Borehole Field in the The Drake Landing Solar Community Okotoks, Alberta

American Association of Physics Teachers

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Drake Landing Solar Community

Briefly

- **First** seasonal solar heat storage community in North America
- **First** community in the world with more than **90%** of the space heating supplied by solar energy
- Reduction of **5 tonnes** of greenhouse gas emissions per home per year
- **Largest** subdivision (with 52 homes) of super energy efficient R-2000 standard single-family homes in Canada

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Slide credit: Natural Resources Canada

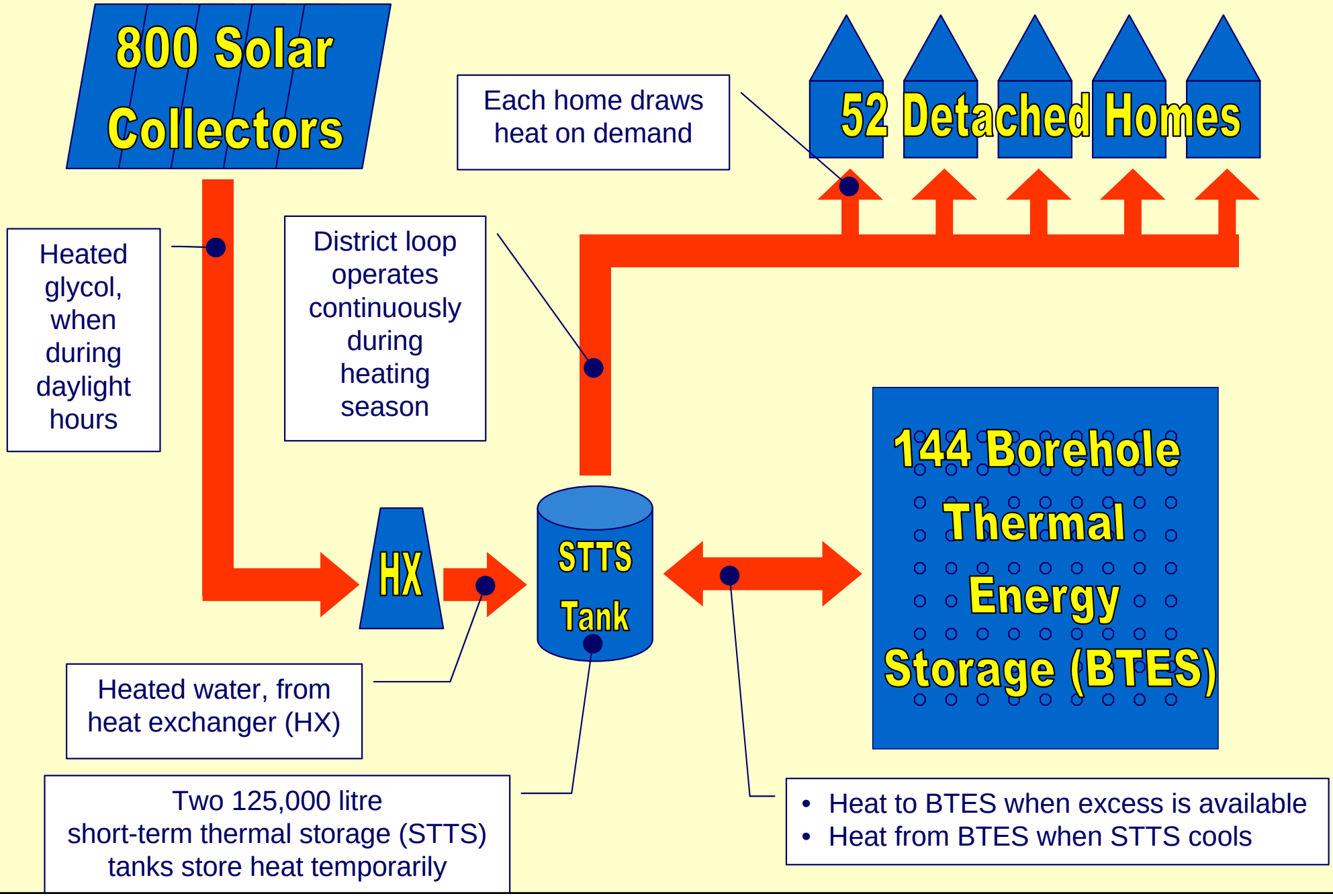
Project Objectives

- **Low energy consumption**: **Provide** over 90% of the space heating by solar energy
- **Low air pollution**: **Achieve** very low greenhouse gas emissions
- **Replication**: **Show** its potential to be duplicated in other communities
- **Demonstration**: **Prove** that the technology can work here. (The project is not about economics… yet.)
- **Simplicity**: **Build** it like a typical subdivision

Design Approach – Energy

- **Separate** space heating needs from domestic water heating needs
  - There are two solar heating systems in the project:
    1) the central solar heating system, which generates heat for home heating,
    2) the solar domestic water heating system on each house
- **Minimise** the house heating needs
- **Store** the heat in two systems:
  - Seasonal from summer to winter – in the ground borehole field
  - Short-term from day to night – in two large tanks
- **Minimize** the amount of electricity used to pump fluid around the system

