University of Nebraska-Lincoln
Architectural Engineering
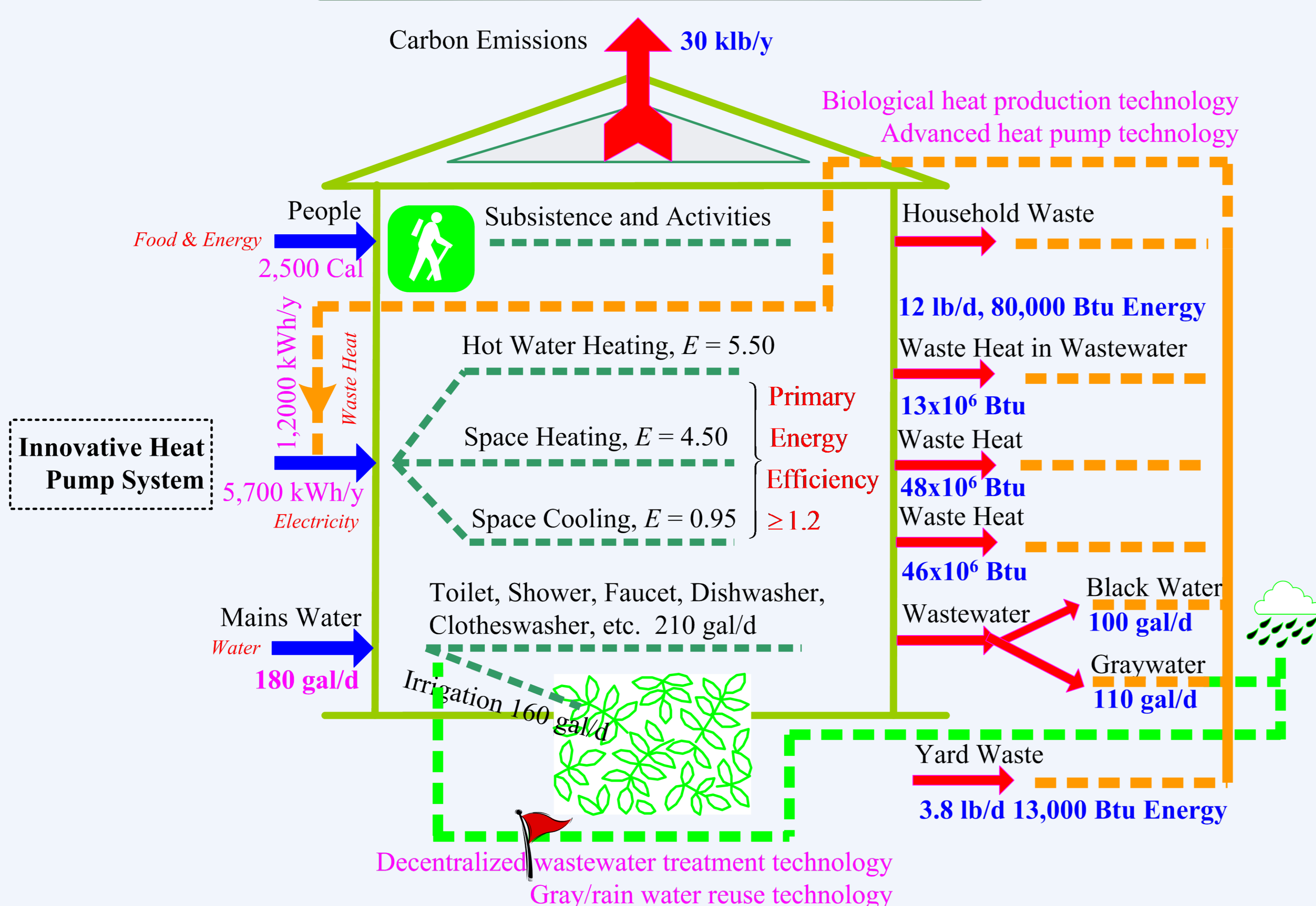Xiaoyu Liu, Dr. Long Ni, Dr. Haorong Li, and
Dr. Siu Kit Lau

