Rethinking Urban Horticulture:

Perspectives from Applied Biotechnology and Environmental Engineering

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ISHS RHS Green Infrastructure Lab UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Phytoremediation of air pollution

Table 1 Top productive countries/regions on botanical research in the indoor environment.

Countries/ Regions	TP	%TP	Years									TC
			2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
USA	71	19.24	7	6	3	2	5	0	3	5	4	6	2006
AUSTRALIA	40	10.84	0	0	2	3	0	1	4	8	9	3	1414
CHINA	38	10.29	3	4	1	1	3	0	3	3	8	6	427
SOUTH KOREA	27	7.31	2	2	1	2	4	2	0	1	0	4	849
THAILAND	22	5.96	1	1	1	2	1	5	1	2	4	3	378
POLAND	17	4.60	1	0	0	0	4	2	1	0	5	3	494
IRAN	16	4.33	0	3	2	0	1	2	0	4	1	3	145
SPAIN	16	4.33	0	1	1	4	0	1	2	3	1	1	381

Tan et al 2022

Urban air pollution – the quiet epidemic

- Urban air is innately polluted: CO, NO_x, SO_x, Volatile Organic Compounds, particulate matter, O_3 — regularly exceed guidelines worldwide (LAWA 2023)
- Indoor air is our *normal environment*, and air pollution is *not* lower indoors

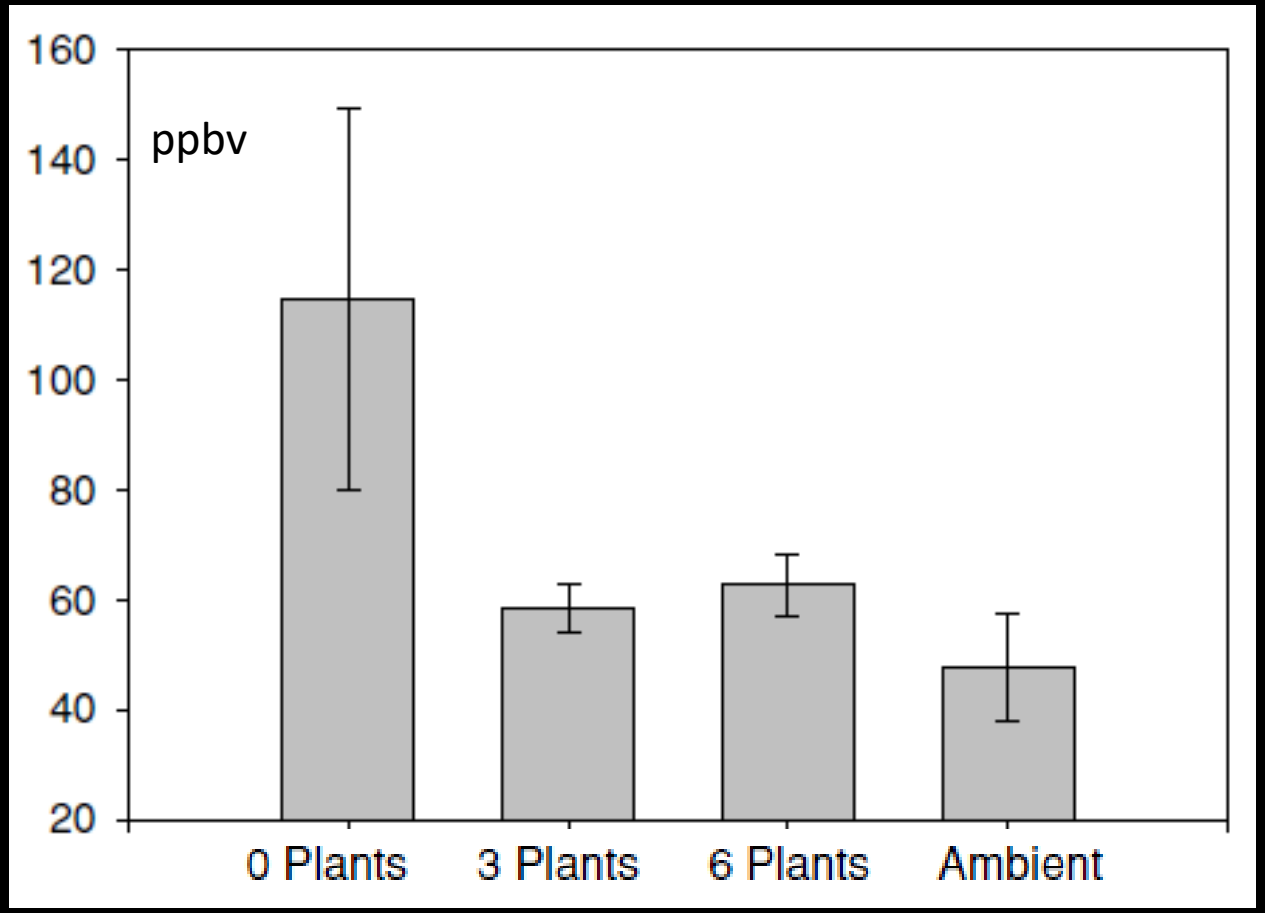
Outcomes

- *The world's (and UK's) largest single environmental health risk* (OECD/IEA 2019)
- 7 M deaths per year worldwide (Covid= 7.01 M deaths total)
- >£24 billion pa in health costs (IQ Air 2024), 1% of world GDP by 2060 (OECD 2022)
- Poor health, lost productivity, low workplace performance