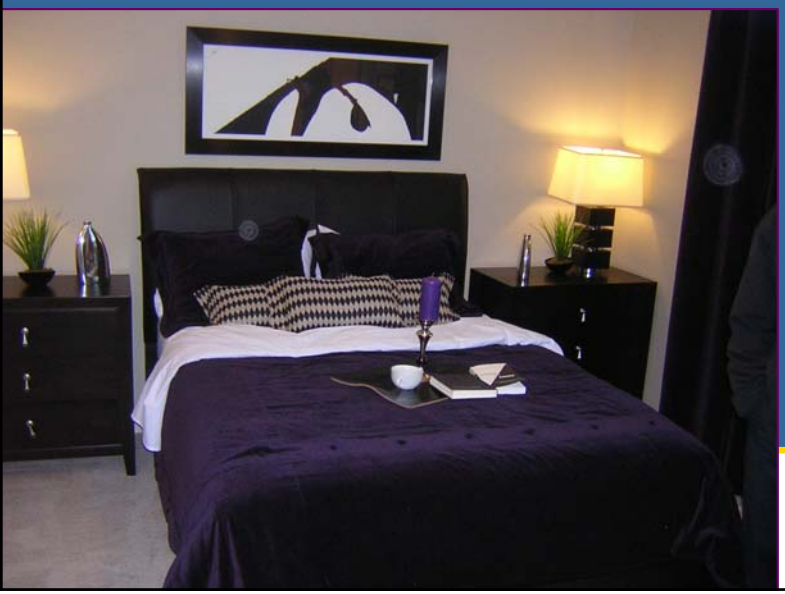
Solar-source district heating system with seasonal heat storage



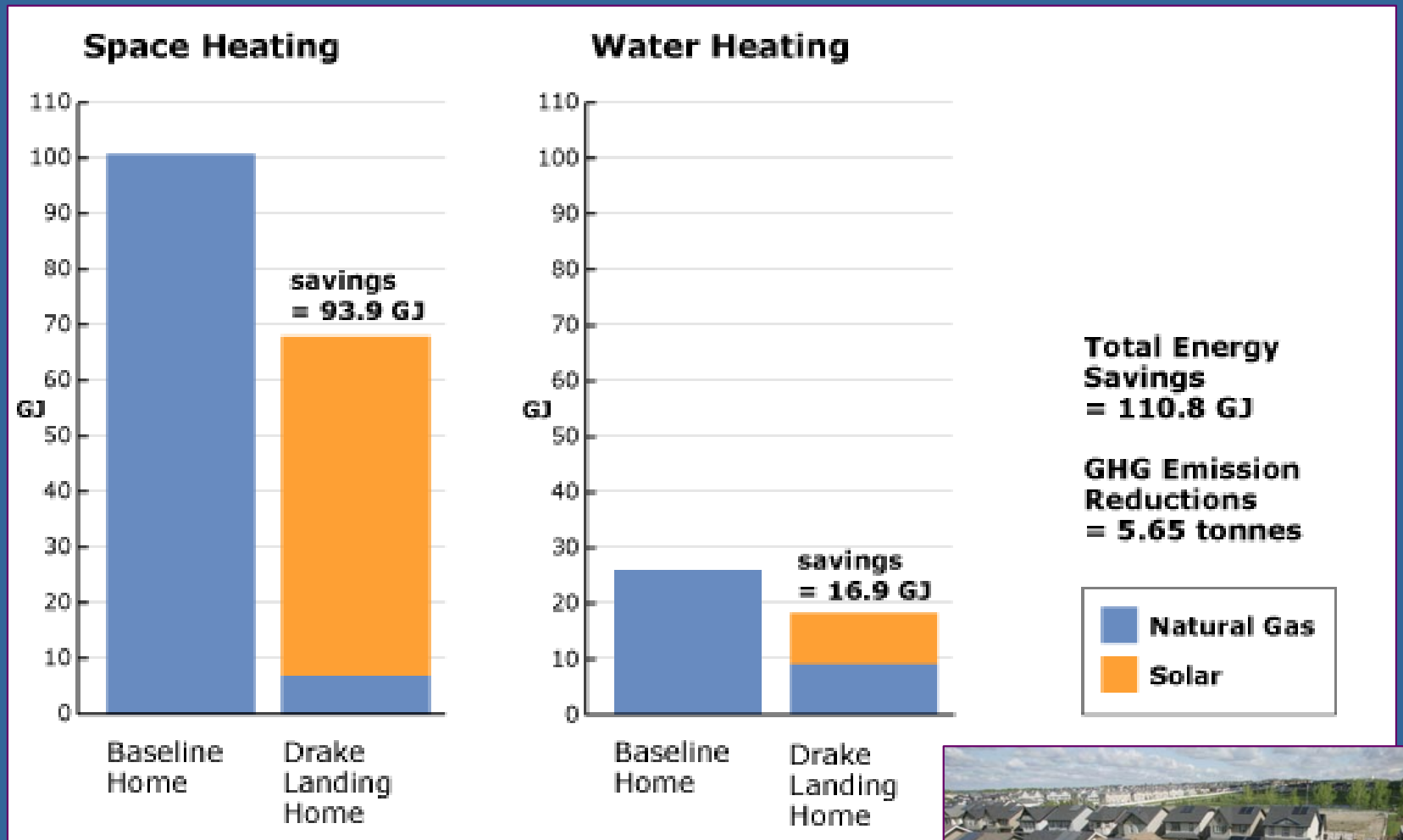
Completed Subdivision

Homes

- 52-home solar community enclave in a larger 835-home Drake Landing subdivision
- Town of Okotoks, 350 km south of Edmonton, near Calgary
- Attractive, quiet. 1490 ft^2 to 1630 ft^2, most are three bedrooms, all have detached rear garages
- ½ face north, and ½ face south. All have south-facing roofs