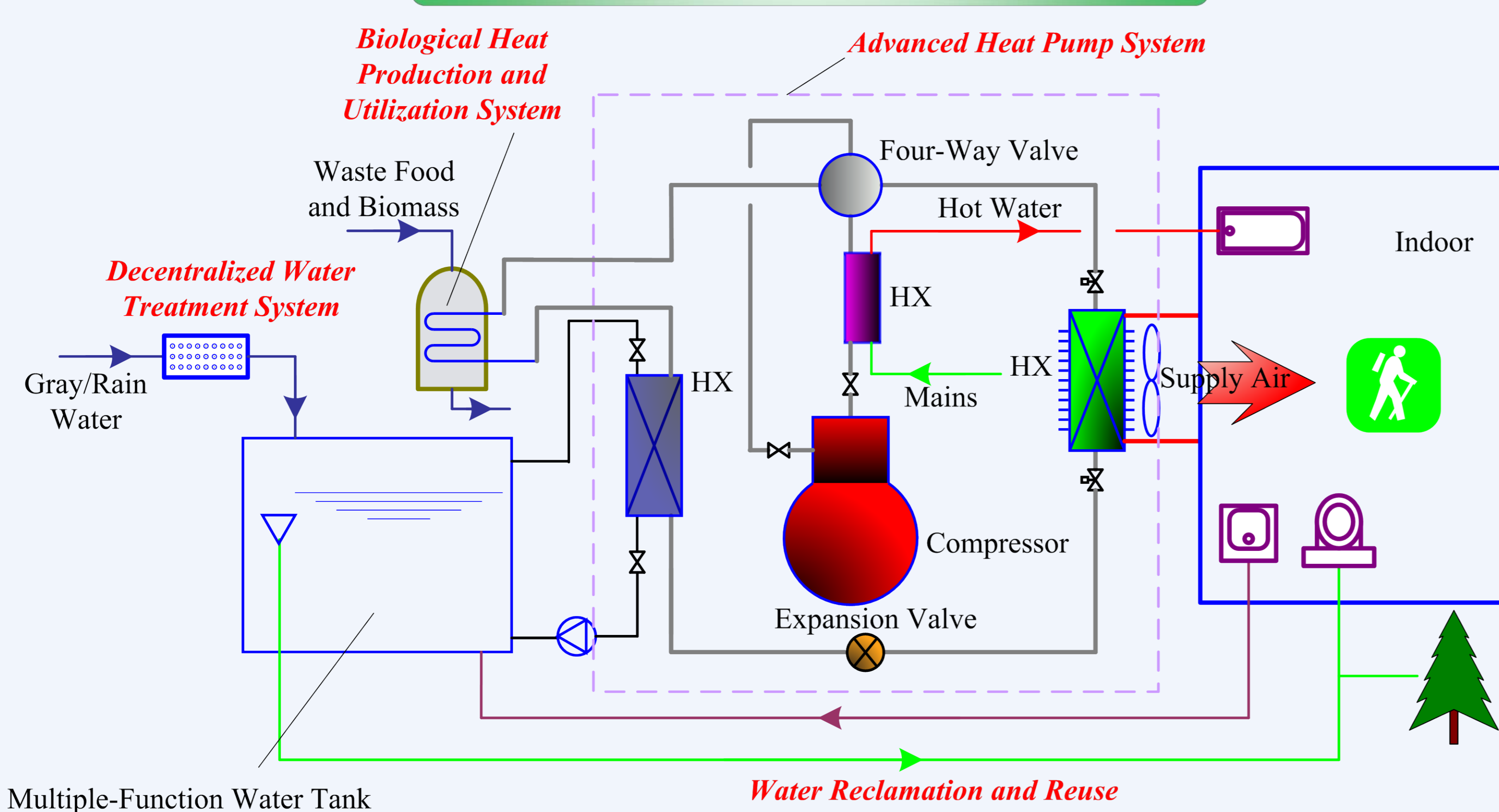# Innovative Wastewater Energy Recovery System

Objectives

- Establish an *optimal and recycling building energy / water system* to maximize the efficiency of resources' usage and to recycle most of energy and water.
- Explore the feasibility of *biological heat production* from sacchariferous waste.
- Develop a *combined heat pump / low-temperature absorbent refrigerating system* for hot water heating, space heating and cooling.
- Integrate *decentralized waste water treatment / reclamation technologies* with building thermal energy system to formulate a comprehensive energy/water strategy

Things Will Be Different

Carbon Emissions 30 klb/y

Biological heat production technology
Advanced heat pump technology

Food & Energy — People 2,500 Cal
Subsistence and Activities
Household Waste

Innovative Heat Pump System

Waste Heat / 1,2000 kWh/y
5,700 kWh/y Electricity

Hot Water Heating, $E = 5.50$
Space Heating, $E = 4.50$
Space Cooling, $E = 0.95$
Primary Energy Efficiency ≥ 1.2

12 lb/d, 80,000 Btu Energy
Waste Heat in Wastewater
13x10^6 Btu Waste Heat
48x10^6 Btu Waste Heat
46x10^6 Btu Wastewater

Mains Water / Water 180 gal/d
Toilet, Shower, Faucet, Dishwasher, Clotheswasher, etc. 210 gal/d
Irrigation 160 gal/d

