Waste-Energy-Leveraged CEA for Year-Round Specialty Crop and Bio-Fuel Feedstock Production in Temperate Climates

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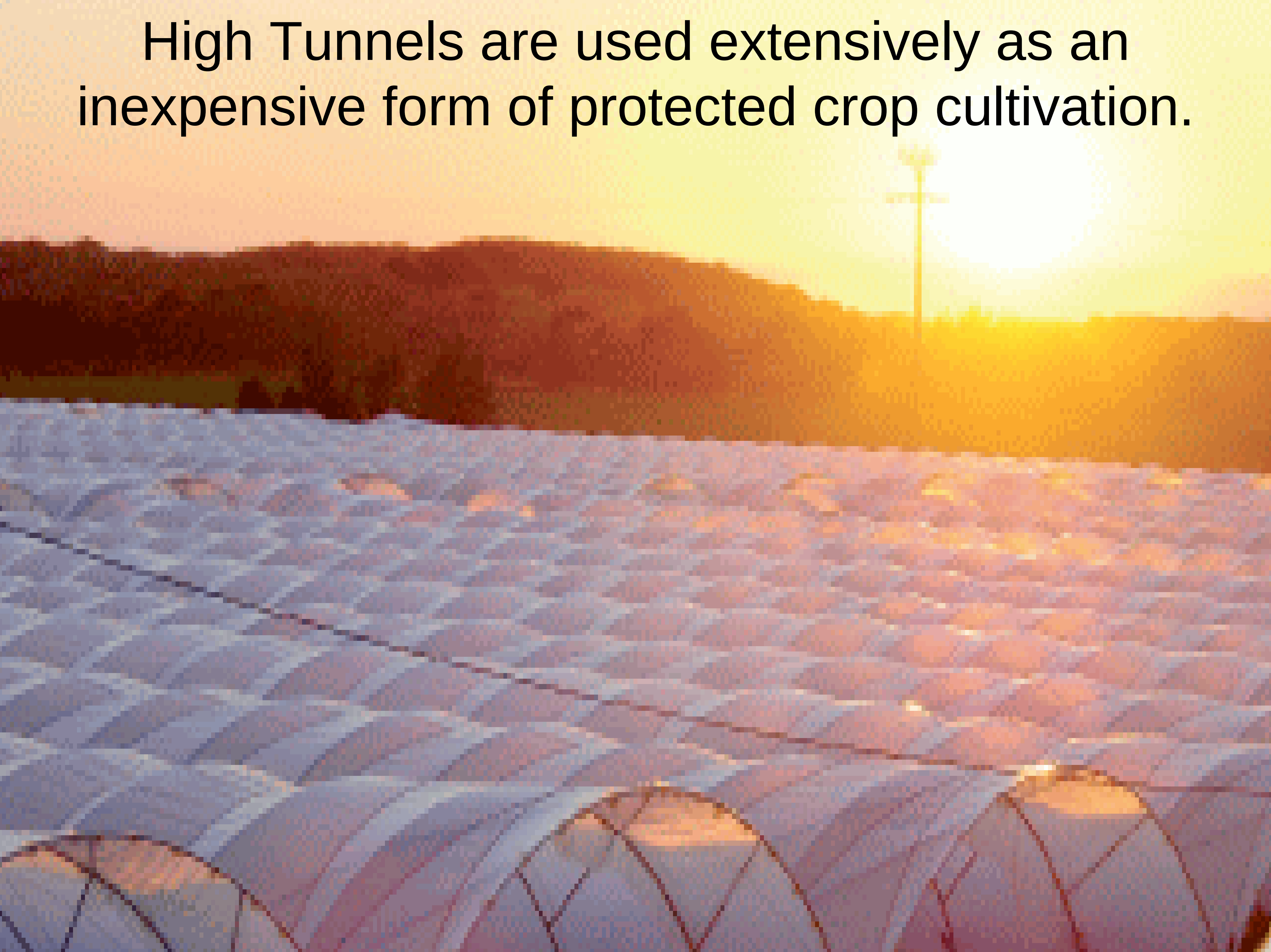
The Concept

Maintaining warm temperatures under cover during cold weather using thermal waste enables local specialty-crop production to be an economically superior alternative to transporting produce long distances from field-production sites in mild climates.

High Tunnels are used extensively as an inexpensive form of protected crop cultivation.



Why high tunnels for crop production?

