Herrick Laboratories PURDUE UNIVERSITY

2014 Purdue Conferences
Compressor Engineering
Refrigeration and Air Conditioning
High Performance Buildings

Energy Modeling of a Botanical Air Filter

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Research Question and Goals

Research Question: Can botanical air filtration improve indoor air quality in energy efficient residences while reducing the need for outside air ventilation?

Performance Objective	Metric	Data Requirements	Success Criteria
Quantitative Performance Objectives			
1. Improve IAQ	VOC and CO_2 levels	Air Quality Sensor(s)	Reduce pollutants by 10-20%
2. Reduce energy	kW, kWh	Power Sensor(s)	Reduce HVAC energy
Qualitative Performance Objectives			
3. Visual Appeal	Plant health/vitality	Evaluation by Horticulturalist	Healthy & thriving plants
4. Maintenance	Amount of watering/maintenance	Track maintenance schedule	Owner maintenance < once a week

Hypotheses and Assumptions

Ho: The botanical air filter has no impact on indoor air quality

Ha: The botanical air filter has a positive impact on indoor air quality

Assumptions

- Homeowner likes gardening
- Designed into energy efficient home
- “black box” plant approach

Problems in IAQ

- Americans spend 90% of their time indoors
- Indoor air is 2-5x more polluted than outdoor air
- Elderly and young more at risk

Source of Productivity Gain	Potential Annual Health Benefits	Potential US Annual Savings or Productivity Gain (1996 $US)
Reduced respiratory illness	16 to 37 million avoided cases of common cold or influenza	$6–$14 billion
Reduced allergies and asthma	18% to 25% decrease in symptoms for 53 million allergy sufferers and 16 million asthmatics	$1–$4 billion
Reduced sick building syndrome symptoms	20% to 50% reduction in sick building syndrome health symptoms experienced frequently at work by ~15 million workers	$10–$30 billion
Improved worker performance from changes in thermal environment and lighting	Not applicable	$20–$160 billion
Total cost of energy in US commercial buildings[a] (for reference, in 1995)	Not applicable	$70 billion

Brief History of Botanical Air Filtration

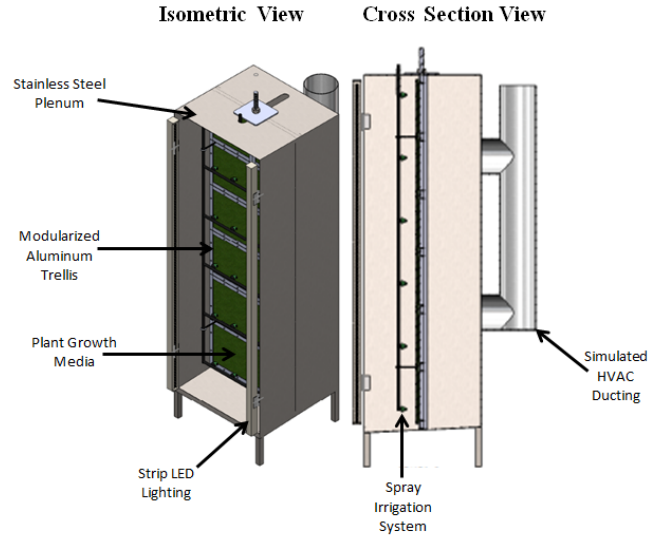
1982
Wolverton studies plants for deep space