Black Water 100 gal/d
Graywater 110 gal/d

Yard Waste
3.8 lb/d 13,000 Btu Energy

Decentralized wastewater treatment technology
Gray/rain water reuse technology

Recycling Building Thermal Energy / Water System

Innovative Technologies

Biological Heat Production and Utilization System
Advanced Heat Pump System

Waste Food and Biomass
Decentralized Water Treatment System
Gray/Rain Water

Four-Way Valve
Hot Water
HX
Mains
HX
Supply Air
Indoor
HX
Compressor
Expansion Valve
Multiple-Function Water Tank
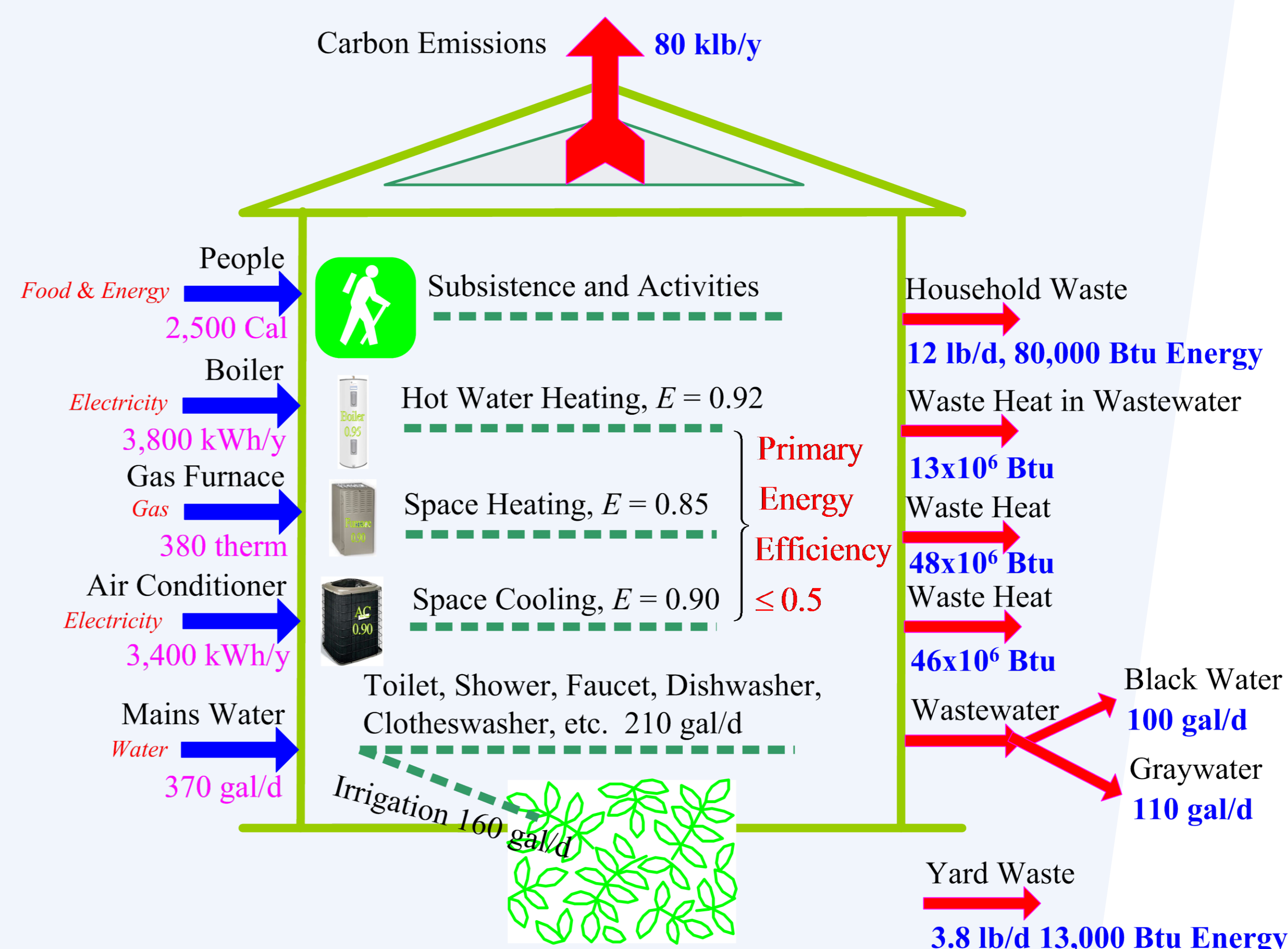*Water Reclamation and Reuse*

- Biological heat production technology
- Advanced heat pump technology
- Low-temperature absorbent refrigerating technology
- Decentralized wastewater treatment technology
- Gray/rain water reuse technology
- Integrated design and installation method
- Optimal thermal energy/water commissioning and control strategy

What Can We Do

- Reduce total *energy usage* for hot water heating, space heating and cooling by *50%*
- Reduce *water usage* in buildings by *50%*
- Reduce *electricity peak demand* by *30%*
- Reduce *total costs* for equipment/installation/maintenance and save the habitable by *50%*

What Things Be

Carbon Emissions 80 klb/y

Food & Energy — People 2,500 Cal
Subsistence and Activities
Household Waste

Electricity 3,800 kWh/y Boiler
Gas 380 therm Gas Furnace
Electricity 3,400 kWh/y Air Conditioner
Water 370 gal/d Mains Water

