

## Living Green Walls for Interior Spaces

# About me

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- ▶ PEDCO
- ▶ 25 years in mechanical HVAC engineering with an interest in sustainable building design
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What a living  
green wall is

Benefits

Practical  
considerations

What you will be learning today

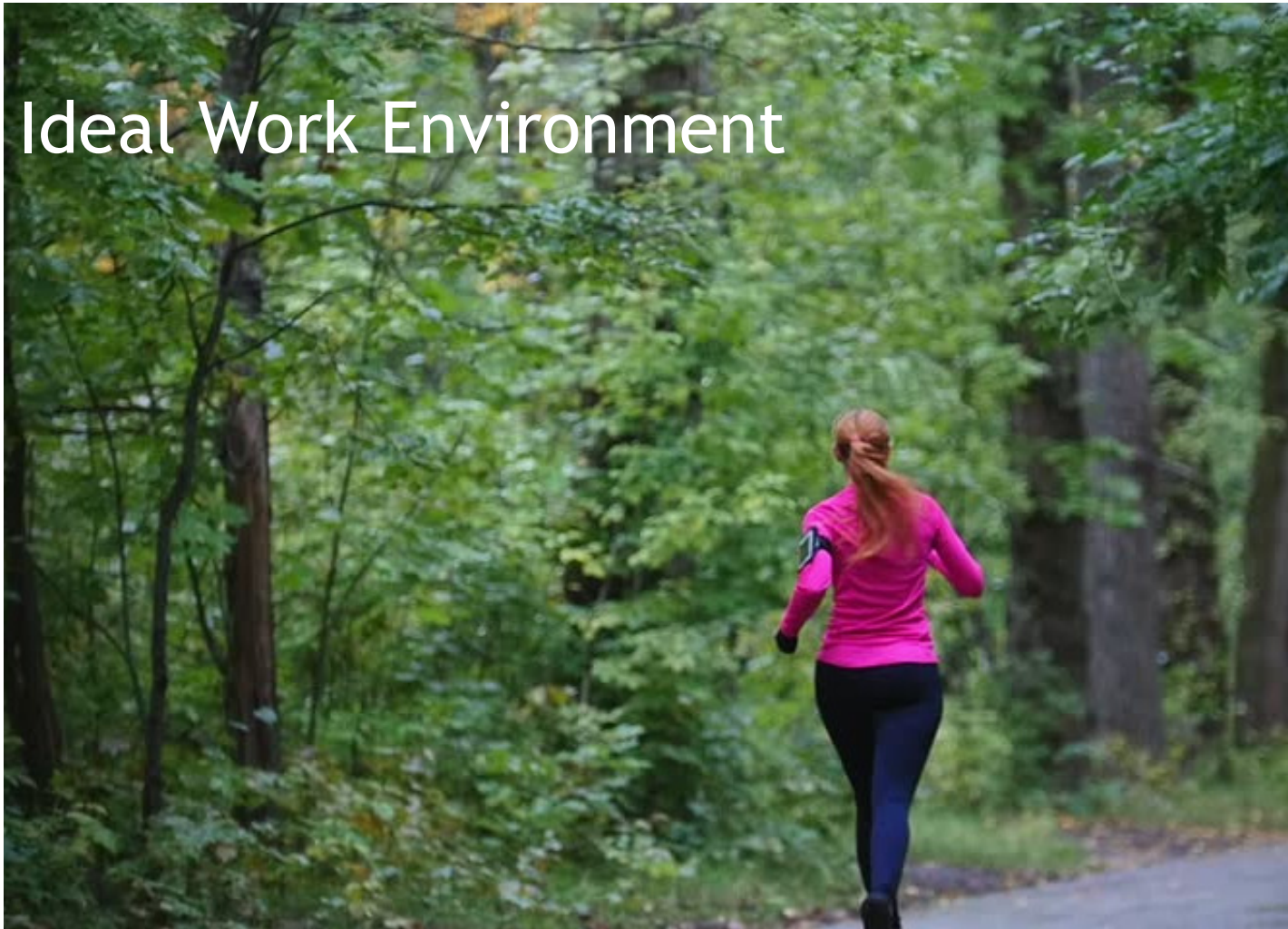




## Important for Engineers to Embrace and Champion New Sustainable Technology

- ▶ Understand it
  - ▶ Impact on the internal environment
    - ▶ IAQ
    - ▶ potentially the energy model
    - ▶ Lighting
    - ▶ Plumbing
- ▶ Embrace and Champion Sustainable Technology

# Ideal Work Environment





Credit Agricole's Village  
of Innovation





## What is a living or green wall?

- ▶ Interior or exterior wall of plants in a structural support system



Georgetown University



Westminster City Hall

# Types of Interior Living Green Walls

## ▶ Main types

- ▶ Tray - plants grown in or separately from tray, installed on-site (can use 4" potted plants)
- ▶ Panel - pre-grown panels of plants inserted into structural system

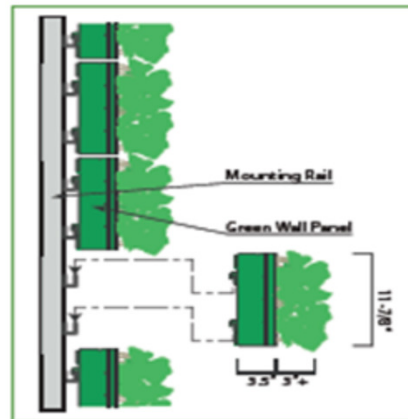


# Example of a Panel System

Ambius, Inc



## ProWall Panel Detail



<http://www.ambius.com/green-walls/>

gsky  
Plant Systems Inc.