Energy Reduction in a Drake Landing Home



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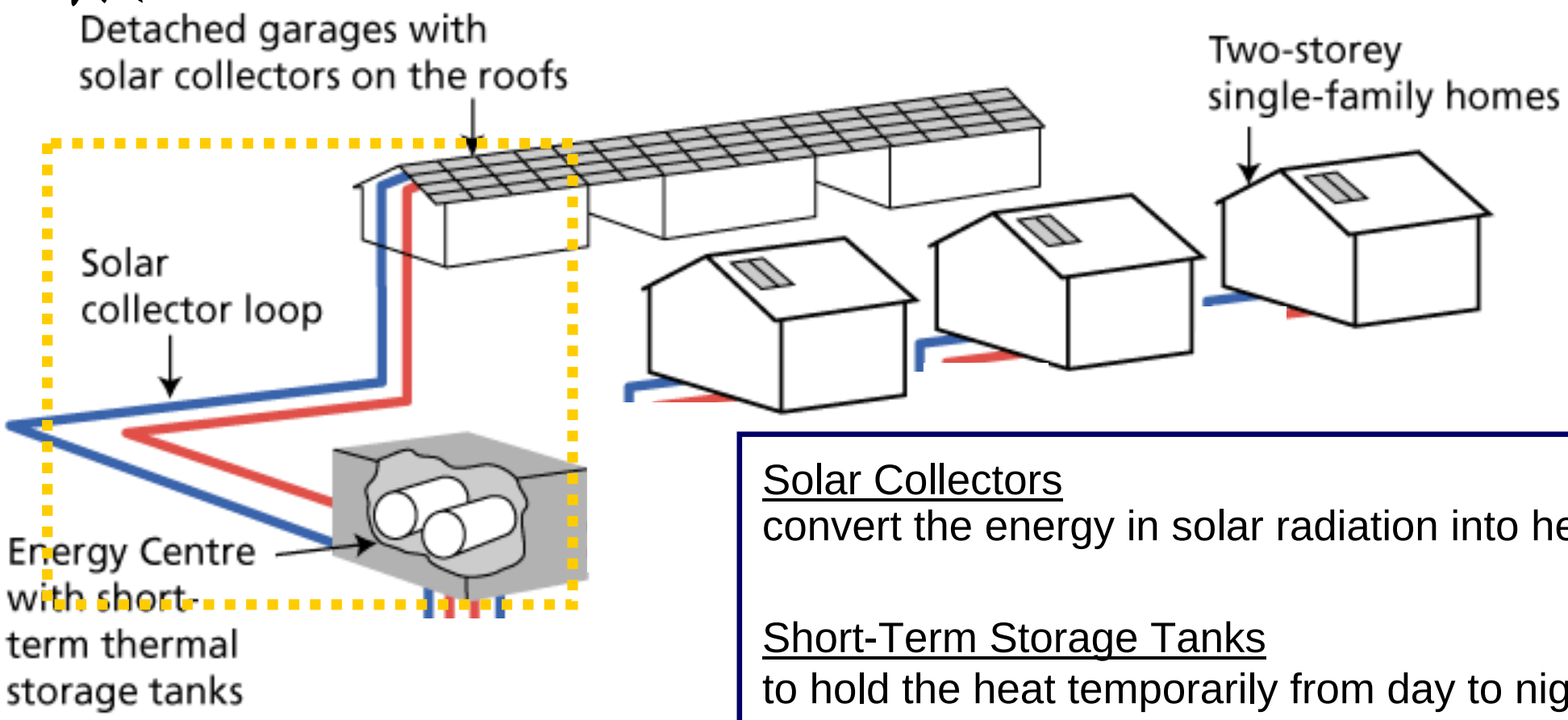
The Solar Collector Loop



Solar Collectors
convert the energy in solar radiation into heat

Short-Term Storage Tanks
to hold the heat temporarily from day to night or over a few days