Plants improve indoor air quality

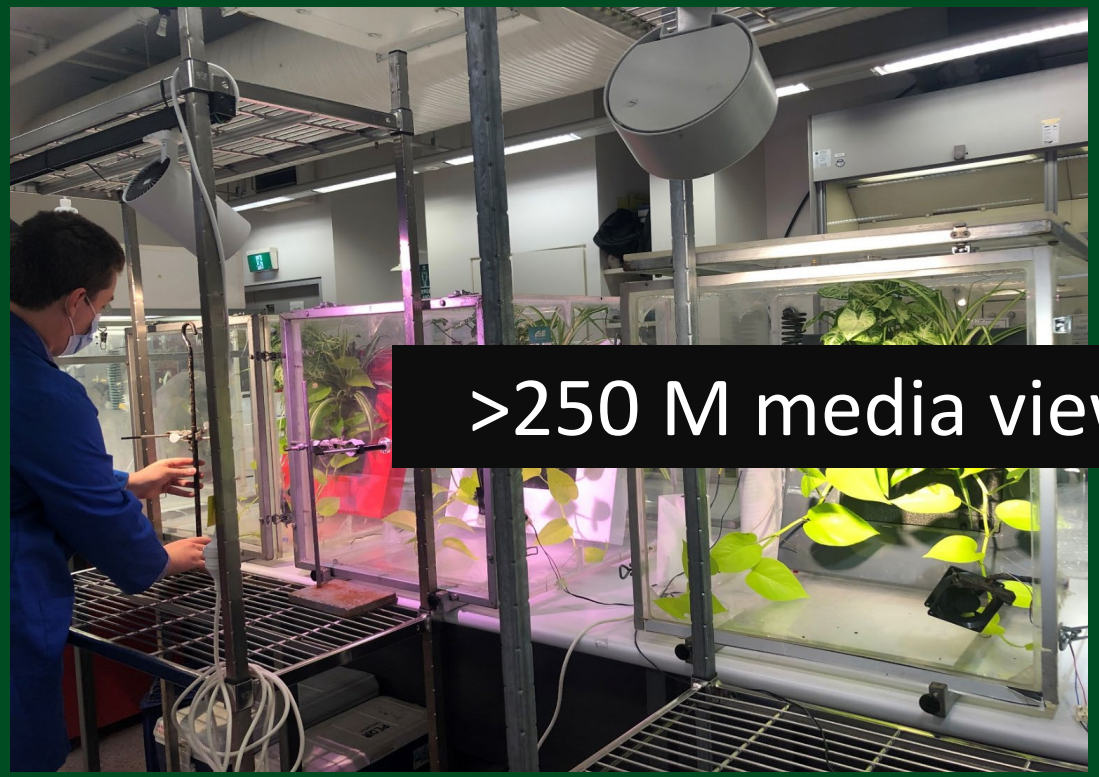
NASA studies (Wolverton *et al*. 1983–1997) showed that plants improved air quality in sealed spacecraft simulators

Total Volatile Organic Compounds in University offices

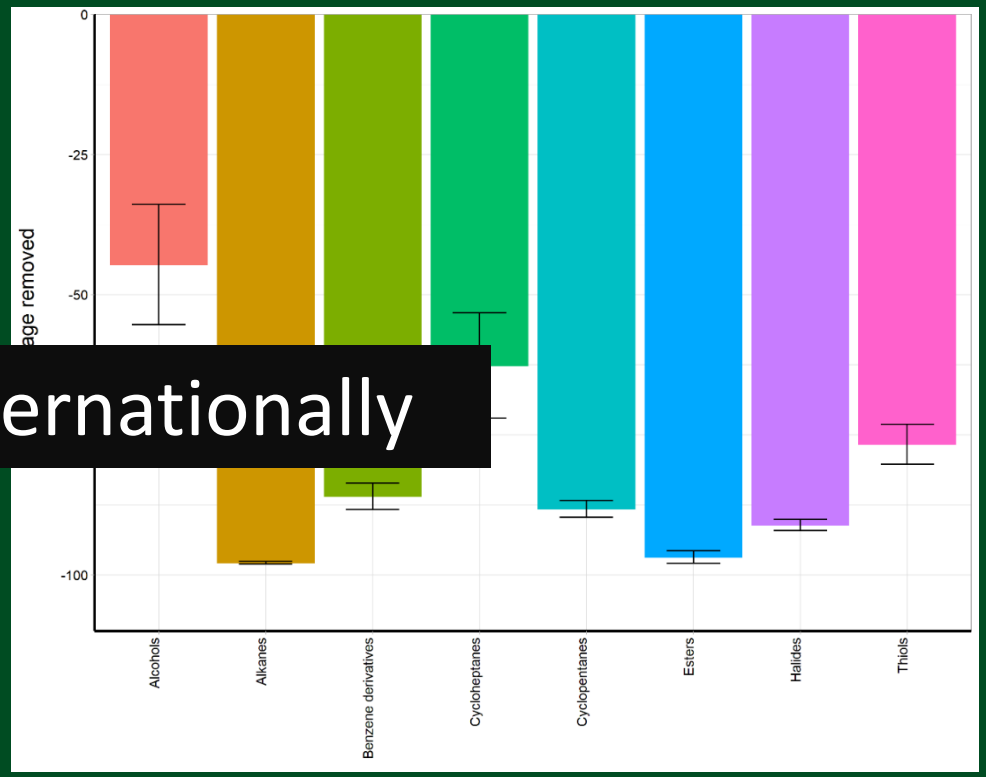


Wood et al. 2006

Phytoremediation of petrol VOCs



>250 M media views internationally



All potted plants can remove *all* VOCs, *mainly* (but not wholly) due to substrate microbial metabolism

