Building-Integrated Agriculture

Current state, potential energy benefits and comparison with green roofs

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In collaboration with Seawater Greenhouse

Overview

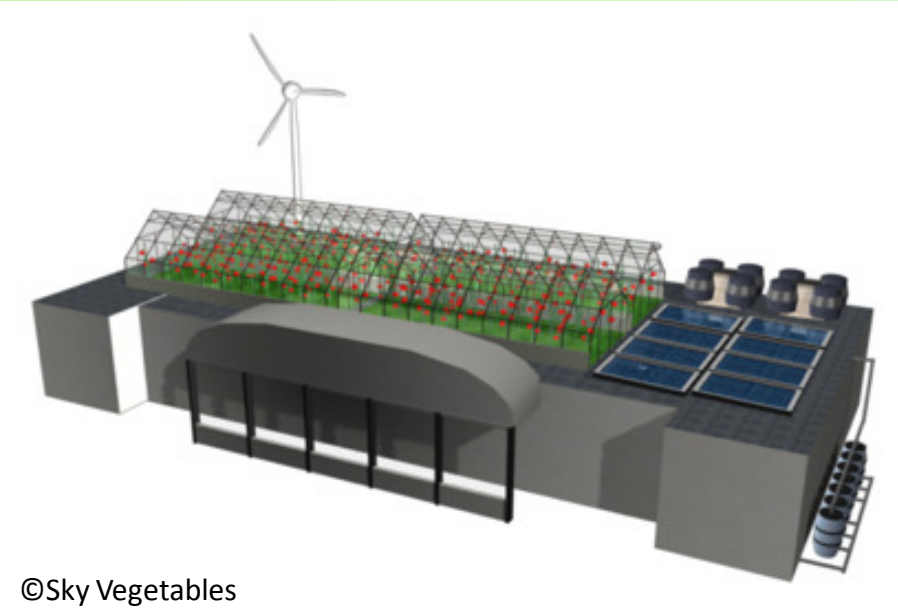
- Urban agriculture - context
- Building-integrated agriculture – what is it?
- Review of major BIA projects
- Energy benefits of BIA – insulation, heating and cooling
- Comparison with green roofs – energy saving, costs and retrofitting potential

Urban Agriculture (UA)

- 9 billion people in 2050. 2/3 in cities by 2030.
- Less land = more intensive farming = more destructive
- Food miles increasing
- Solution: grow food in cities (UA)
  - Local
  - Reduce pollution and Urban Heat Island effect
  - Reduce stormwater runoff
- But not much space available...

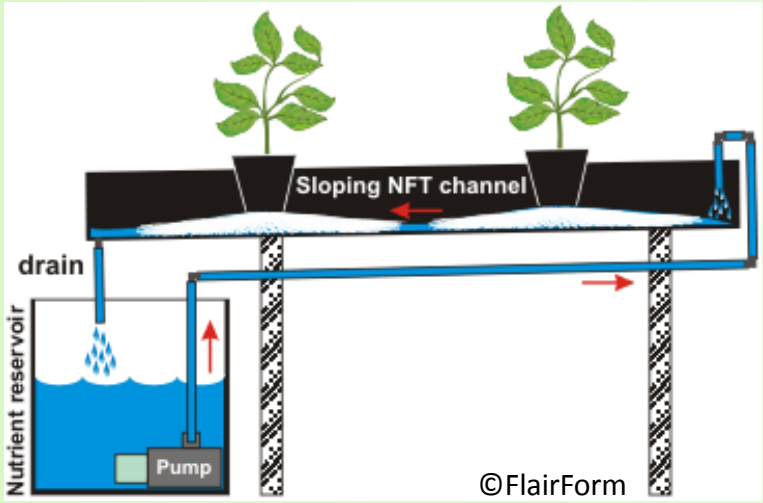
Building-integrated agriculture (BIA)

- Integrating hydroponic greenhouse methods to buildings
  - *Horizontal rooftop greenhouses*
  - Vertically integrated in double-skin facades



Hydroponics and Controlled-Environment Agriculture (CEA)

- Optimal growth conditions
- Recirculating
- Thin film of water and nutrients – no soil
  - Lightweight
- Extremely efficient
  - Doubled growth rate
  - 10-20 x less land
  - 5-10 x less water
- High quality, pesticide-free food year-round



Review – The Science Barge

- Facility for research into BIA, built on steel-deck barge on Hudson River by NY Sun Works
- 121 m^2 equipped with rainwater harvesting
- Electricity demand (25kWh/day) met by onsite solar/wind, heating by biodiesel furnace
- Yield 40-70 kg/m^2/year, no pesticides, no fertiliser runoff.