## ProWall System Components:

- 1 **Stainless Steel Mounting Frames:** the frames can be mounted on concrete, CMU, and metal or wood frame structures.
- 2 **Stainless Steel Panels:** standard panels are one foot square or panels can be custom sized to fit any design or wall size.
- 3 **Non-Soil Structural Growth Medium:** the patent-pending non-eroding growth material promotes strong root structure which ensures plant longevity.
- 4 **Plants:** our plants are pre-grown into the panels to ensure health, longevity, and beauty.
- 5 **Remote Irrigation/Fertilization System:** the 24/7 remote monitoring system by GSKy is a computerized vertical drip irrigation system with temperature, moisture, and freeze-thaw sensors.



# Tray System

## Live Wall, Inc.



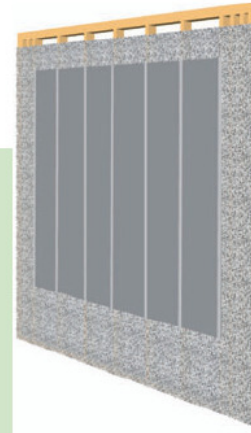
These plants were "dropped in" in about 20 minutes following installation of the LiveWall indoor system.

<https://livewall.com/living-wall-system/indoor-living-wall/>

3

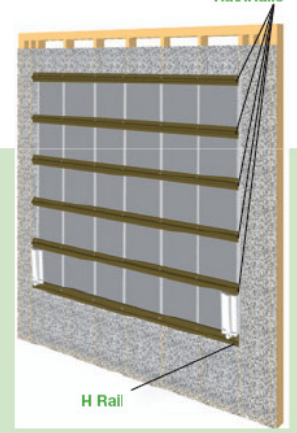
Install the VertiRail Aluminum furring tracks to the wall, over the waterproofing material on 16 to 32 inch centers.

NOTE: Installer chooses and sources proper anchors for attachment of VertiRail® furring tracks to wall or studs.



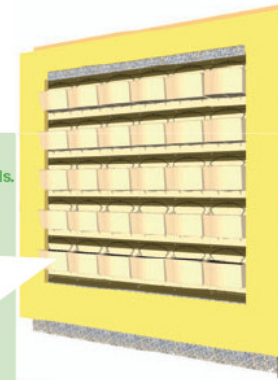
4

Using the 16" GapTools space and attach the RainRails (for automatically irrigated version), or H-Rails (for hand watered version).



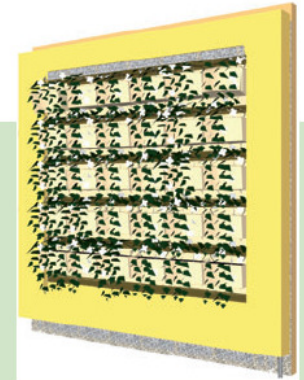
7

Install WallTer wall planters into RainRails.



8

Drop in pre-planted WallTer inserts from grower of your choice.

