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Creating the World's Healthiest Airport

Lessons from SFO

Creating the World's Healthiest Airport – Lessons from SFO

Course Description:

Airports move millions of people daily—what if they could also improve their health? At San Francisco International Airport (SFO), real-time data is turning this vision into reality for over 50 million passengers yearly. With multiple LEED, WELL, and Fitwel certifications, SFO is advancing sustainability leadership by prioritizing human health. As part of its five-year goal to "Deliver an airport experience where people and our planet come first," SFO has made indoor air quality (IAQ) a fundamental pillar of passenger and employee well-being, and as part of their Air Quality Framework, implemented a large-scale airport-wide IAQ monitoring initiative, with the goal to actively managing air quality across its terminals, offices, and other occupied facilities. This presentation will introduce this airport's approach to improved environmental quality and highlight how health and well-being are key to an exceptional guest experience while utilizing LEED, WELL, and Fitwel certifications.

Information will be provided on the use of IAQ monitors as a part of the airport's Air Quality Framework, helping the airport better understand the relationship between outdoor and indoor air and to better manage air quality in occupied spaces. Air quality monitor technology will be explained and air quality data, obtained from the sensors will be used to demonstrate and guide indoor air quality operational improvements. The use of air quality monitors to support the green building rating systems will also be discussed.

SFO has conducted a Triple Bottom Line Cost Analysis (TBL CBA) to quantify the economic, environmental, and social benefits of air quality monitoring. TBL CBA data will be presented to demonstrate a strong business case for integrating real-time air quality strategies into infrastructure projects. The use of TBL CBA to support green building and infrastructure rating systems will also be discussed.

This session is essential for airports, large campuses, commercial buildings, and policymakers looking to integrate data-driven air quality strategies into high-performance environments while demonstrating measurable business value.

Enter Learning Objectives (4)/ Learning Level

1. Understand the role of airport air quality in health, well-being, and guest experience.
2. Evaluate implementation strategies for large-scale air quality monitoring projects.
3. Demonstrate how real-time data can be used to optimize the built environment, provide support to different operational use cases, and contribute to long-term sustainability initiatives
4. Articulate how to assess the financial, environmental, and social benefits of air quality monitoring through TBL CBA, and build a compelling business case.

Learning Level: Intermediate

Creating the World's Healthiest Airport – Lessons from SFO

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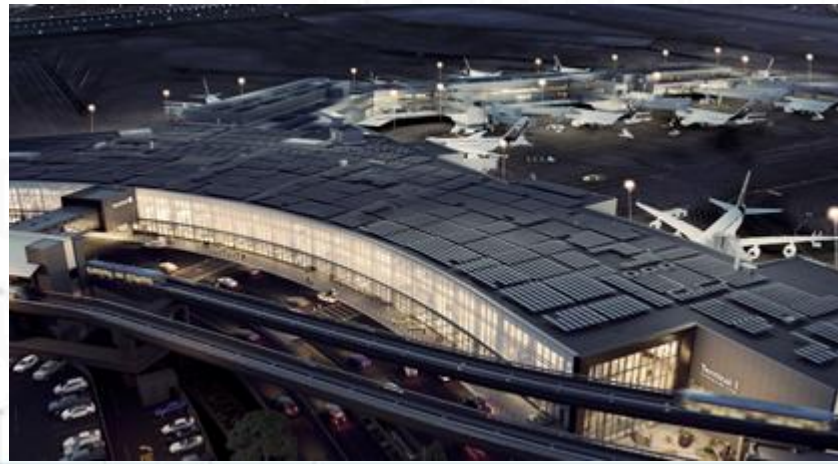
Autocase

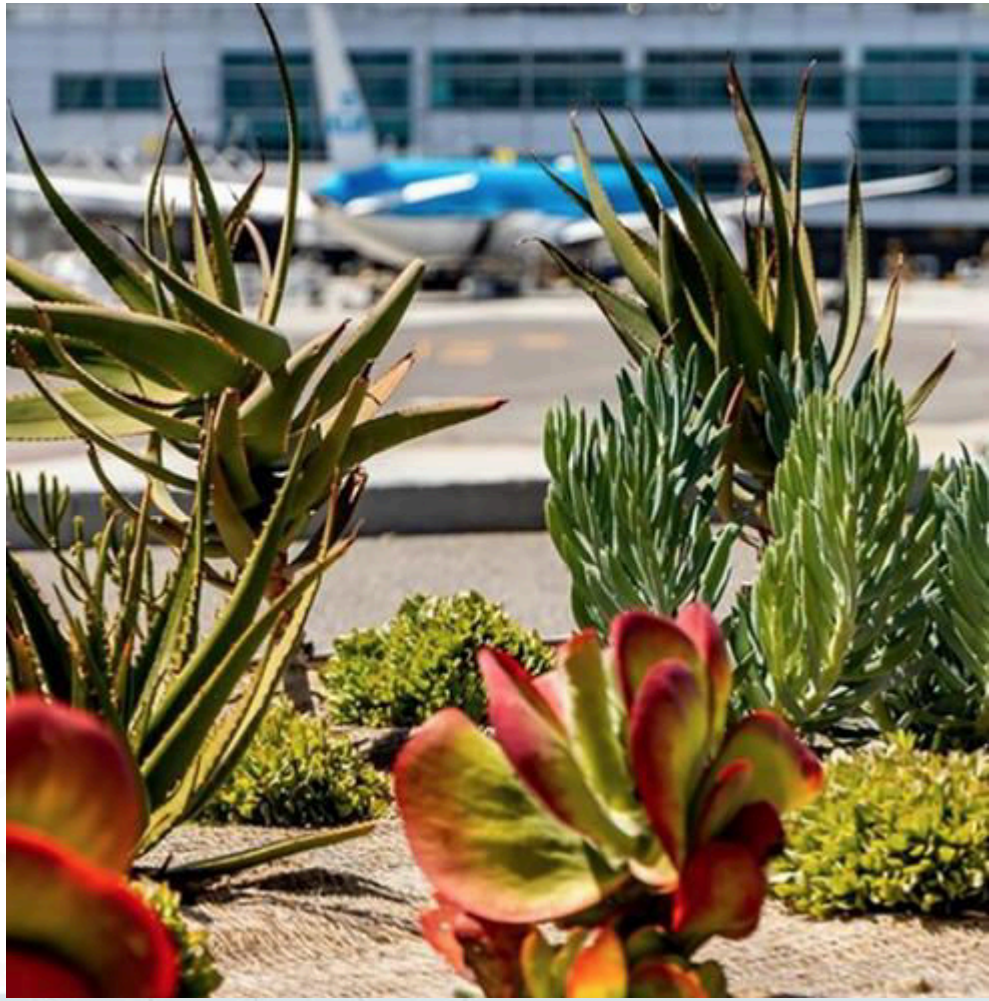
Photo credit: Jason O'Rear



Creating the World's Healthiest Airport – Lessons from SFO

Agenda:

1. Airport's Path to Health and Wellbeing for All
2. Air Quality Measurement Technology
3. Business Case
4. Lessons Learned
5. Q&A



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Airport’s Path to Health and Wellbeing for All

SFO by the Numbers

Operations
- 58 Million Annual Passengers
- 21,000,000 sq. ft. facilities
- 561,806 metric tons cargo

Direct Economic Impact
- $8.4 Billion in business activity
- 42,800 jobs

Land Use
- 102 Buildings, 6mi of AirTrain
- 2100 acres (3.3sq mil) land
- 250 mi 12kv electrical; 51mi water, 18 mi natural gas pipes

Opportunity
- Peak Load 55MW; targeting 247MVA
- 2347 Motorized GSE (1Mgal Fuel)
- 486 Fleet Vehicles (.5MG Fuel)
- 210,656 landings; 45 airlines (1B Jet-A)

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SFO's Strategic Plan 2023-2028

Photo credit: Jason O'Rear

VISION

Inspiring the Extraordinary

MISSION

Delivering an airport experience where people and our planet come first.

CORE VALUES

SAFETY & SECURITY	TEAMWORK	EXCELLENCE	CARE	EQUITY
Safety & Security is our first priority.	We are one team.	Being your personal best makes our airport exceptional.	Promoting the well-being of our guests, our tenants, our community, and each other.	We are anti-racist, inclusive, and respectful (AIR); committed to equitable outcomes for all.

