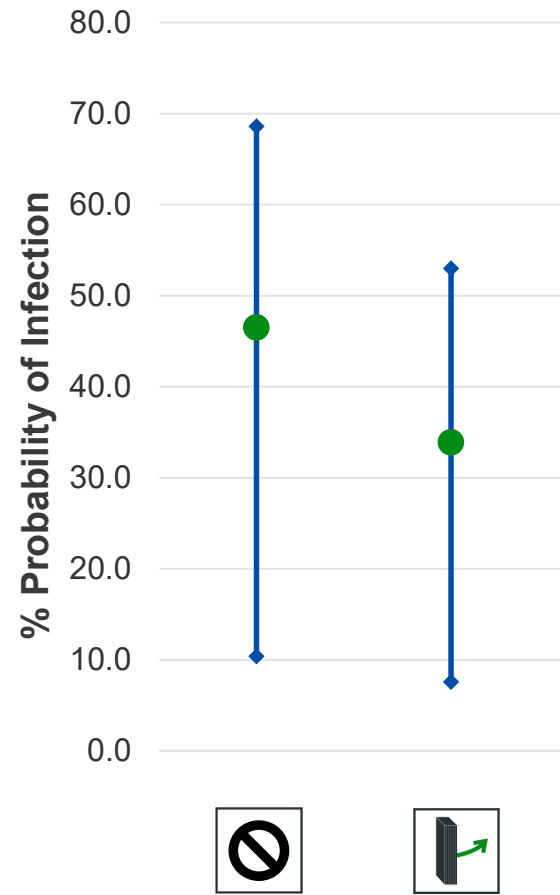
**WHAT THE RESULTS LOOK LIKE**

## Probability of Infection K12 Classroom



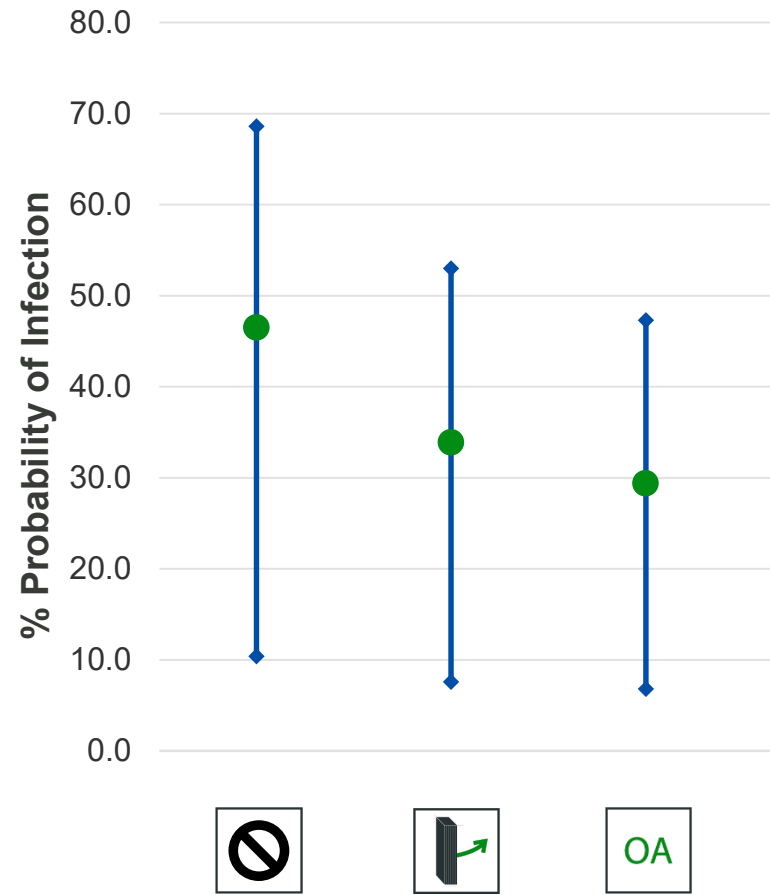
**K-12 CLASSROOM RESULTS**

## Probability of Infection K12 Classroom



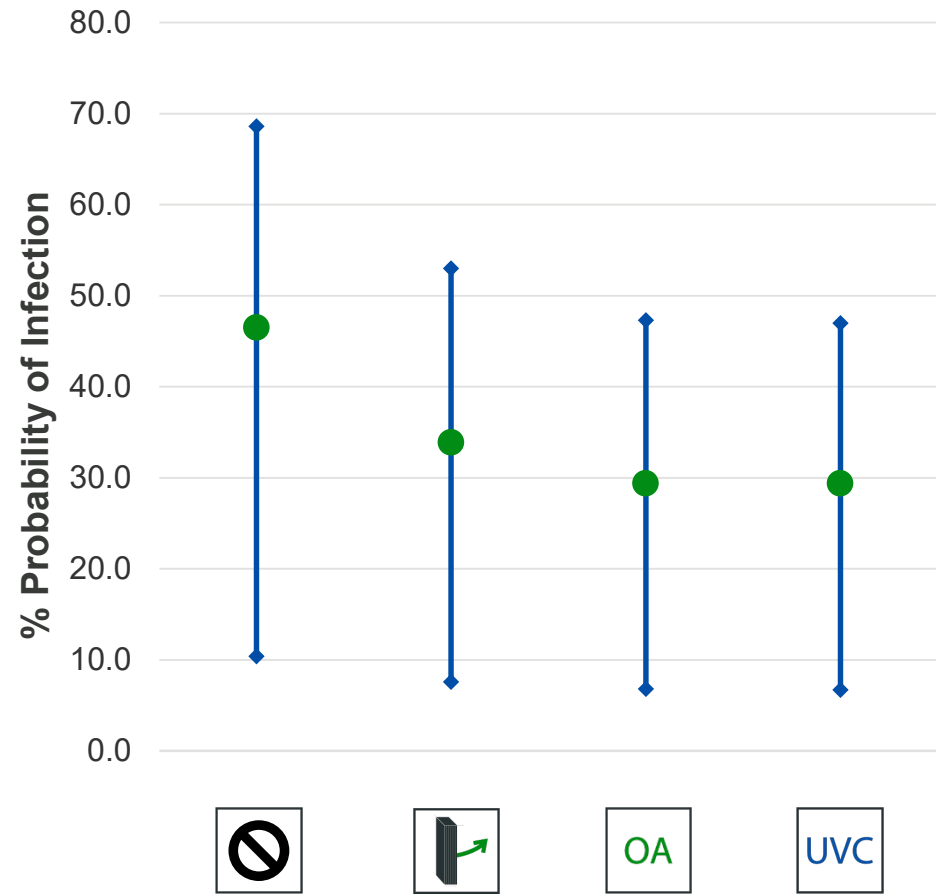
**K-12 CLASSROOM RESULTS**

## Probability of Infection K12 Classroom



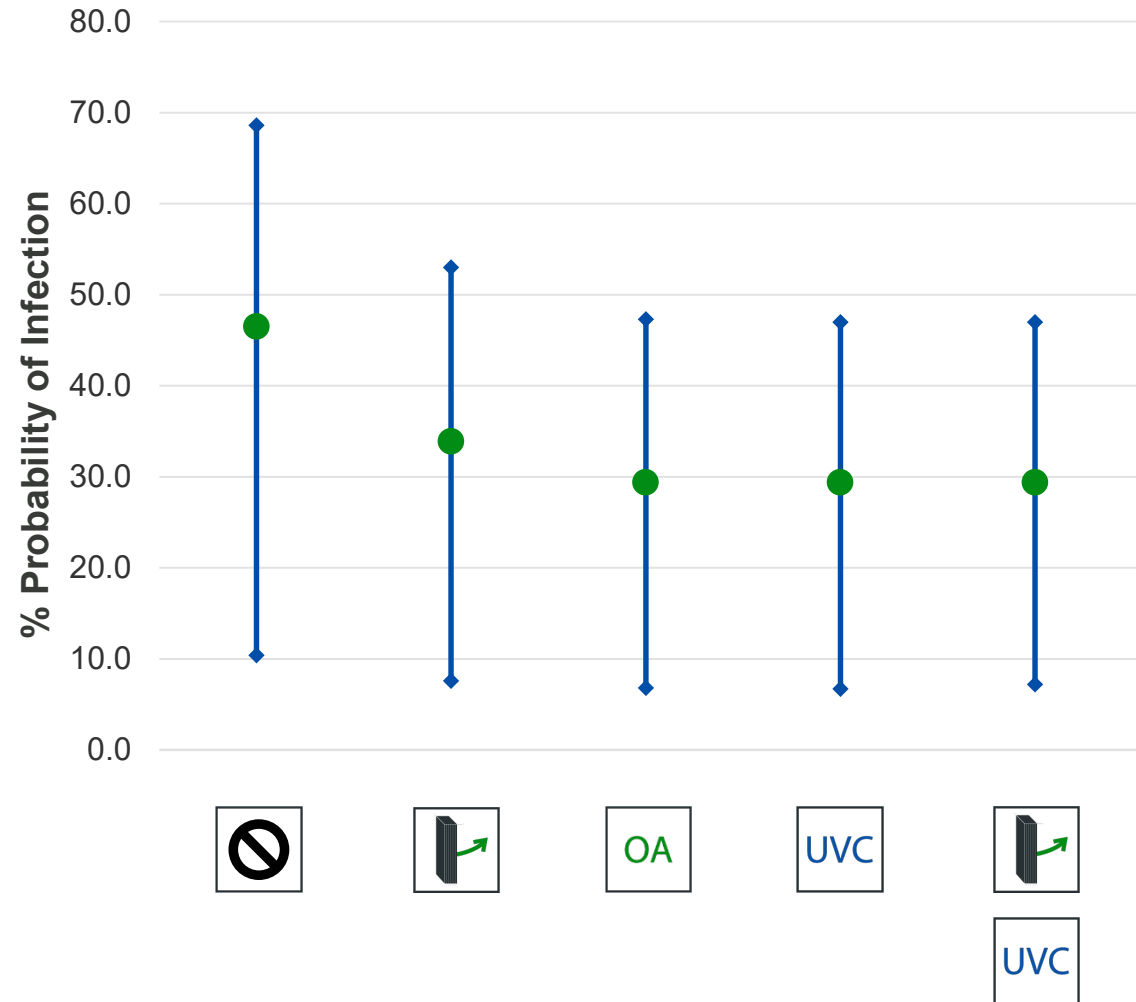
**K-12 CLASSROOM RESULTS**

## Probability of Infection K12 Classroom



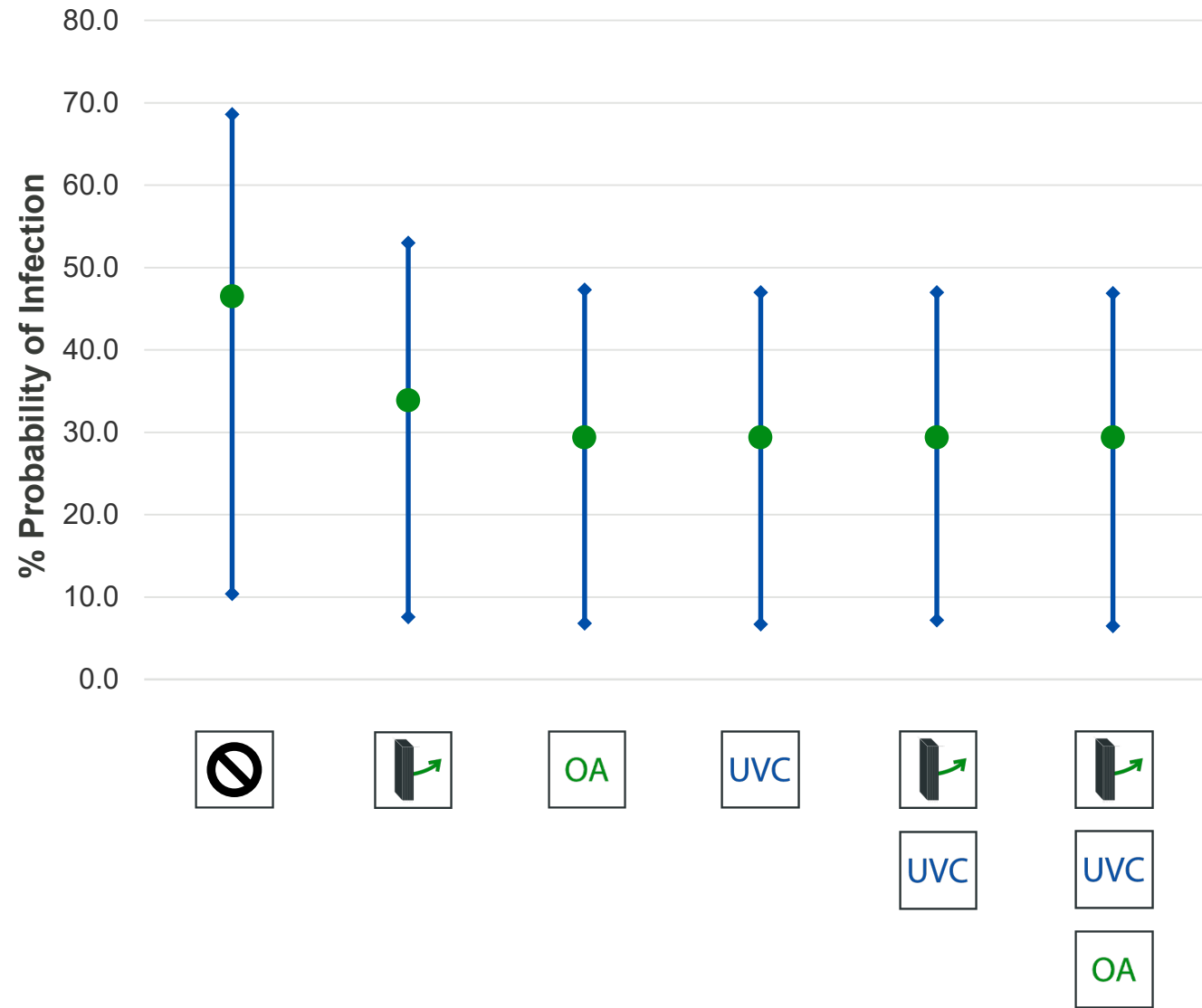
**K-12 CLASSROOM RESULTS**

# Probability of Infection K12 Classroom



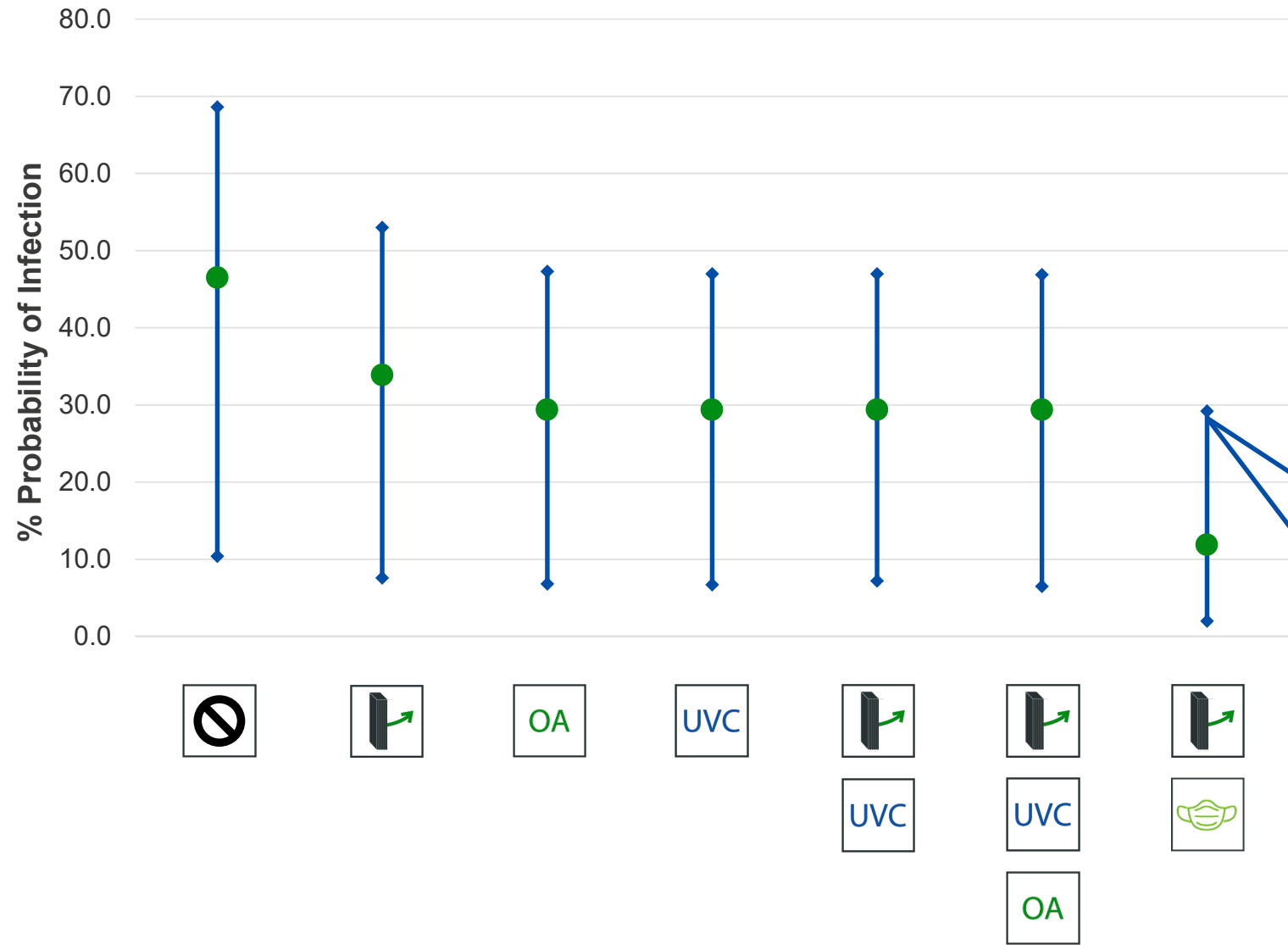
## K-12 CLASSROOM RESULTS

# Probability of Infection K12 Classroom



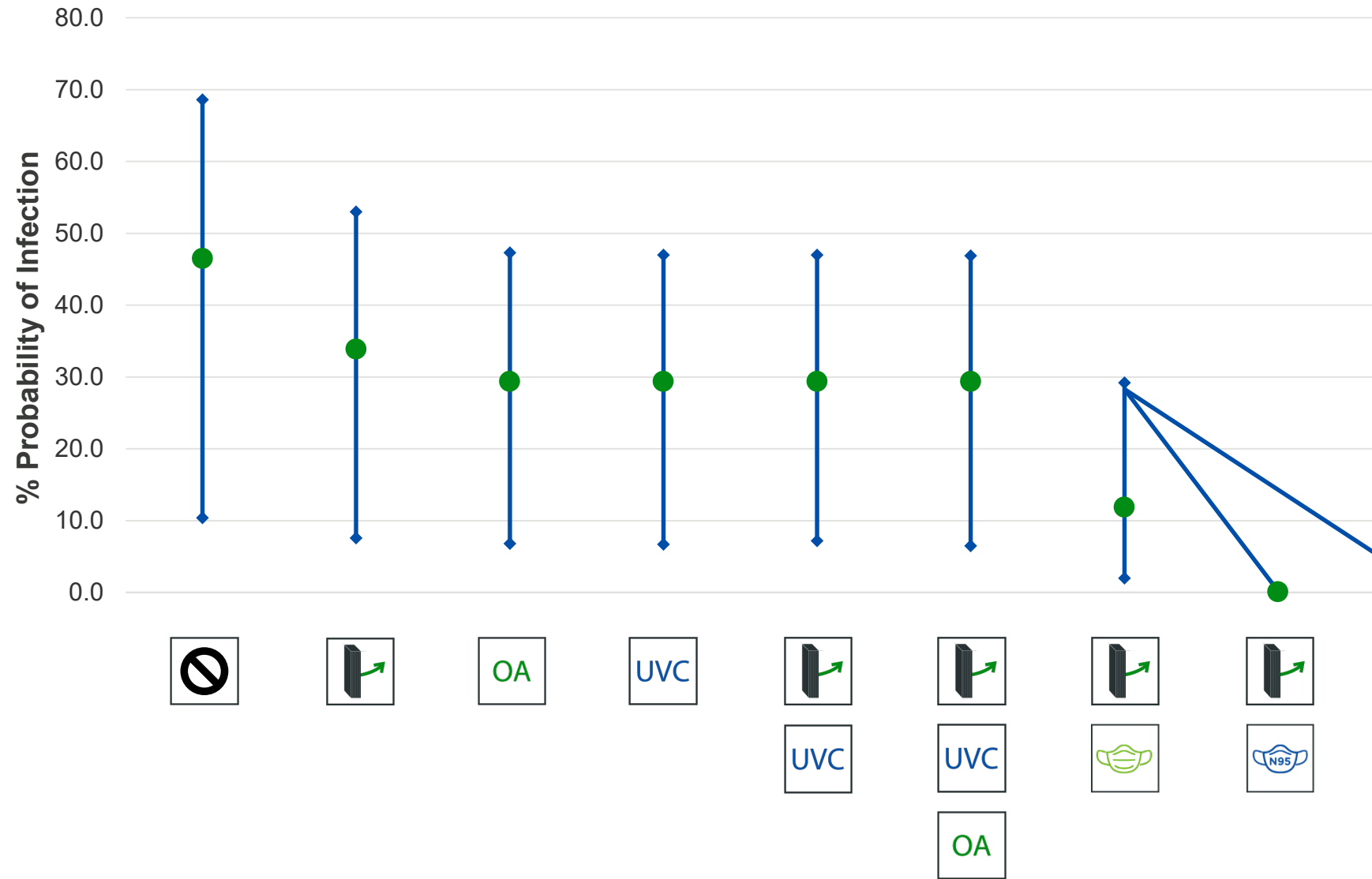
**K-12 CLASSROOM RESULTS**

# Probability of Infection K12 Classroom



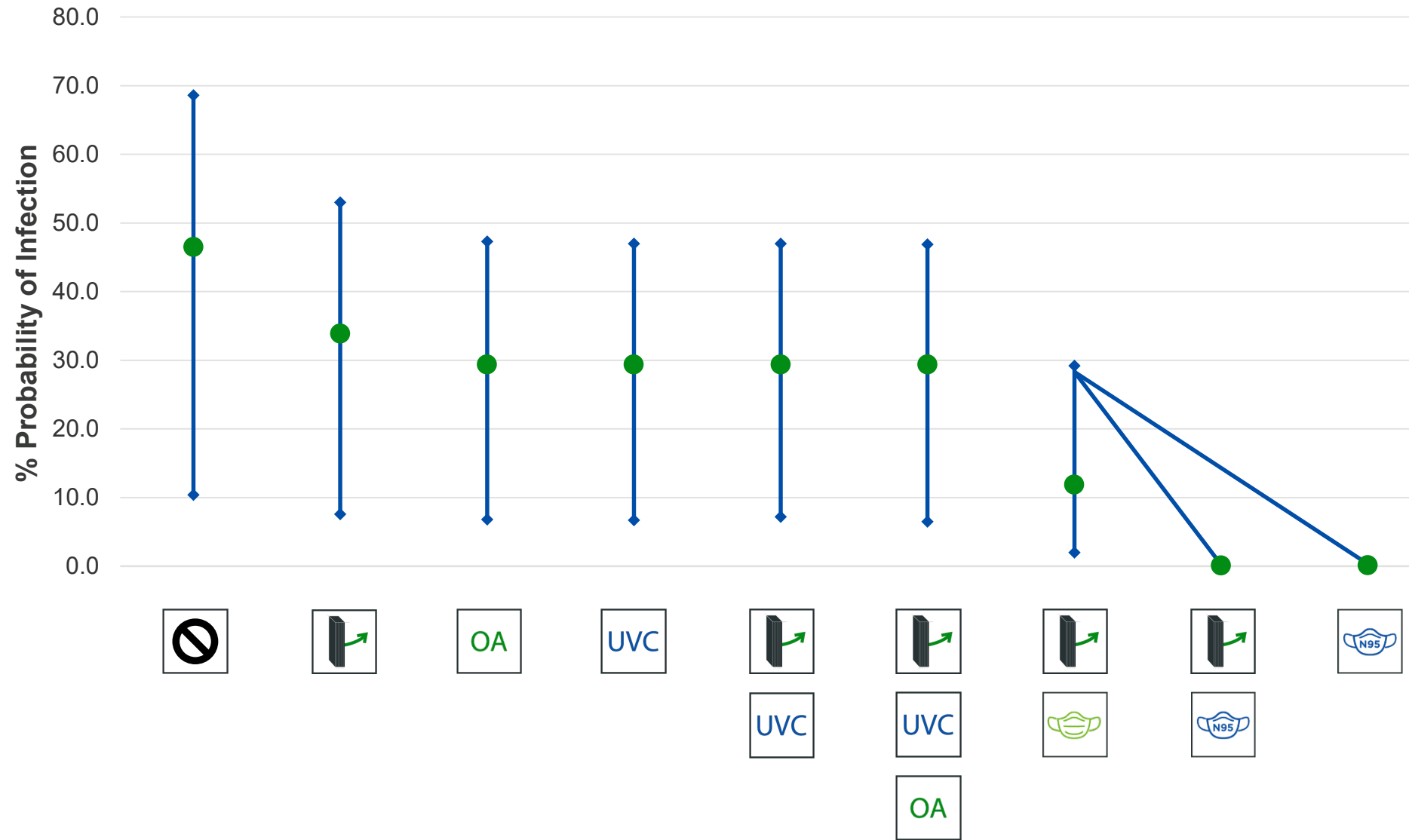
**K-12 CLASSROOM RESULTS**

## Probability of Infection K12 Classroom



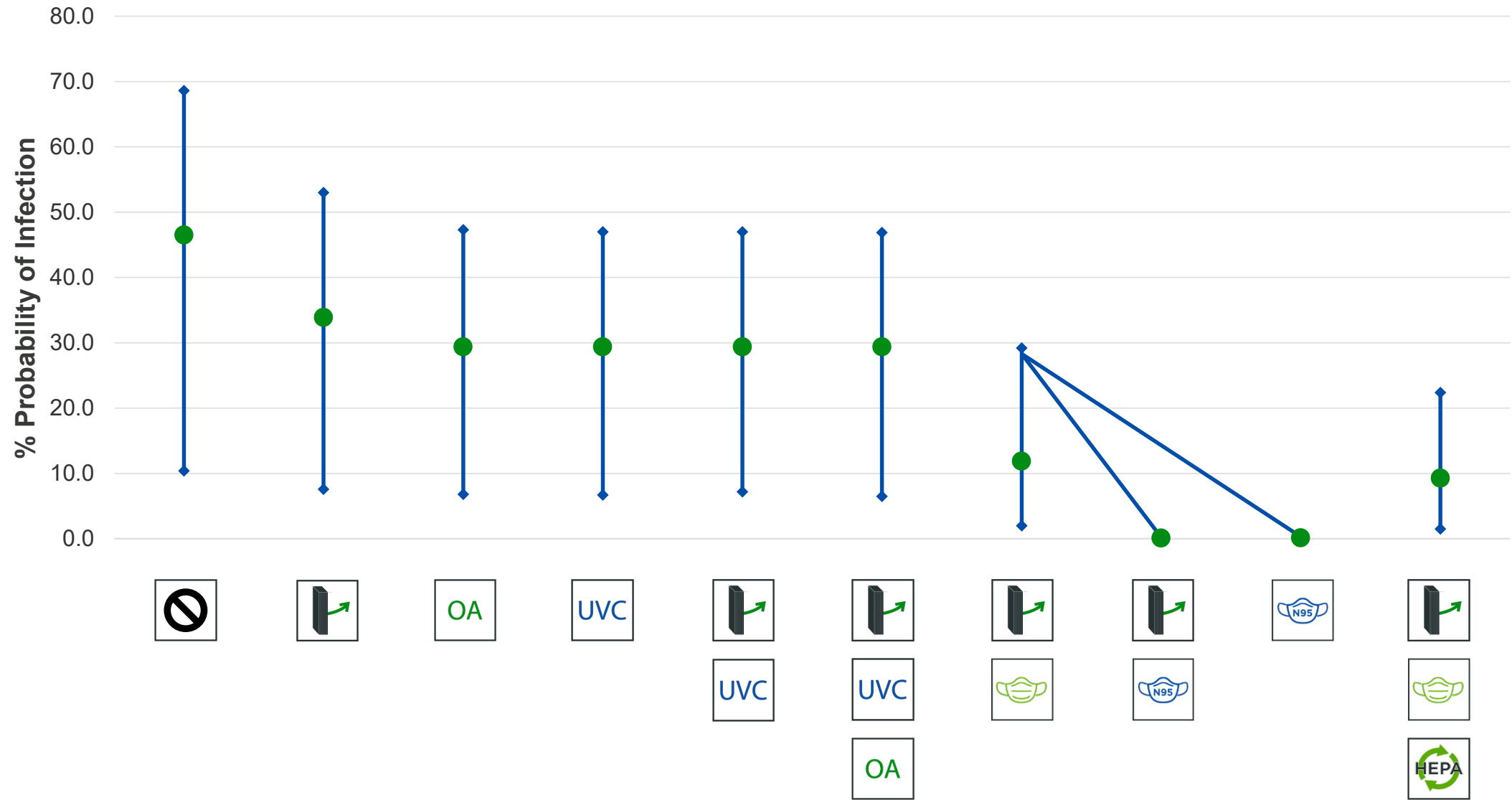
**K-12 CLASSROOM RESULTS**

# Probability of Infection K12 Classroom



**K-12 CLASSROOM RESULTS**

## Probability of Infection K12 Classroom



**K-12 CLASSROOM RESULTS**

## K-12 CLASSROOM TAKEAWAYS

- Maximize mask wearing, even when social distancing can be maintained. Masks mitigate aerosol and large droplet transfer.