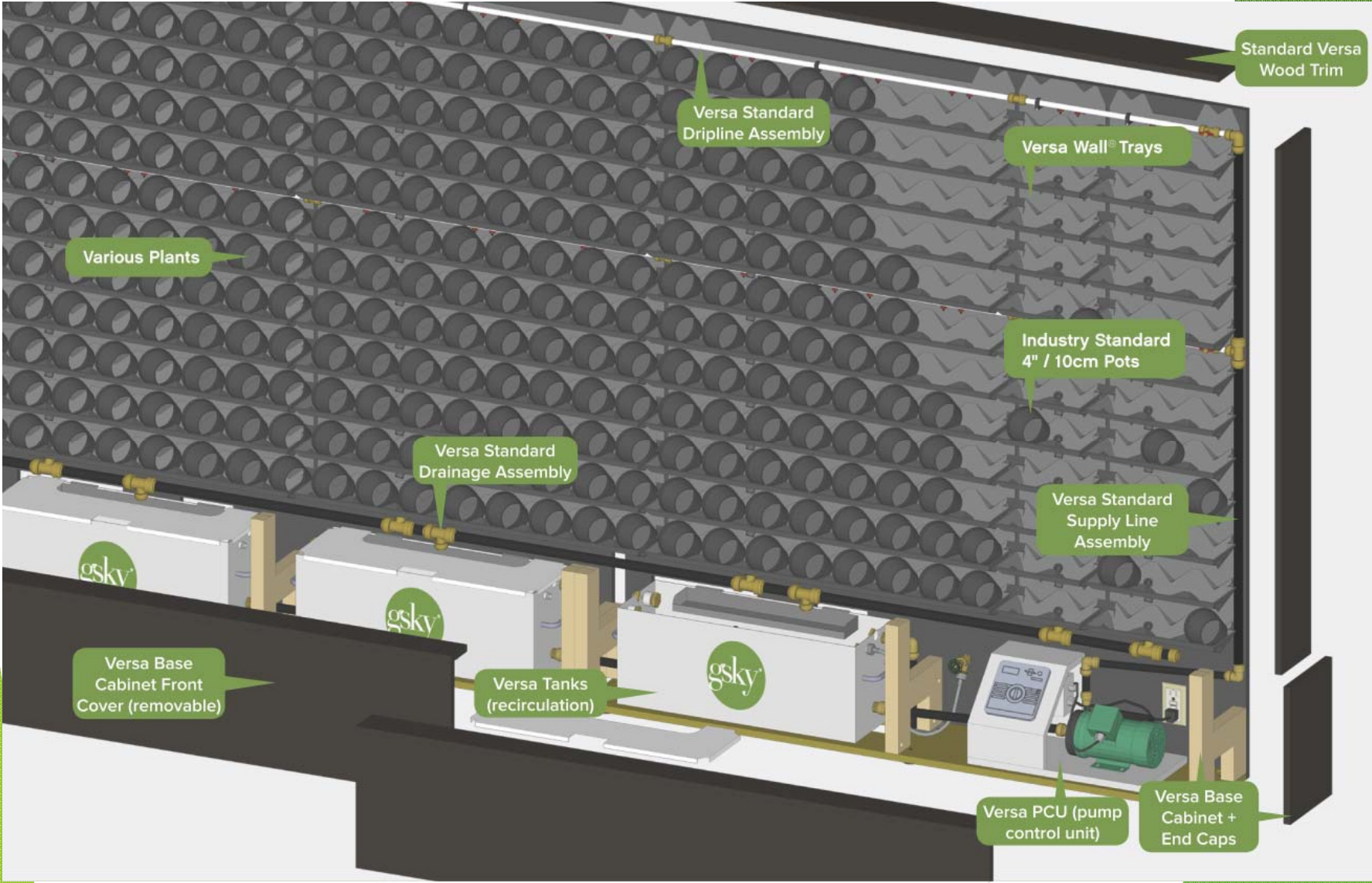


A. Connect drainage elbows to WallTers and connect tubing harness prior to installing WallTers.