Pumps – transfer heated fluid into the tanks

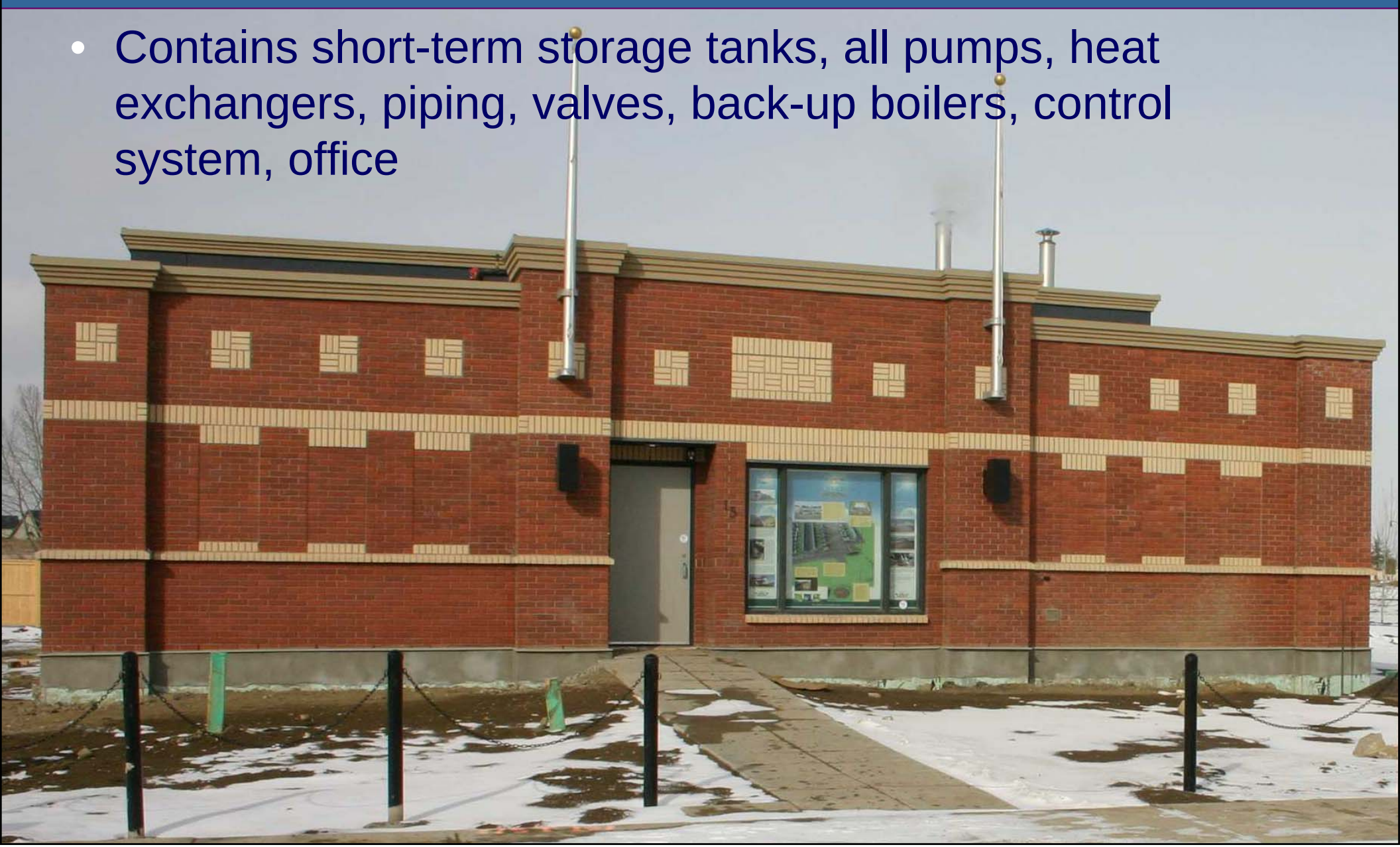
Controls – control the pumps automatically

Location of Solar Collector Arrays

Solar collectors, on south side of garages

Energy Centre

- The heart of the whole heating system
- Contains short-term storage tanks, all pumps, heat exchangers, piping, valves, back-up boilers, control system, office



