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Systems Engineer, Technologist, Entrepreneur

Problem

Fossil fuels are causing climate change

Climate change is rapidly reducing productive agricultural land worldwide, with:

- Drought
- Flooding
- Excessive heat
- Intense weather events

As agricultural land decreases, the cost of food increases, ***and global food security is threatened***

Standard greenhouses

Most greenhouses on the market today:

- Are **NOT** solar greenhouses
  - Clue: you can see through all sides of these greenhouses!
- Although they admit solar energy and natural light, they **are not true solar greenhouses**

Standard greenhouses are part of the problem:

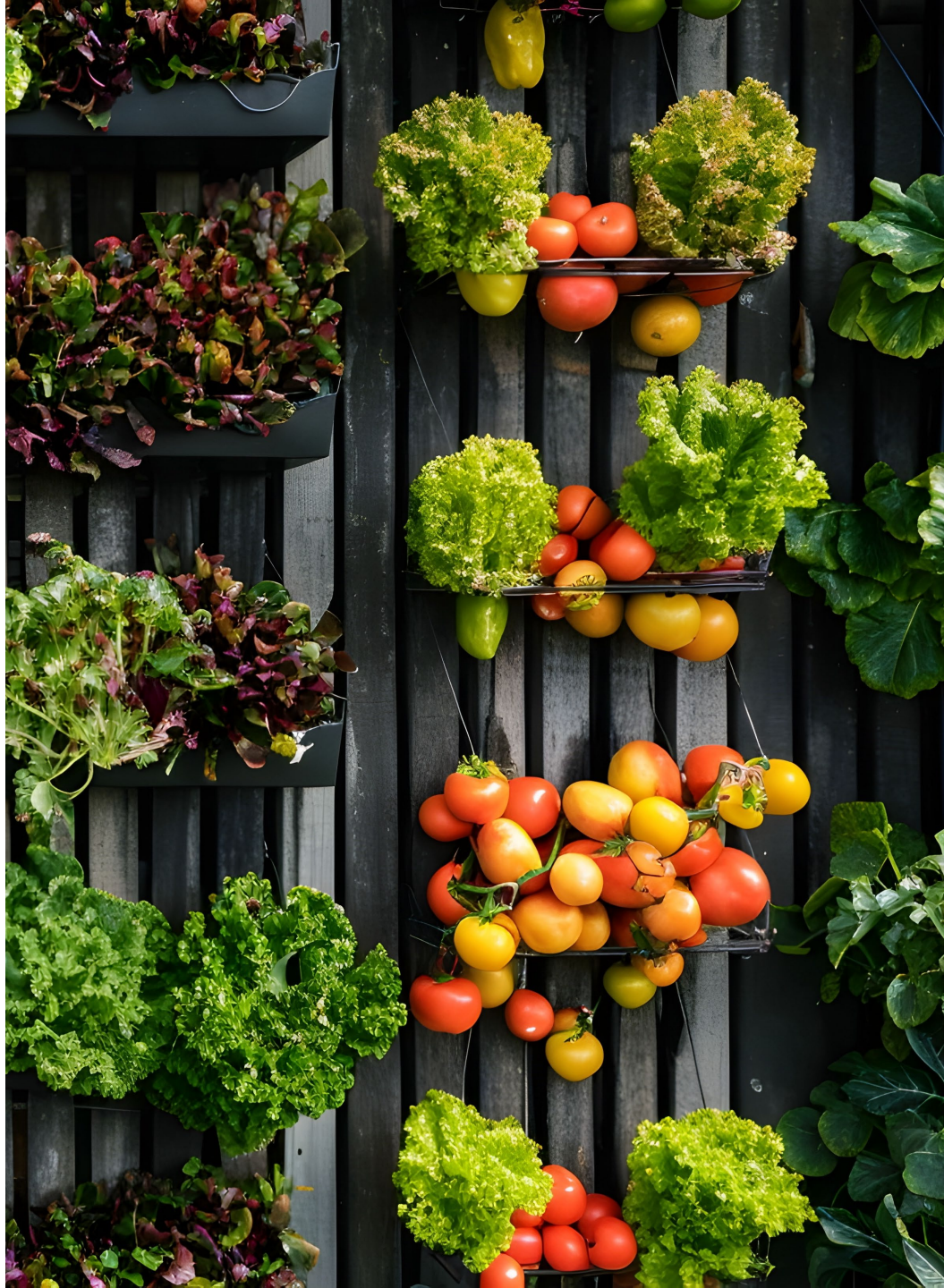
- **They depend on fossil fuels** for heating and cooling to extend the growing season, and
- **They depend on electric-grid power**
- They do little, if anything, to reduce greenhouse gas emissions

The imperative: Climate-Smart Agriculture

The RBC stresses the need for Canada to shift to **Climate-Smart Agriculture (CSA)**,[1] a set of agricultural practices and technologies designed to increase agricultural productivity and incomes without negatively impacting the environment.