Review – Sun Works Centre for Environmental Studies

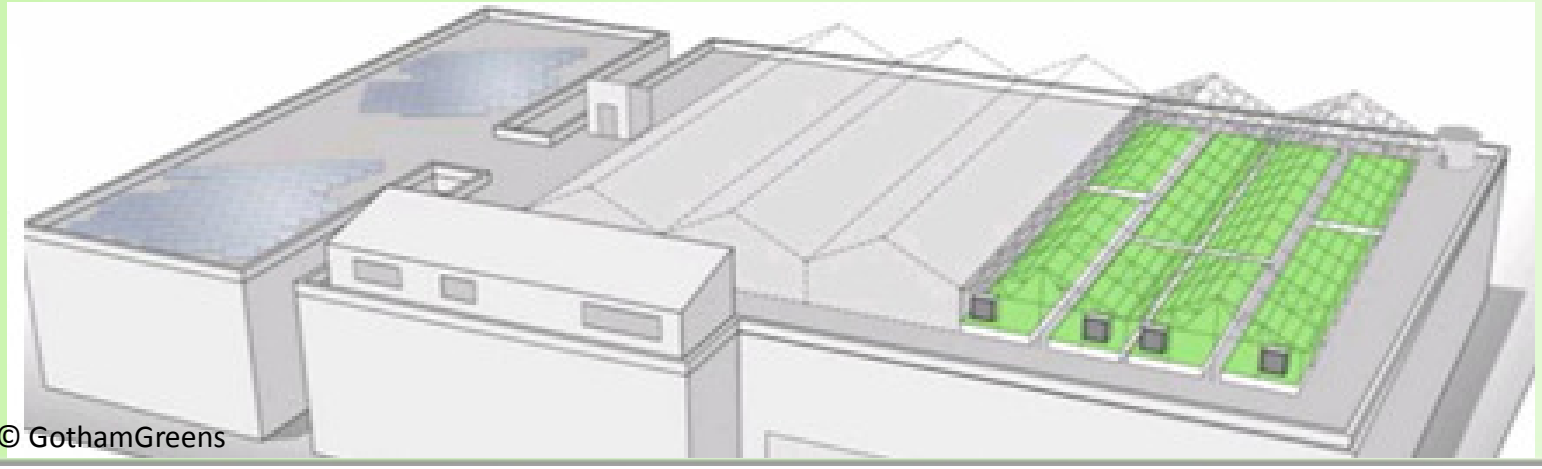
- Rooftop of primary school in Manhattan
- 132 m^2, rainwater harvest, aquaponics
- Yields ≈ 28 $kg/m^2/year$
- Classroom of 35 inside
- Excellent educational tool
- Fresh, quality and pesticide-free food for school cafeteria

Review – Blue Sea Development

- 1000 m^2 greenhouse on top of affordable housing complex in low-income area (Bronx, NY)
- Fully integrated – use waste heat from building below to heat greenhouse
  - Captures 225 MWh/year of waste heat (26kW avg)
- Fresh, quality produce for 450 people year-round, in otherwise 'food desert' area
- Improves public health, education and creates jobs

Review – Gotham Greens

- £0.88million commercial 1100m^2 greenhouse on top of industrial building in Queens, NY.
- Use of waste heat from building's HVAC, rainwater harvest, PV arrays...
- Yield between 30 and 50 tons pa with wholesale value of ≈£310,000
- Estimated to save 6.8 GWh over 20 years compared to conventional agriculture (39kW avg)