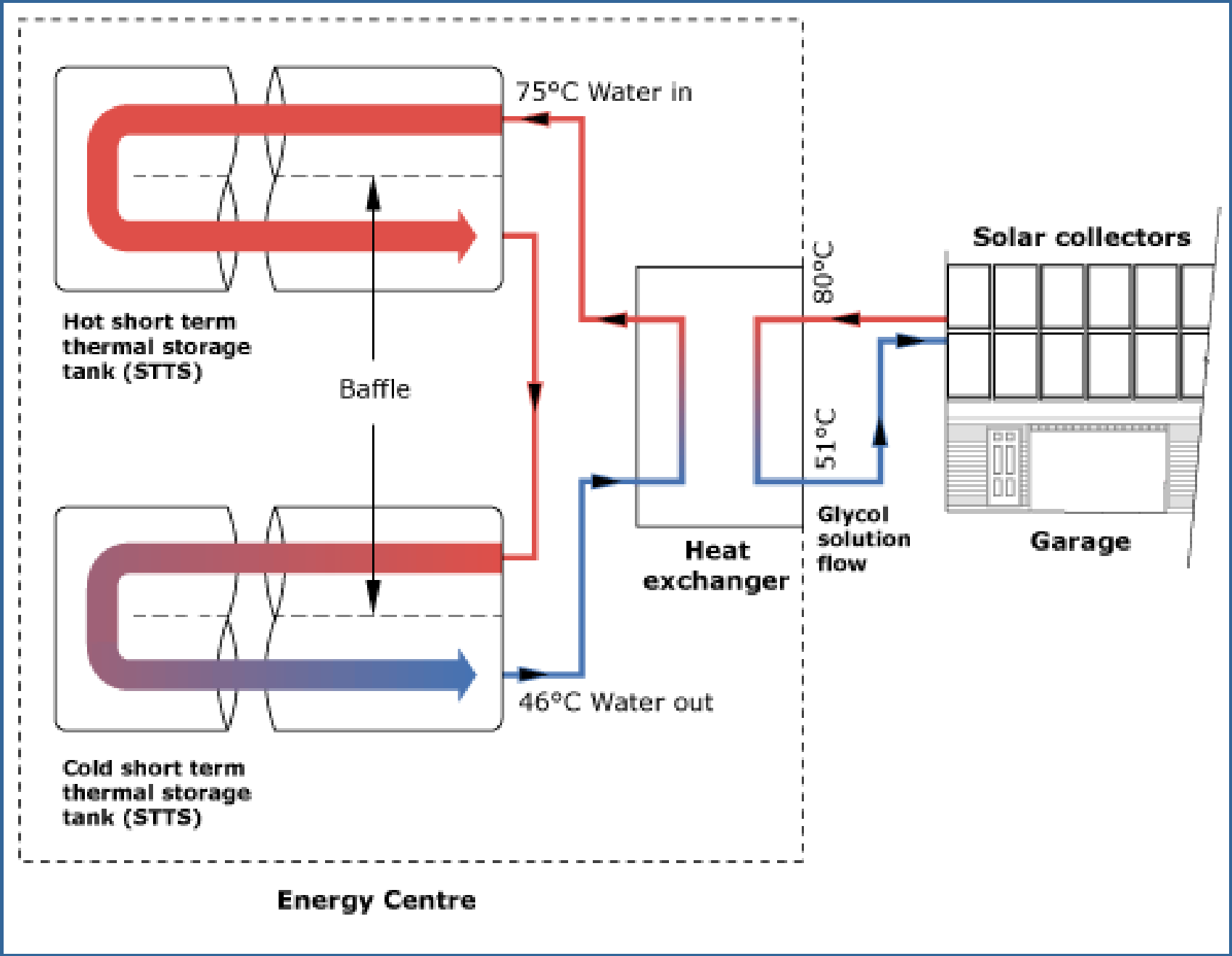
Short-term Storage Tanks

Short-term heat storage tanks

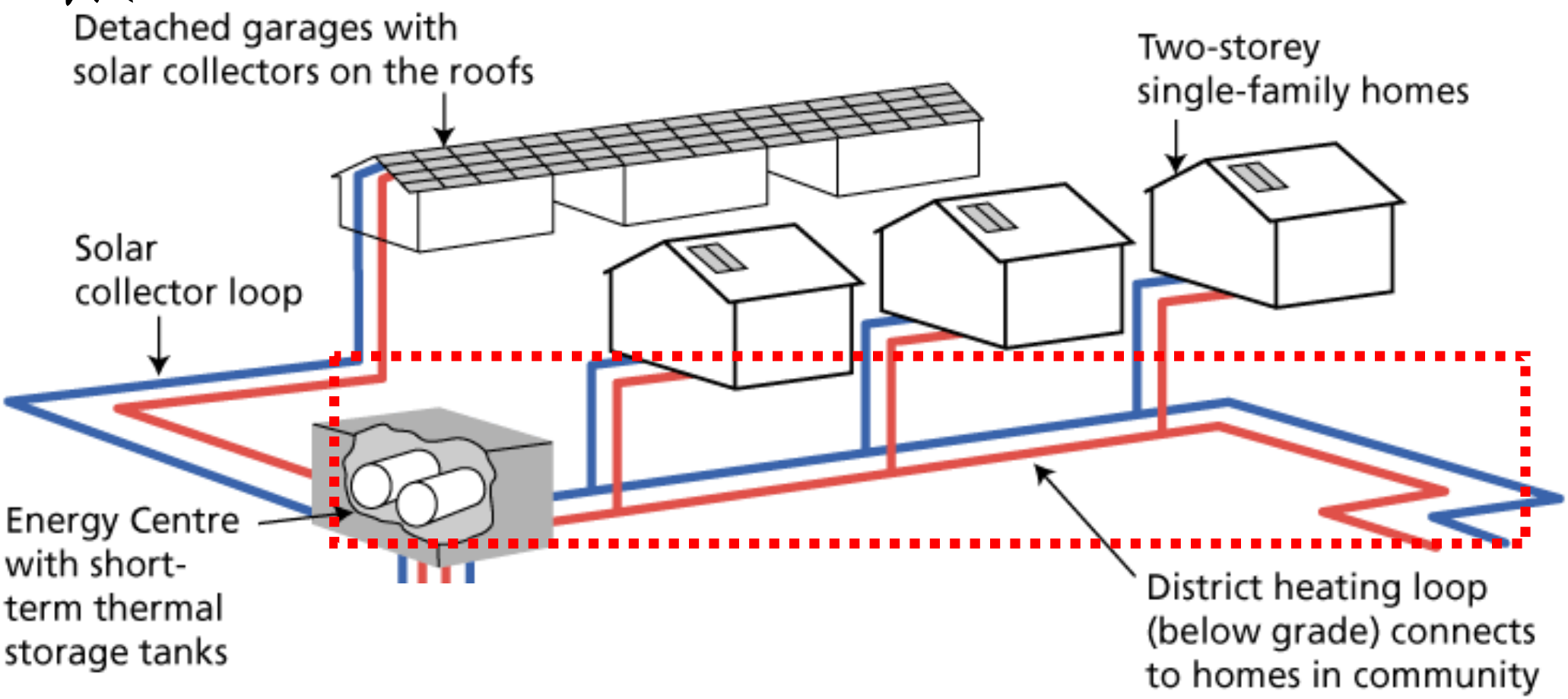
Each tank holds 125 000 litres.