B. Test irrigation system



# gsky Tray System





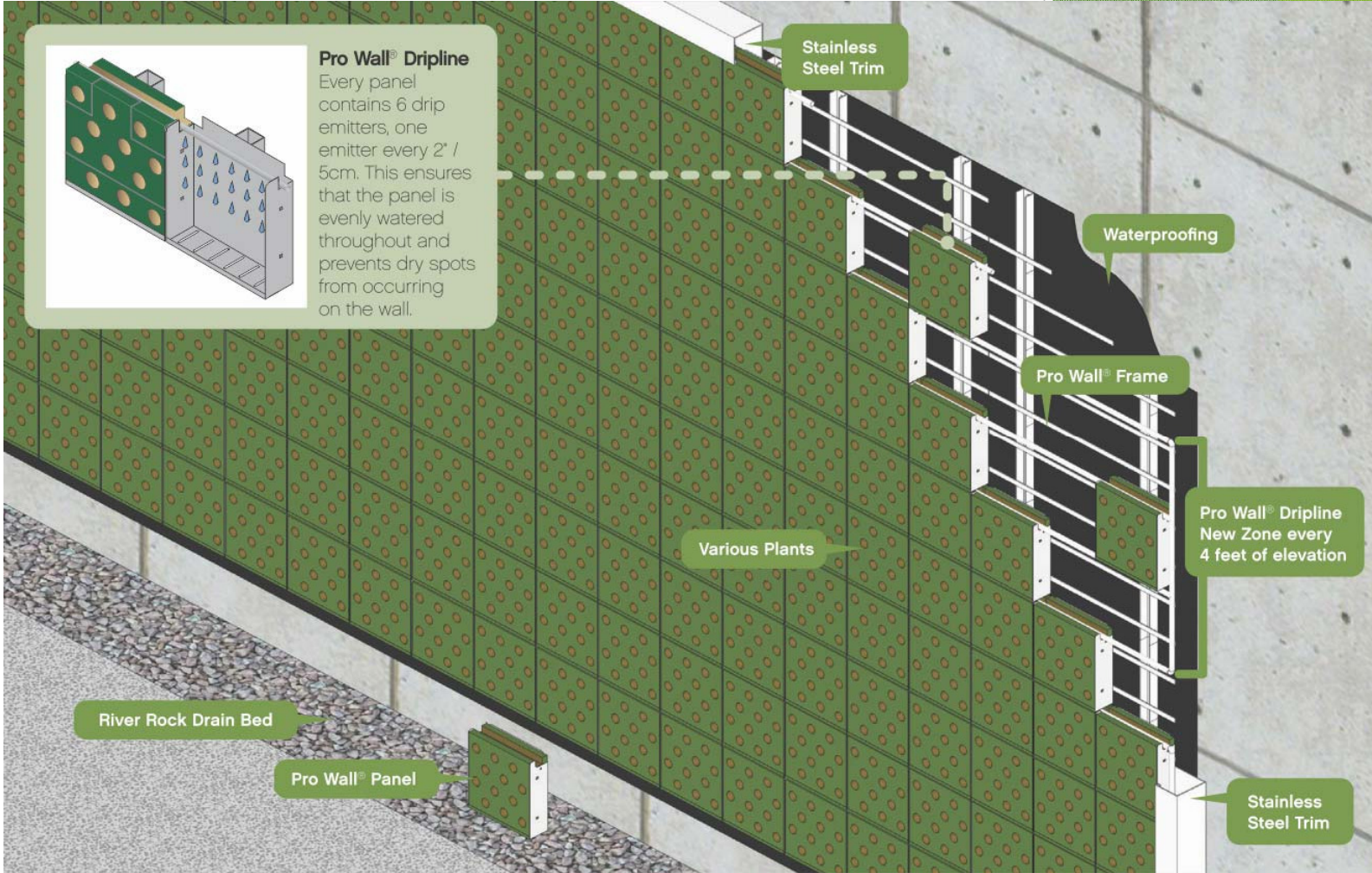
gsky  
Tray System  
(VersaWall)  
planted