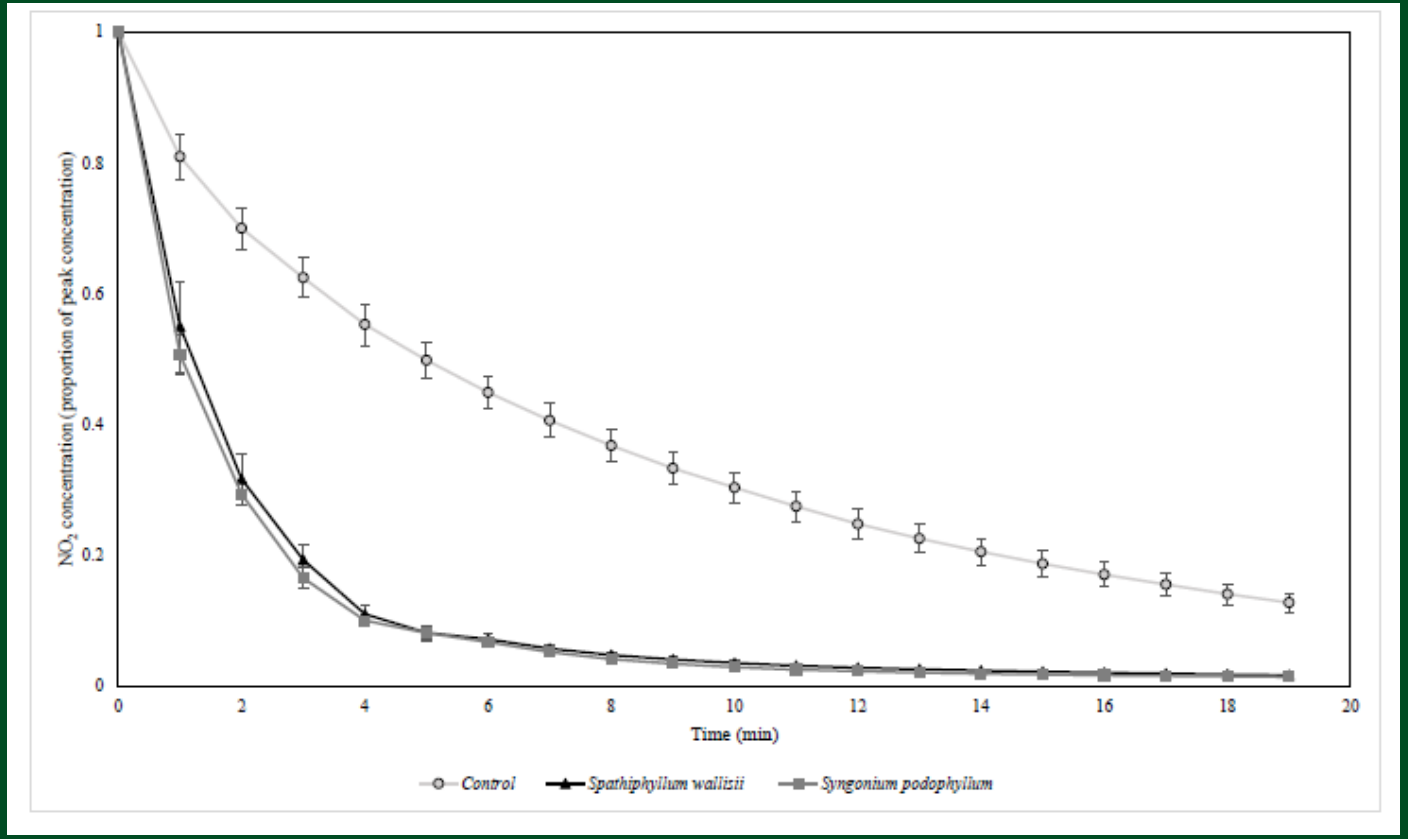
% removal within 8 h. Matheson et al., (2023)

Plants remove air pollutants

SO_x and NO_x: Dissolve into water film on leaves, taken up and internally reduced

O_3: Usually removed

- Preferentially damages plant?



Plants remove air pollutants

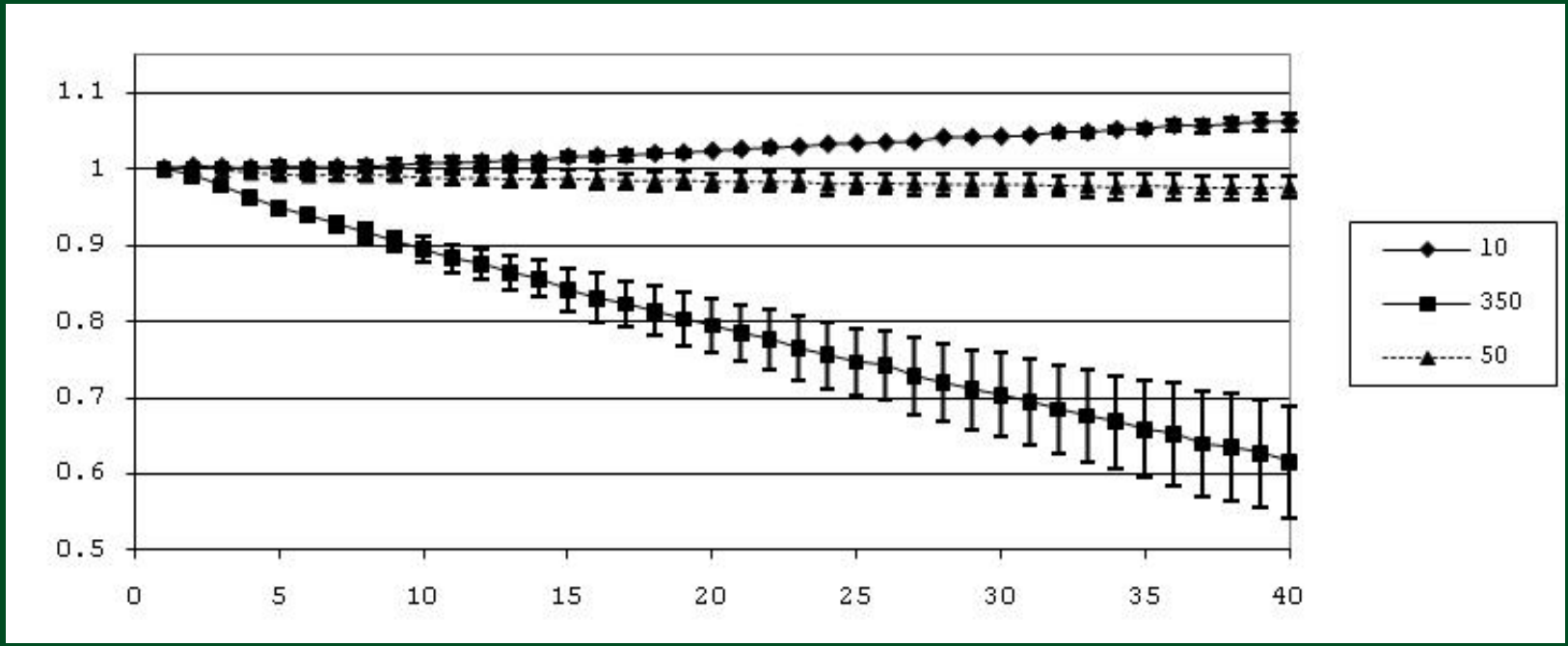
- **PM:** Interception and adhesion to leaves

Fig. 2. Visible particulate matter accumulation on a *S. amate* leaf (arrows).