- Infrastructure
  - inexpensive, not permanent
  - minimal utilities
  - local labor for construction
- Creates favorable microclimates
  - extends growth seasons
  - moderates daily / seasonal temperatures
  - avoids wind stress
  - reduces drought stress


HTs provide shade and wind / rain protection during warm weather.


Cheap, temporary infrastructure
Side, end ventilation in summer
Plants grow directly in the ground

Implications for waste-powered protected cultivation of specialty crops in temperate climates

- Eliminates long-distance transportation costs
- Minimizes food safety / security concerns
- Creates a non-seasonal green industry
- Creates local jobs / revenue
- Enables water conservation
- Reduces pollution by utilizing waste CO_2

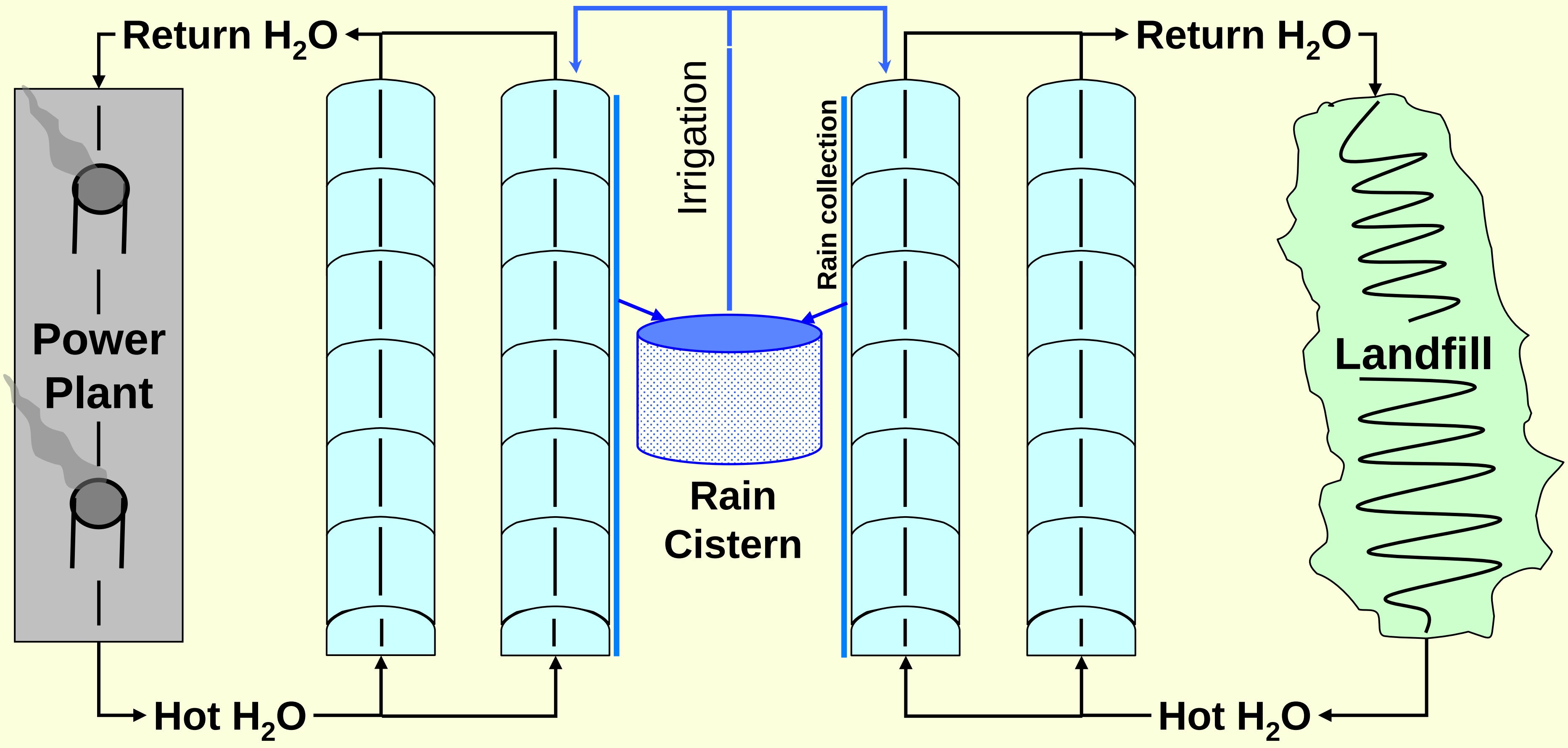
Common sources of thermal and / or organic waste that could be “mined” for heat, power, CO_2