Goal #1
SAFETY AND SECURITY

Creation of a research-driven framework for a **healthy** and thriving airport community

Goal #2
GUEST EXPERIENCE

Safeguard the **health and well-being** of all who travel through and work at SFO by improving our built environment

Goal #4
BOLD CLIMATE ACTION

Implement a comprehensive **sustainability** strategy

https://www.flysfo.com/about/about-sfo/strategic-plan

Air Quality Study

Photo credit: Jason O'Rear

Photo credit: Joe Fletcher

Goals:

1. Confirm Life-Cycle Building Performance
2. Establish Relationship Between Indoor & Outdoor Air Quality
3. Manage HVAC System for Energy Efficiency + Improved Human Health
4. Support Airport's Strategic Plan

Phase I: Air Quality Sensor Pilot Program

Phase II: Business Case

Phase III: Sensor Based-Management

Air Quality Study: Air Pollutants

Air Pollutant	Type	Source Examples	Health Affects
Volatile Organic Compounds (VOCs)	Primary and Secondary	Fuel vapors, gasoline evaporation, solvents, cleaning products	- Eye, nose, and throat irritation, headaches, nausea - Damage to liver, kidney, and central nervous system
Benzene (VOC)	Primary	Fuel combustion, mobile sources, industrial processes	- Short-term exposure may cause drowsiness, dizziness, headaches, as well as eye, skin, and respiratory tract irritation
Toluene (VOC)	Primary	Solvents, mobile sources, tobacco smoke	- Central Nervous System dysfunction and narcosis with symptoms of fatigue, sleepiness, headaches, and nausea
Formaldehyde (HCHO)	Primary	Building materials, fuel burning appliances, tobacco smoke	- Irritation of the skin, eyes, nose, and throat - Exposure to high concentrations causes some types of cancers
Napthalene (C10H8)	Primary	Fuel exhaust, tobacco smoke, pesticide	- Headaches, nausea, dizziness, and/or vomiting - Cancer
Particulate Matter (PM_{10} $PM_{2.5}$ & PM_{10})	Primary and Secondary	Dust, fuel combustion, mobile sources, smoke, industrial processes	- Premature death in people with heart or lung disease - Nonfatal heart attacks, irregular heartbeat - Aggravated asthma, decreased lung function - Increased respiratory symptoms, coughing or difficulty breathing
Ozone (O_3)	Primary	Aircrafts create NOx and VOCs, and then ozone if formed in sunlight	- Coughing and sore or scratchy throat - Increase difficulty breathing - Aggravate lung diseases such as asthma, emphysema, and chronic bronchitis
Carbon Monoxide (CO)	Primary	Incomplete fuel combustion, mobile sources, industrial processes	- Low concentrations may cause fatigue and chest pain - High concentrations may cause impaired vision, headaches, dizziness, confusion, and nausea
Sulfur Dioxide (SO_2)	Primary	Fuel combustion, industrial processes, electric utilities	- Wheezing, shortness of breath and chest tightness
Carbon Dioxide (CO_2)	Primary	Fuel combustion, mobile sources, electric utilities	- Wheezing, shortness of breath and chest tightness, unconsciousness, coma, convulsions, and death
Nitrogen Dioxide (NO_2)	Primary and Secondary	Fuel combustion, mobile sources, electric utilities	- Aggravate respiratory diseases - Coughing, wheezing, and difficulty breathing

SFO Sustainable Planning, Design, & Construction Standards

- Preface
- Chapter 1 Introduction
- Chapter 2 Sustainability Performance Schedule
- Chapter 3 Site
- Chapter 4 Water
- Chapter 5 Energy and Carbon
- Chapter 6 Materials and Resources
- Chapter 7 **Human Health**

Requirements

Stretch Goals

- **Reach**
- **Regenerative**

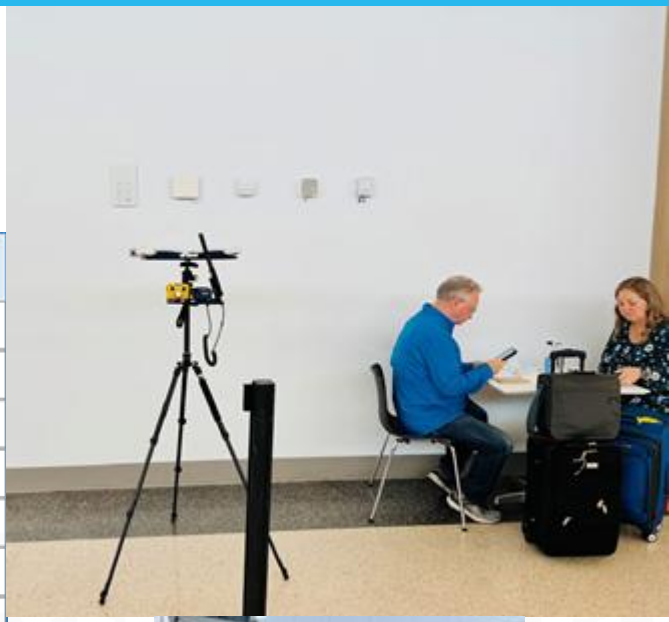
Contaminant	Acceptable SFO Concentration Limit (µg/m³)	Threshold Reference
1,4-Dichlorobenzene	800	LEED v4.1
Acetaldehyde	140	WELL v2 Feature A05.1
Benzene	3	WELL v2 Feature A05.1
Formaldehyde	9 (18.5 µg/m³ in commercial kitchens)	WELL v2 Feature A05.1
Naphthalene	9	WELL v2 Feature A01, LEED v4, LEED v4.1
Styrene	900	LEED v4.1
Toluene	300	WELL v2 Feature A01
Particulates	$PM_{2.5}$: 12 µg/m³; PM_{10}: 20 µg/m³	WELL v2 Feature A05.1, CAAQS
Inorganic gases	LEED v4.1 thresholds	LEED v4.1
Substances listed in CA OEHHA CREL	The more stringent of the level listed in the CRELs for long-term exposure, and those listed above	CA OEHHA CREL

Standards Available at: https://www.sfoconnect.com/abr-ae-standards-tenant-improvement-guide

Air Quality Study: Air Quality Monitor Selection Criteria

Sensor Selection Parameters
Pollutants measured
Compliance with guidance standards
Data storage and transmission
Connectivity to power source
Connection to BMS
Ease of installation
Security
Durability and quality of construction
Longevity
Recyclability
Usability
Cost
Customer service
Circular Economy
Sensor calibration

Quality Assurance Parameters
Bias. Is it routinely high or low with respect to the true value
Precision. How repeatable is the measurement
Accuracy. How does the data compare to direct read device
Calibration. Does it respond in a systematic fashion
Drift. How stable is the response
Detection limit. How low and high will it measure successfully
Response time. How fast does the response vary with change
Data aggregation. Value in aggregating data (1 sec, 1 min, 1 hr., etc.)
Climate susceptibility. How does temperature, RH, direct sun, etc. impact data
Interferences. Gas sensors often respond to other pollutants
Accuracy of timestamp. What response output relates to the event
Response to loss of power. What happens when it shuts down



Institutionalize Success: Green Building Certifications

LEED Certification

- ✓ LEED Campus Master Site Program v4/4.1 Platinum
- ✓ LEED For Communities: Existing v4.1 Platinum
- ✓ LEED: 16 SFO Gold + 2 Platinum

WELL Building Standard

- ✓ Harvey Milk Terminal 1 Boarding Area B v4/4.1 Platinum
- ✓ Courtyard 3 Connector Office Building v2 Pilot Pre-Certified

Fitwel Certification

- ✓ Harvey Milk Terminal 1 Center 3-Star

Living Building Net Zero Certification

- ✓ Airport Operations Facility

ParkSmart Certification

- ✓ Long Term Parking Garage #2 - Gold

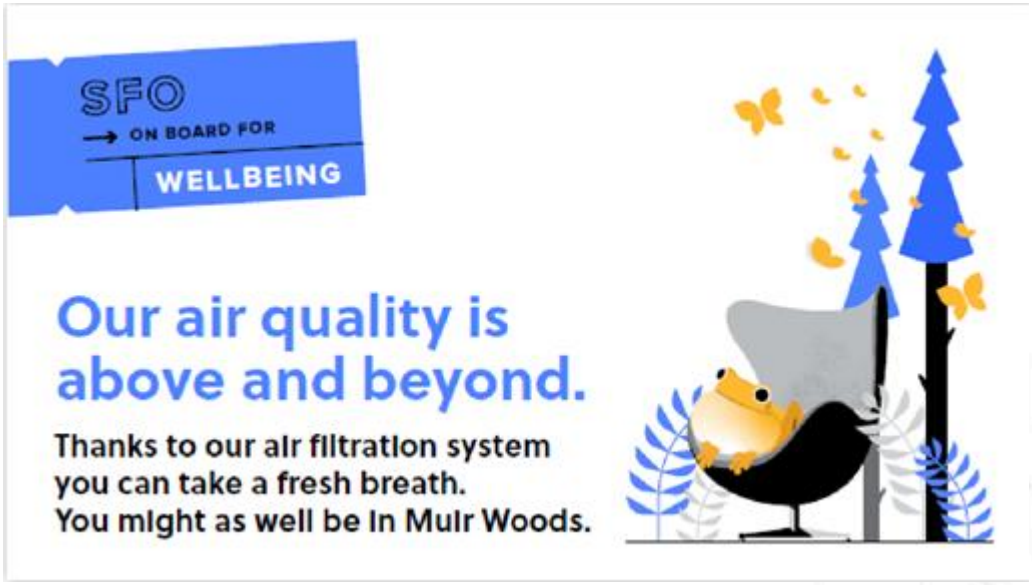
Total:
3,217,779 sq. ft.
298,941 sq. m.