Plants remove air pollutants

CO_2: Photosynthetic draw down

- 40% of energy in the built environment used to ventilate CO_2…



Changes in test-chamber CO_2 by *Howea fosteriana* at 10, 50 & 350 µmol m^{-2} s^{-1}. (Torpy et al. 2014)

Passive phytosystems

- All pollutant removal is rate limited by diffusion (Irga et al 2018)
- *Pollution removal effect sizes by passive vegetation are low per unit of green space*

Junglefy, Australia

VOC CADRs of passive indoor plants

Pollutant	CADR ($m^3.h^{-1}.plant^{-1}$)	Reference
Formaldehyde	**0.22**	Aydogan and Montoya (2011)
Benzene	**0.038**	Orwell et al. (2004)
Toluene	**0.050**	Orwell et al. (2006)
Xylene	**0.068**	Orwell et al. (2006)
TCE	**0.0073**	Wolverton et al. (1989)
Chloroform	**0.00095**	Zhang et al. (2018)

Cummings and Waring 2020

The effect sizes provided here will be small for most pollutants

Ideal solution

7,000 trees will be planted in London to improve air quality

The Mayor of London, Sadiq Khan has announced that in order to help reduce air pollution and carbon dioxide (CO_2), thousands of trees will be planted across 20 boroughs in London.

Paris plans to go green by planting "urban forest" around architectural landmarks

India Block | 26 June 2019 | 21 comments

4th September

Southend: 'Plant grass and plants on top of our town's bus stops to help the environment'

By Ellis Whitehouse | @E_Whitehouse293
Senior Reporter

Asia Pacific

Pakistan seeks to bring fresh air to polluted cities with 10 billion trees

By Umar Farooq

Experts identify 'super-plant' that absorbs roadside air pollution

Bushy variety of cotoneaster works best in areas of heavy traffic, say researchers, while other plants can cool buildings or reduce flooding

HOME » NEWS » INDIA » INDORE TO PLANT 2 LAKH PLANTS TO IMPROVE AIR QUALITY BY INDEPENDENCE DAY

1-MIN REA

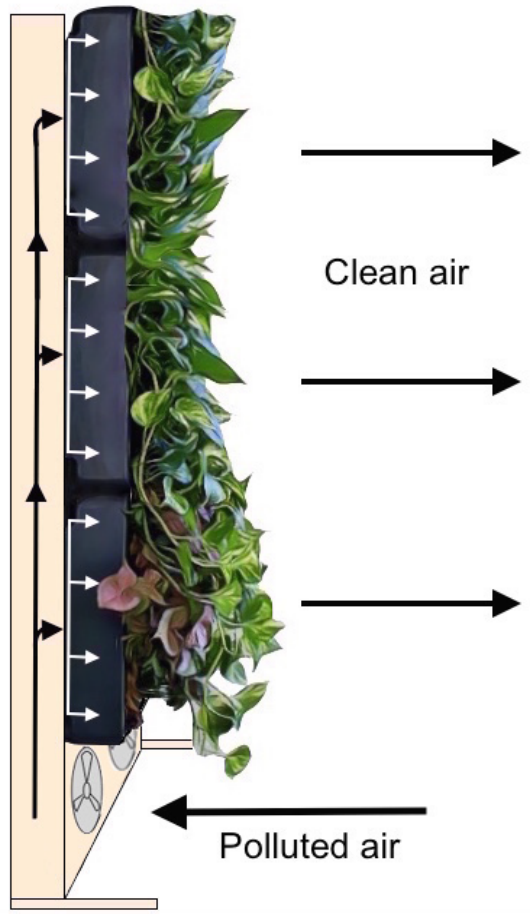
Indore to Plant 2 Lakh Plants to Improve Air Quality by Independence Day

- Planting density increased
- Improved substrate exposure
- All pollutant removal rates increased

Indoor Plants Ver. 2: Active botanical biofiltration

NATURVENTION

NAAVA



JUNGLEFY

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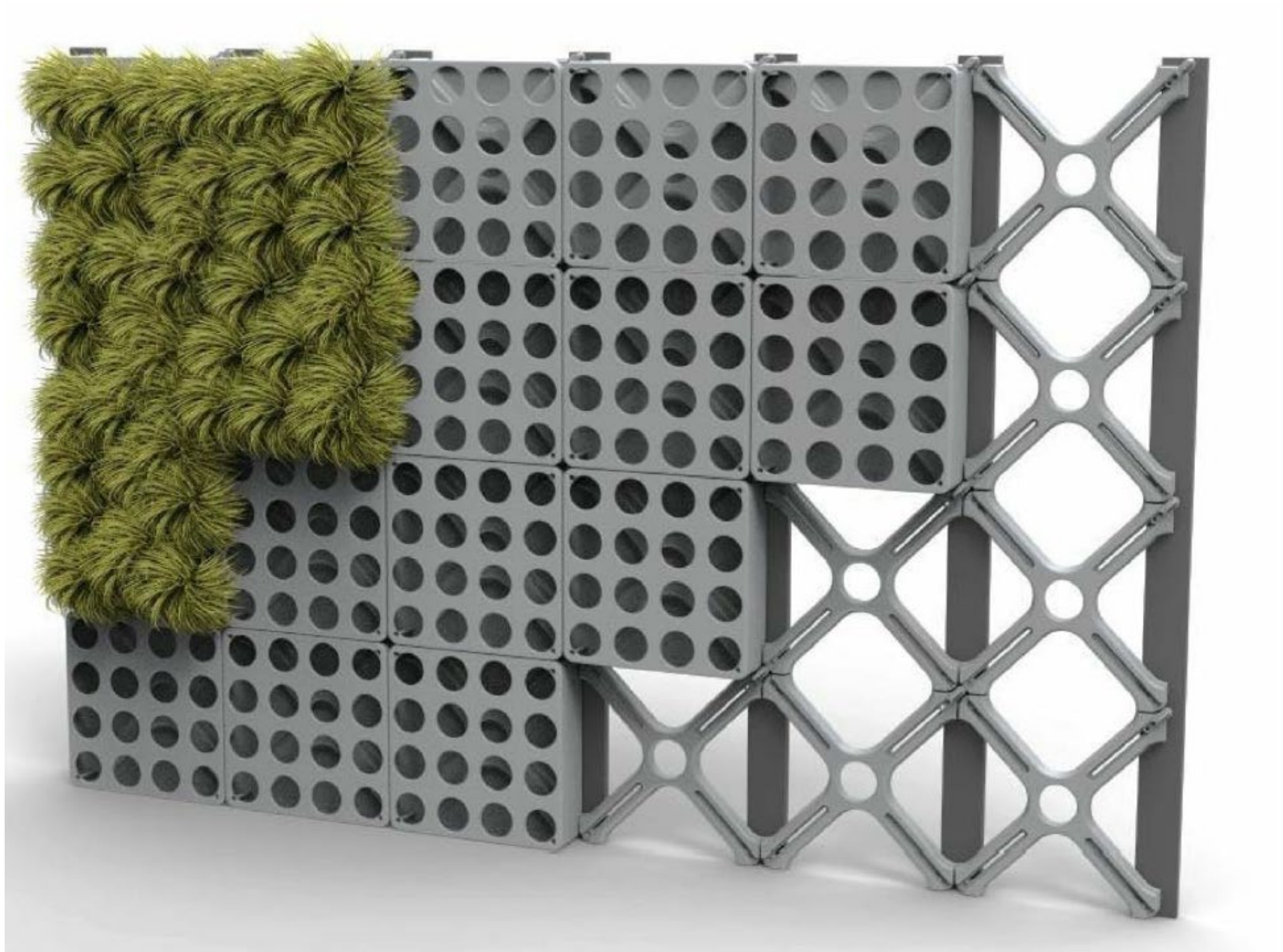