Slide credit: Natural Resources Canada

Short-term Storage Tanks



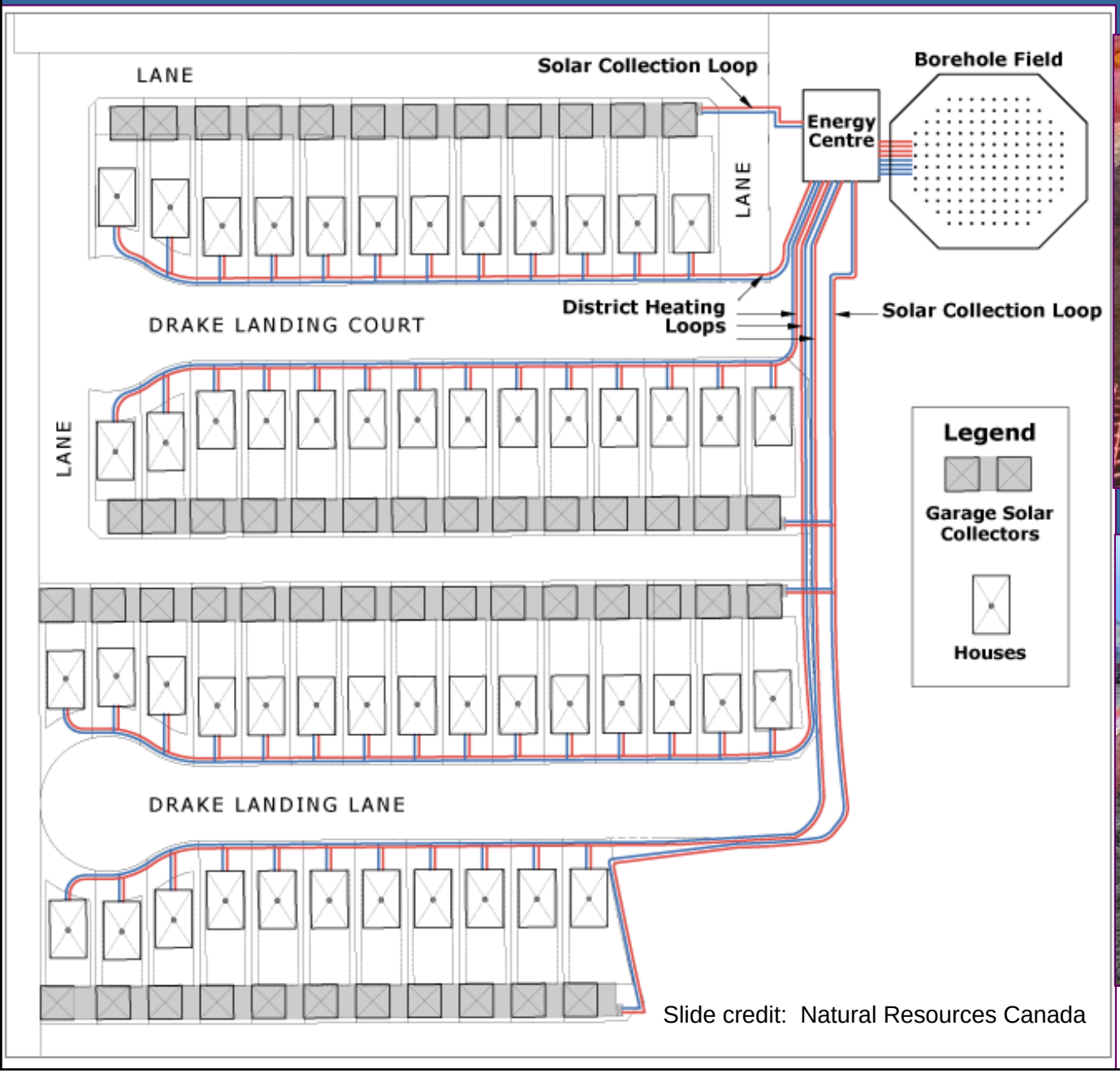
The District Heating Loop



District Heating Loop
distributes the heat to the houses

Pumps – transfer heated fluid to the homes
Controls – control the pumps automatically