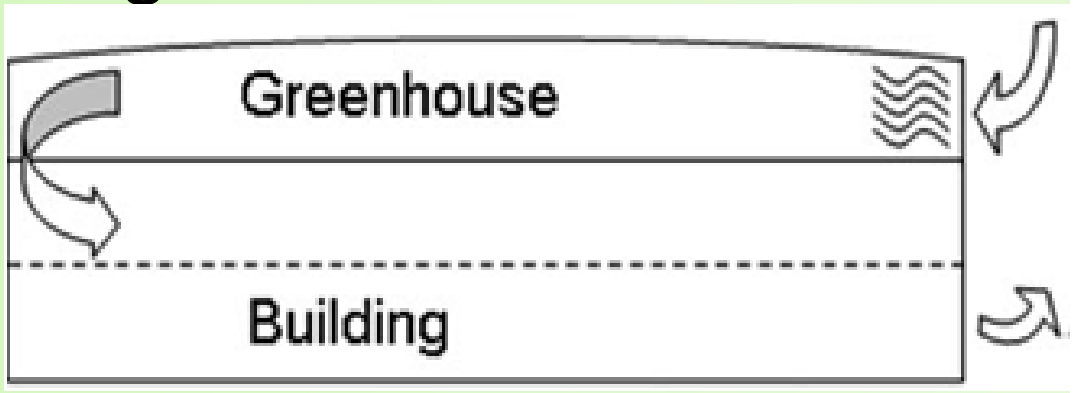


Insulating, heating and cooling

- Rooftop greenhouse = extra layer
  - Reduces heat gains and losses through roof
- Capture waste heat from building to heat GH
- Use excess solar gains in GH to heat building (on cold but sunny days)
- Use evaporative cooling in GH to cool both
- CO_2 and O_2