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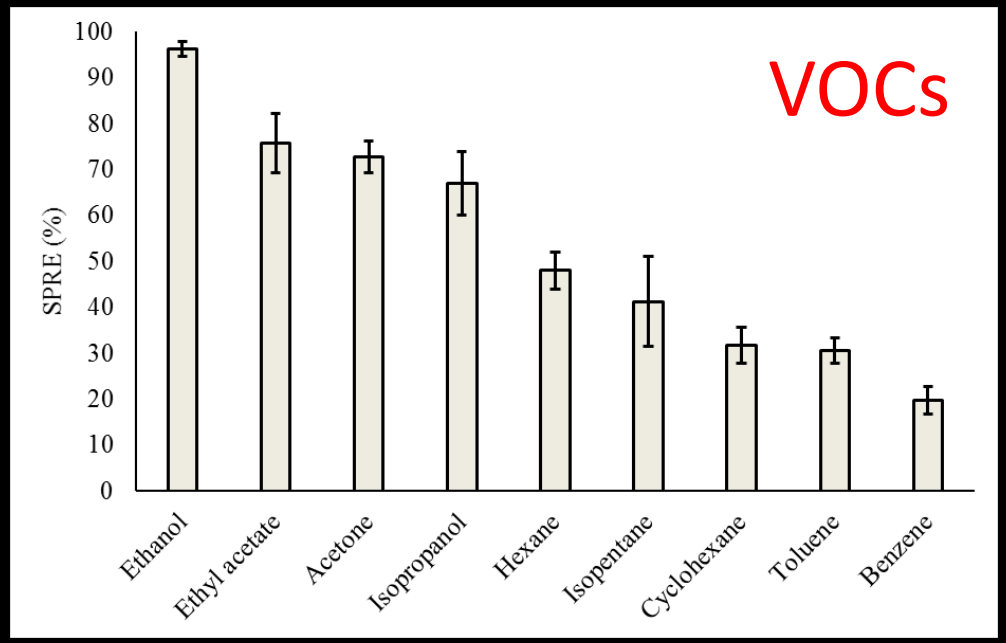
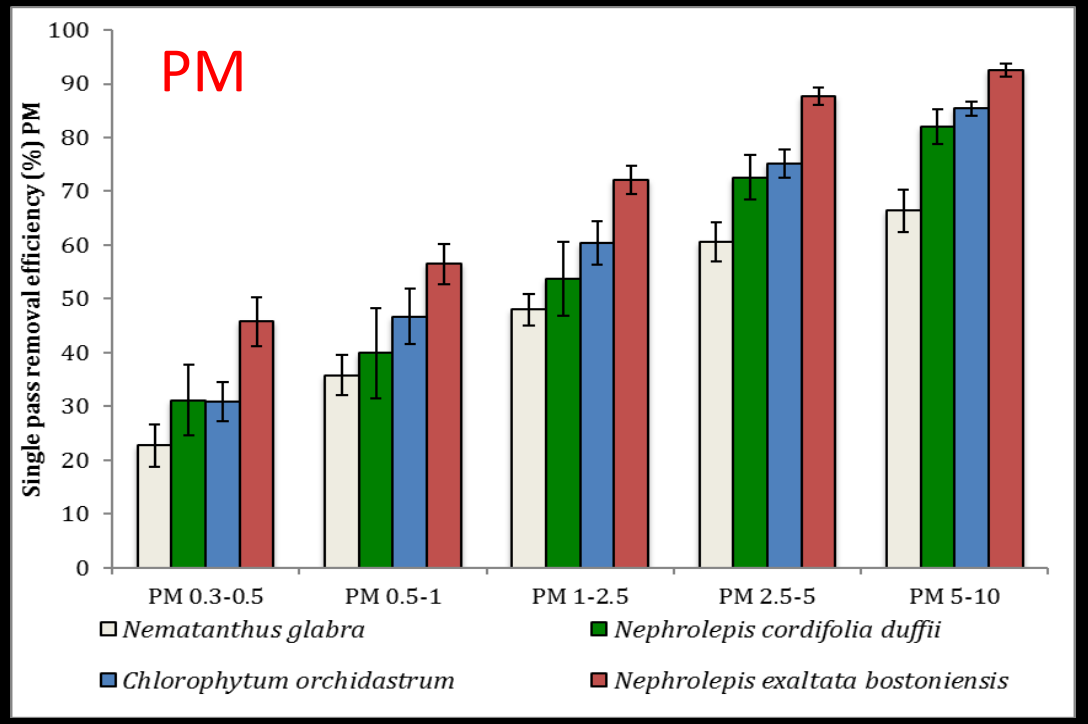
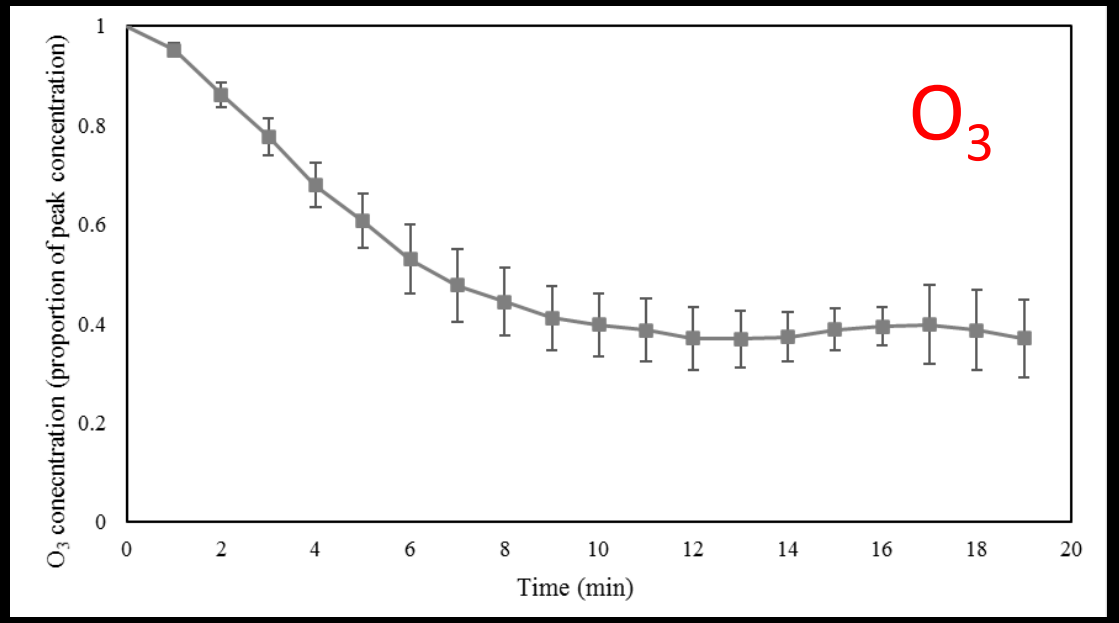
Active phytosystem performance