District Heat Distribution Loop



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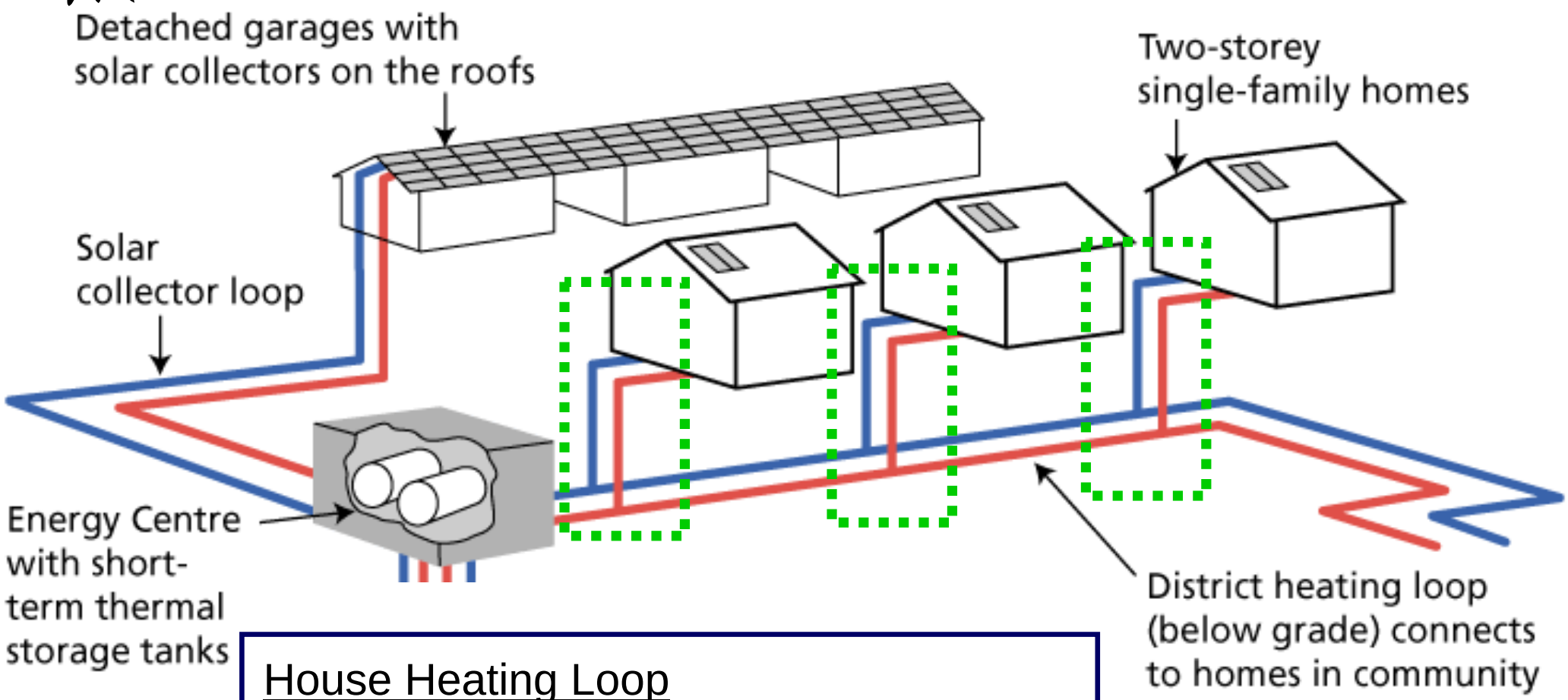
The House Heating Loop



House Heating Loop
Brings the heat into the houses from the district heating loop

Pumps – transfer heated fluid into the homes
Controls – control the pumps automatically

House Heating Loop

Tie-in to district loop underground

Connections to house in basement

Looks almost
like a furnace!

Air Handler Unit Delivers Heat to the House

House heating controlled
by a standard house thermostat

Heat-recovery ventilator

Ventilation controlled by
internal controls and
push-button timers

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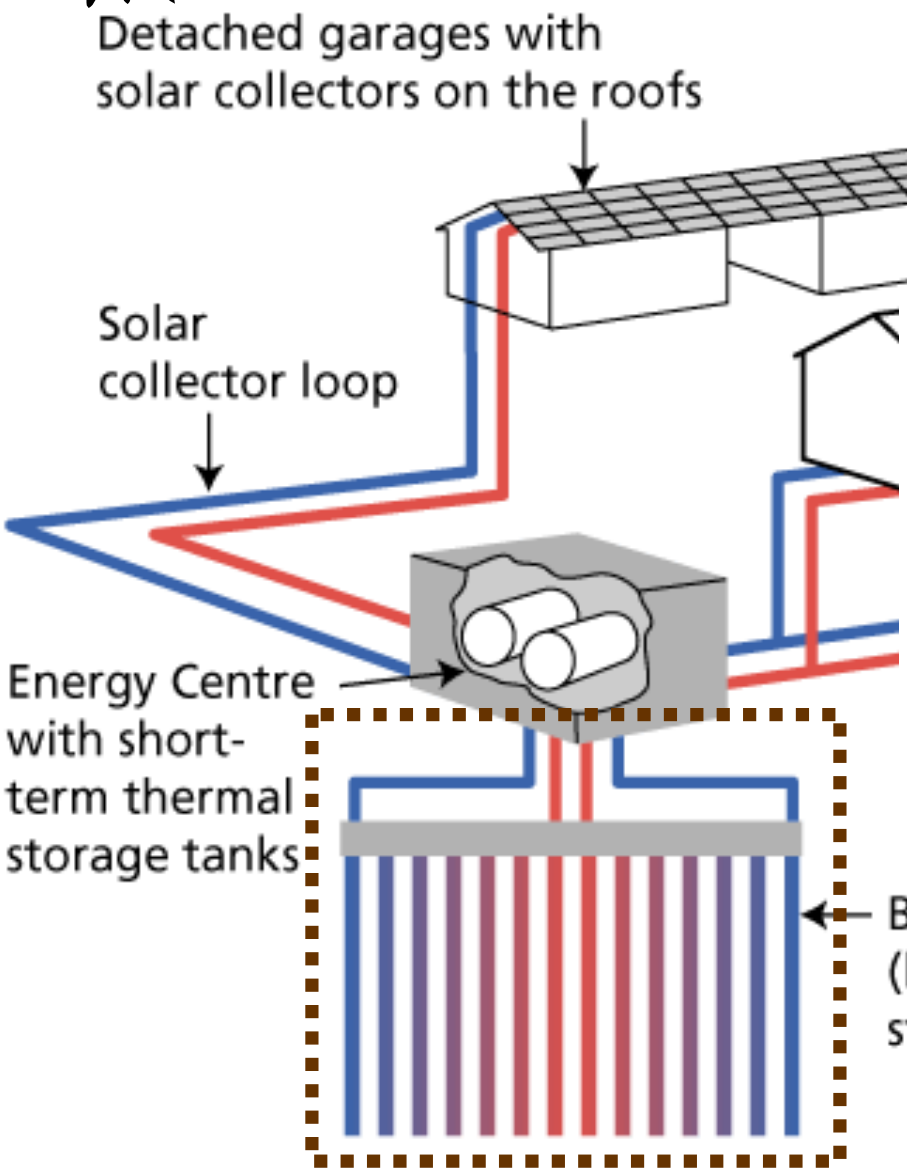
The Borehole Field Loop