Next Steps

Having put the current initiatives in place:

1. What additional policies and strategies should the Airport consider?

2. What technologies might be available for implementation at the Airport to measure and manage the air quality in real time to provide improved healthy environments?



Air Quality Monitors: Pilot Projects

Pilot Project 1

- Courtyard 3 Connector Office Building (WELL Building Standard)

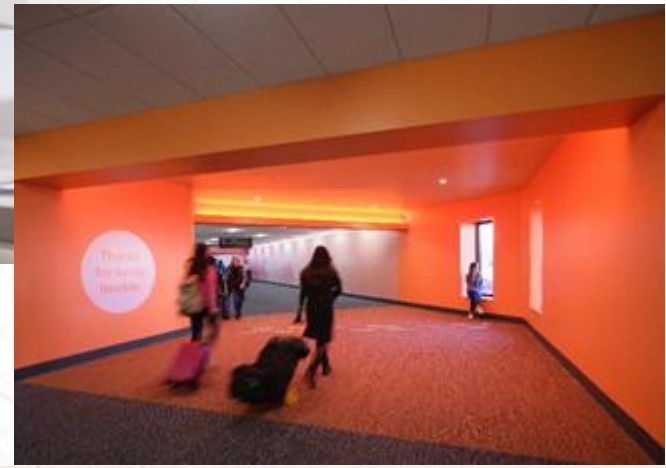
Pilot Project 2

- Terminal 3 West

Other Projects

- International Terminal Building Phase 2 (Customs & Border Protection Offices)
- Terminal 3 West Interim Corridor
- To be determined

Photo credit: Bruce Damonte



Air Quality Monitoring Devices: Test Reusable Filter Program

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Air Quality Measurement Technology

SFO is deploying a range of air quality monitors across the airport

New Build Projects

Wired devices

Indoor

Sensedge

Indoor

Sensedge Mini

- T3 Interim Corridors
- Courtyard 3 Connector

Outdoor

Sensedge Mini Outdoors

- Outdoors (ground level and AHU)

Retrofit Projects

Wireless devices

Indoor

Sensedge Go

- Air Filter Pilot
- Terminal 3 West*

Outdoor

Sensedge Go Outdoors

Induct

Coming soon

A range of IAQ and IEQ parameters are measured based on different project needs

	Sensedge Go for WELL WIRELESS - INDOOR	Sensedge Mini for WELL WIRED - INDOOR	Sensedge Mini Outdoors WIRED - OUTDOOR
CO_2	✓	✓	✓
Temp & RH	✓	✓	✓
PM_1, $PM_{2.5}$, PM_{10}	✓	✓	✓
TVOC	✓	✓	
O_3	✓	✓	
CO	✓	✓	
NO_2	✓	✓	
Air Pressure	✓		
Light (Lux & Spectrum)	✓		
Occupancy	✓		

- Fully compliant with WELL v2 (replacing on-site testing and earn up to to 9 points)
- Support LEED v4.1 BD+C and LEED v4.1 O+M
- Fully compliant with LEED v5 O+M (up to 10 points)
- Easy calibration and future proofing with hot-swappable sensor modules

Rapid scaling from two primary pilots (C3C and T3W) to airport-wide rollout

	Live Deployments				Upcoming Projects (TBD)			
Project Name	**T3W Interim Corridor (West)**	**T3W Interim Corridor (East)**	**Courtyard 3 Connector (C3C)**	**K&N Washable Air Filter Pilot**	**International Terminal CBP**	**Boarding Area G**	**Terminal 3 West (T3W)**	**West Field Cargo Facilities**
Indoor	Yes	Yes	Yes	Yes	Yes	TBD	TBD	TBD
Outdoor	Yes	Yes	Yes	-	-	TBD	TBD	TBD
CO_2	Yes	Yes	Yes	Yes	Yes	Yes	TBD	TBD
$PM_{2.5}$	Yes	Yes	Yes	Yes	Yes	Yes	TBD	TBD
PM_{10}	Yes	Yes	Yes	Yes	Yes	Yes	TBD	TBD
CO	-	-	Yes (partial)	-	TBD	Yes	TBD	TBD
Temperature	Yes	Yes	Yes	Yes	Yes	Yes	TBD	TBD
Humidity	Yes	Yes	Yes	Yes	Yes	Yes	TBD	TBD
NO_2	-	-	Yes (partial)	-	TBD	Yes	TBD	TBD
O_3	-	-	Yes (partial)	-	TBD	Yes	TBD	TBD
TVOC	Yes	Yes	Yes	Yes	Yes	Yes	TBD	TBD
Light	-	-	-	Yes	TBD		TBD	TBD
Occupancy	-	-	-	Yes	TBD		TBD	TBD

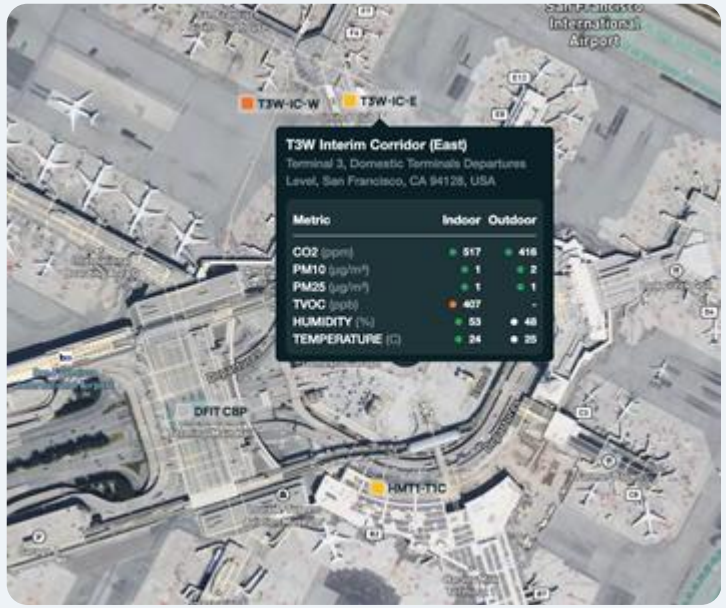
One solution to comply with multiple certifications, streamlining crosswalks

Certification	Relevant Features / Credits	Points Available	IAQ & IEQ Parameters	Compliance
WELL v2	A01 Air Quality A03 Ventilation Design A05 Enhanced Air Quality A06 Enhanced Ventilation Design A08 Air Quality Monitoring & Awareness T01 Thermal Performance T06 Thermal Comfort Monitoring T07 Humidity Control *I01 Propose Innovation*	Up to 3 preconditions & 9 optimization points *(excluding innovation points)*	$PM_{2.5}$ & PM_{10} TVOC CO_2 CO Ozone NO_2 Temperature Relative humidity	✓
LEED v5 O+M	Indoor Air Quality Performance	Up to 10 points	CO_2 $PM_{2.5}$ TVOC	✓
Fitwel v2.1	Indoor Air Quality Testing Indoor Air Quality Testing Results	Up to 3.92 points	$PM_{2.5}$ TVOC CO_2 Relative humidity	✓
Fitwel v3	Indoor Air Quality Assessment Air Quality Assessment Results	Up to 2.58 points	$PM_{2.5}$ CO_2 Temperature Choose 3: TVOC/RH/Ozone (testing only)/CO(testing only)/NO2(testing only)/ HCHO(testing only)	Partially compliant

Aligning performance thresholds to SFO and broader industry standards

Parameter	Kaiterra Default Thresholds (WELL V2)	SFO Custom Thresholds (Where Applicable)
$PM_{2.5}$	≤15 µg/m³ *(A01 Precondition)*	**≤12 µg/m³** *(WELL V2 A05 Enhanced - Tier 1)*
PM_{10}	≤ 50 µg/m³ *(01 Precondition)*	**≤20 µg/m³** *(WELL V2 A05 Enhanced - Tier 2)*
TVOC	≤500 µg/m³ *(A01 Precondition)*	N/A - Aligned *(WELL v2, LEED v4.1)*
CO_2	≤900 ppm *(A03 Precondition)*	N/A - Aligned *(WELL v2, LEED v4.1)*
CO	≤9 ppm *(A01 Precondition)*	N/A - Aligned *(WELL v2, LEED v4.1)*
Ozone	≤51 ppb *(A01 Precondition)*	N/A - Aligned *(WELL v2, LEED v4.1)*
NO_2	≤40 µg/m³ *(A05 Enhanced)*	N/A - Aligned *(WELL v2)*
Temperature	70-77 °F *(T01 Precondition)*	N/A - Aligned *(WELL v2)*
Relative humidity	30–60% *(T07 Optimization)*	N/A - Aligned *(WELL v2)*