2000
Darlington relates to health effects

2011
Rodgers builds first Biowall

2011
Wang relates to energy consumption

Experimental Design

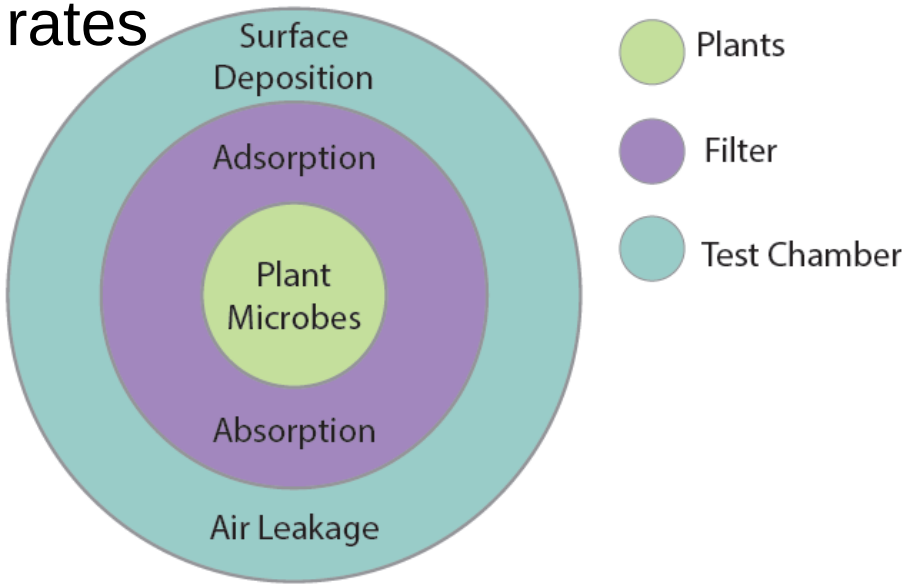


Outside Test Chamber

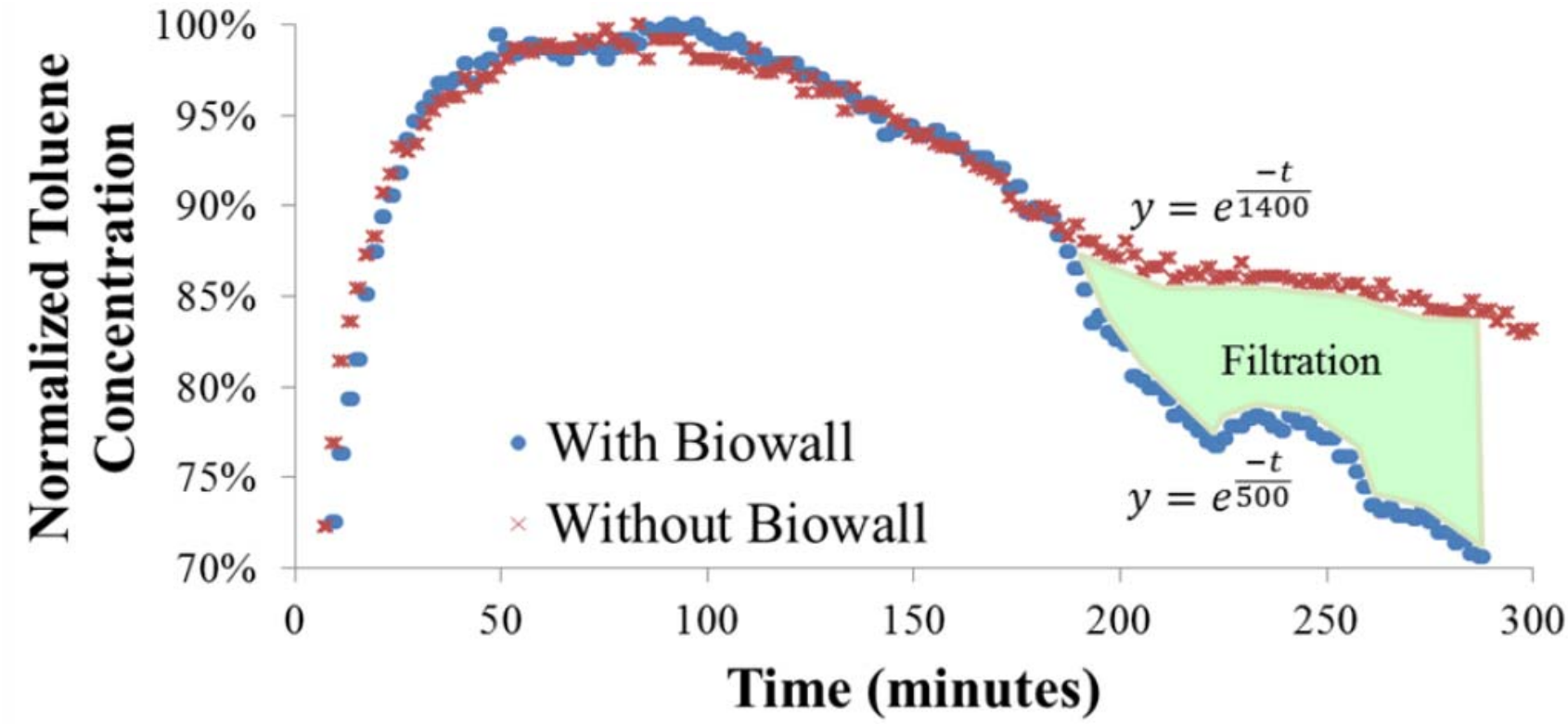