- Reduction of greenhouse gas emissions
- Increasing soil health
- Increasing biodiversity
- Decreasing water and energy consumption
- Enhancing resiliency to climate change

[1]Royal Bank of Canada. “ A New Ag Deal: A 9-Point Plan for Climate-Smart Agriculture.” October 3, 2023.



"Family farms should continue investing in the latest farming practices"[1]

- “Nearly all farms in Canada are still owned and operated by families. These families, often multi-generational, are among the most efficient operators in the world.”[2]
- According to Mr. Heitmann, the “latest farming practices” should include solar-powered greenhouses and agrivoltaics to reduce operation costs and greenhouse gas emissions, and to increase income.
- The irony: Despite the report's call to adopt the latest farming practices, this image from the article shows only conventional, non-solar-powered greenhouses

1 "The Future of Family Farms," TheFutureEconomy.ca, April 26, 2024. https://bit.ly/40p5UPi

2 Ibid

The solution: True solar greenhouses

- **Reduce fossil fuel and electric-grid usage**
  - ~90%-100% annual reduction during an extended growing season
  - 50% annual reduction during year-round growing
  - Reduce greenhouse gas emissions by using natural gas for backup only
- **Increase local fresh-food production**
  - Extend growing season from 6 weeks to up to year-round, depending on climate and growing zone
  - Enable colder climate growers to farm vegetables, fruits, and ornamental crops indigenous to warmer climates
  - Increase agricultural productivity and small farm incomes
- **Reduce water use by 75-90% when coupled with water-efficient growing methods**:
  - Hydroponics, vertical farming, aquaculture, permaculture

Solar-powered Greenhouse Prototype
(in three phases from 2017 – 2023)

Key innovations

Novel, TRUE solar greenhouse design elements:

- Designed to be extensible and can be built by two people
- Parabolic south-facing wall for strength and optimal sun exposure
- Insulated vertical north-facing wall, reflective internally for winter heat gain and shaded in summer
- Concrete slab for thermal mass and containing a thermal battery, both for heat gain and cooling. Gravel floor for heat gain and drainage.
- A proprietary phase-change (PCM) solar-thermal battery with solar recharging method for heating and cooling
- Structure flexes with expansion and contraction, summer and winter
- Inexpensive PVC conduit spines combined with small aluminum struts to give snow-load strength
- Tough, clear, corrugated polycarbonate outside “skin” and internal twin-wall polycarbonate for additional insulation
- Solar-electric power for pumps, ventilation fans, lighting, and plant grow-lamps
- Grid-tie interface to enable agrivoltaic farming

Key innovations

PVC electrical conduit is innovative because

- PVC electrical conduit is strong, all-weather, UV-resistant, inexpensive, and easily obtained
- The parabolic curve forms naturally, so no prefab or bending is needed
- Snow-load strength is achieved with inexpensive aluminum struts:
  Total cost: $34 per spine compared to 1” OD **steel @ $97.60 per spine,** excluding pre-forming cost

Key innovations

Expansion joints

- The prototype greenhouse structure flexes with summer and winter expansion and contraction
- This is important because polycarbonate expands and contracts with changes in temperature, which can crack the polycarbonate
- Over a temperature range from -17.8C to 48.9C, the length of this 3.7m sheet can change as much as 12.7mm
- It’s flexible if someone needs to work on the roof for maintenance

Conventional thermal battery

Start by digging a 10’W x 15’L x 9’D pit

The pit must be excavated before the greenhouse is built.

Lay down a polyethylene vapor barrier (bottom, sides, and opening for drainage). Install air circulation ducts. Cover sides with 2” foam insulation. Fill the pit with 12” concrete slab and 8’ gravel, which serves as a thermal mass.

Key innovations

Major innovation:
Rechargeable thermal battery

- No need to excavate a 2.4m – 3m deep pit
- No need to waterproof and insulate a large pit
- Can install after the greenhouse is completed
- Excavate an area below the frostline. Can be done manually with shovel.
- Lay foam bats and place thermal tubes on top
- The thermal battery tubes could be mass-produced
- Assembly at site
- 25-year life

Key innovations

North interior insulated and **reflective aluminum wall** with DIY **vertical hydroponic grow wall** (not Zipgrow). **Black fan** (left-middle) pulls cool air (winter) into the thermal-battery and blows warmed air out at the base of the grow wall.

Concrete and gravel thermal-mass components. One of two thermal batteries located under concrete slab.

Key innovations

Digital thermostats automatically turn on fans that intake cooler outside-air and exhaust inside heat when the temperature exceeds 78F.

If the ceiling temperature rises above 90F, misters automatically turn on, and the fans work as evaporative coolers.

The air temperature drops below 78F in about 7 minutes, and misters and fans turn off.

Solar-powered greenhouse with light snow load

Solar-powered greenhouse with
aluminum mesh curtains to reflect summer-heat

Greenhouse vibrancy