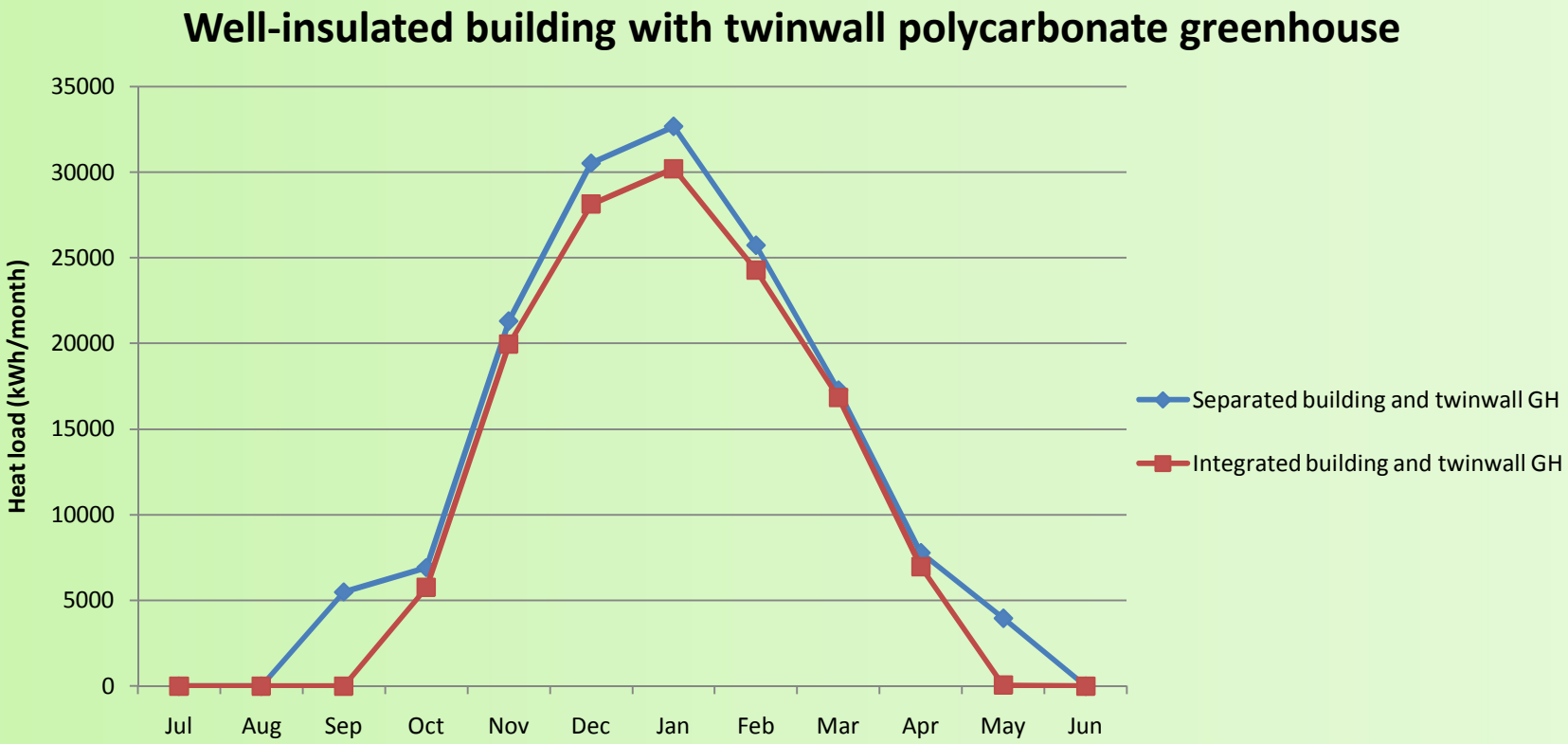
exchange between

occupants and plants



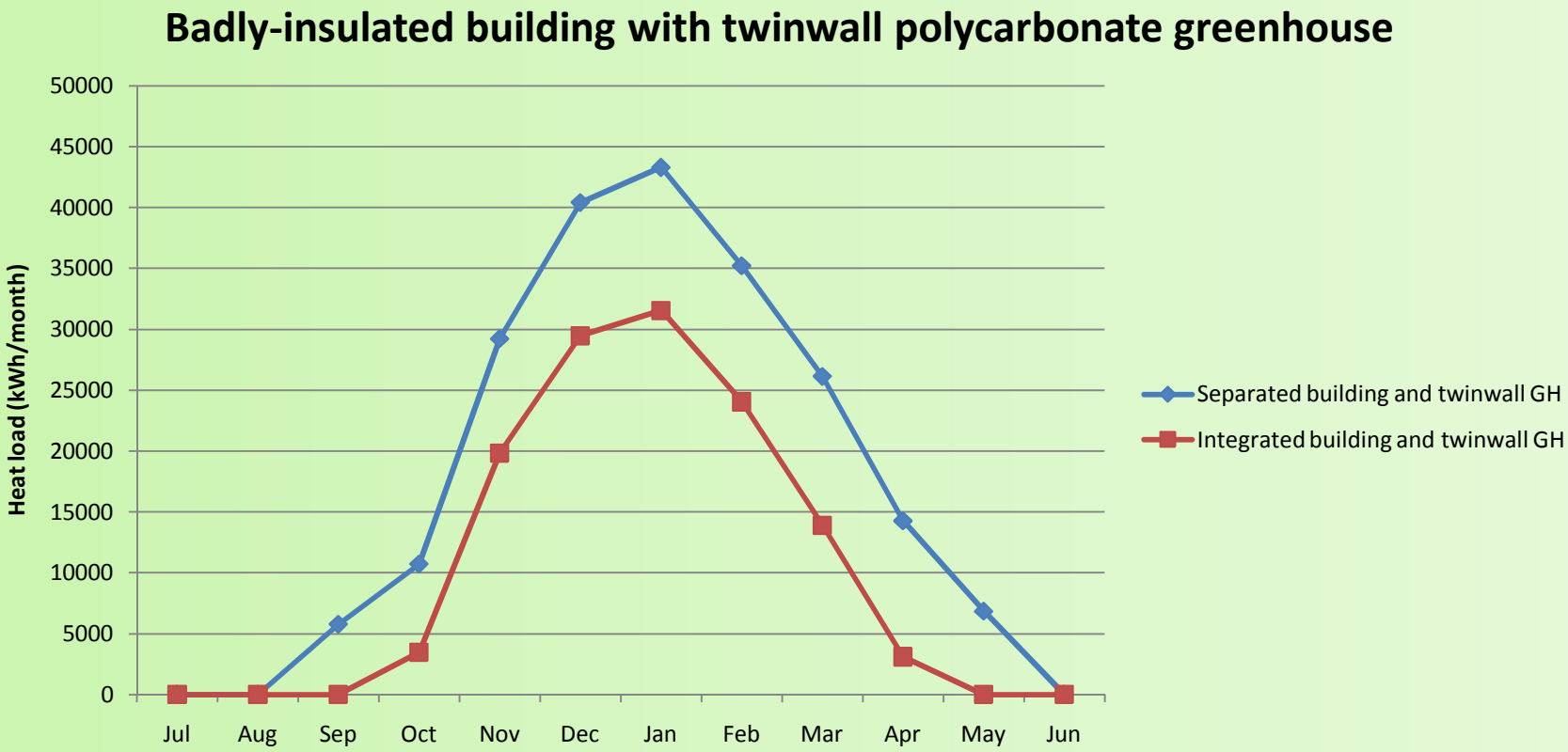
Caplow & Nelkin (2007)