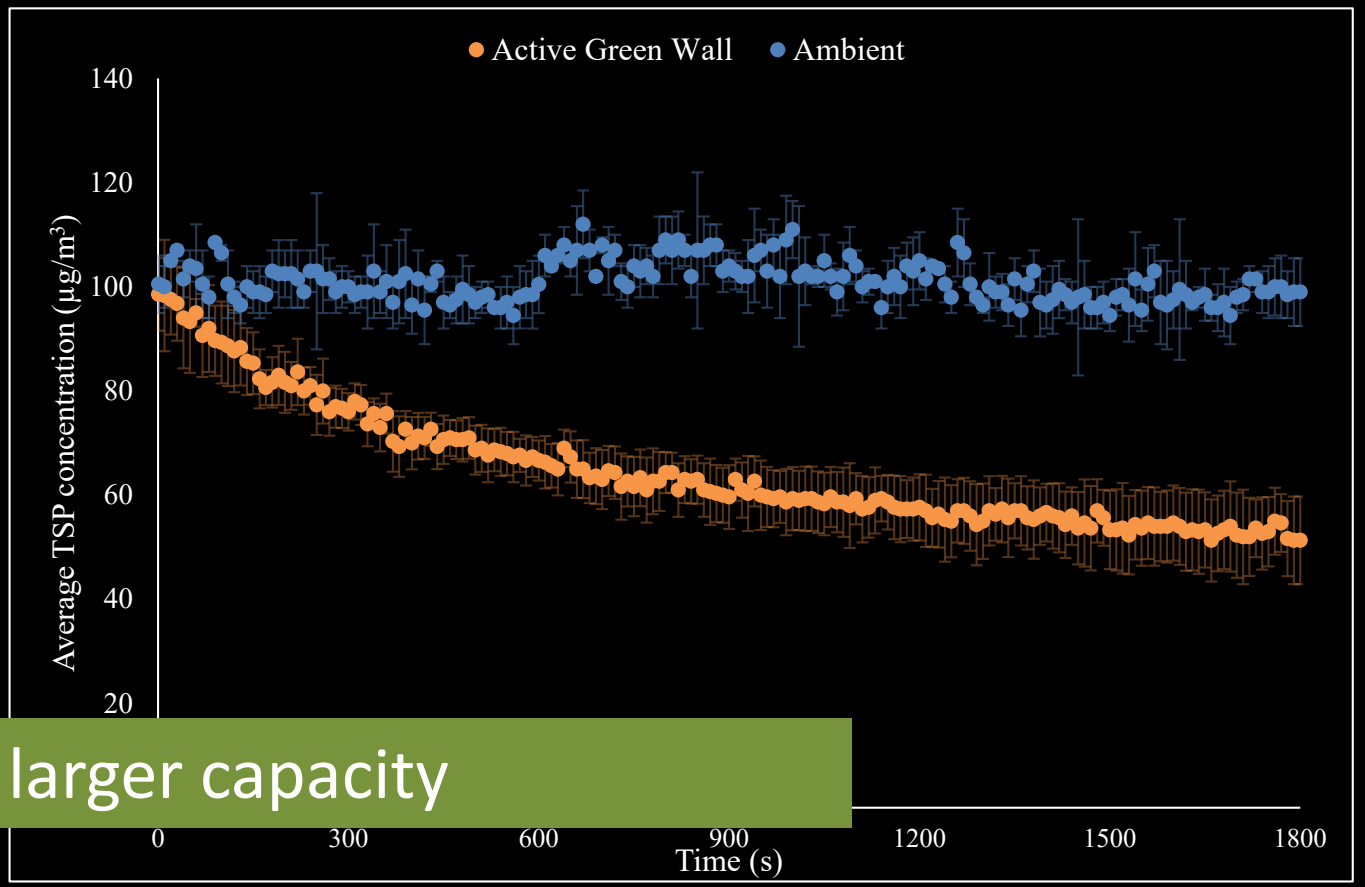
(Pettit et al 2019a,b)

SPRE = Single Pass removal Efficiency

In situ *testing of active phytosystems: Indoors*

- Classr

Active green walls can filter PM more effectively than HVAC



With much larger capacity

北京市花木有限公司
Beijing Florascape Co.,Ltd.