Hot Water Heating, $E = 0.92$
Space Heating, $E = 0.85$
Space Cooling, $E = 0.90$
Primary Energy Efficiency ≤ 0.5

Toilet, Shower, Faucet, Dishwasher, Clotheswasher, etc. 210 gal/d
Irrigation 160 gal/d

12 lb/d, 80,000 Btu Energy
Waste Heat in Wastewater
13x10^6 Btu Waste Heat
48x10^6 Btu Waste Heat
46x10^6 Btu Wastewater
Black Water 100 gal/d
Graywater 110 gal/d

Yard Waste
3.8 lb/d 13,000 Btu Energy

- Buildings represent about *40%* of primary energy, *70%* of electricity consumption and *38%* of carbon emissions.
- The existing building thermal energy systems are designed to use *three separate systems to serve three functions*.
  - A boiler for hot water heating
  - A furnace for space heating
  - An air conditioner for cooling

- *Water usage is very wasteful*
  - Drink water for toilet flushing
  - Drink water for garden irrigation and fire protection
- A huge amount of *energy residing in trash and wastewater* is discharged without being used.
  - Wastewater with heat in winter and cooling in summer
  - Waste food, grass, leaves and biomass with sugar
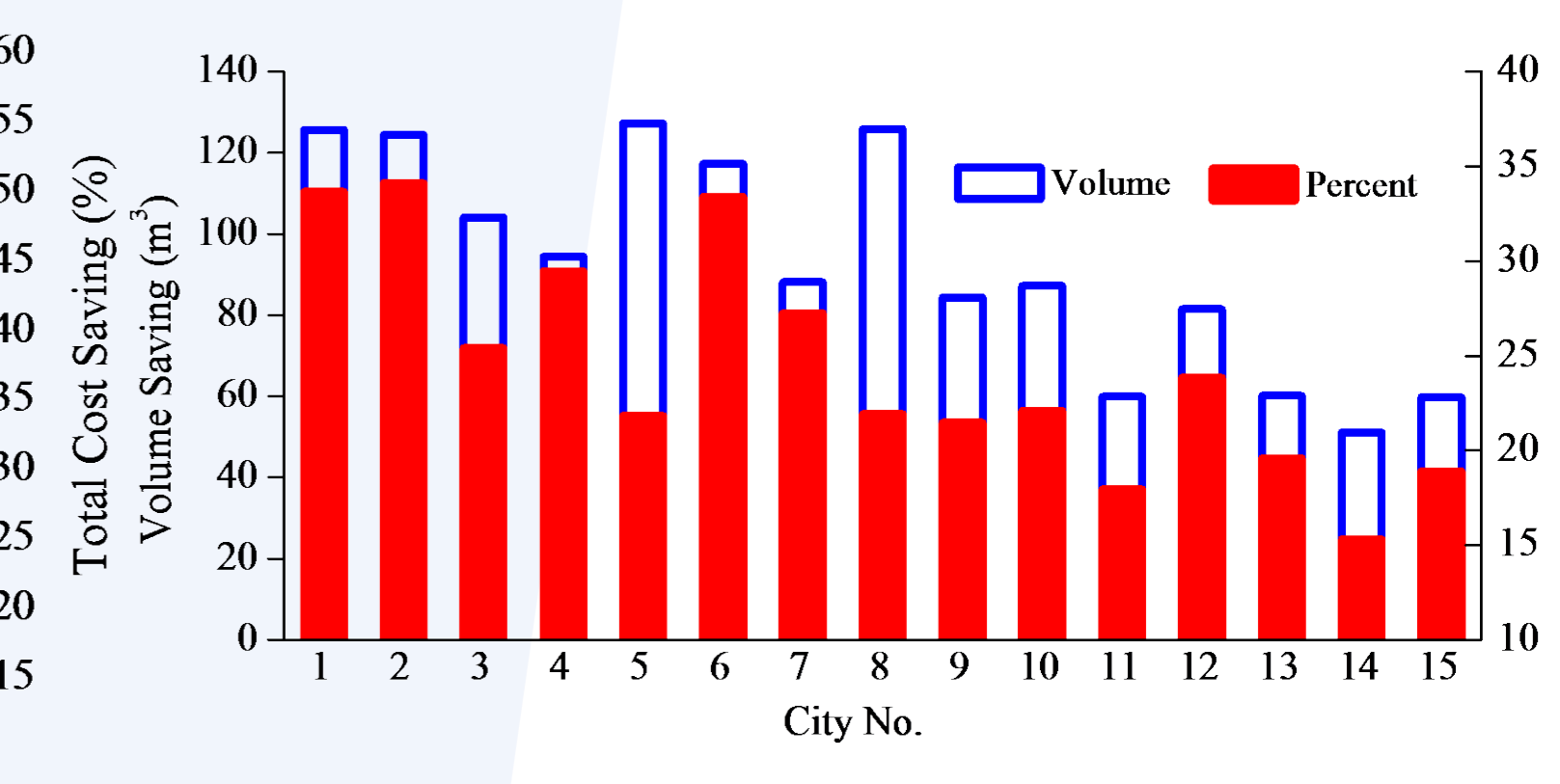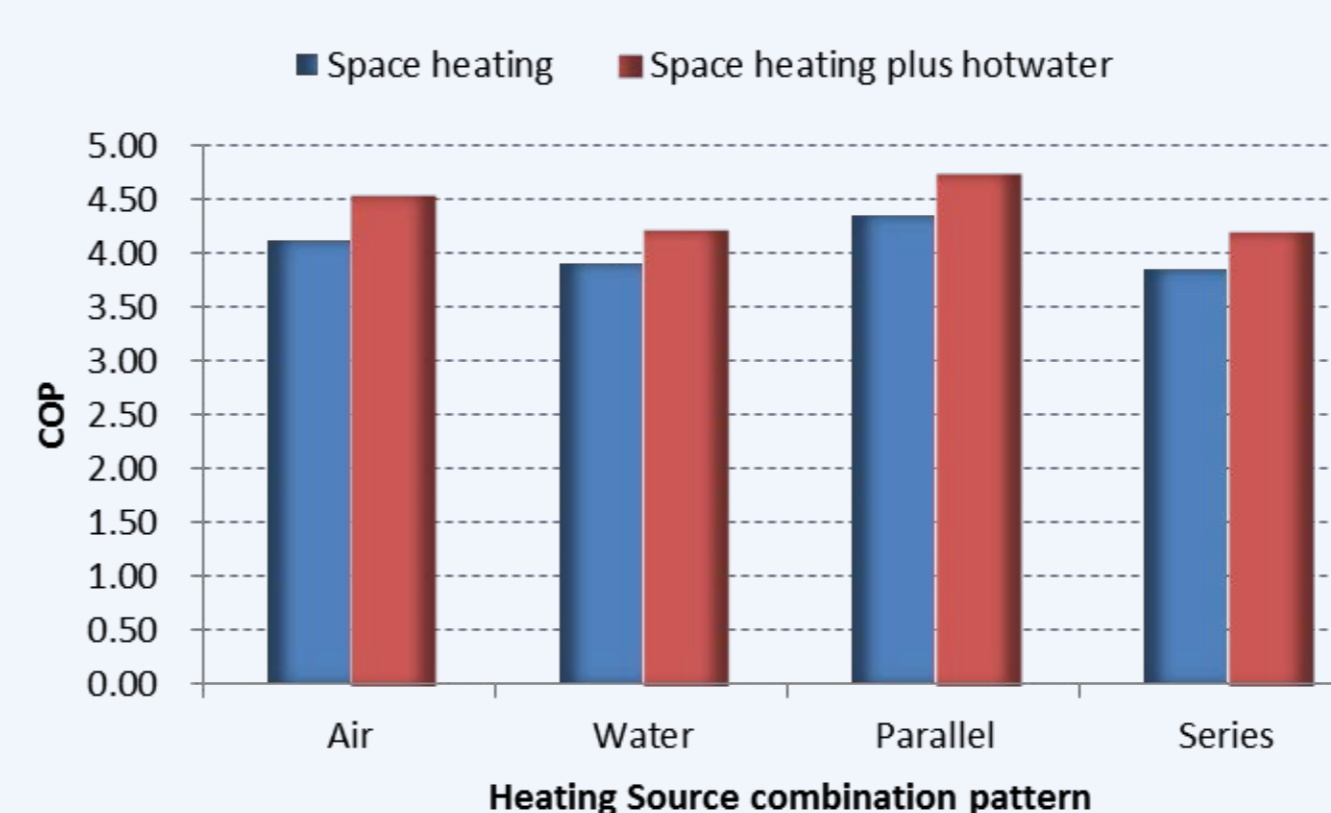
Simulation and Experiments
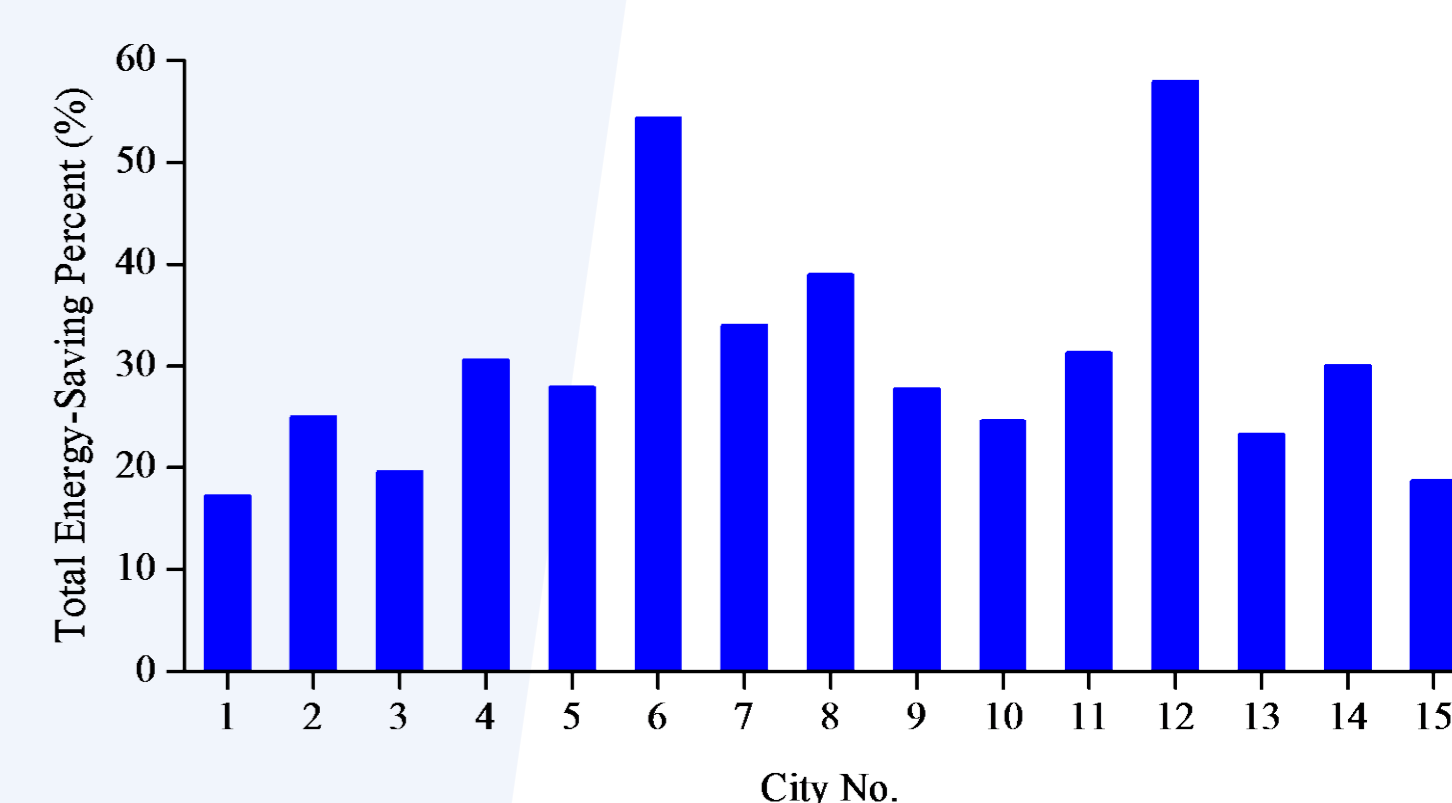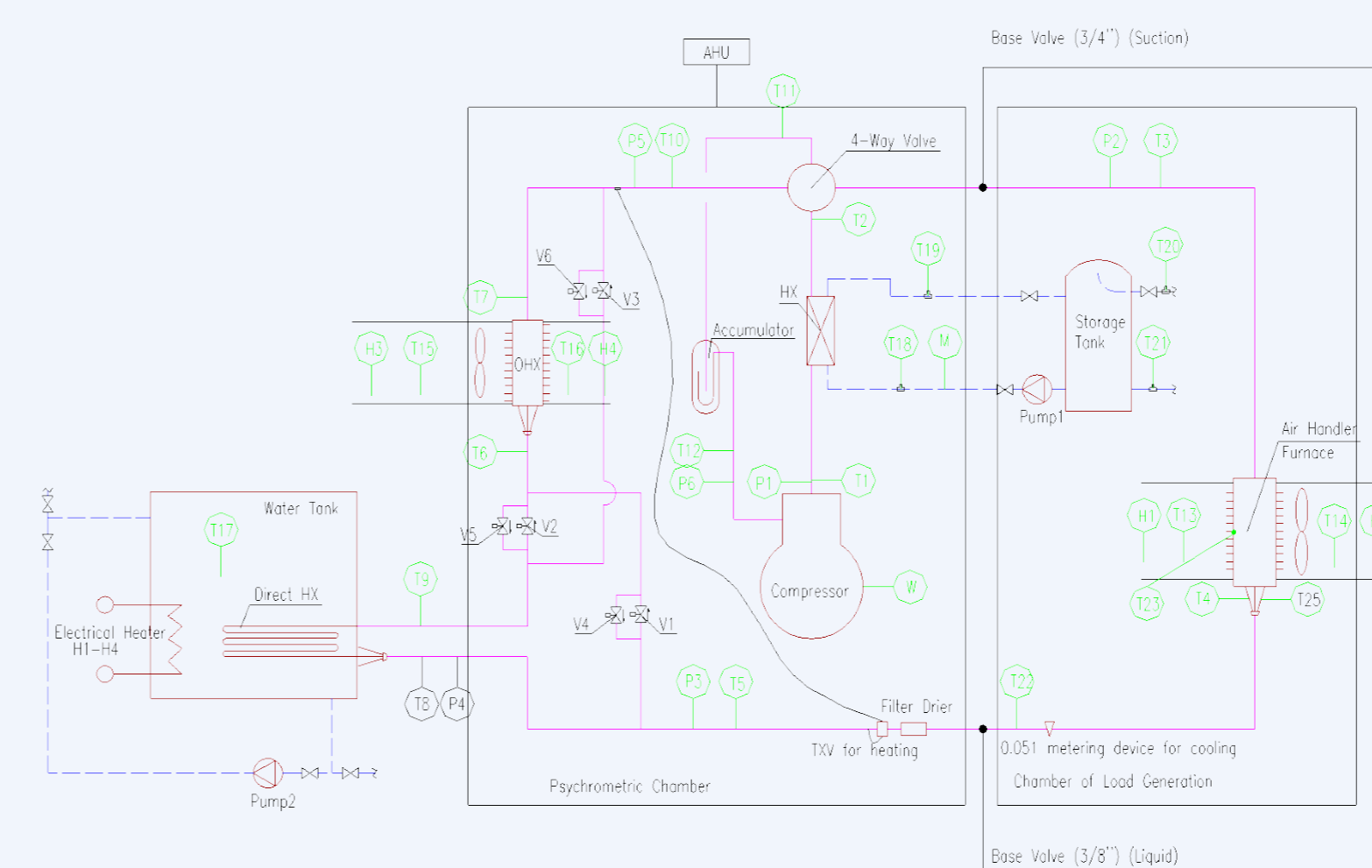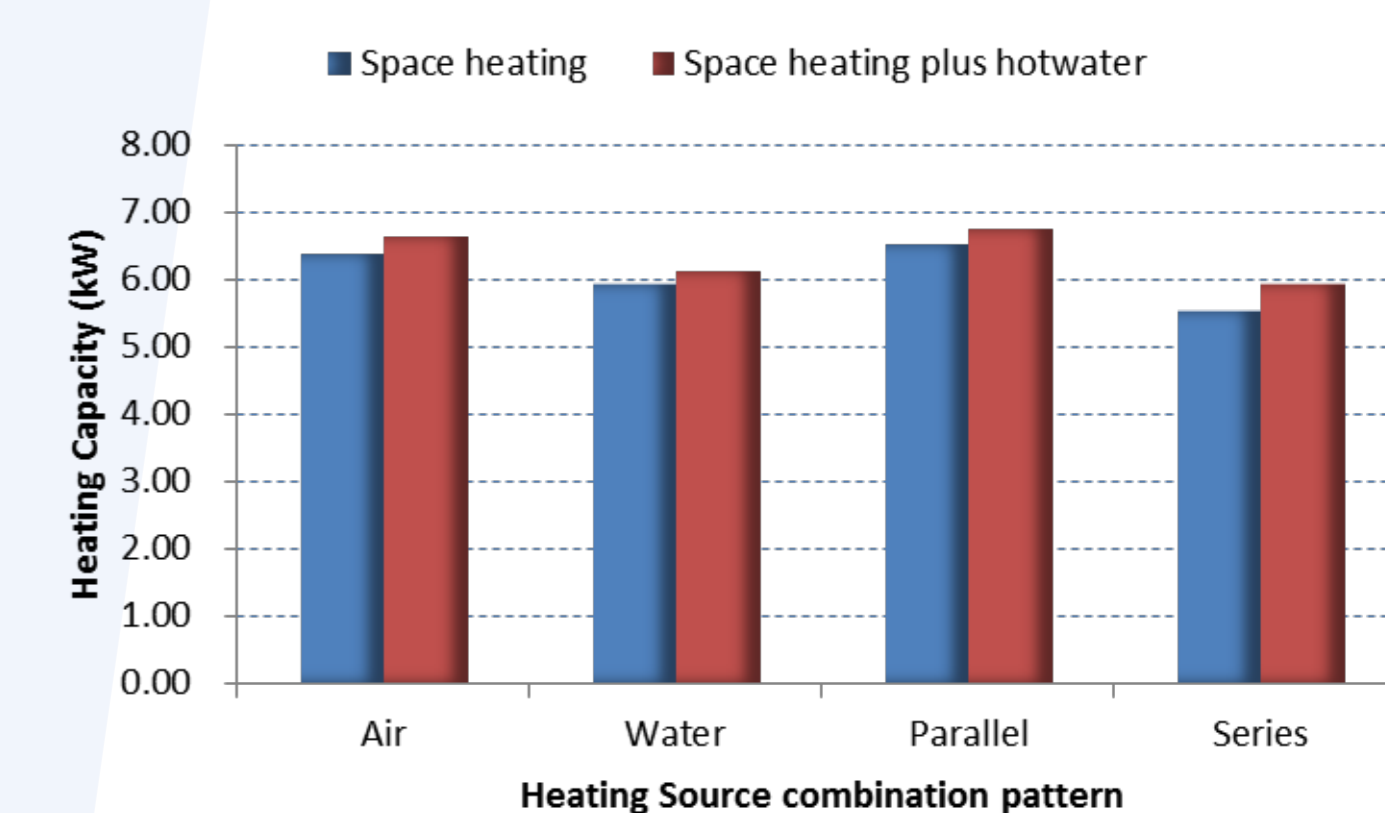