- Landfills: generate CH_4 → heat, power, CO_2
- Power plants
- Heavy industry / manufacturing
- CAFOs, dairies, feedlots
- Food-, feed-processing plants
- Biorefineries (ethanol, bio-diesel)
- Sewage-, water-treatment plants
- Sawmills / lumber yards

(Power plants; Heavy industry / manufacturing) → heat, CO_2

(CAFOs, dairies, feedlots; Food-, feed-processing plants; Biorefineries (ethanol, bio-diesel); Sewage-, water-treatment plants; Sawmills / lumber yards) → CH_4

Leveraging Waste Thermal Energy for Cold Weather

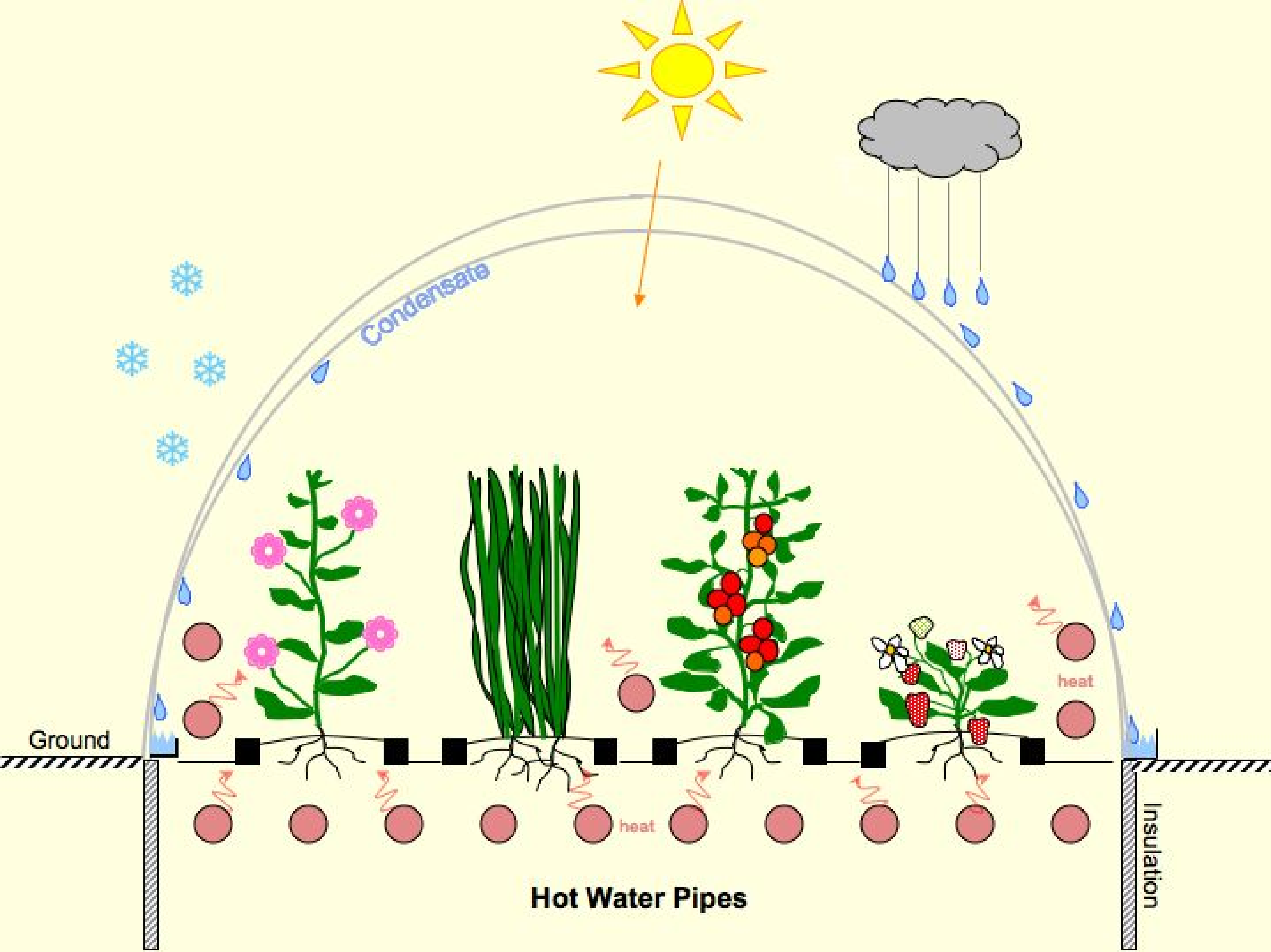


The Purdue High-Tunnel Project

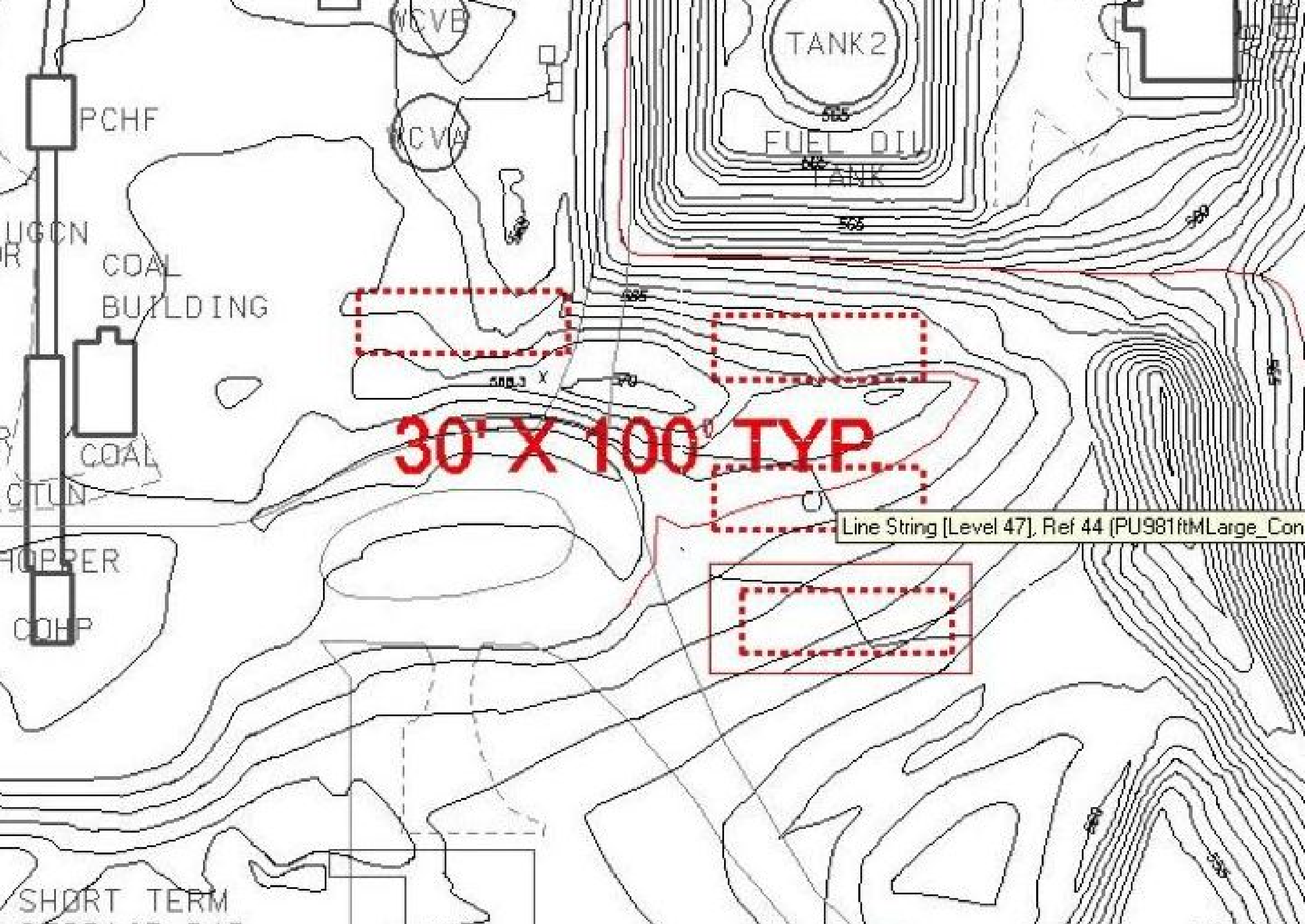
Proof of concept will be tested for the feasibility of greatly extending cropping seasons using high tunnels bottom heated with water recirculating between the campus power plant and a nearby high-tunnel crop-production site.