- Maximize air change rate in the space so that you can use the filters at the unit.
- Provide MERV 13 filters.
- Keep surfaces clean and wash hands often to help reduce fomite transmission.



A photograph of an open office environment. In the foreground, a man with glasses and a beard, wearing a green and white plaid shirt, is smiling and looking towards a woman on the right. The woman has long brown hair and is wearing a white sweater. They appear to be in a conversation. In the background, another person is visible, and there are cubicles with computer monitors. A green horizontal bar is overlaid across the middle of the image, containing the text "OPEN OFFICE" in white, bold, uppercase letters.

**OPEN OFFICE**



**OPEN OFFICE**




















## KNOWN AND INPUTS

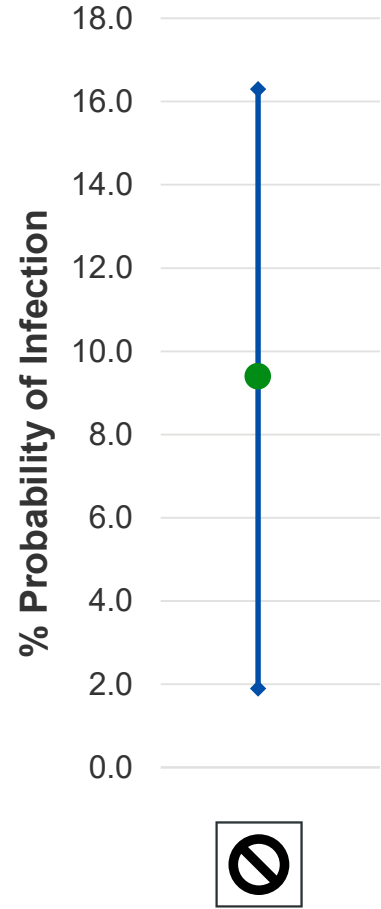
### OPEN OFFICE FLOORPLAN

- 32000 SQFT with 10.5 ft. ceilings
- Primary Air of 32,320 CFM (1.01 CFM/SF). Assumed constant for the simulation.
- Outside Air percentage is 20% OA.
- 180 occupants (177 SQFT/person)
- 1 assumed to be infectious
- Breathing rate of 12.56 L/min.
- Duration of 8.0 hours
- Q estimate 100-1100 with est. mean of 600