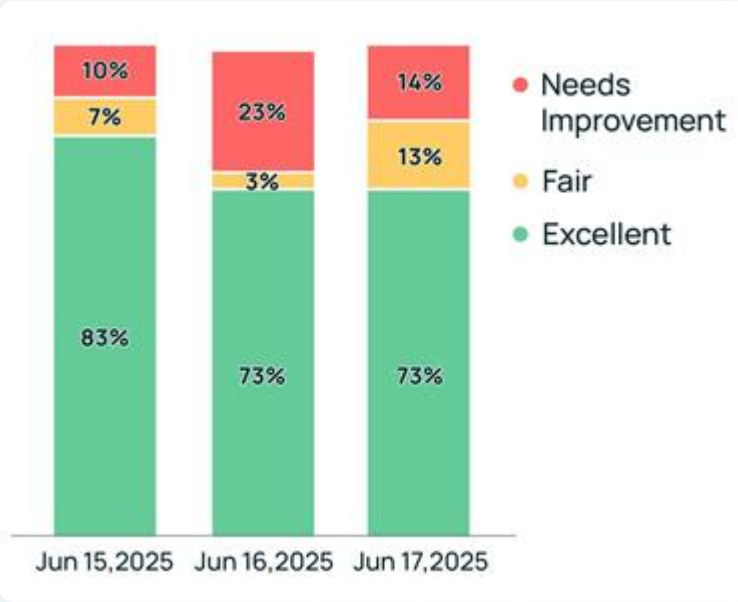
Continuously track airportwide performance in real-time and over time in the SFO dashboard



View live data across SFO campus map

Building	CO_2	Temperature
Courtyard 3 Connector (C3C)	100%	97.7%
Harvey Milk Terminal 1 BAB	100%	87.1%
T3W Interim Corridor (West)	100%	81.7%
T3W Interim Corridor (East)	100%	81.4%
Harvey Milk Terminal 1 Center	100%	79.5%

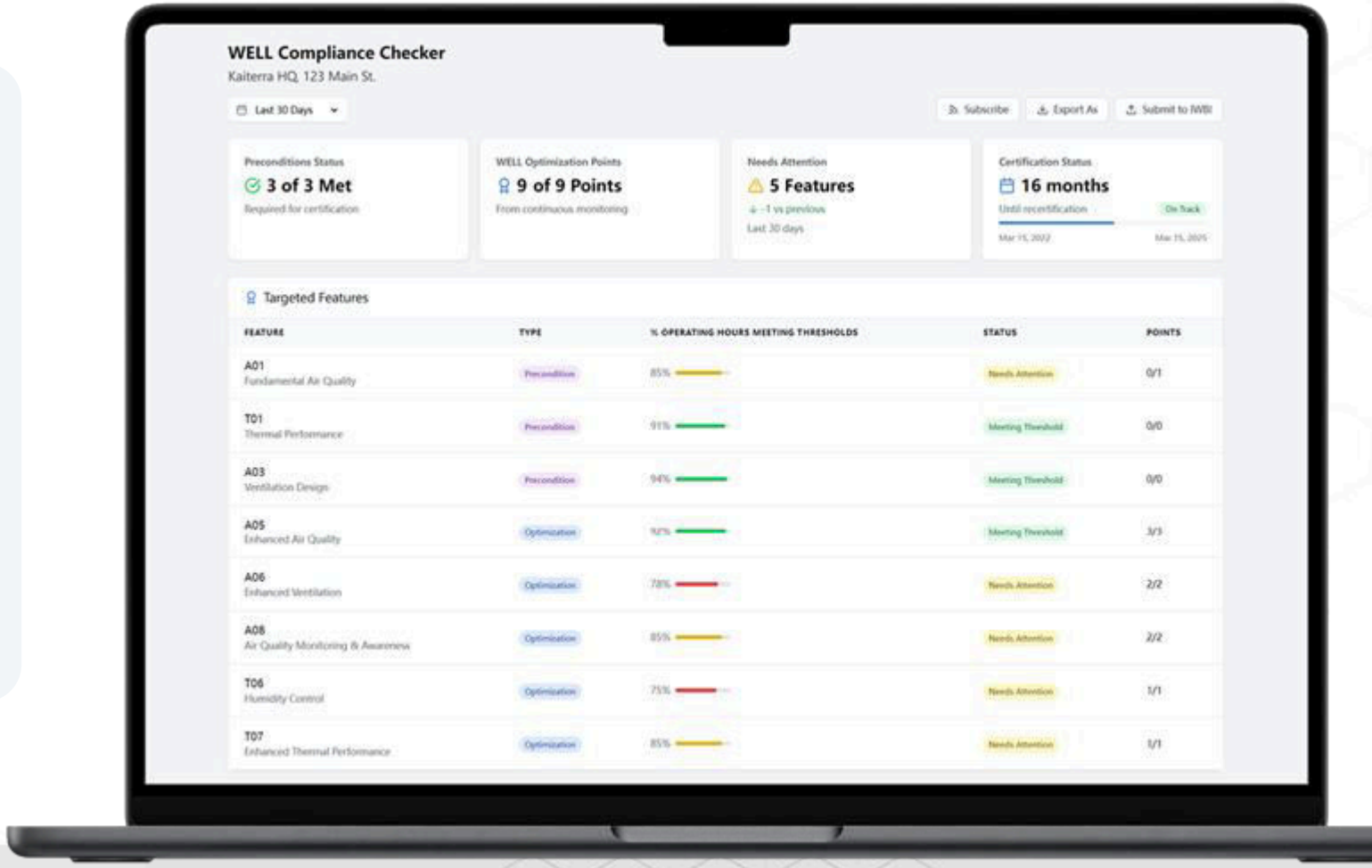
Access and rank portfolio by performance



Track performance changes over time

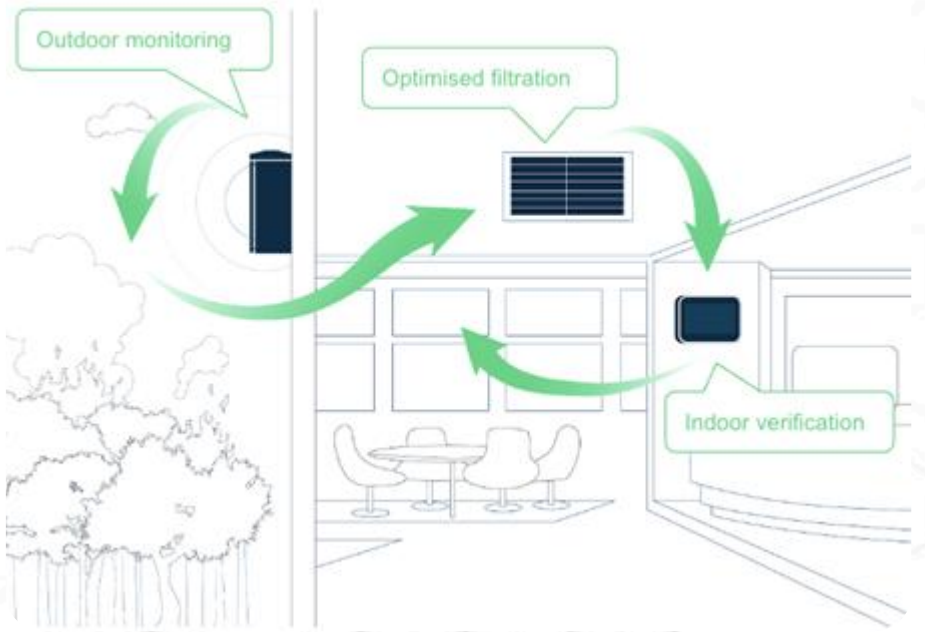
Derisk, streamline and reduce cost of individual SFO green building certifications

- Replace annual on-site testing & contractors for certifications ($$$)
- Save 100+ hours on data preparation and submission
- Check compliance in real-time
- Flag risks or missing data ahead of submission
- Identify and fix issues faster
- One-click data submission