Ornatec

Pettit et al (2020)

Infrastructure scale phytosystems

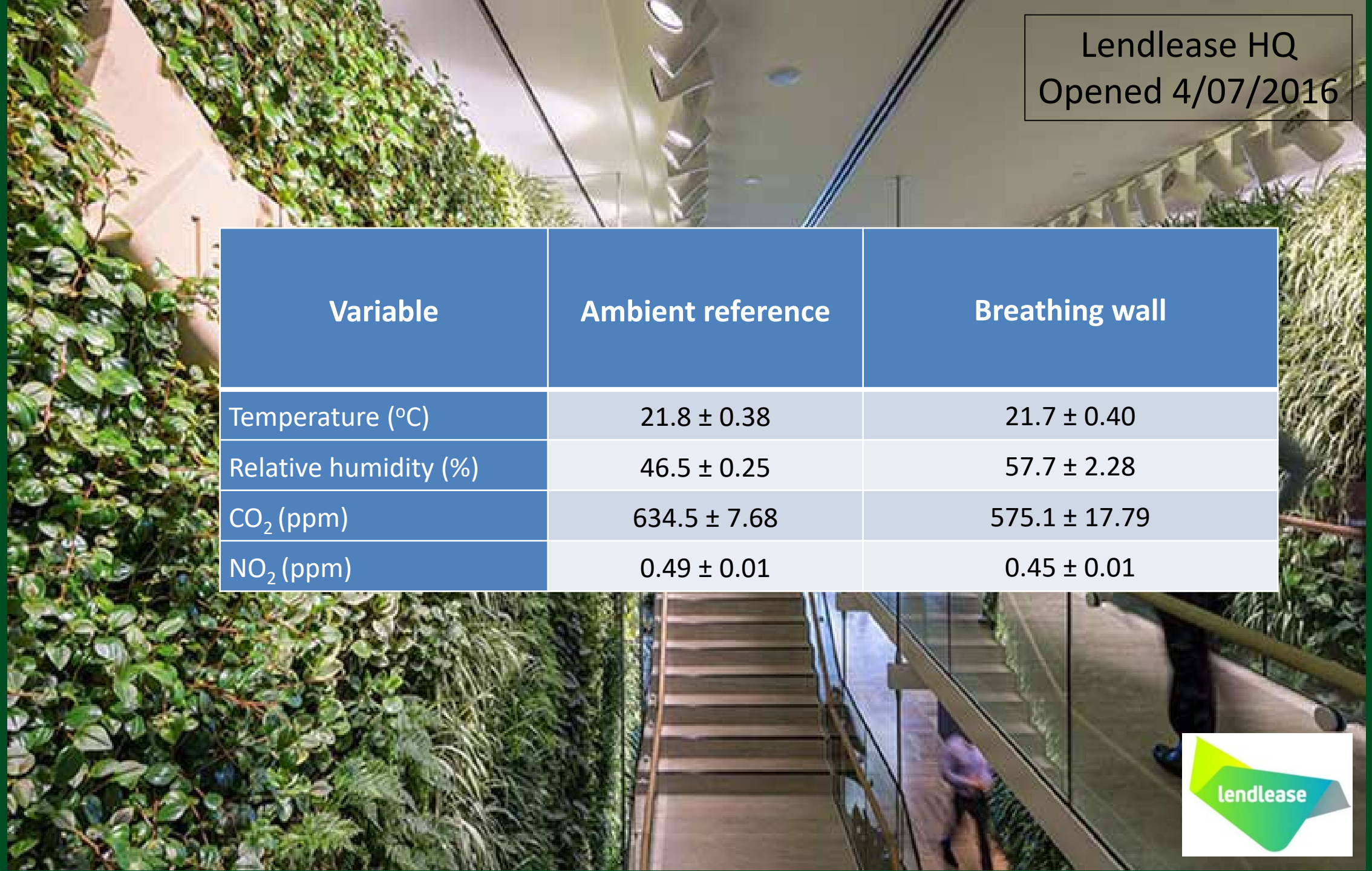
Campbelltown Rail

St Leonards

LendLease HQ, Barangaroo

Brisbane Airport Link

Manly Vale B-Line



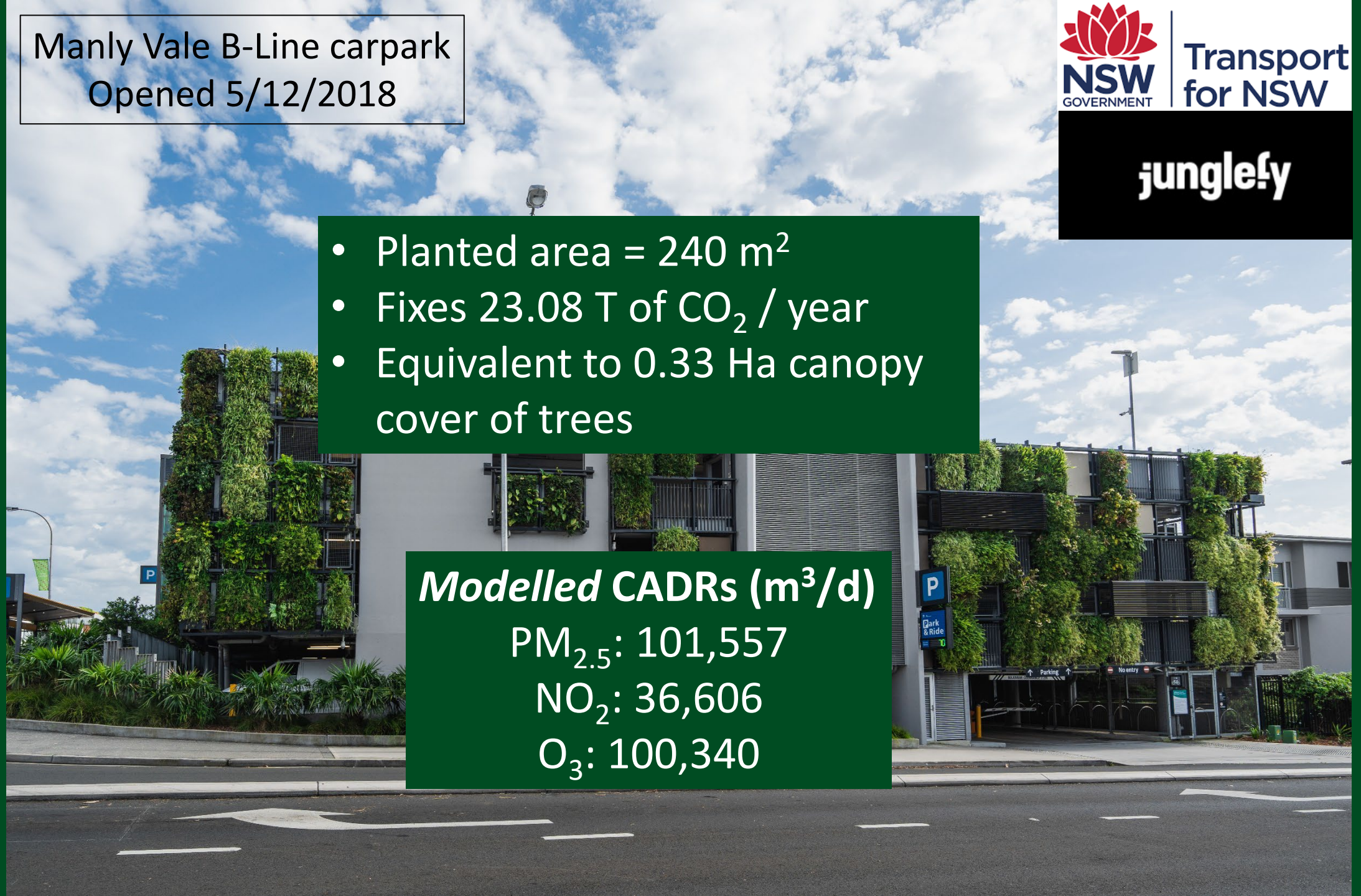
Lendlease HQ
Opened 4/07/2016

Variable	Ambient reference	Breathing wall
Temperature (°C)	21.8 ± 0.38	21.7 ± 0.40
Relative humidity (%)	46.5 ± 0.25	57.7 ± 2.28
CO_2 (ppm)	634.5 ± 7.68	575.1 ± 17.79
NO_2 (ppm)	0.49 ± 0.01	0.45 ± 0.01

Manly Vale B-Line carpark
Opened 5/12/2018

NSW GOVERNMENT Transport for NSW

junglefy



- Planted area = 240 m^2
- Fixes 23.08 T of CO_2 / year
- Equivalent to 0.33 Ha canopy cover of trees

***Modelled* CADRs (m^3/d)**

$PM_{2.5}$: 101,557

NO_2: 36,606

O_3: 100,340

Active phytosystem road pollution CADR

Pollutant	CADR ($m^3.h^{-1}.m^{-2}$ biofilter area)
NO_2	121
O_3	50
$PM_{2.5}$	40

NSW GOVERNMENT Transport for NSW

junglefy

Pettit et al 2020, 2021

What now?

We seem to have overcome most of the ‘green washing’ problem

But there are still barriers: BVOCs, COVID 19, balance with HVAC, net zero contribution, maintenance costs, ROI.

- Capacity in the horticultural industry?

Convince and compete

- Cross disciplinary and industry engagement
- TNFD

Diversification and uptake

- Existing AGWs are ‘pilot’ technology
- Details are fully published…