## MODELING STRATEGY

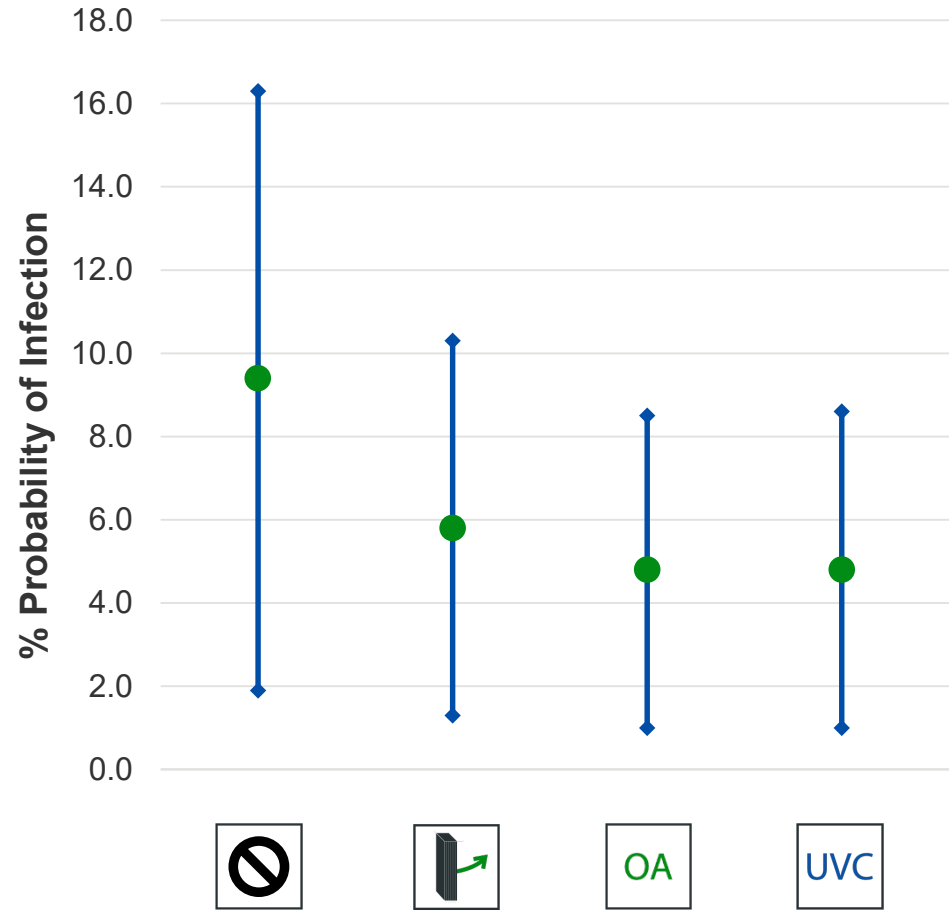
1. Base run with Code OA, MERV 7, no masks, no mitigation 
2. MERV 13 
3. 100% OA 
4. In-duct UVC 
5. MERV 13 + UVC  
6. MERV 13 + UVC + 100% OA   
7. MERV 13 + cloth masks  
8. MERV 13 + tight fitting N95 masks  
9. Tight fitting N95 masks 
10. MERV 13 + cloth masks + in-room HEPA @ 3 ACH   