# Panel System

mfg: gsky



So besides the aesthetics, what benefits do green walls offer?





# What constitutes air quality and what usually compromises it

- ▶ For Indoor Air Quality, we consider CO<sub>2</sub>, TVOCs, and because of the specific area, there may be other areas of interest
- ▶ CO<sub>2</sub> - produced by humans breathing, concentrations always higher inside vs. outside
- ▶ TVOCs - produced by low level "off gassing" from carpets, pressed wood fiber products, papers, many others - typically 2 - 5 times and up to 10X higher indoors
- ▶ CO - carbon monoxide from nearby auto exhaust, fuel fired appliances

TVOC - Total Volatile Organic Compounds, includes formaldehyde, benzene, toluene, others

# Plants improve indoor air quality

- ▶ NASA research Bill Wolverton

“If (people are) to move into closed environments, on Earth or in space, they must take along nature’s life support system. Plants.” -Dr. Bill Wolverton





# Plants improve indoor air quality

- ← University of Technology, Sydney study on plants in office buildings
  - ← Not mechanically ventilated building
  - ← 3 11" potted plants per office, 130 SF office
  - ← Reduced TVOC levels from 300-500 ppb to less than 100 ppb (about the same as outside air)
  - ← Lowered CO<sub>2</sub> levels 10-25%, CO levels 90%

Second UTS study performed in a well ventilated building showed much lower rates of removal of TVOCs, CO<sub>2</sub>

Conclusion from both studies: inclusion of plants in the office environment could reduce building ventilation requirements and save energy

TVOC - Total Volatile Organic Compounds, includes formaldehyde, benzene, toluene, others

## How do plants remove VOCs?

- ▶ The soil bacteria created by the roots in the potting soil or hydroponic media
- ▶ Plant species differ somewhat in the ability to remove VOCs but not substantially
  - ▶ Lab studies on over 200 species





# BREATH OF FRESH AIR

Below are common indoor plants that laboratory tests have shown to be particularly adept at reducing airborne contaminants emitted from household products such as dry-cleaned clothing, paints and thinners, furniture, cleaning supplies, gasoline, building materials and tobacco smoke.



**English Ivy**  
*Hedera helix*

benzene, toluene, octane, alpha-pinene and trichloroethylene, formaldehyde



**Mother-in-Law's Tongue**  
*Sansevieria trifasciata*

alcohol, acetone, benzene, formaldehyde, xylene



**Weeping Fig**  
*Ficus benjamina*

formaldehyde, ammonia, n-hexane, benzene



**Peace Lily**  
*Spathiphyllum*

acetone, ammonia, benzene, ethyl acetate, formaldehyde, methyl alcohol, trichloroethylene, xylene, n-hexane, toluene