What now?

- The effect sizes of GI are substantial and well-proven
- The ‘Green Washing’ problem has passed
- Some minor research gaps (BVOCs, viruses, HVAC energy savings)

- But there are still barriers to widespread use
- COST and MAINTENANCE
- The knowledge on how to make simple and safe systems is freely available (NB: bioparticles!)
- Proof-of-concept for profitable industries
- …Transdisciplinary and industry engagement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NSW GOVERNMENT Planning & Environment
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Fulton Hogan
MULTIPLEX Built to outperform.
aurecon
Rozelle Interchange WestConnex JOHN HOLLAND CPB CONTRACTORS
DesignInc
Southbank by Beulah
mirvac
ambius
wsp
OCULUS
CPB CONTRACTORS
WOODS BAGOT
National Institute of Horticultural and Herbal Science Republic of Korea
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NORTH SYDNEY COUNCIL
Randwick City Council a sense of community
Ornatec
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Australian Government Australian Research Council
BVN
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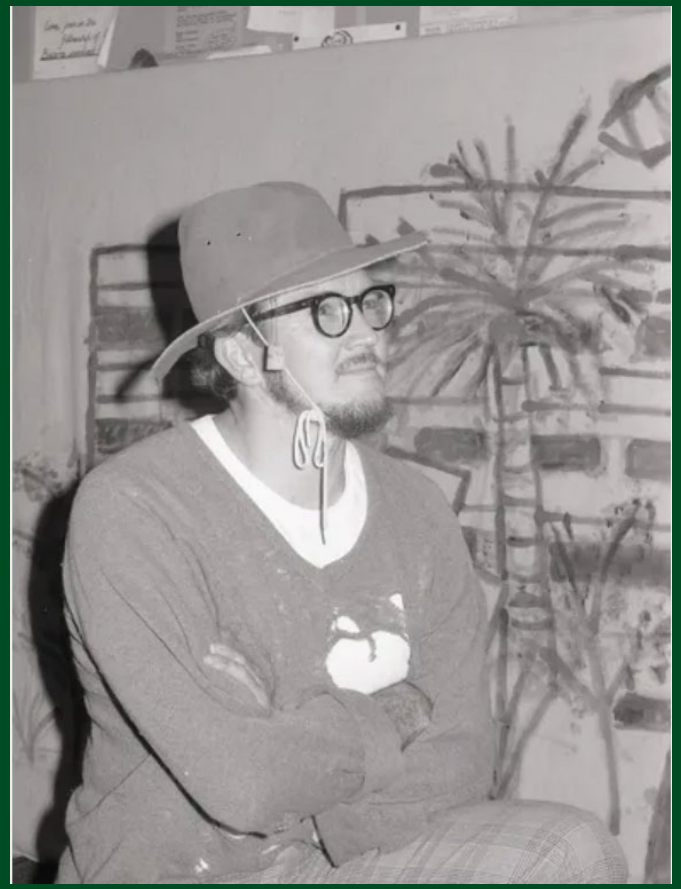
Plants are a universal core component of sustainable cities

Dedicated to
Ron Wood and Ralph Orwell



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