# Probability of Infection Open Office



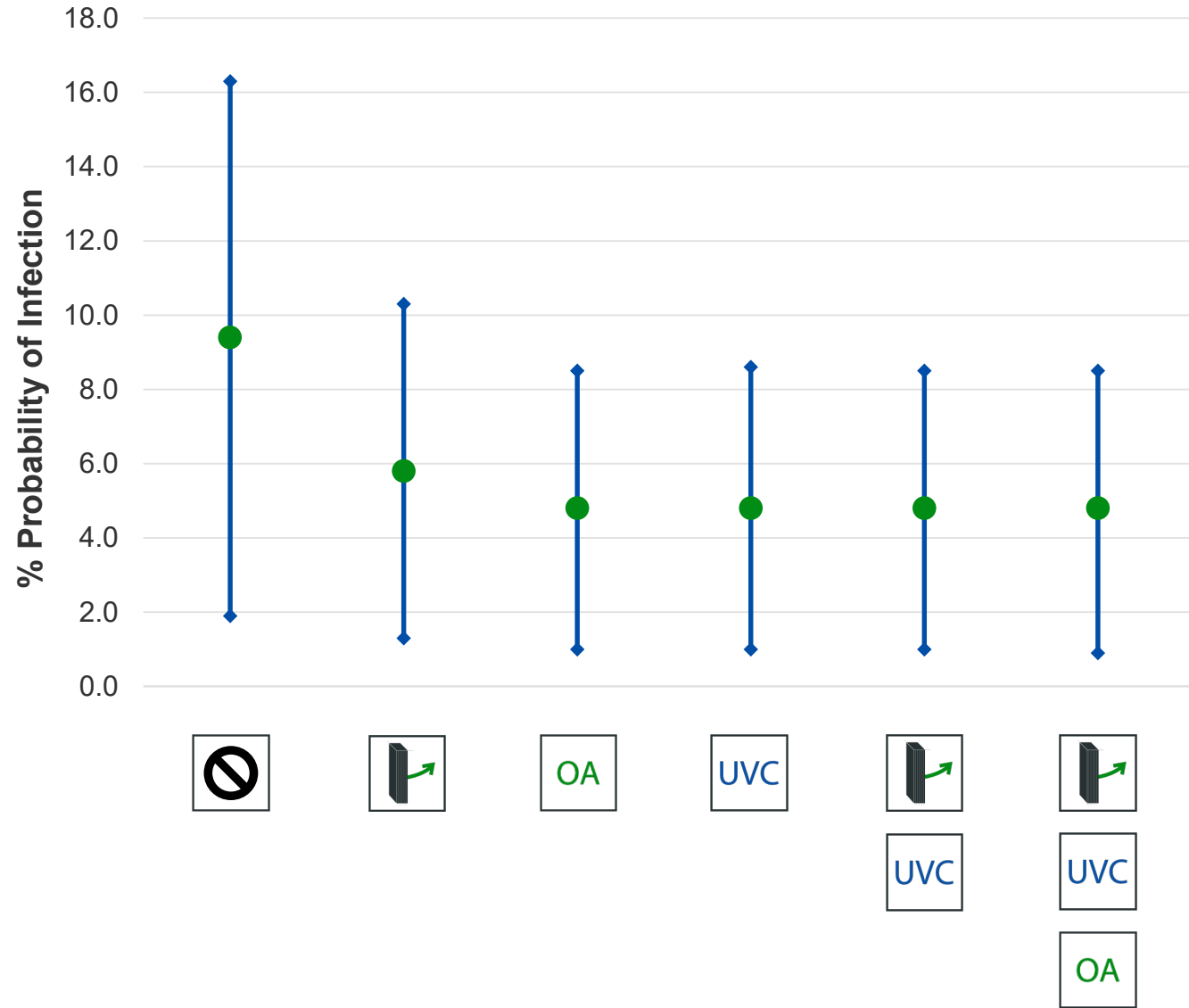
**OPEN OFFICE RESULTS**

# Probability of Infection Open Office



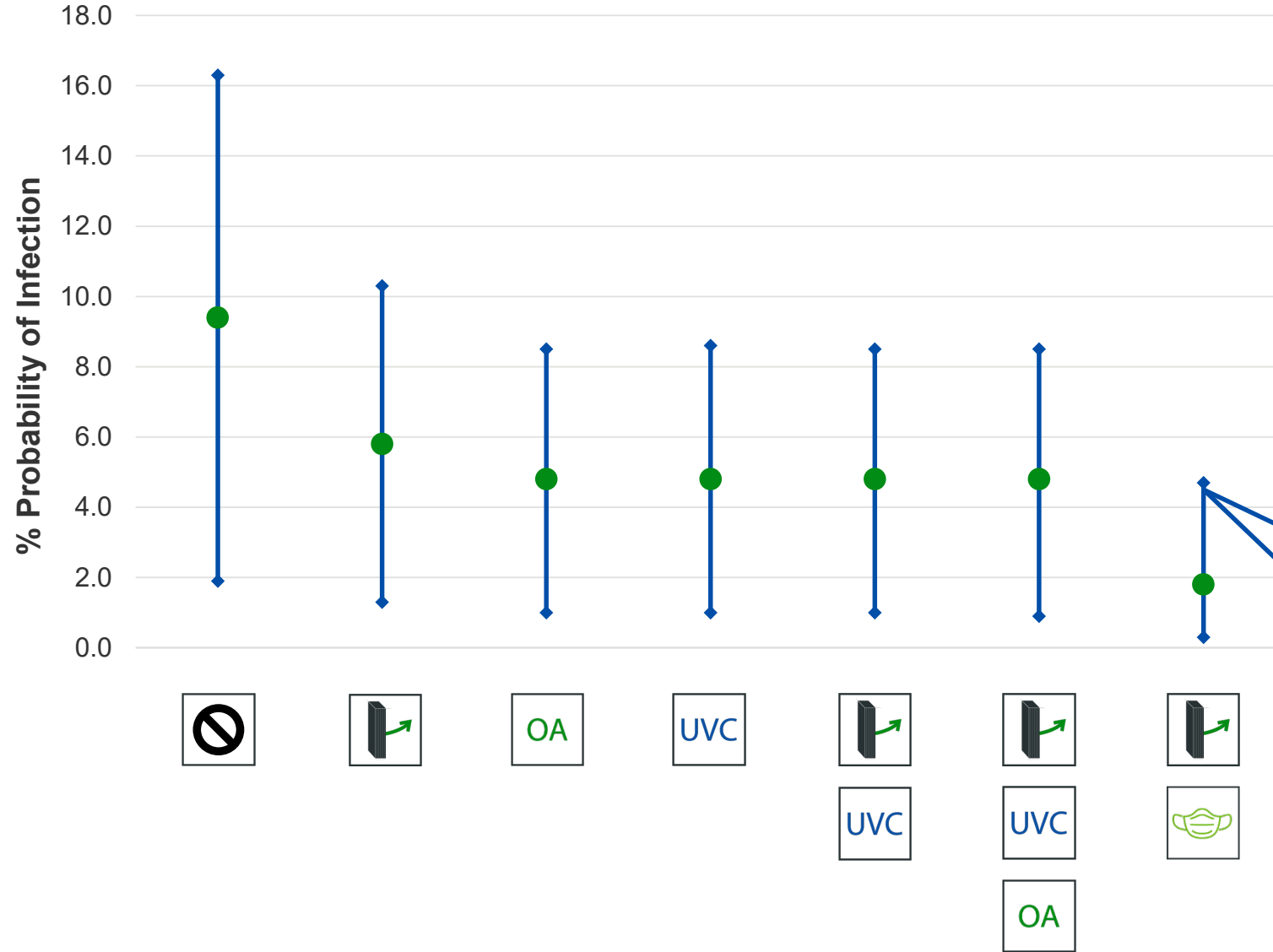
**OPEN OFFICE RESULTS**

# Probability of Infection Open Office



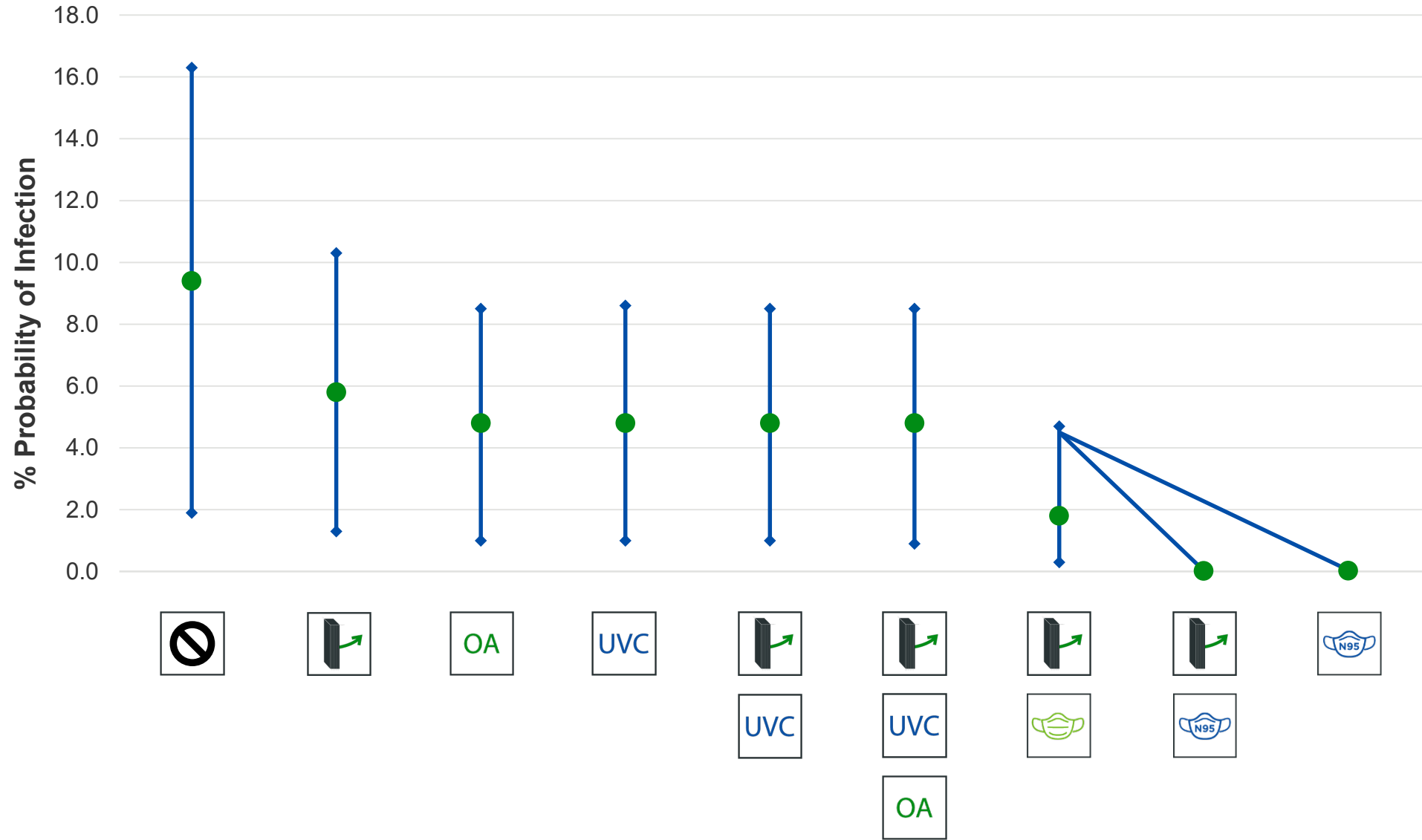
**OPEN OFFICE RESULTS**

# Probability of Infection Open Office



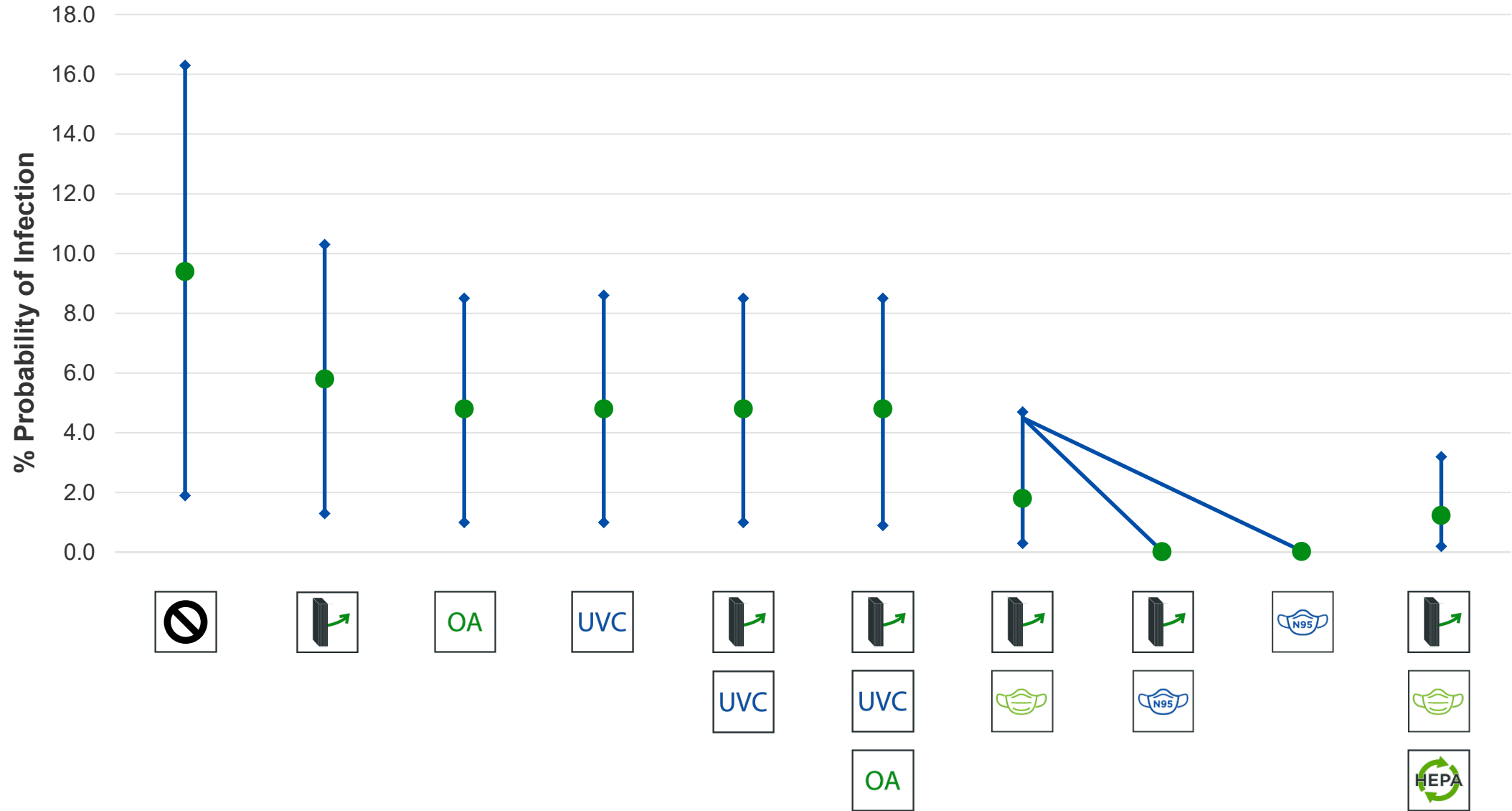
**OPEN OFFICE RESULTS**

# Probability of Infection Open Office



**OPEN OFFICE RESULTS**

# Probability of Infection Open Office

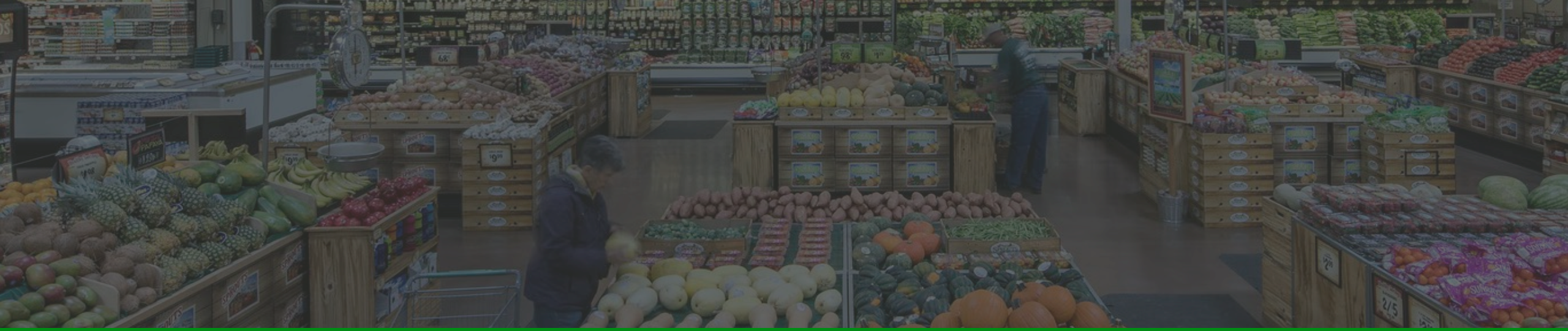