**Devil's Ivy**  
*Epipremnum aureum*

carbon monoxide, formaldehyde, benzene



**Flamingo Flower**  
*Anthurium*

ammonia, formaldehyde, toluene, xylene, benzene



**Janet Craig**  
*Dracaena deremensis*

trichloroethylene, formaldehyde, benzene

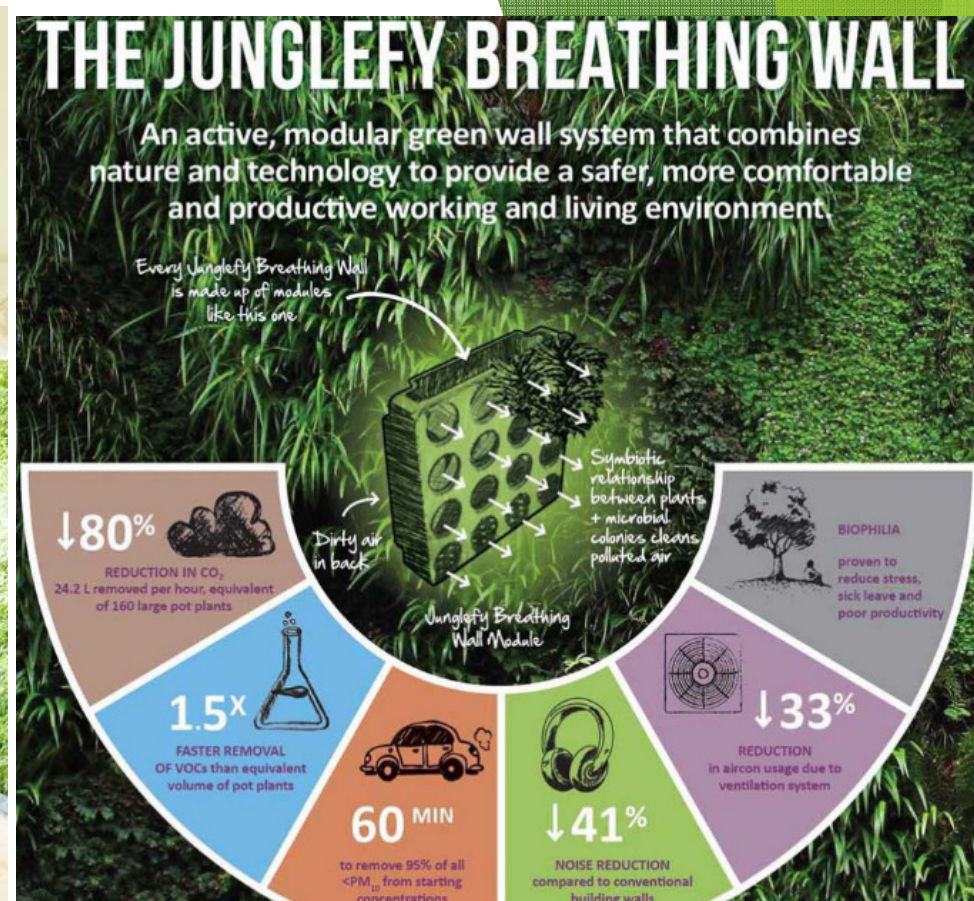
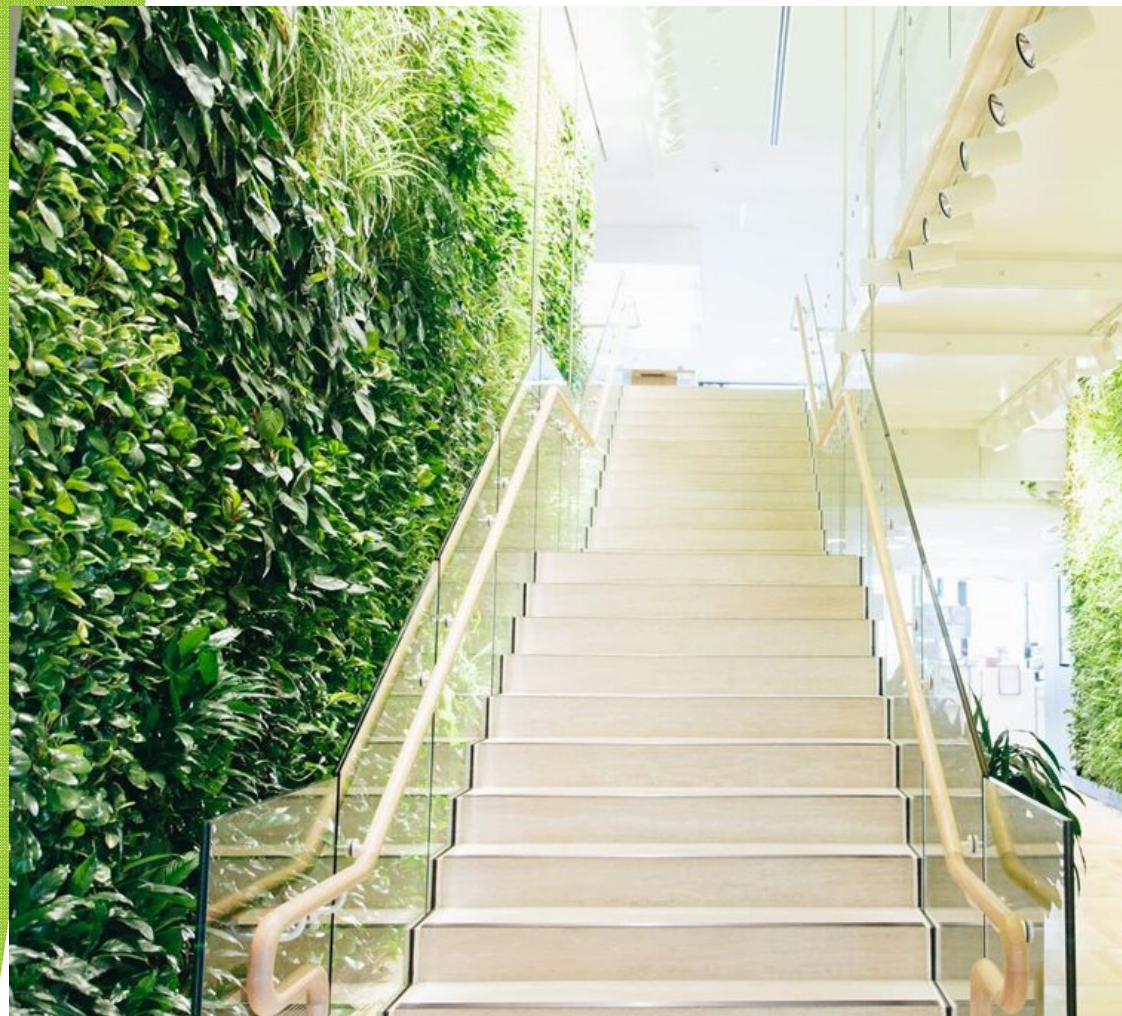