Inside Test Chamber

Experimental Protocol

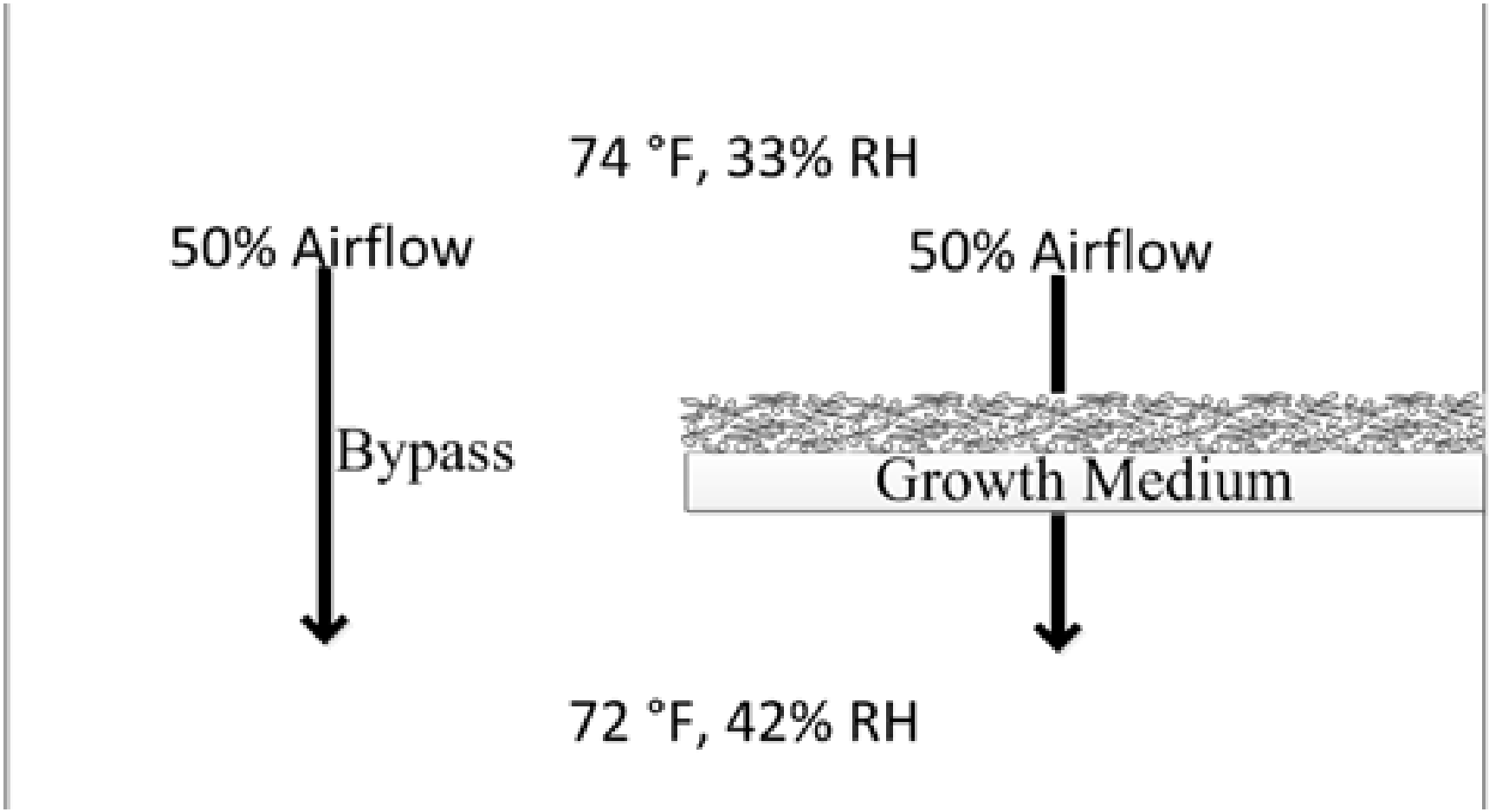
- Monitor introduction, generation and decay of toluene each test
- Multiple tests for each scenario, with and without Biowall
- Comparisons using decay rates