**OPEN OFFICE RESULTS**

## OPEN OFFICE TAKEAWAYS

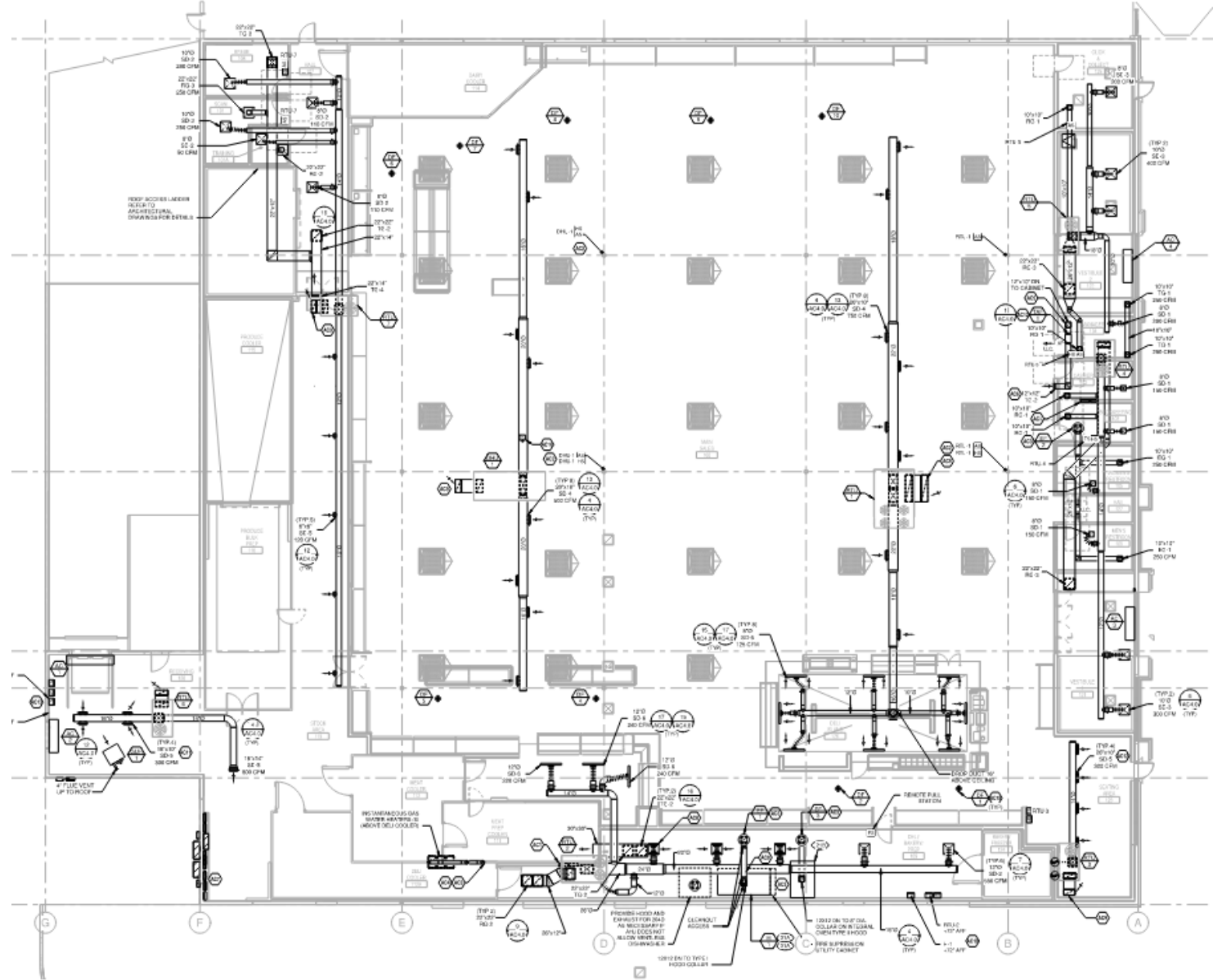
- Relatively low risk on an open office plan with large volume and low density.
- Model is only assuming a **single infectious person** out of 180 occupants.
- Policies allowing masks removal at a person's desk result in a "no mask" scenario - 3x risk.
- Very hard to predict open office because of the behavior of the occupants.
  - They move around a lot and congregate in areas where large droplet and fomite transfer could be risky.
- Moving to a conference room or personal office for an hour changes risk profile significantly.
  - Not reflected in this simulation.