**Asparagus Fern**  
*Asparagus densiflorus*

benzene, toluene, octane, alpha-pinene and trichloroethylene

Sources: NASA; University of Georgia; Wolverton Environmental Services; University of Technology, Sydney; Photos: Costa Farms (8)





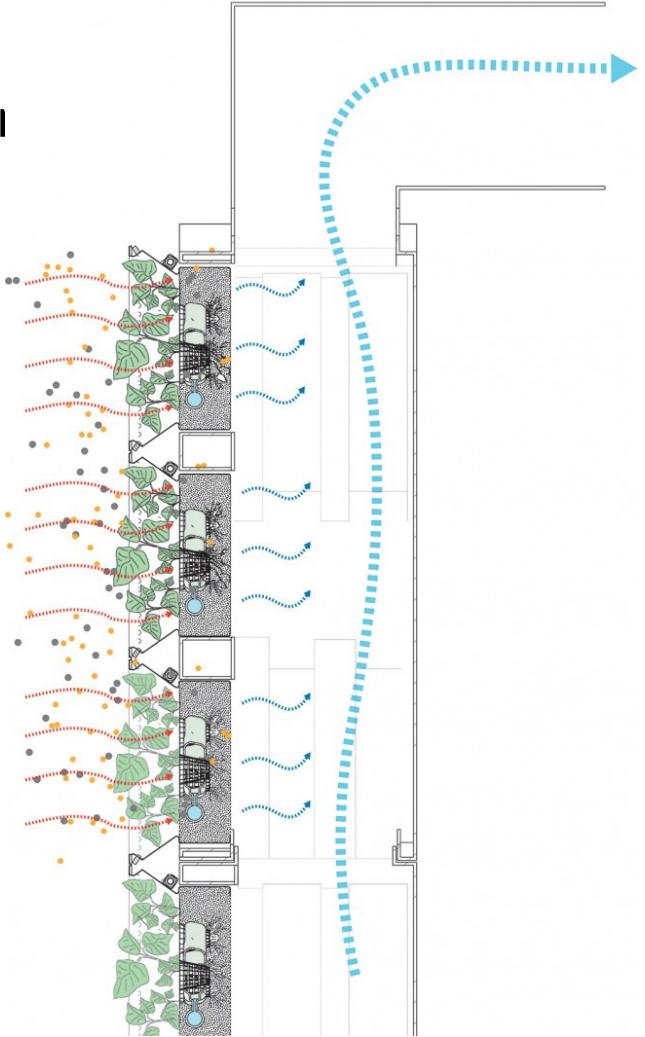
## Ventilated Living Wall

Lendlease Global Headquarters, Sydney

<http://junglefy.com.au/science-innovation/>



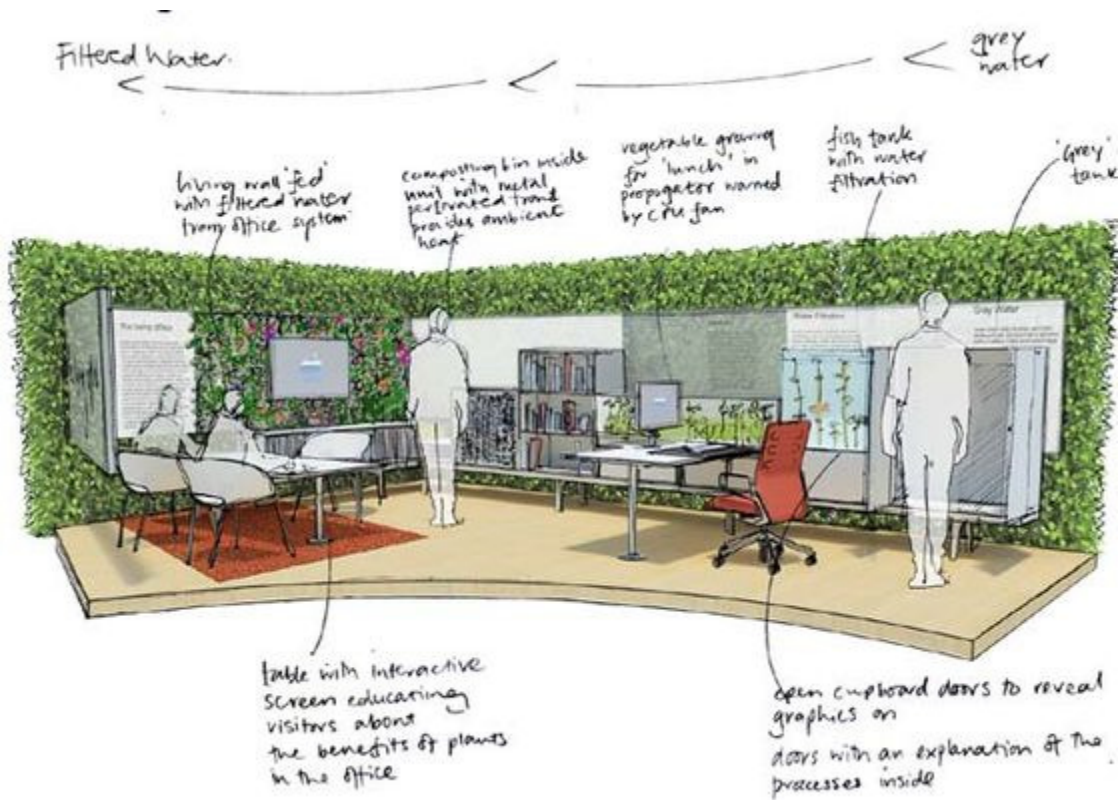
CASE AMPS  
(Active Modular  
Phytoremediation  
System)  
PSACII (City of  
New York)



© Skidmore, Owings & Merrill LLP



# Other benefits of green walls



- ▶ Increases productivity, creativity and well-being
- ▶ 6-10 degree F drop in indoor temps, adds humidity
- ▶ Reduces ambient noise level
- ▶ Helps people recover from illness more quickly



# Application to LEED

- ▶ No direct, specific point for indoor green walls
- ▶ If greywater is utilized, could qualify for Innovative Wastewater Technologies
- ▶ Could earn an Innovation credit
- ▶ Can contribute to many of the point categories (MR, Water efficiency etc)
  
- ▶ Outside green walls (on a building façade) could qualify directly for Heat Island Effect - Non-roof and Stormwater - Quantity

<http://www.greenovergrey.com/green-wall-benefits/leed-credits.php#Indoor>

# Application to WELL building standard

- ▶ Much newer (V1.0 2014) standard, focuses on the health of the building occupants
- ▶ Many synergies with LEED
- ▶ Directly contributes to Well point, Biophilia (incorporating nature into the interior environment)





# Plants

## ► Five Golden Rules (from Live Walls, Tropical Plant Design Guide)

- 1. Design Simplicity (unless you're an expert)
- 2. Compatible growth habits
- 3. Appropriate Sizes
- 4. Compatible Moisture Requirements
- 5. Compatible Light Requirements

**Golden Rule # 5, Combine Plants with Similar Light Requirements.** The quantification of natural light is not an exact science, and different artificial lights yield different results (due to their different spectra\*) but for the sake of plant pairing and ongoing care, we use the following descriptions of light levels.

**Intense Light** pertains to an indoor location within an atrium or sunroom with unshaded light throughout most of the day. This is almost equivalent to growing outdoors in full sun.

**Bright Light** = pertains to an indoor location with direct light from a south or west exposure where the plants receive 2 or more hours of direct sun, but preferably not during the hottest part of the day.

Artificial Bright Light = approximately equal to a four tube florescent fixture in close proximity to the planting, in the range of **400 to 600+ foot candles, for 12 to 15 hours per day.**

**Medium Light** = pertains to an indoor location with direct light for a couple of hours in the morning or afternoon (from east or west facing windows), or from a south facing window provided the location is several feet interior of south facing windows.