Indoor Air Quality Results



Psychrometric Data Collection



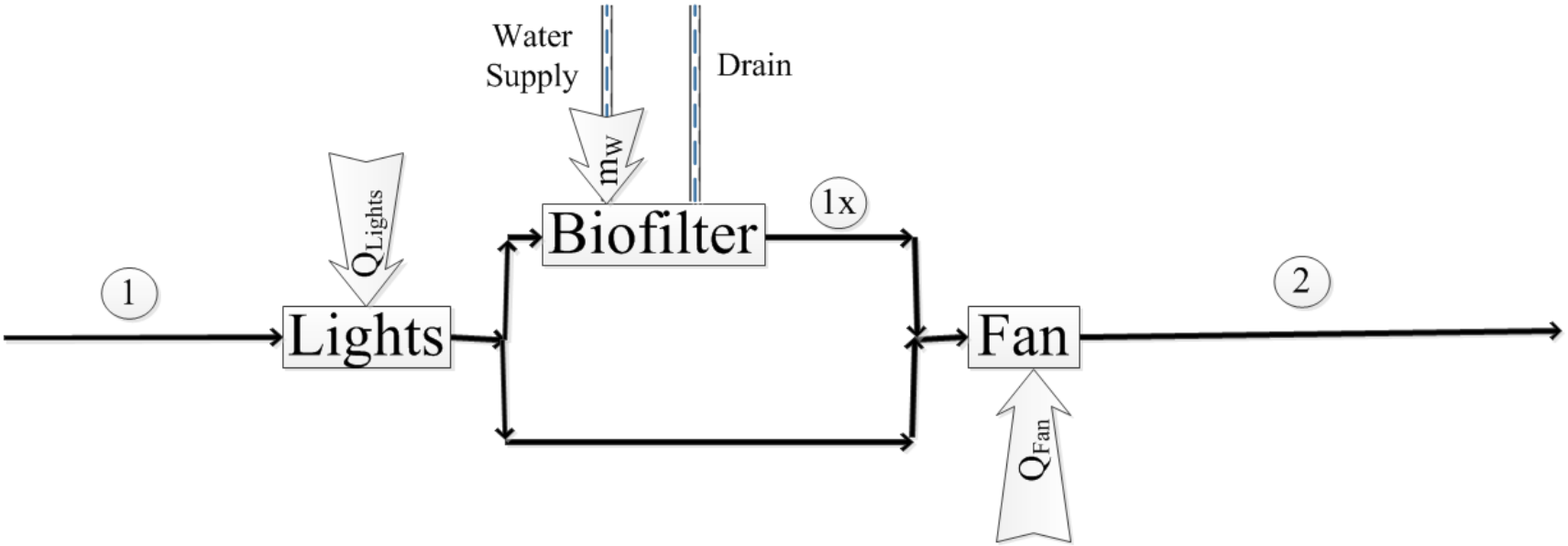
Model Calibration

$$BP = \frac{\dot{V}_{BP}}{\dot{V}_T}$$

$$Q_{lights} = \dot{m}(h_{1x} - h_1)$$

$$\varepsilon = \frac{T_{1,DB} - T_{2,DB}}{T_{1,DB} - T_{1,WB}}$$

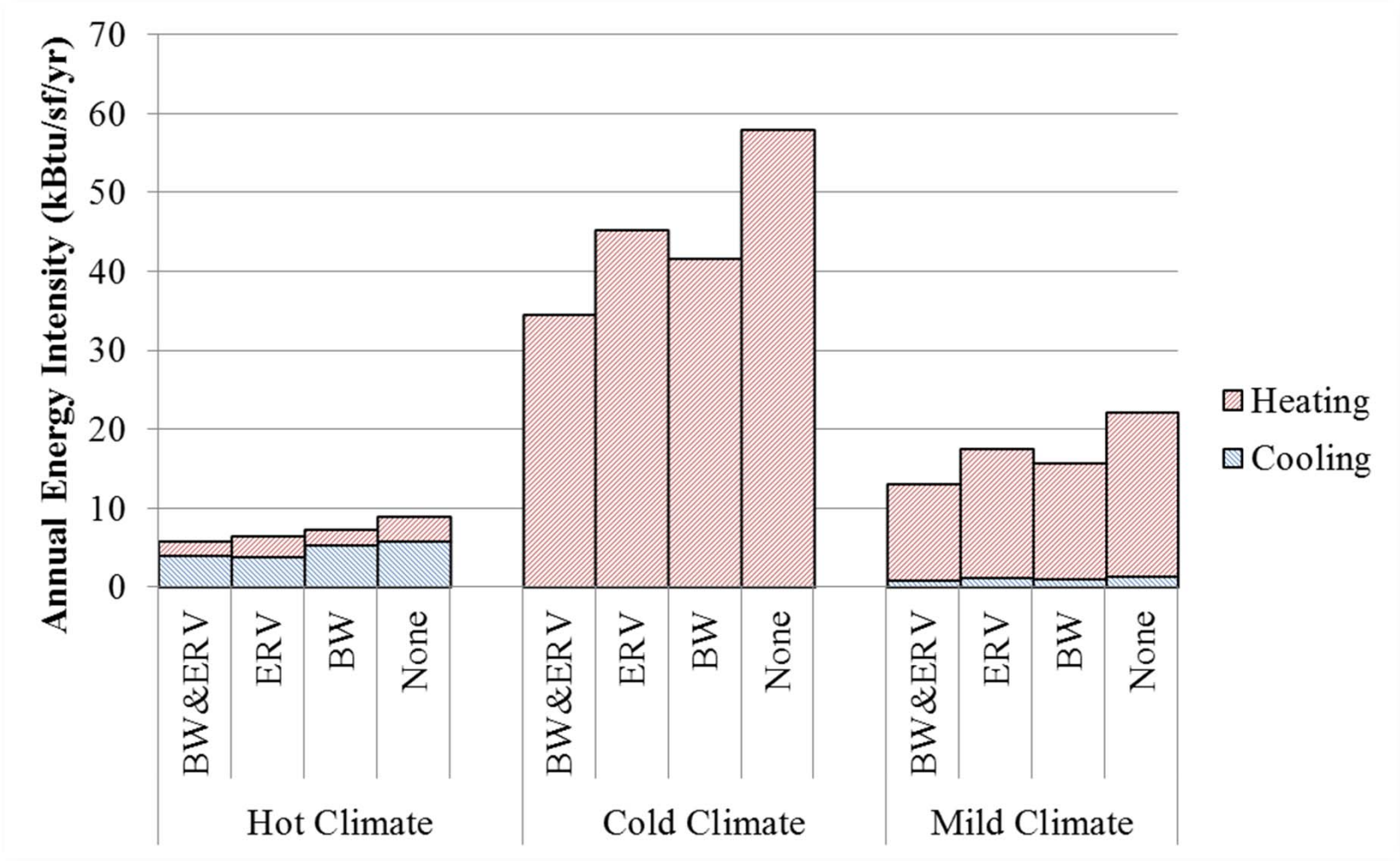
$$\omega_2 = (1 - BP)w_{1x} + BPw_1$$



Calibrated Energy Model Results

Biowall Parameter	Measured	Modeled	Error
Outlet temperature, T_2 (°F)	72.0	72.6	1%
Outlet humidity, RH_2 (%)	42	42	0%

Further Energy Results



Future Project Application

- Informing USGBC performance based standards
- Product optimization and field testing
- End commercialization goal: 1-800-Biowall

So What?

People

- Aesthetics
- Health and Productivity
- Social Justice

Planet

- Resources
- Scalability

Prosperity

- 125 Billion Dollars
- 25% energy savings

Acknowledgements

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Questions?