Crop candidates for production in waste-powered high tunnels

- Vegetables – cole crops, leafy greens, tomato, pepper, herbs, sweet corn
- Small Fruits – strawberry, raspberry, blackberry
- Ornamentals – foliage plants, bedding plants
- Biofuel Feedstocks – switchgrass, indian grass, elephant grass, giant reed, napiergrass, forbes

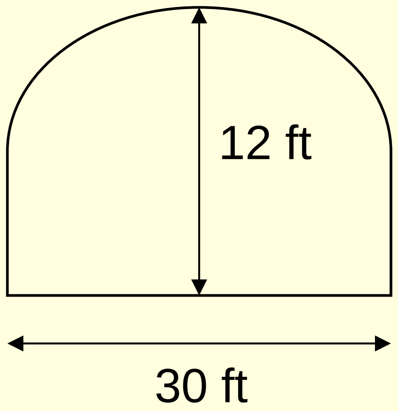

Condensate
Ground
heat
heat
Insulation
Hot Water Pipes

High-tunnel site south of Purdue power-plant cooling towers



Topographic Map of Tunnel Site

High Tunnel Project



Length = 100 ft

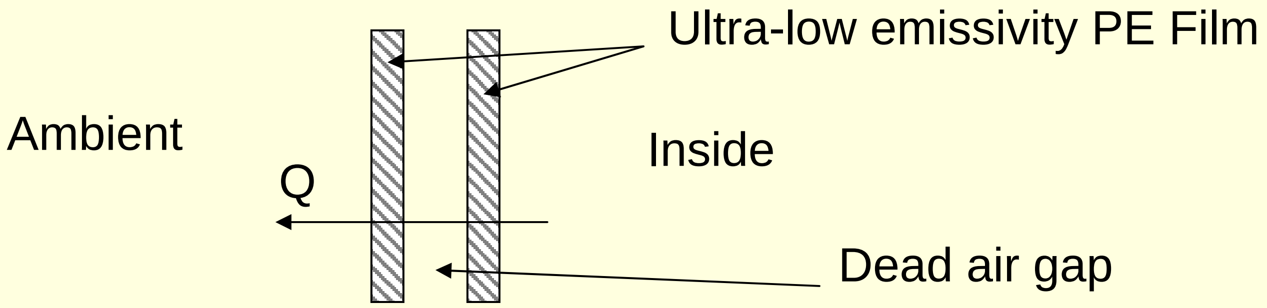
- Tunnel skin: Two polyethylene sheets (6 mil thick) separated by an air gap
- Soil bed: Silt loam

Worst-case assumptions:

- Ambient outside temperature: -15 °F
- Wind speed: 30 miles/hr
- Goal: to maintain 55 °F soil temperature and 50 °F inside air temperature under the above outside conditions

High Tunnel Project

Part A: Heat Loss Estimation



$$Q = Q_{convection} + Q_{Radiation}$$

Convection / conduction heat loss is estimated by calculating heat transfer coefficient inside and outside of the tunnel = 6.3 kW