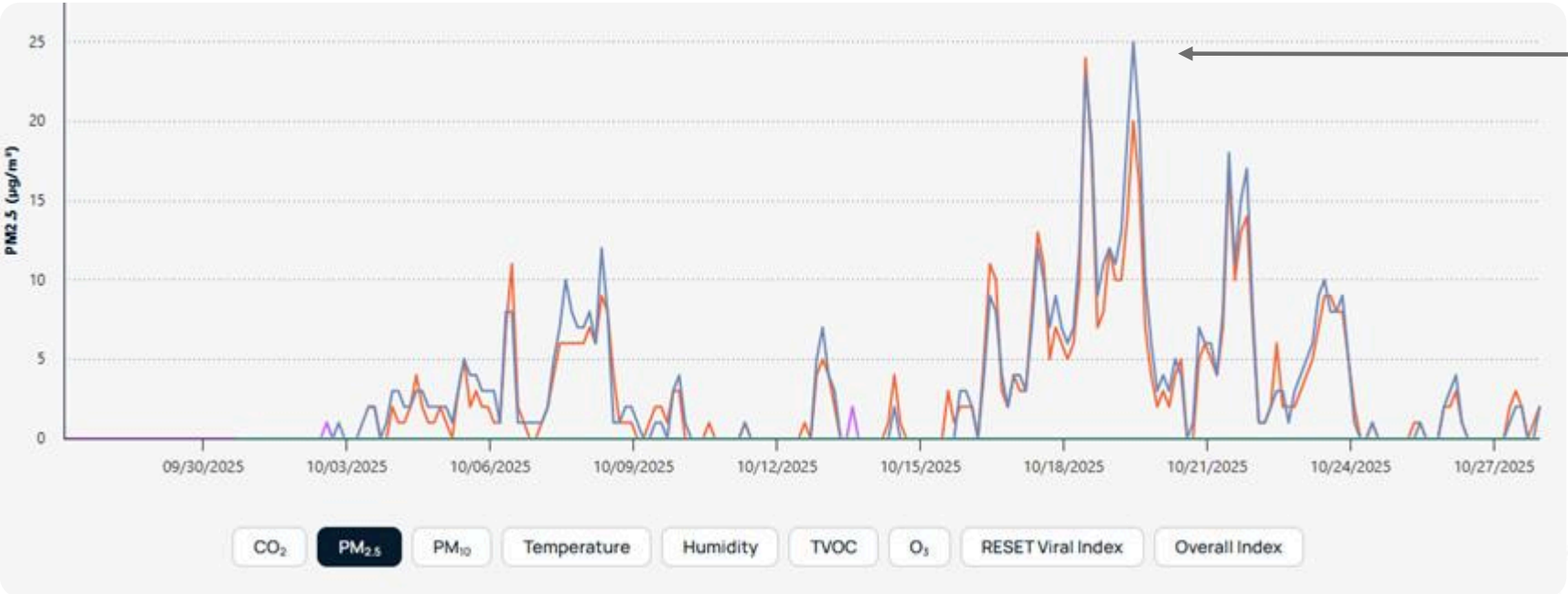


Proactively Manage Indoor Air Quality with Real-Time Outdoor Data

- **Optimize Outdoor Air Intake:** Real-time data lets SFO maximize fresh air when clean and minimize intake when polluted.
- **Verify Filtration:** Comparing outdoor intake to indoor levels provides real-time validation of filter effectiveness.
- **Promote Health Equity:** Dedicated ground-level monitors track air quality for frontline staff, protecting all SFO employees.
- **Proactive Event Response:** Correlating data helps SFO anticipate impacts from outdoor events (e.g. jet fumes and wildfires).
- **Enable Future Automation:** Enables smart BMS controls to optimize ventilation based on real-time outdoor data.

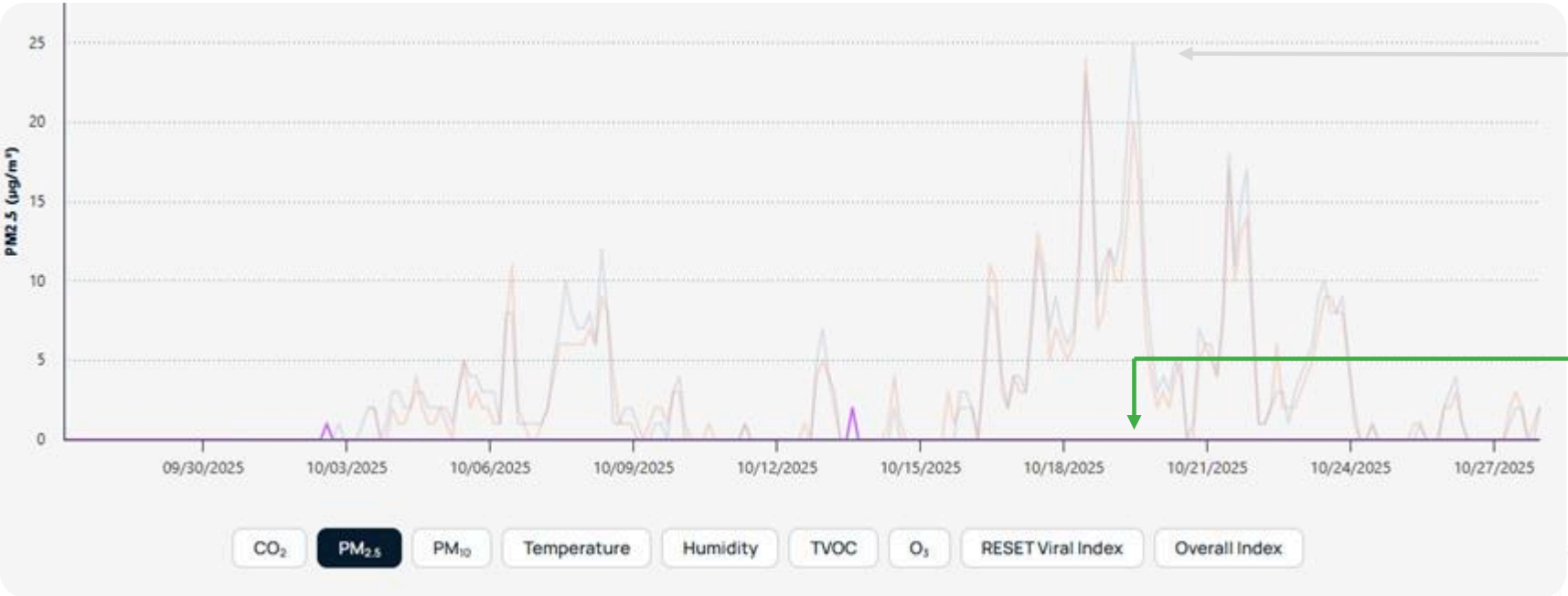


C3C Example 1: Verifying Filtration & Equity



OUTDOOR AIR:
Volatile spikes in PM2.5 and nearly identical between ground-level and roof-level monitors

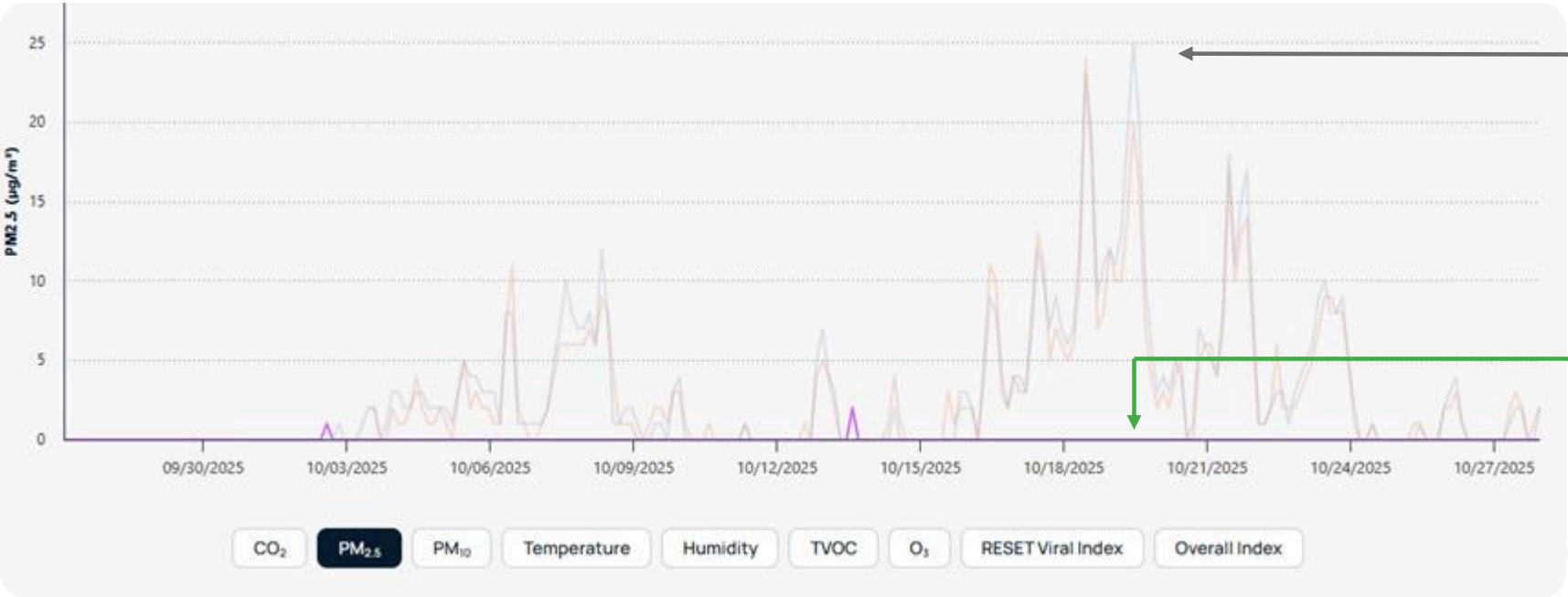
C3C Example 1: Verifying Filtration & Equity