# GROCERY STORE





**GROCERY STORE**




















## KNOWN AND INPUTS

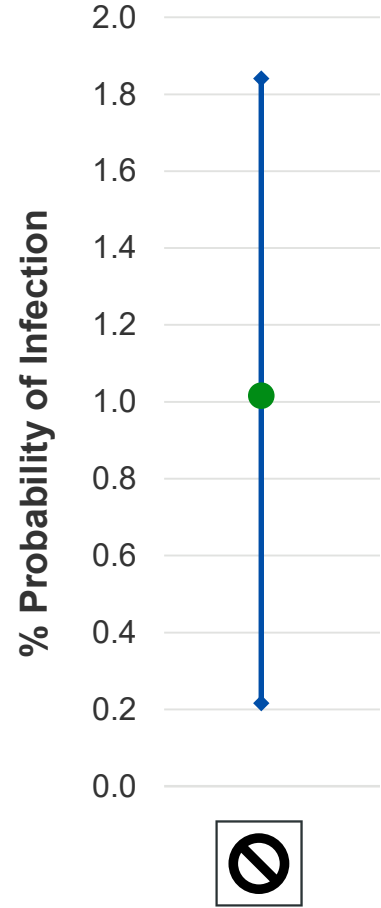
### GROCERY SALES FLOOR/RETAIL AREA

- 20,000 SQFT with 14 ft. ceilings
- Primary Air of 10,000 CFM (0.5 CFM/SF).
- 4000 CFM of OA
- 160 occupants (125 SQFT/person)
- 1 assumed to be infectious
- Breathing rate of 14.56 L/min.
- Duration of 45 minutes
- Q estimate 100-1100 with est. mean of 600

## MODELING STRATEGY

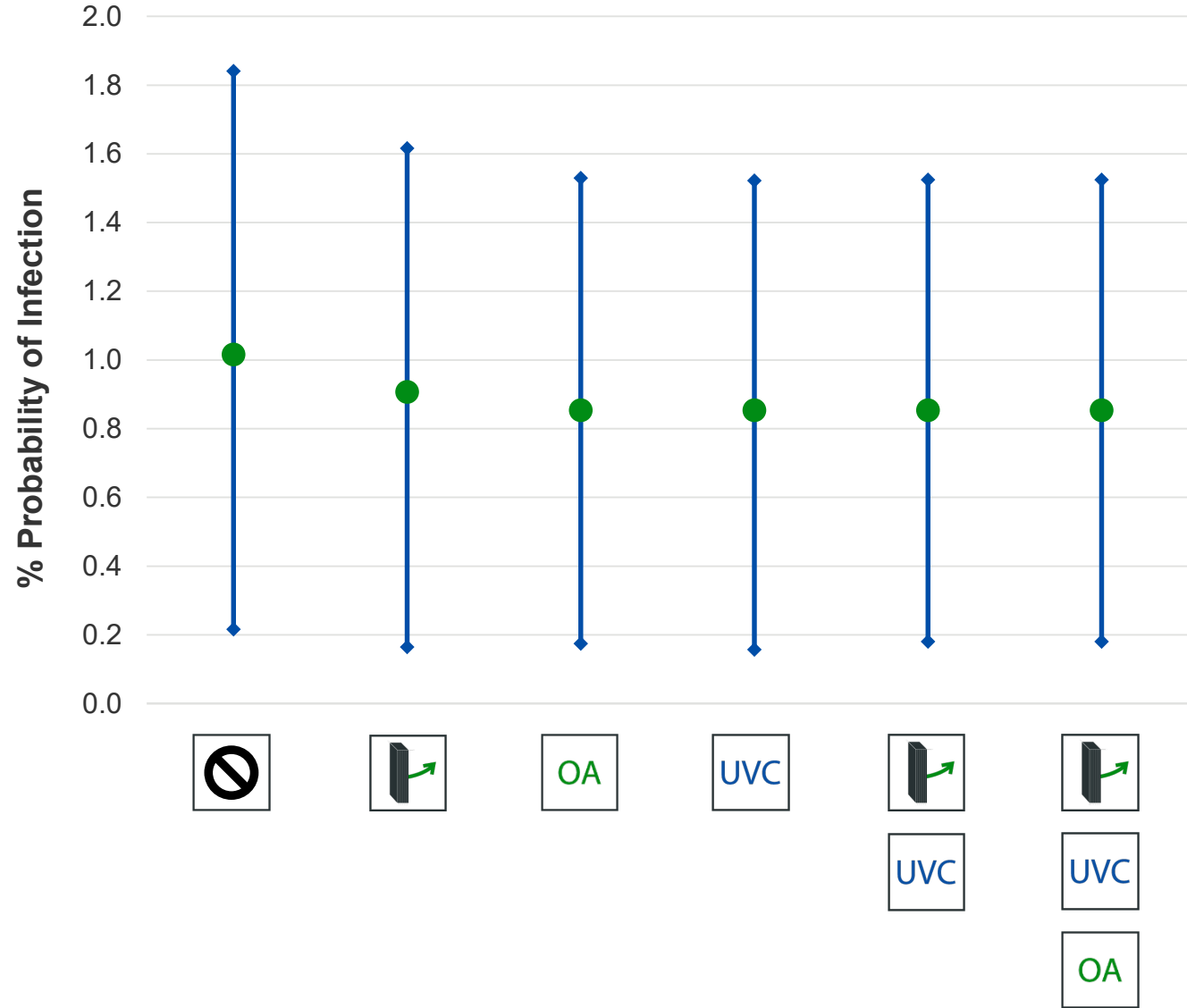
1. Base run with Code OA, MERV 7, no masks, no mitigation 
2. MERV 13 
3. 100% OA 
4. In-duct UVC 
5. MERV 13 + UVC  
6. MERV 13 + UVC + 100% OA   
7. MERV 13 + cloth masks  
8. MERV 13 + tight fitting N95 masks  
9. Tight fitting N95 masks 
10. MERV 13 + cloth masks + in-room HEPA @ 3 ACH   