Radiation heat loss calculated assuming soil temperature of 55 °F = 3.2 KW

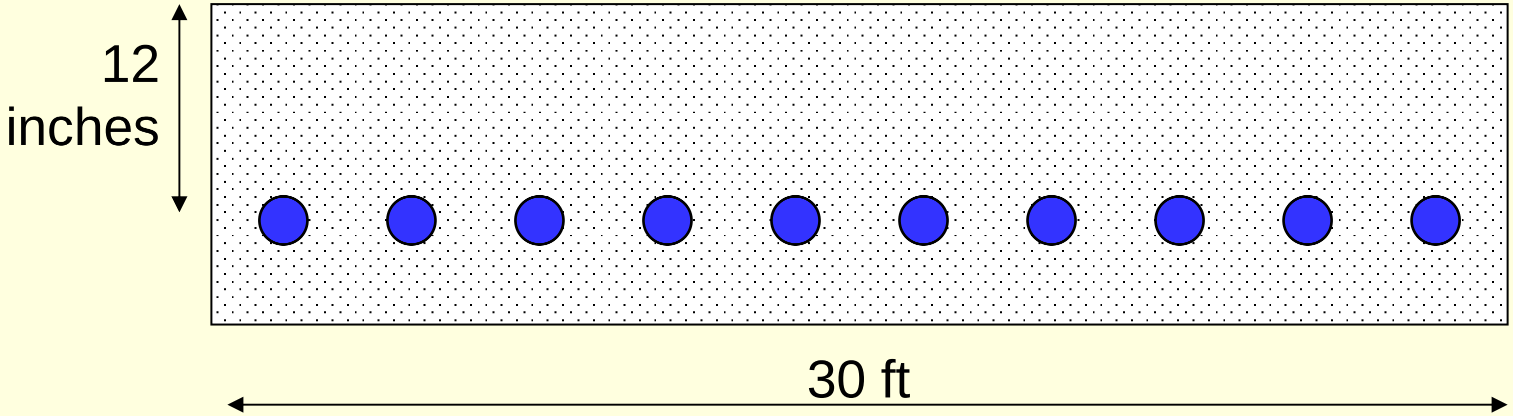
Net heat loss from the tunnel = 9.5 kW

High Tunnel Project

Part B: Heat Transfer from Hot Water

Inlet water temperature = 81 °F

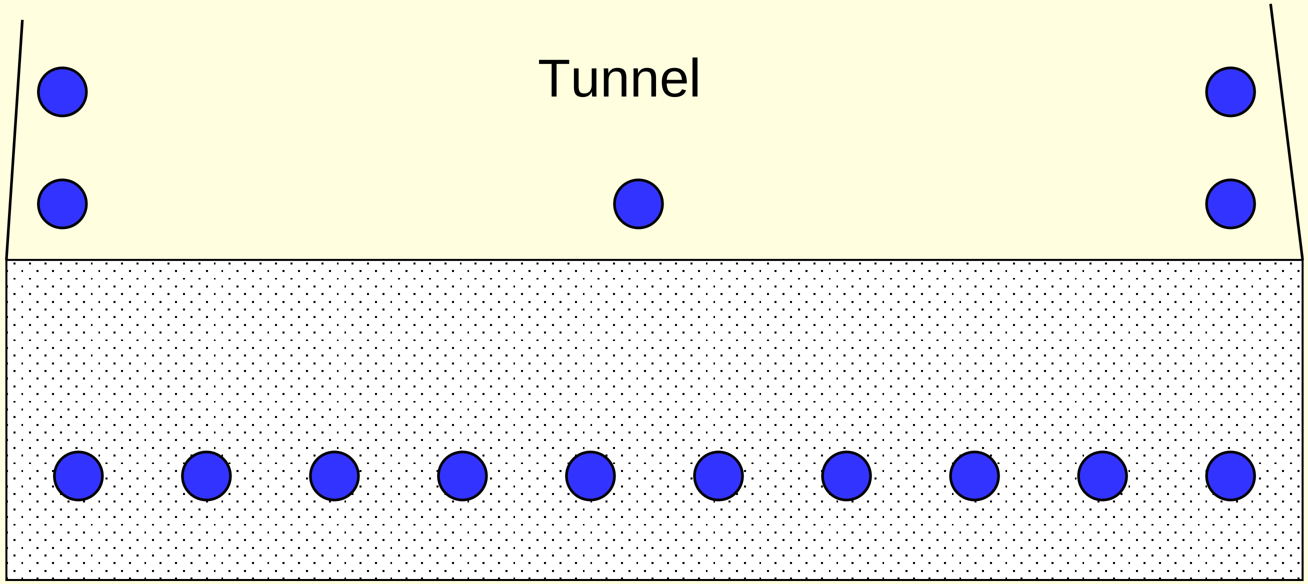
Exit water temperature = 70 °F