OUTDOOR AIR:
Volatile spikes in PM2.5 and nearly identical between ground-level and roof-level monitors

INDOOR AIR:
All indoor monitors show '0' PM2.5, proving exceptional filtration.

C3C Example 1: Verifying Filtration & Equity



OUTDOOR AIR:
Volatile spikes in PM2.5 and nearly identical between ground-level and roof-level monitors

INDOOR AIR:
All indoor monitors show '0' PM2.5, proving exceptional filtration.

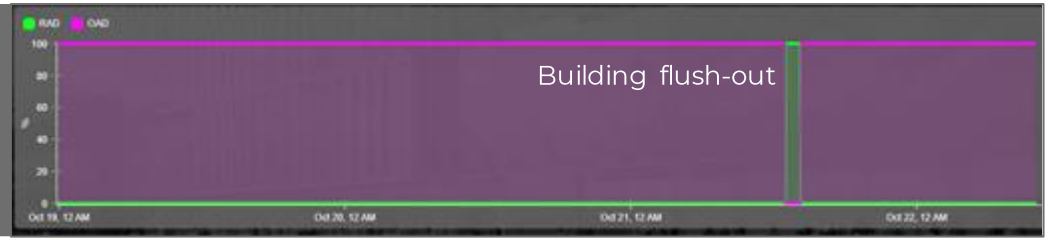
PROVEN FILTRATION
Indoor "flat-line" data (vs. spiky outdoor data) provided the first real-time proof of exceptional filter performance.

DATA-DRIVEN EQUITY
Correlated ground-level and roof-level data gives SFO real-time awareness to protect frontline staff.

FUTURE SUSTAINABILITY
Unlocked condition-based filter maintenance, which can reduce material waste and operational costs.

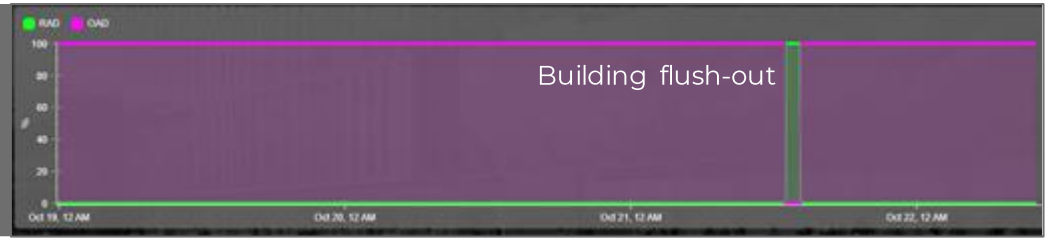
C3C Example 2: Correlating Data During an Outdoor Event

The "Cause": Building Operations (BMS Data)

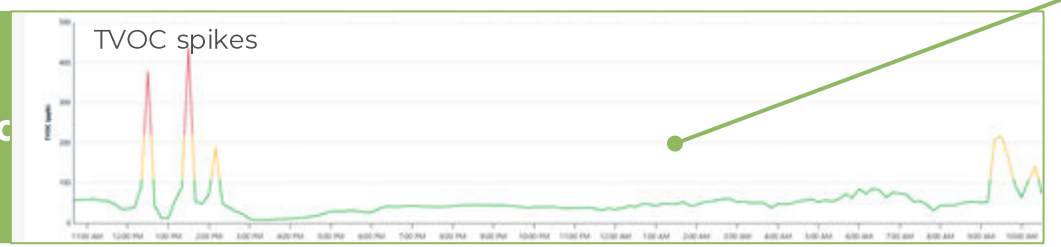


C3C Example 2: Correlating Data During an Outdoor Event

The "Cause": Building Operations (BMS Data)



The "Effect": Real-Time IAQ (Dashboard Data)



C3C Example 2: Correlating Data During an Outdoor Event

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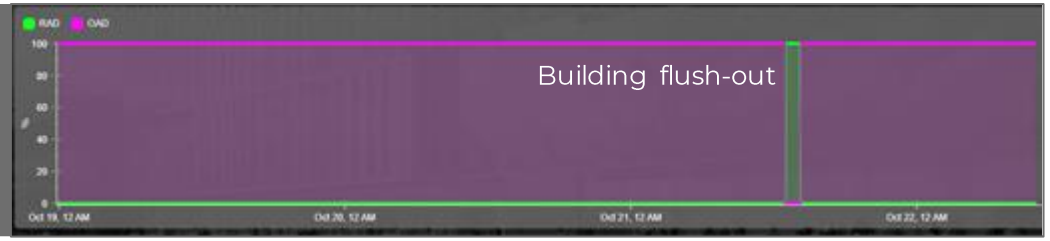

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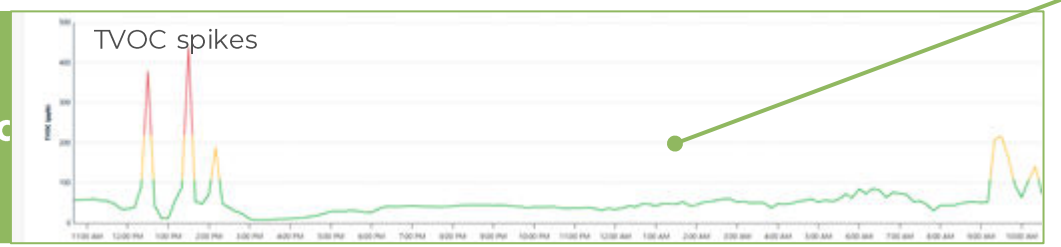

THE EVENT

A planned "building flush" (dampers at 100%) coincided with an outdoor air event (jet fumes).

THE CORRELATION

The IAQ dashboard instantly correlated the two data streams, showing the TVOC impact in real-time.

THE INFORMATIVE WIN:

This insight was a "WIN!" for SFO, providing the data needed to refine future operational plans and set up proactive alerts.

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Business Case (Triple Bottom Line Analysis)

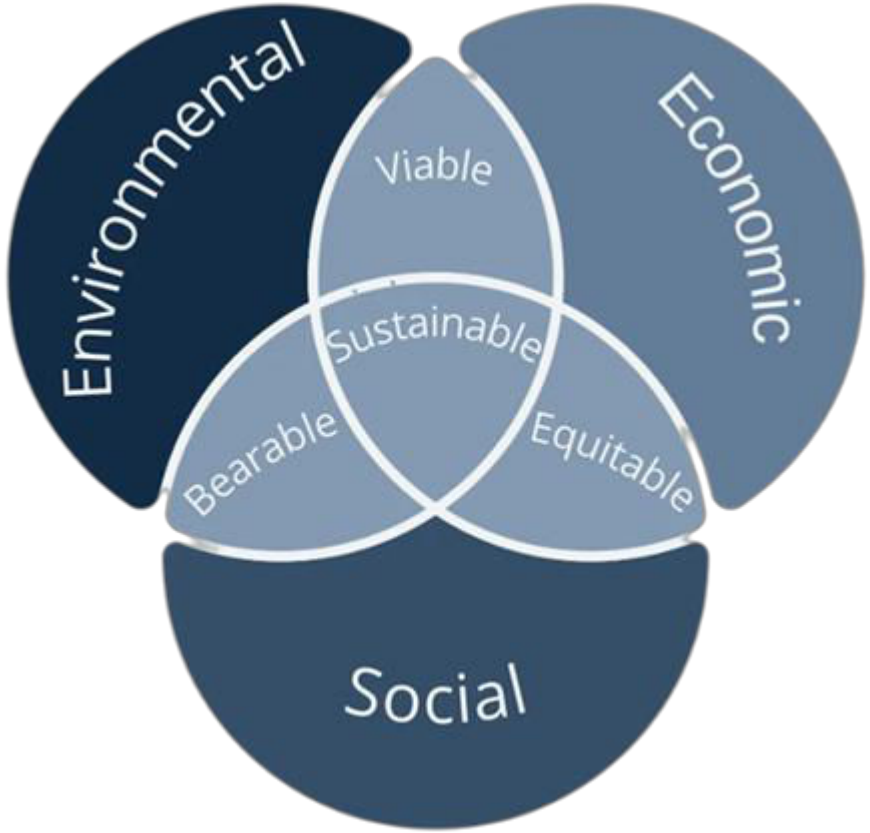
Why Real-Time Air Quality Pays Off

Problem: Suboptimal air quality often goes undetected for days.