# Probability of Infection Grocery Sales Area



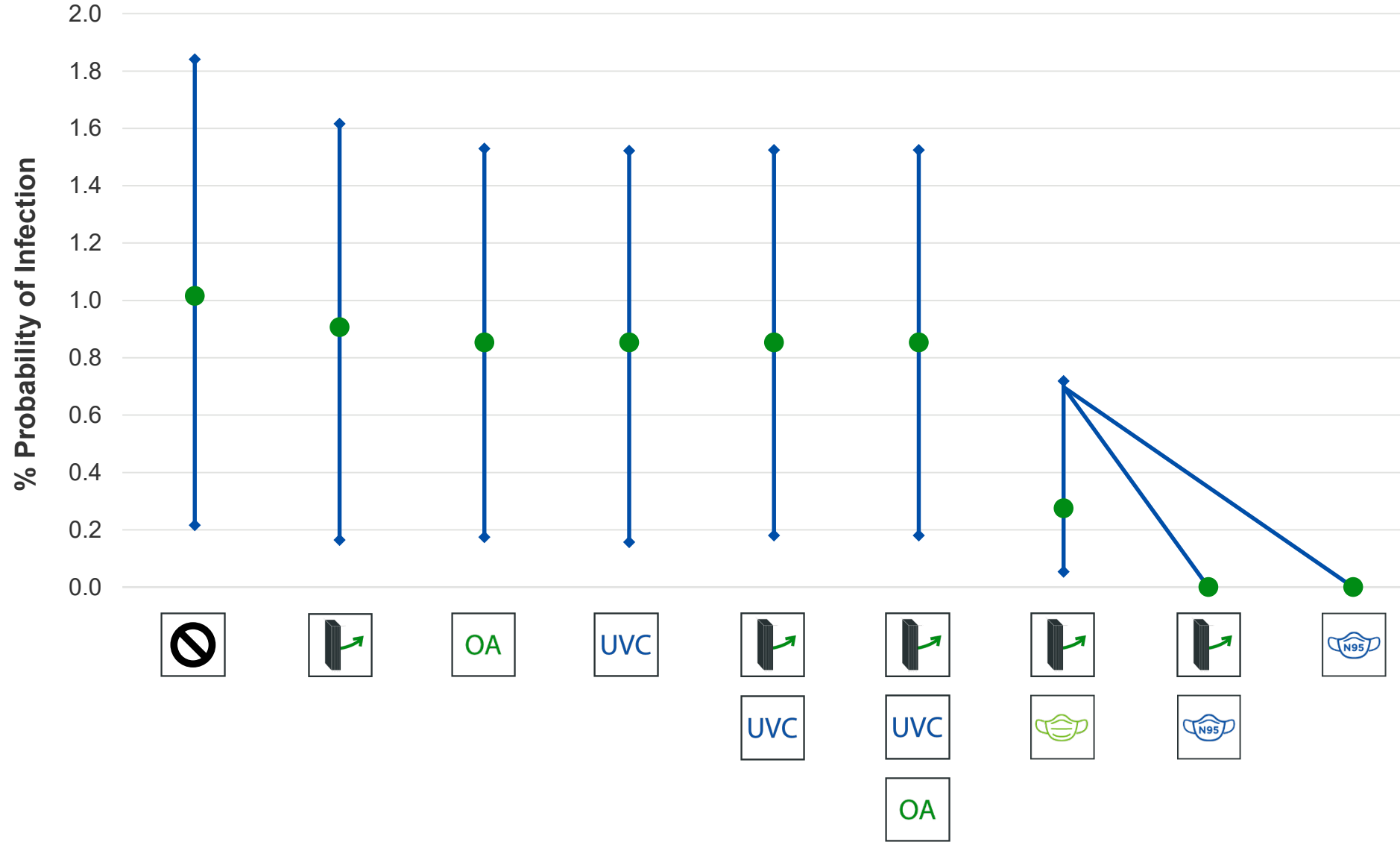
**GROCERY STORE RESULTS**

# Probability of Infection Grocery Sales Area



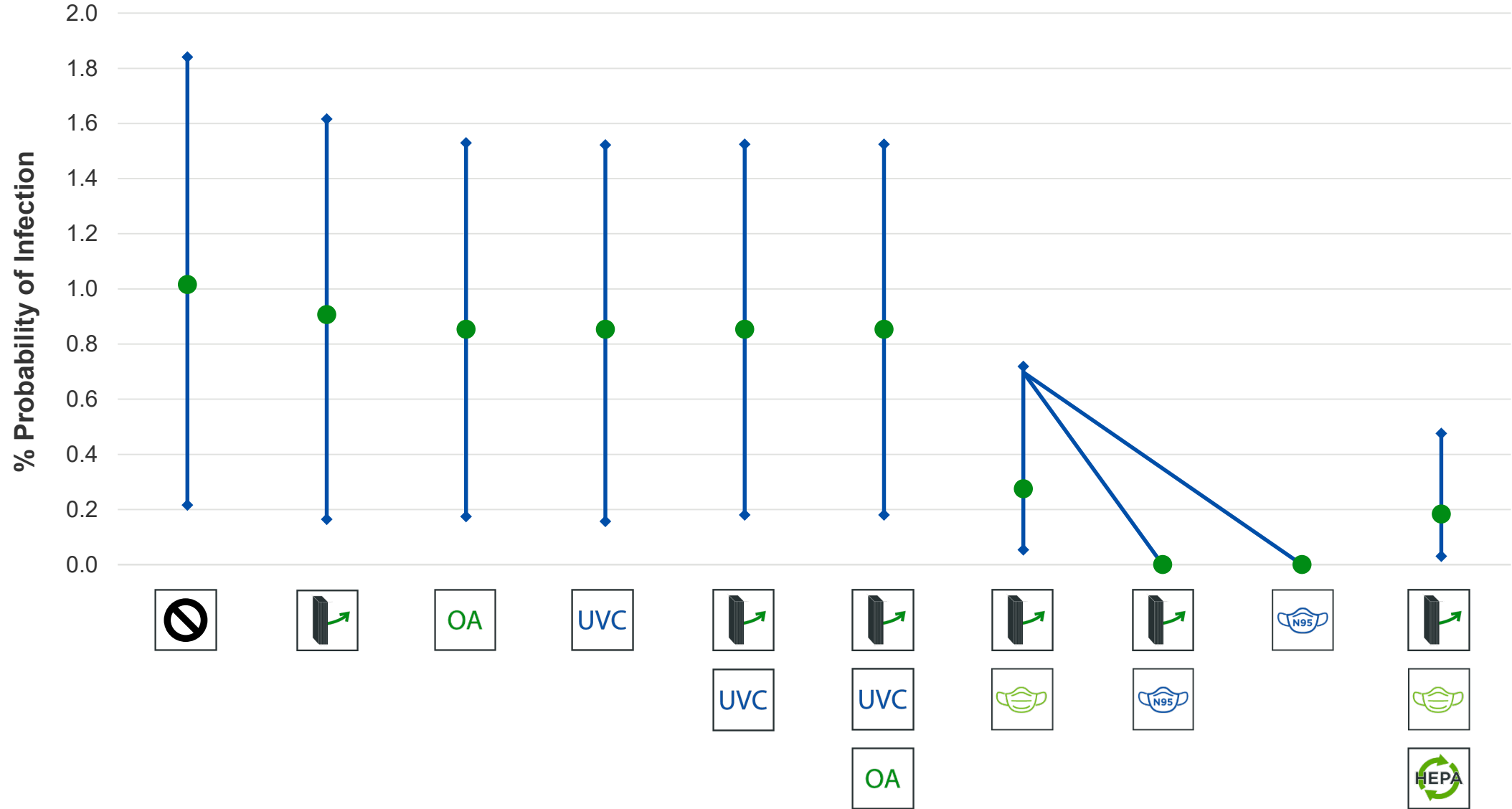
**GROCERY STORE RESULTS**

# Probability of Infection Grocery Sales Area



**GROCERY STORE RESULTS**

# Probability of Infection Grocery Sales Area



**GROCERY STORE RESULTS**

## GROCERY STORE TAKEAWAYS

- The risk is low starting out because of the large volume and high ventilation.
- Model is only assuming a **single infectious person** out of 160 occupants.
  - May be more appropriate to estimate more than one person infected in the space.
- Mitigation strategies help, but only cut down on an already low risk.
  - Masks are the most reliable strategy.
- Aerosolized quanta probably won't be uniform across the large volume.
- Fomite and large droplet transmission paths need to be considered.
  - Social distancing and hand sanitizer are best practices for a grocery store.





# CONFERENCE ROOM





**CONFERENCE ROOM**

























## KNOWN AND INPUTS

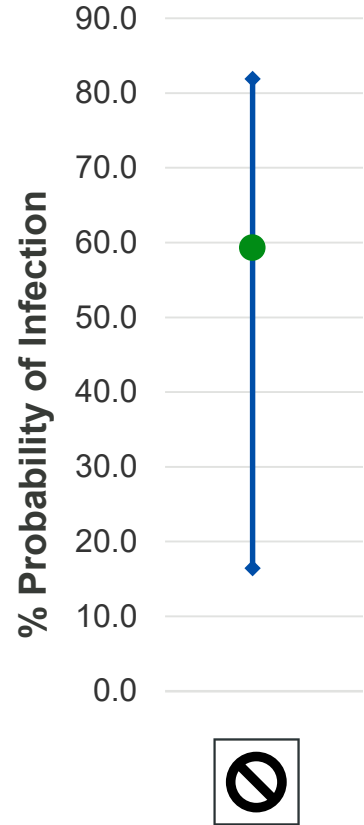
### OFFICE CONFERENCE ROOM

- ~300 SQFT with 10 ft. ceilings
- Primary Air of 296 CFM (1.00 CFM/SF).
- Outside Air determined by ASHRAE 62.1. Results in 97 CFM OA
- 12 occupants (25 SQFT/person)
- 1 assumed to be infectious
- Breathing rate of 12.56 L/min.
- Duration of 1 hour
- Q estimate 100-1100 with est. mean of 600

## MODELING STRATEGY

1. Base run with Code OA, MERV 7, no masks, no mitigation 
2. MERV 13 
3. 100% OA 
4. In-duct UVC 
5. MERV 13 + UVC  
6. MERV 13 + UVC + 100% OA   
7. MERV 13 + cloth masks  
8. MERV 13 + tight fitting N95 masks  
9. Tight fitting N95 masks 
10. MERV 13 + cloth masks + in-room HEPA @ 3 ACH   
11. MERV 13 + cloth masks + in-room HEPA @ 6 ACH   