Results – Integrated vs Separated



- London climate; 2-story building, 361m^2 floor area.
- U-value$_{roof}$ = 0.4 Wm^{-2}K^{-1}; U-value$_{walls}$ = 0.8 Wm^{-2}K^{-1}
- Integrated structure saves 19,500 kWh/year
  - **13% saving** over conventional load

Results – Integrated vs Separated



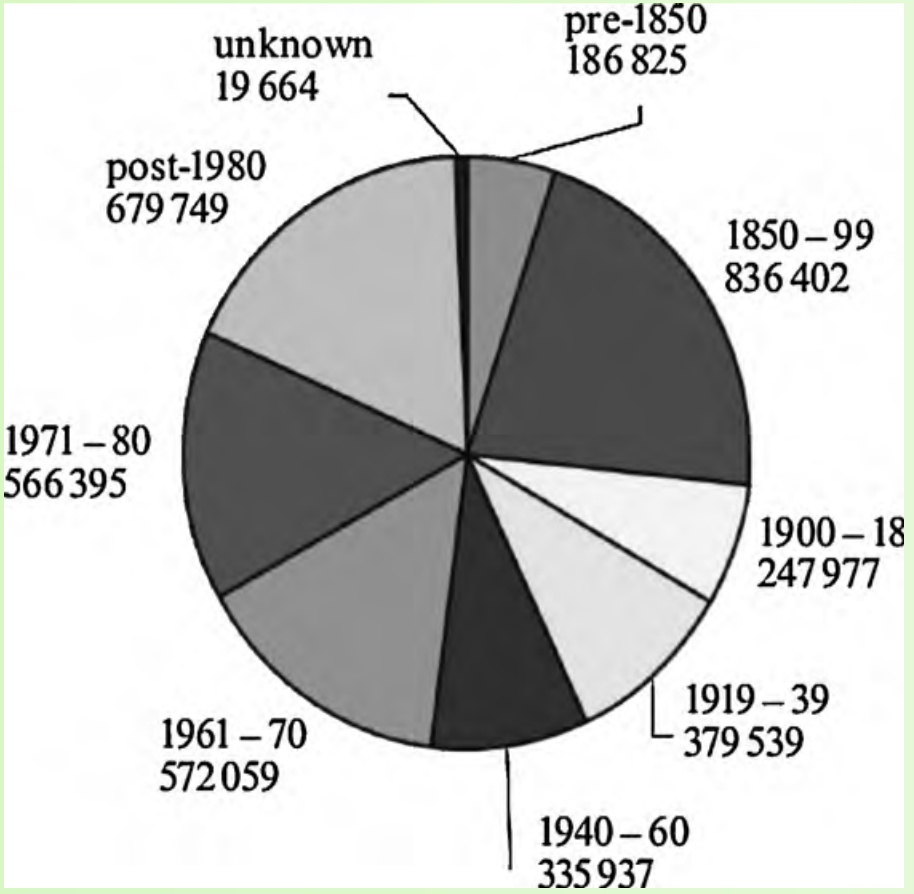
- U-value$_{roof}$ = 8 Wm^{-2}K^{-1}; U-value$_{walls}$ = 2 Wm^{-2}K^{-1}
- Integrated structure saves 86,500 kWh/year
  - **41% saving** over conventional load

Rooftop greenhouse or green roof?

- Similar energy benefits (but no scientifically rigorous comparisons can be made for now)
- Structural weight:
  - Green Roof: lightest at 49-98 kg/m^2, usually 120-150 kg/m^2
  - Greenhouse: 49-73 kg/m^2 on main field of roof.
- Costs:
  - GR: typically ≈£150/m^2
  - GH: £400-540/m^2 for new constructions, £680 – 810/m^2 for retrofits
  - GHs have commercial value: £270/m^2/year (Gotham Greens)
- Commercially viable with sale of produce alone (estimated gross profit 46%, EBITDA 23%)

Potential for retrofit

- High energy savings for badly insulated buildings
- Over half of UK building stock from before 1965 (no insulation regulations)
- Strong case for retrofitting in UK!



Brown *et al.* (2000)

Concluding remarks

- Urban agriculture
- Lack of space → Building-integrated CEA
- Initial projects successful, very young field
- Benefits include: Stormwater management; pesticide-free; year-round production; no fertiliser runoffs; education; jobs; high yields
- Energy savings similar to green roofs
  - Especially beneficial to badly insulated buildings
- Strong potential for retrofit in UK cities
- More research and empirical data needed

Selected references

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