Solution: Air quality monitors flag issues within 1 day (vs. 7) to trigger faster response.

Result: Shorter exposure windows, healthier people, and better operations.

Triple Bottom Line: ROI Beyond Dollars



What Drives ROI at SFO?

- Occupancy & exposure duration for employees and passengers
- Pollutant concentrations and thresholds (CO_2, $PM_{2.5}$, VOCs)

- Complaint data baseline (278/year)
- 85% reduction with air quality monitors

- Dose response functions mapping exposure to health outcomes
- ↓ Air Pollutant Exposure = ↑ Health Outcomes

Quantifying the Benefits

Financial Impacts	Avoided complaint maintenance and lab costs
	Lower compliance costs (e.g., WELL recertification)
Social & Environmental Impacts	Improved occupant health and comfort
	Better passenger experience and trust
	Reduced criteria air contaminant exposure (e.g., CO2, VOCs, PM2.5)
	Reduced greenhouse gas exposure

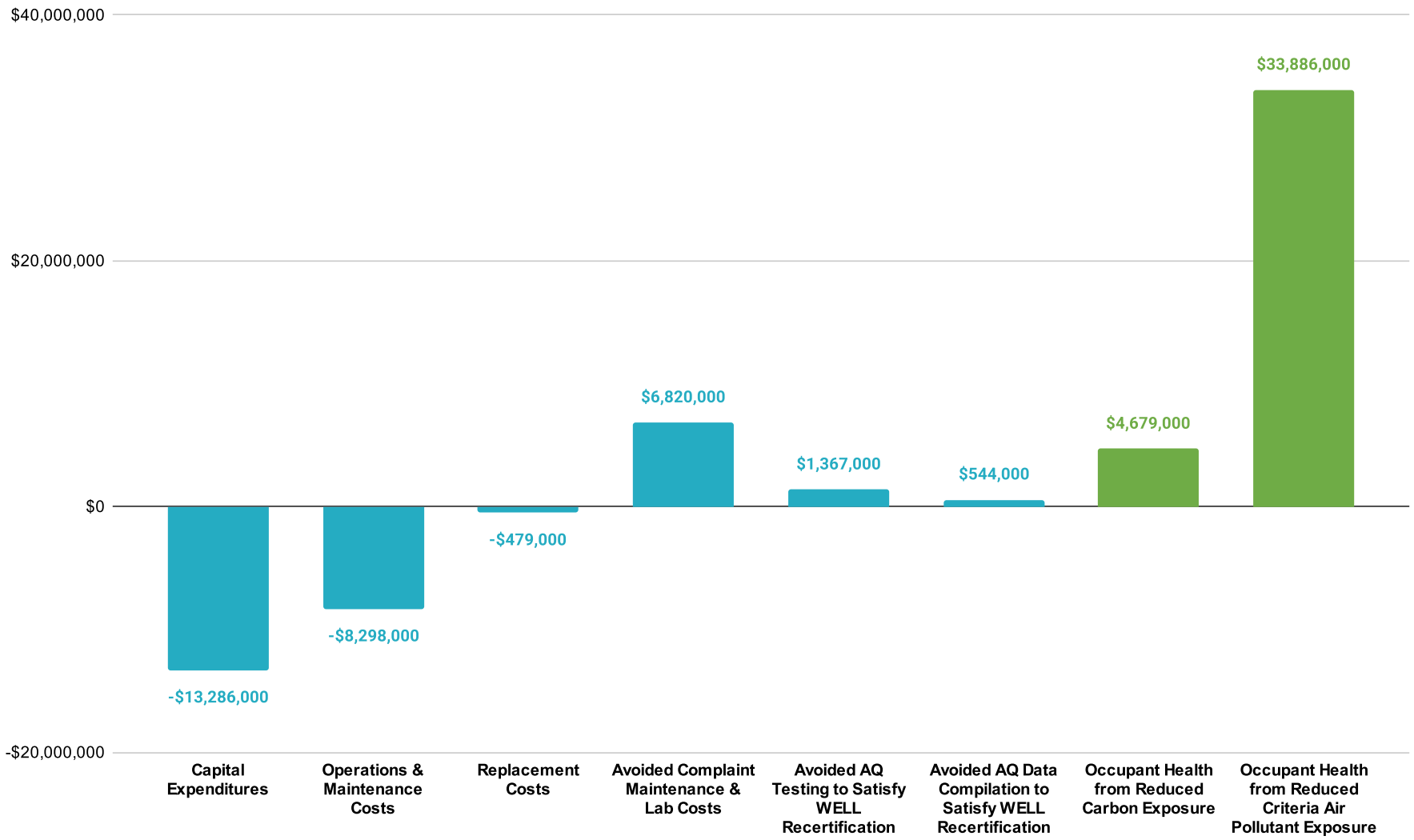
Pilot Project – Courtyard 3 Connector

Air Quality Monitoring Devices Triple Bottom Line NPV (over 20-years)		
Financial	Capital Expenditures	-$306,000
	Operations & Maintenance Costs	-$191,000
	Replacement Costs	-$11,000
	Avoided Complaint Maintenance & Lab Costs	$157,000
	Avoided AQ Testing to Satisfy WELL Recertification	$31,000
	Avoided AQ Data Compilation to Satisfy WELL Recertification	$13,000
Environmental & Social	Occupant Health from Reduced Carbon Exposure	$108,000
	Occupant Health from Reduced Air Pollutant Exposure	$780,000
Financial NPV		**-$307,000**
Environmental & Social NPV		**$888,000**
TBL-NPV		**$581,000**
TBL-BCR		**2.1**

Scaling the Strategy

Campus Wide Air Quality Monitoring	1 air quality monitor per 10,800 square feet of Airport terminal space, aligning with the WELL Building Standard requirements.
	90% of SFO's total gross floor area is terminal space, where air quality monitors would be installed.
	1,478 air quality monitors required for 15.9 million square feet of Airport area that will need to be monitored and evaluated.

Campus Wide Air Quality Monitoring



Sustainable Operations

The Business Case - Reusable Air Filters	SFO has 300+ AHUs serving employees, tenants, and passengers
	Reusable filters: lower pressure drop, potential fan energy savings
	Two maintenance options evaluated: in-house vs. service contract

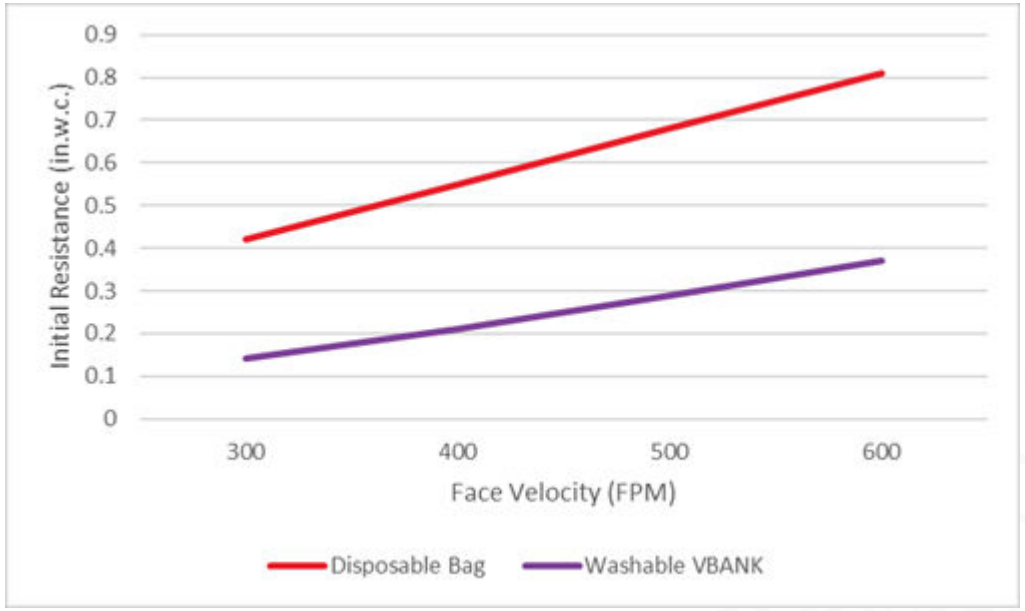
Filters – Side-by-Side Comparison

Disposable Filters	VS	Reusable Filters
Replaced seasonally; only recycled packaging		15+ year lifespan; wash & swap with backups
Higher pressure drop → higher fan energy		Lower pressure drop → potential energy savings
Ongoing transport and landfill trips		Requires storage and wash logistics

Pressure Drop Over Time

Performance

- The reusable filters are shown to have lower pressure drop than their disposable counterparts, resulting in lower fan energy costs.