10 HDPE pipes (1.207” outside diameter, 0.079” wall thickness)

Depth of pipes below ground level = 12 inches

High Tunnel Project



5 additional pipes are used above the ground level

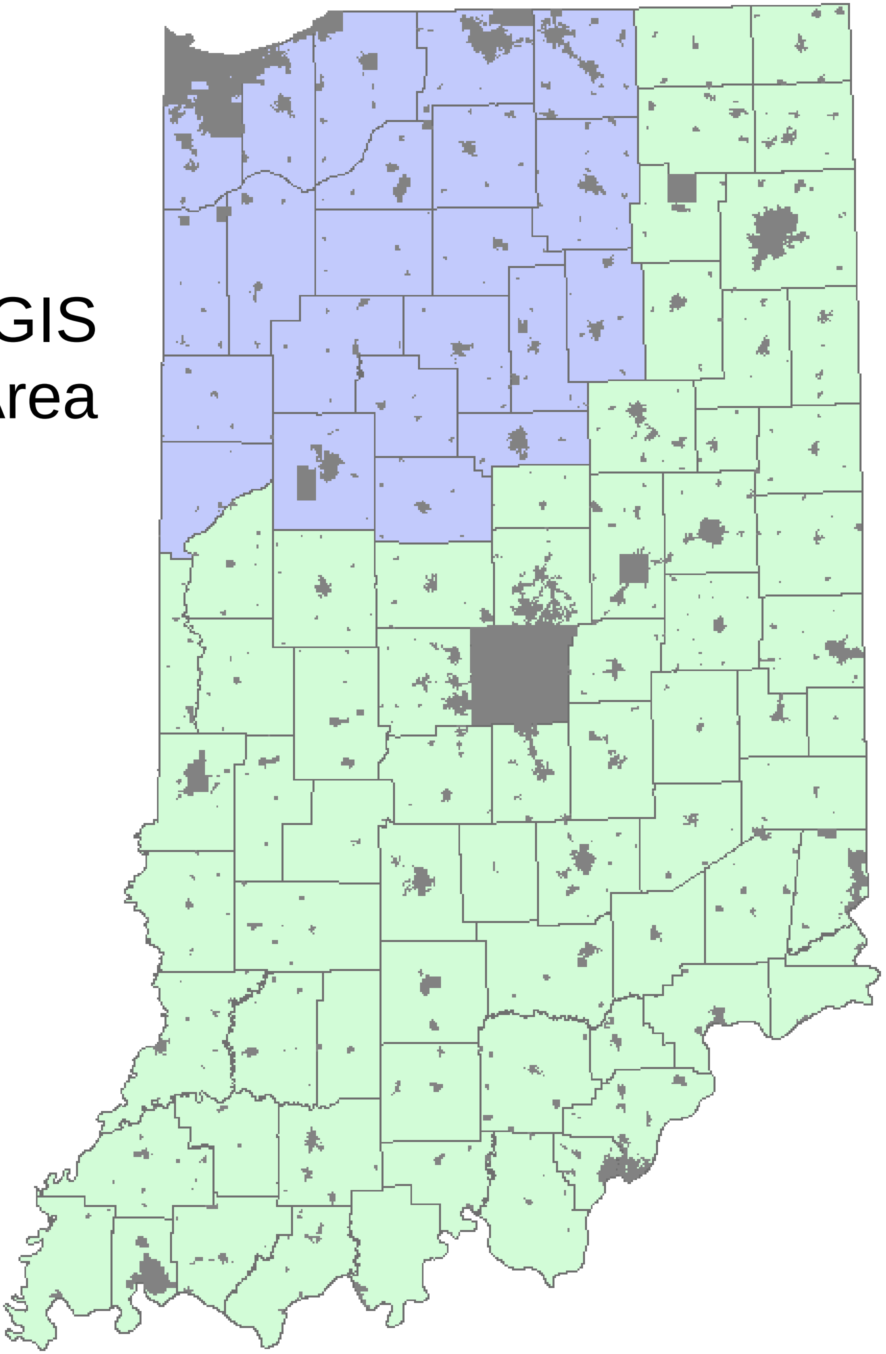
Total flow rate of water = 1000 gal/hr   Heat in water = 26.85 KW