Artificial Medium Light = Approximately equal to a two tube florescent fixture, 2 or 3 feet from the foliage, in the range of **100 to 400 foot candles for 12 to 15 hours per day.**

**Low Light** = pertains to an indoor location that is not close to windows or supplemental lighting--typically a north or east exposure.

Artificial low light = is enough to read a newspaper, in the range of **25 to 100 foot candles for 12 to 15 hours per day**

# Plants

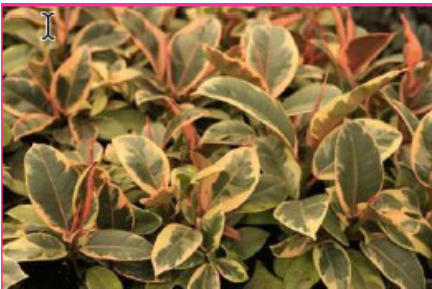
**Upright Habit**  
**Water Class 2 Inch**  
**Bright Light**



**Dracaena 'Janet Craig'**  
(**'Janet Craig'** Dracaena)



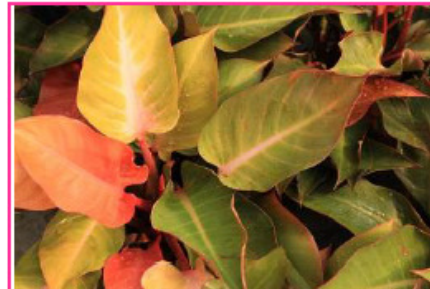
**Dracaena 'Janet Craig  
Limelight'**  
(**'Janet Craig Limelight'**  
Dracaena)



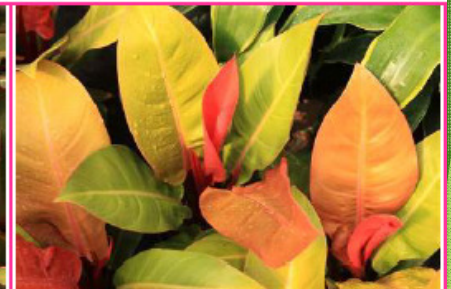
**Ficus elastic 'Teneke'**  
(**'Teneke'** Rubber Tree)



**Ficus lyrata**  
(**Fiddleleaf Fig**)



**Philodendron 'McColley's  
Finale'**  
(**'McColley's Finale'**  
Philodendron)



**Philodendron 'Prince of  
Orange'**  
(**'Prince of Orange'**  
Philodendron)



# Lighting

- ▶ Plant selection will determine specific light requirements
  - ▶ LED with red and blue spectrum producing white light
    - ▶ Specialty fixture, not a typical office LED
  - ▶ Metal Halide
    - ▶ Less expensive, but most energy intensive and will produce heat
- ▶ Timer controlled to stay on for 12-15 hours/day







Copyright, Green over Grey  
Birmingham International Airport, Alabama

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Artists : *Mike Weinmaster & Murray Jobstov*



# What causes live walls to fail?

- ▶ Failure of the structural materials
  - ▶ Corrosion, algae growth
  - ▶ Incorrect material selected for hydroponic application, insufficient oxygen reaches the roots
- ▶ Overwatering
  - ▶ Can be triggered by low light conditions
  - ▶ Malfunctioning irrigation
- ▶ Do best if maintained by the installing company for 3 months to a year to ensure that irrigation and nutrients are adjusted correctly



## Costs

- ▶ Live Wall, Inc.
  - ▶ \$90 - \$135/SF (material costs, \$45 - 70/SF)
  - ▶ Costs decreases with increased SF
  - ▶ Irrigation system is proprietary but costs similar to a lawn or planter system
  - ▶ Does not include lighting



# Research and Case Studies

- ▶ Wolverton, B.C. **Houseplants, Indoor Air Pollutants and Allergic Reactions**, NASA-TM-108057, 1986.
- ▶ Case study of PSAC II, [urbanomnibus.net/2015/11/ventilation-goes-vegetal-cases-plant-based-air-filtration-system/](http://urbanomnibus.net/2015/11/ventilation-goes-vegetal-cases-plant-based-air-filtration-system/)
- ▶ Burchett, Margaret D, PhD. **Potted Plants Can Significantly Reduce Urban/Indoor Air Pollution**. Survey of research, July, 2012
- ▶ Fernandez-Canero, Rafael et al. **Assessment of the Cooling Potential of an Indoor Living Green Wall using Different Substrates in a Warm Climate**. Indoor and Built Environment 2012;21;5:642-650
- ▶ **Office plants boost well-being at Work**. <https://phys.org/news/2013-07-office-boost-well-being.html>
- ▶ Franklin, Deborah. **How Hospital Gardens Help Patients Heal**. Scientific American, March, 2012

The background features a complex geometric design. On the left, there is a solid black area. To its right, several overlapping, semi-transparent green shapes in various shades (from dark forest green to bright lime green) create a layered, 3D effect. The right half of the image is a solid, bright lime green. The text '► Questions?' is centered in the white space between the black and green areas.

► Questions?