# Probability of Infection 300 SQFT Conference Room (12 occupants)



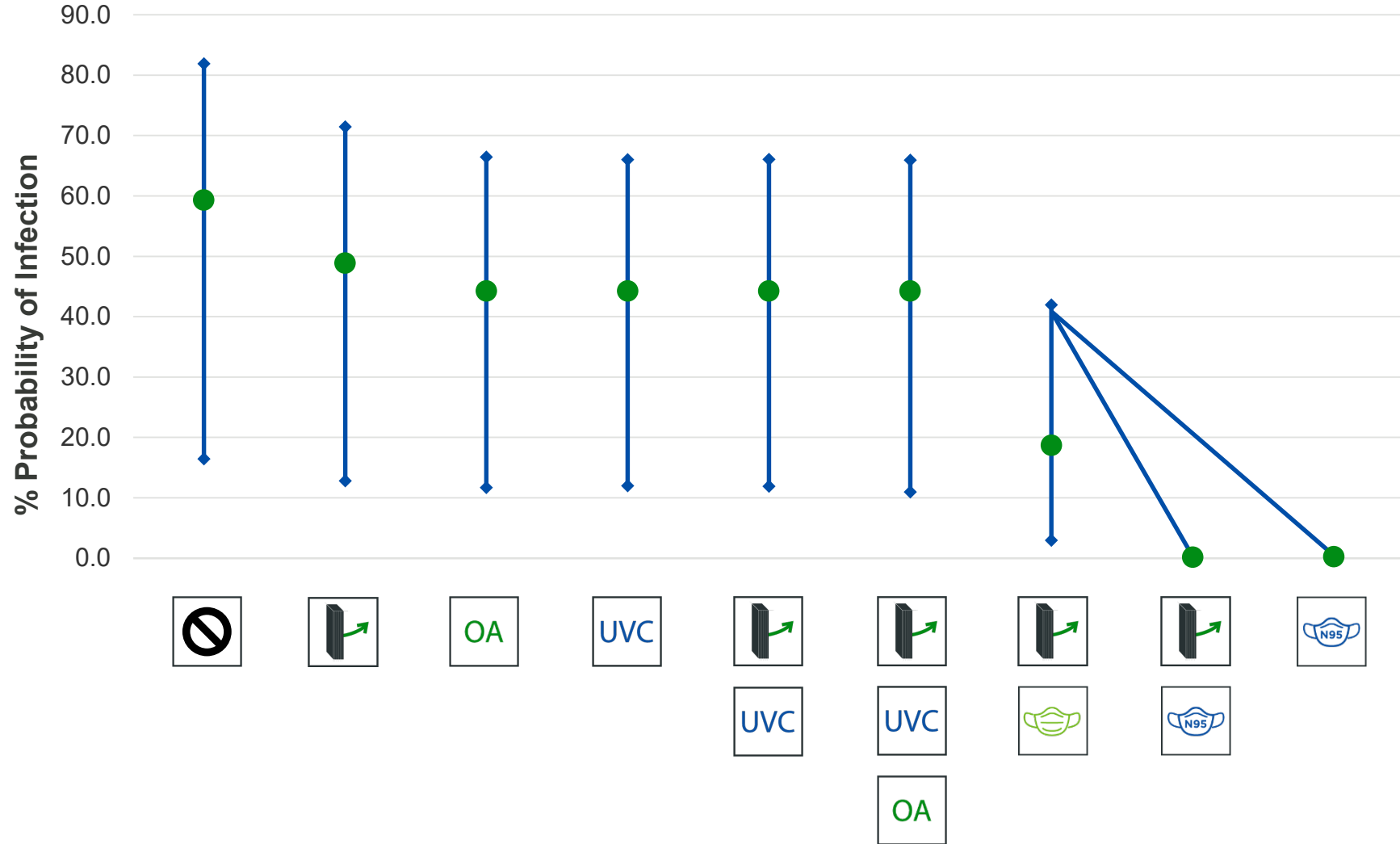
**CONFERENCE ROOM RESULTS**

# Probability of Infection 300 SQFT Conference Room (12 occupants)



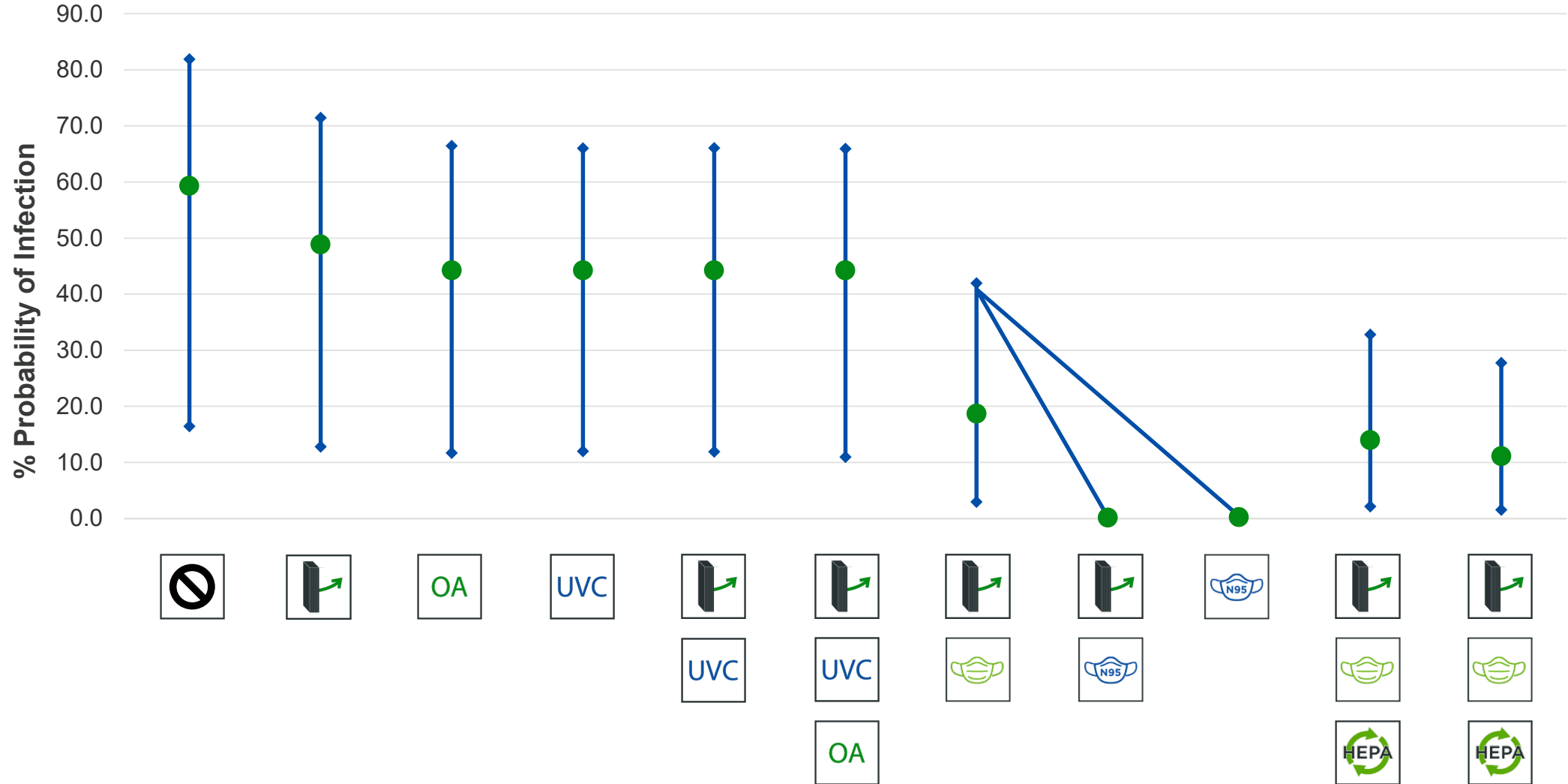
**CONFERENCE ROOM RESULTS**

# Probability of Infection 300 SQFT Conference Room (12 occupants)



**CONFERENCE ROOM RESULTS**

## Probability of Infection 300 SQFT Conference Room (12 occupants)



**CONFERENCE ROOM RESULTS**

## CONFERENCE ROOM TAKEAWAYS

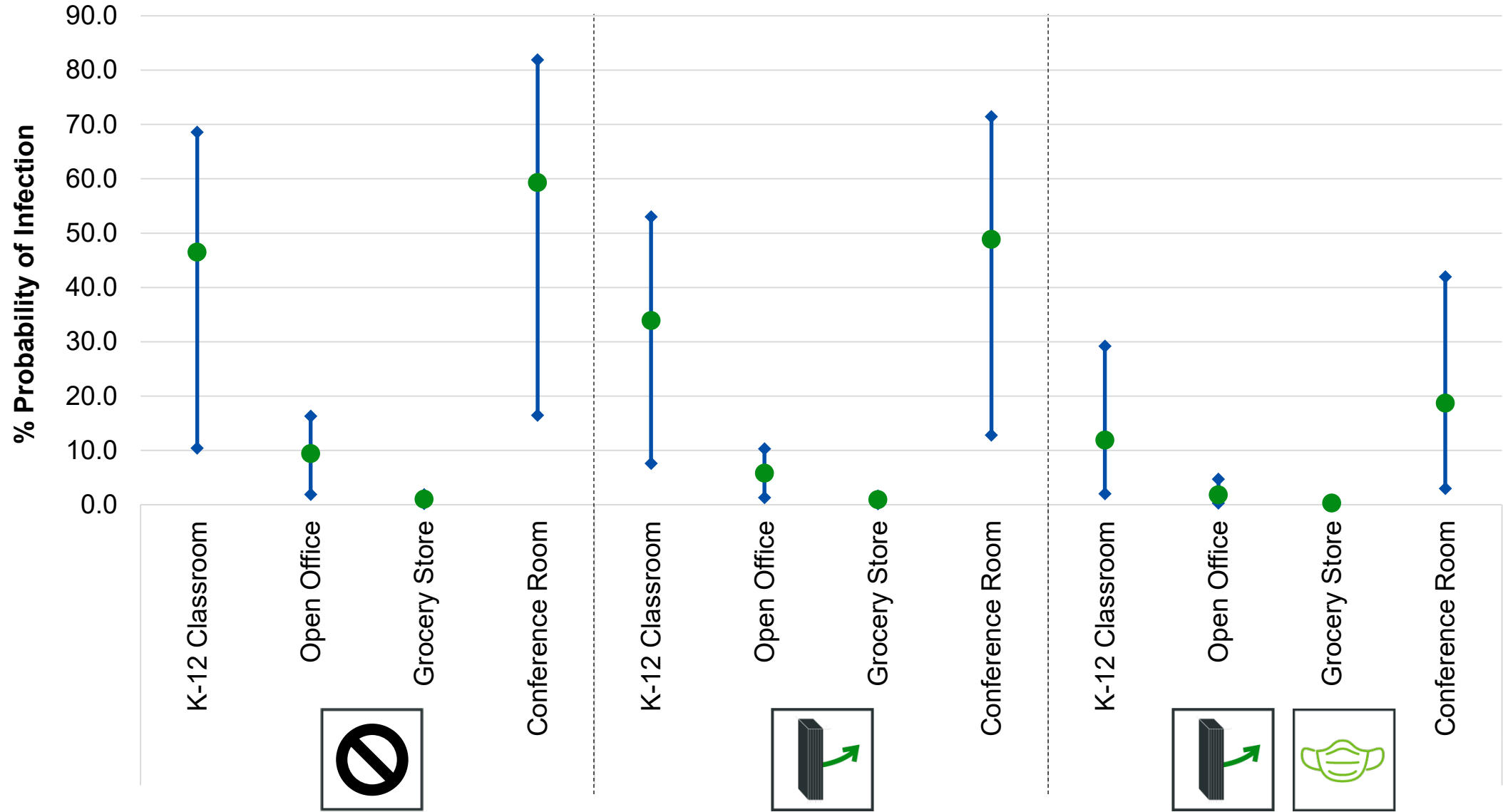
- This is risky.
- Don't do in-person conferences.
- Aerosol transmission is more likely in a confined space.
- Good application for in-room/portable HEPA filter.
- Masks are essential.



A blue-toned background image showing a hand holding a glowing globe. The globe is illuminated with a bright, multi-colored light, possibly representing a network or data. The hand is positioned at the top, and the globe is centered. The overall scene is set against a dark blue background.

# FINAL THOUGHTS

# Probability of Infection Through Aerosolized Transmission




**FINAL RESULTS**

**QUIZ TIME**

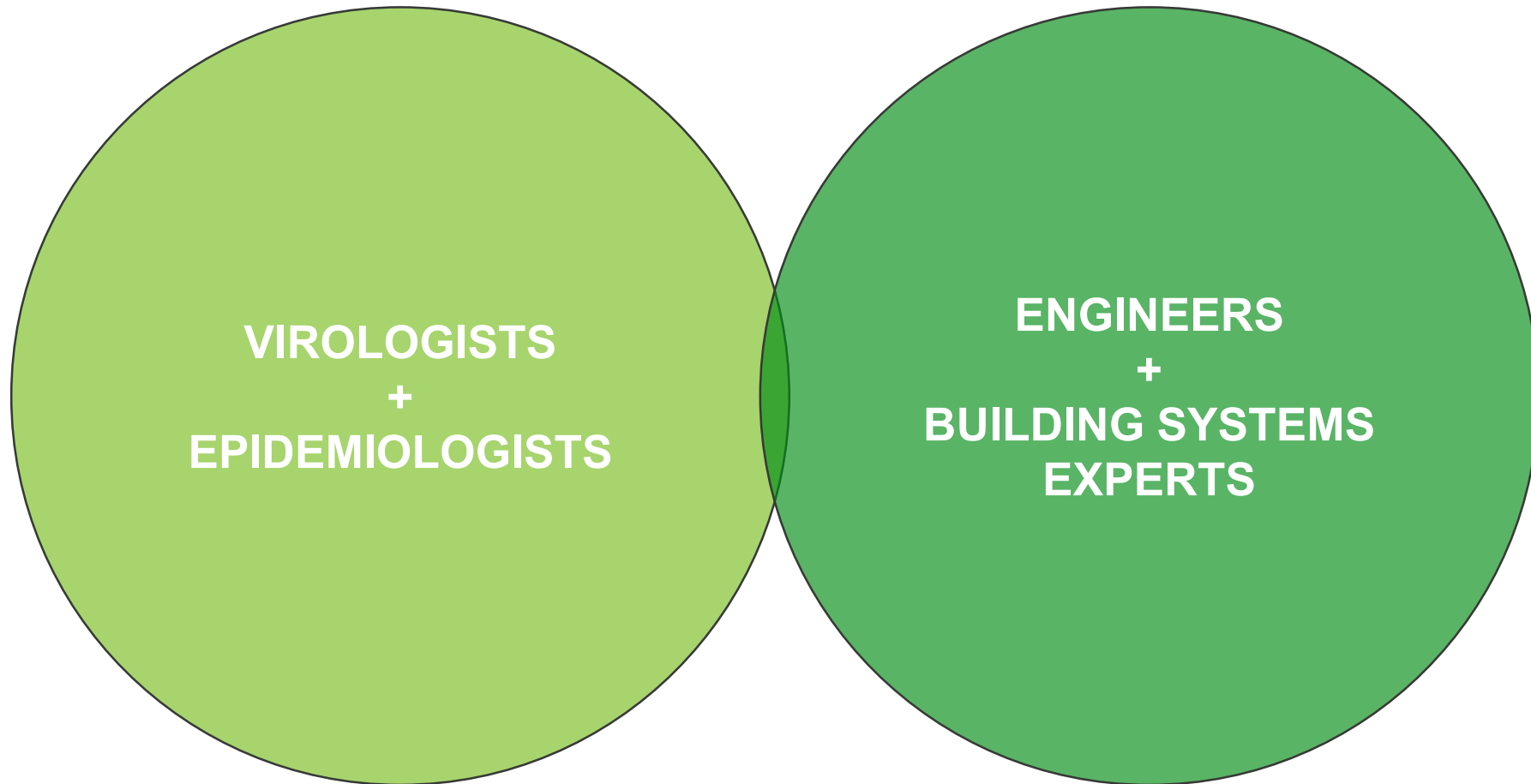
**+**

**5 MINUTE BREAK**



**TYING IT ALL TOGETHER**





**THE WHY BEHIND THIS CONVERSATION**



# THANK YOU

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**Dustin Schafer PE | Director of Engineering**  
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