Heat transferred from underground pipes = 7.0 KW

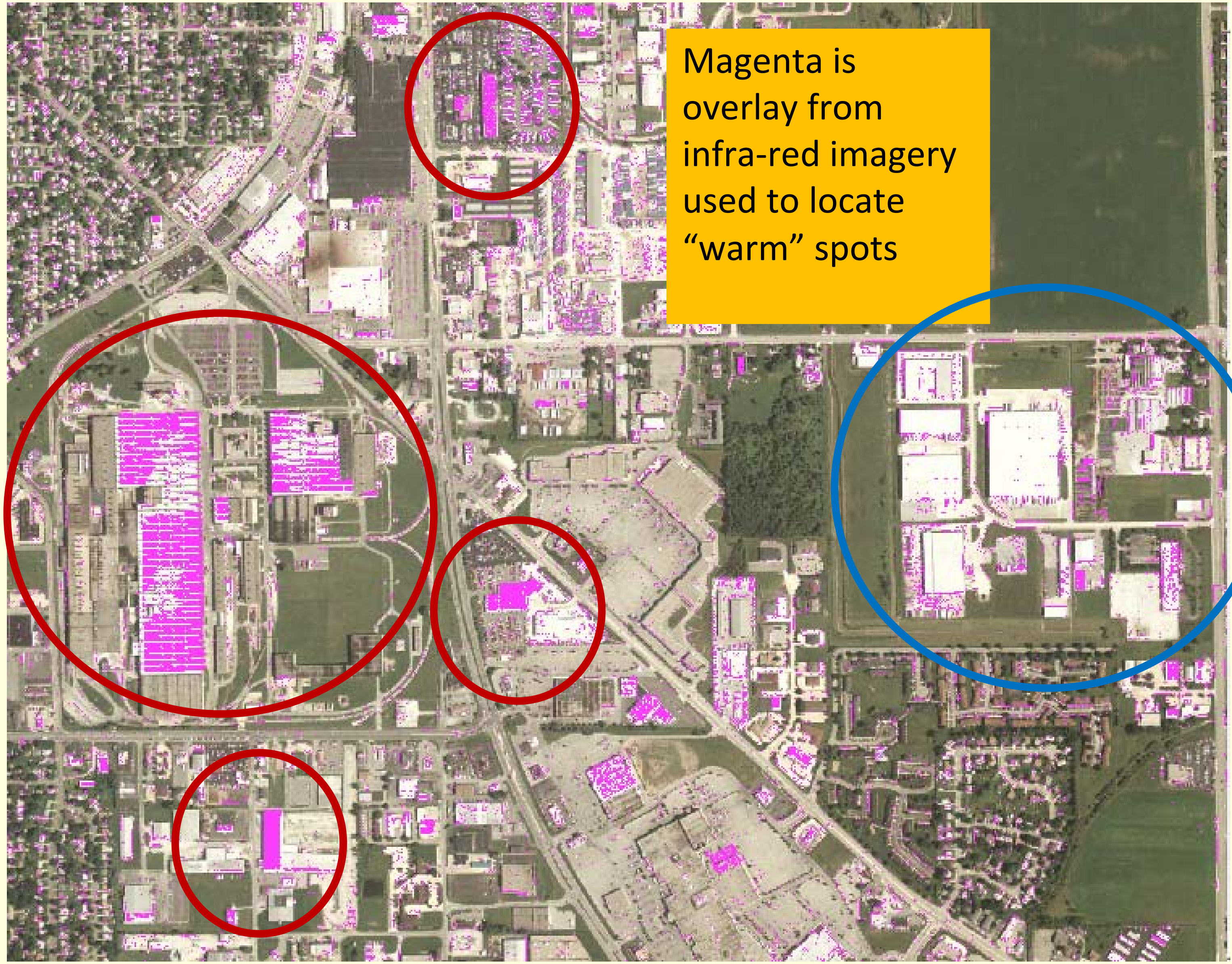
Heat transferred from above-ground pipes = 3.5 KW

Total heat transfer from 15 pipes = 10.5 kW

NW / NC Indiana GIS
Waste-Site Test Area



Aerial image of commercial development in Lafayette, Indiana



Large red circle is a foundry (heat source). Large facility in blue circle is an engineering design group – not a heat source. Small circles are warm but too small.

Waste-Powered HT Production Issues

- Pollination challenges
  - alternatives to insect pollinators
  - spectral transmission of covering film
- Disease control without freeze-thaw cycles
- Pest control with / without ventilation
- Enhancing crop water-use efficiency
  - rainwater & condensate collection / recycling
  - limited use of irrigation
- Filtering / injecting waste CO_2 into closed HTs

Production R & D Issues continued…

- Enhance natural lighting within tunnels
  - – Line lower inside hoop surfaces with reflective film
  - – Reflective A-frames / hanging strips between beds
  - – Reflective mulches covering raised beds
  - – Use more transparent covering films
  - – Use spectrally selective covering films

- "Fool" crops to produce out of season
  - – Use photoperiodic cues (night break in winter)
  - – Use thermal cues (chilling, forcing)
  - – Use growth regulators (parthenocarpic fruit set)
  - – Use supplemental lighting with LED panels where CH_4 abundant

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