Heat pump prototype
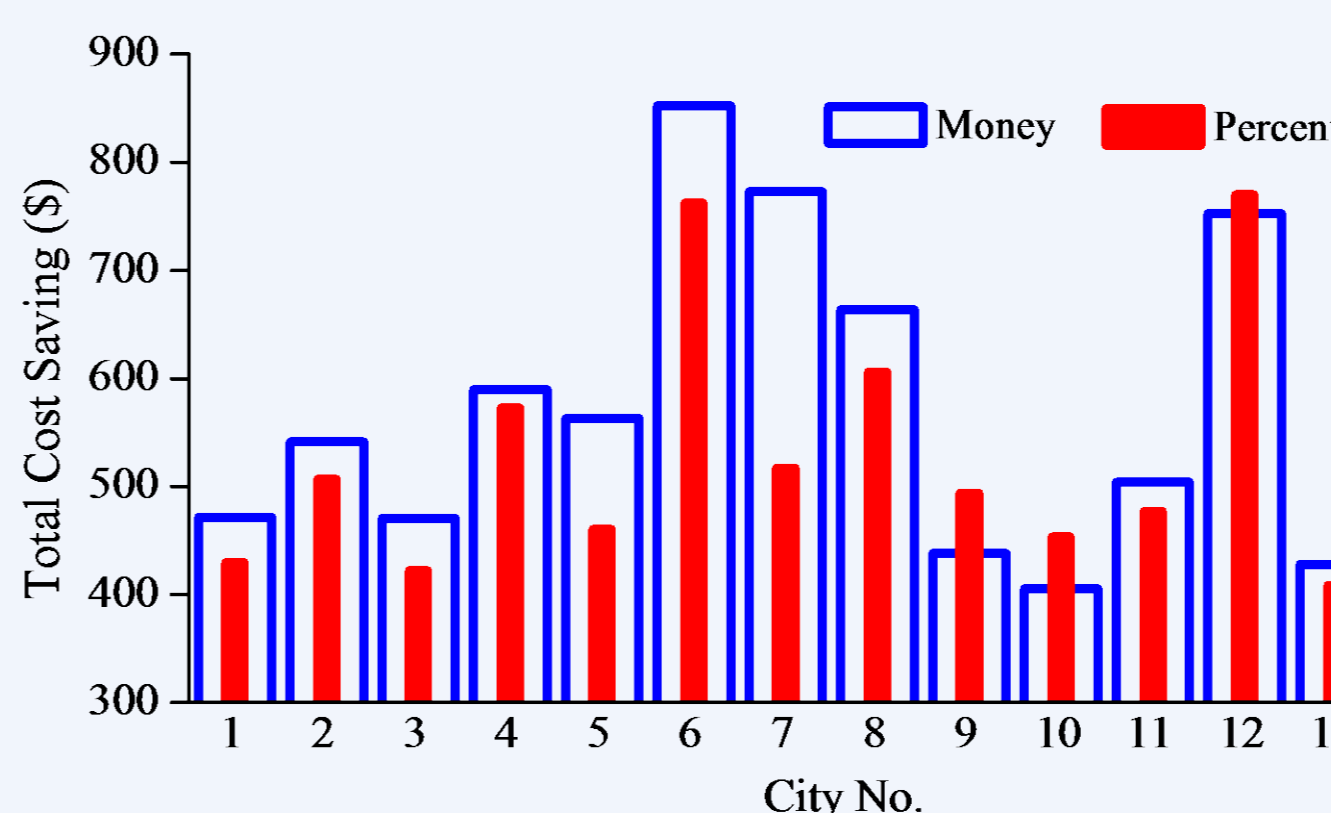
Energy saving percent

Cost saving

Water saving

1 = FL_Miami; 2 = TX_Houston; 3 = AZ_Tucson; 4 = GA_Atlanta; 5 = CA_Lancaster; 6 = CA_San. Francisco; 7 = NY_New.York; 8 = NV_Las.Vegas; 9 = OK_Oklahoma; 10 = NE_Omaha; 11 = CO_Denver; 12 = WA_Bellingham; 13 = MN_Minneapolis; 14 = MT_Helena; and 15 = ND_Jamestown

COP at outdoor temperature 60 ℉

Heating Capacity at outdoor temperature 60 ℉