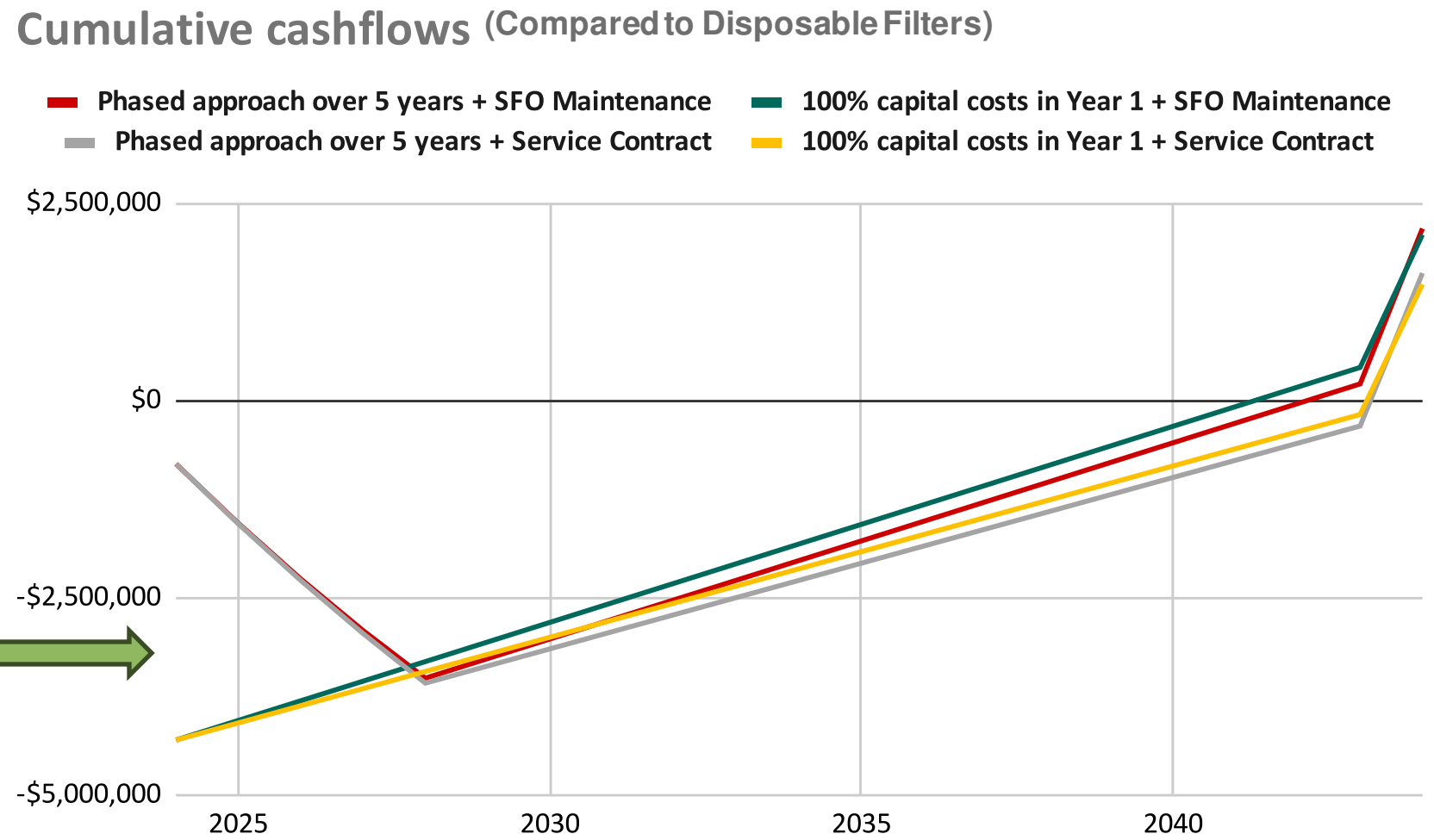


Source: Arup

Maintenance

- Washing versus filter replacement labor
- SFO is considering two options: (1) in-house maintenance or (2) service contract.

Best Option – In-House Maintenance



Reflects the cost difference of 100% replacement vs. phased approach

Affirms that in-house maintenance is the most cost-effective deployment option

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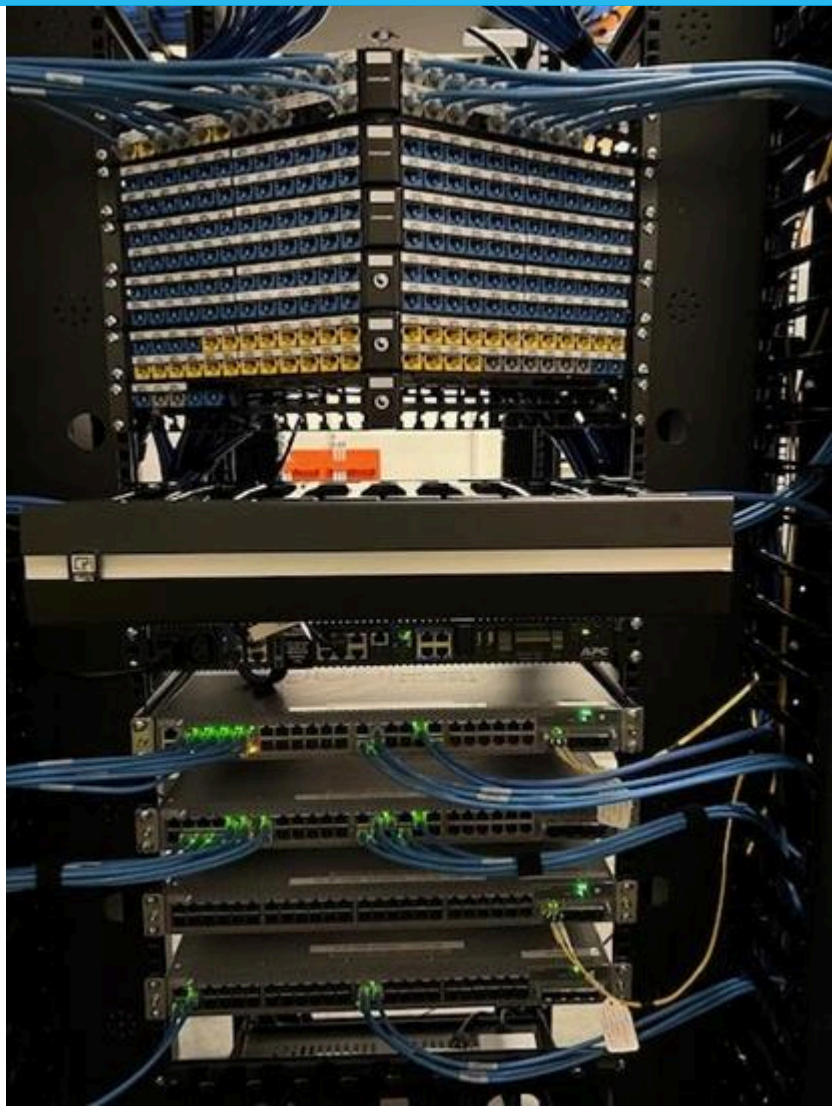
Lessons Learned

Lessons Learned from SFO

- **Data security** is a major consideration at an airport.
- **Dedicated champion** to review and utilize the data.
- **Roles and responsibilities**
- **Cost** includes procurement & installation + operation & maintenance.
- **Potential legal concerns** with having and/or publishing the data.
- **Owner commissioning** process.



Key Takeaways for Owners & Operators

Results are tempered from the large capital cost difference between disposable filters and reusable filters

Incurring 100% of the capital costs in Year 1 has a slightly higher NPV than the phased approach over 5 years

It is most cost effective for SFO to wash the reusable filters in-house instead of a 3rd-party

In both deployment cases, the investment payback period is reduced by over 2 years through in-house maintenance.

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Q&A

Creating the World's Healthiest Airport – Lessons from SFO

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