Borehole Field
stores heat from the summer to the winter

Pumps – transfer heated fluid into and out of the borehole field
Controls – control the pumps automatically

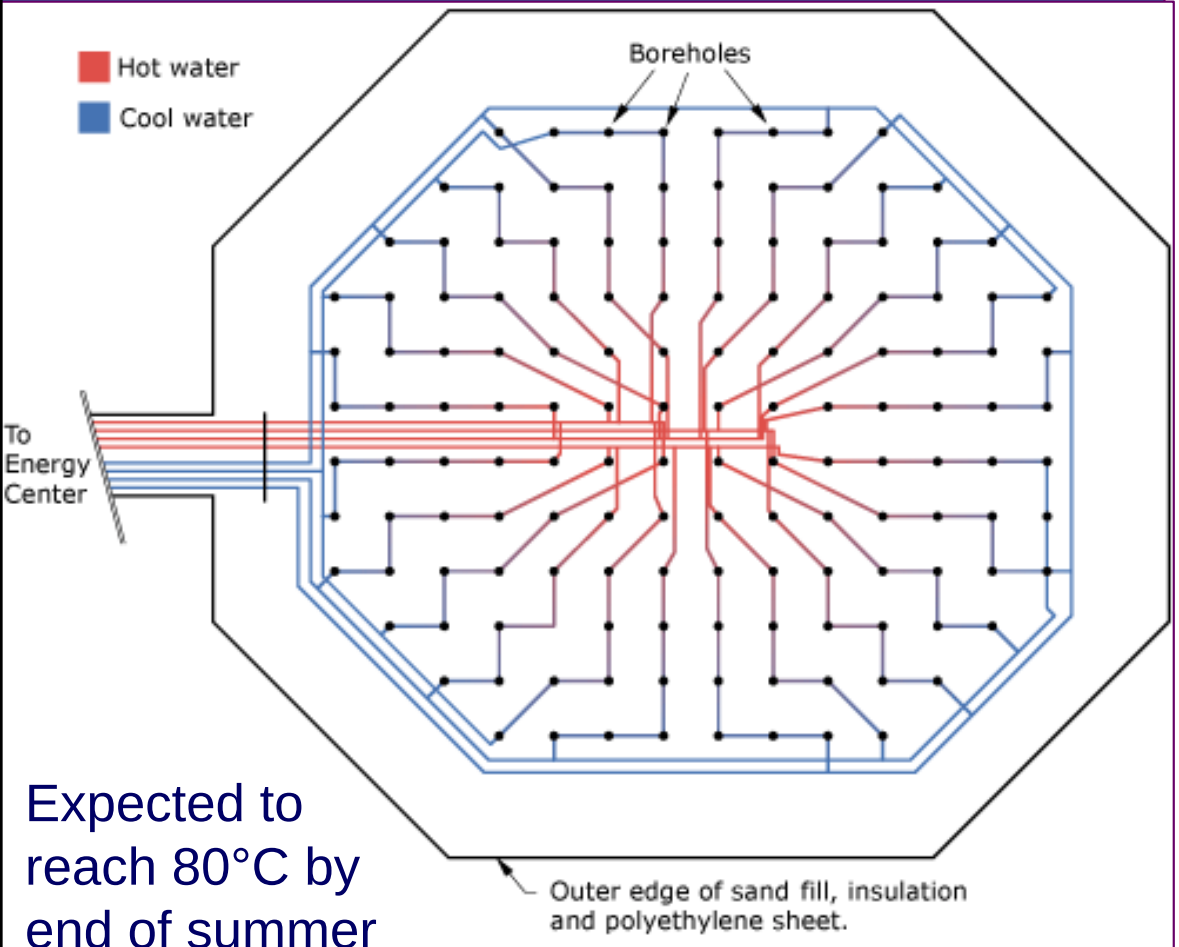
Backup Heat
boilers to provide additional 10% of heat

Backup Electricity
runs pumps and controls in case of power failure

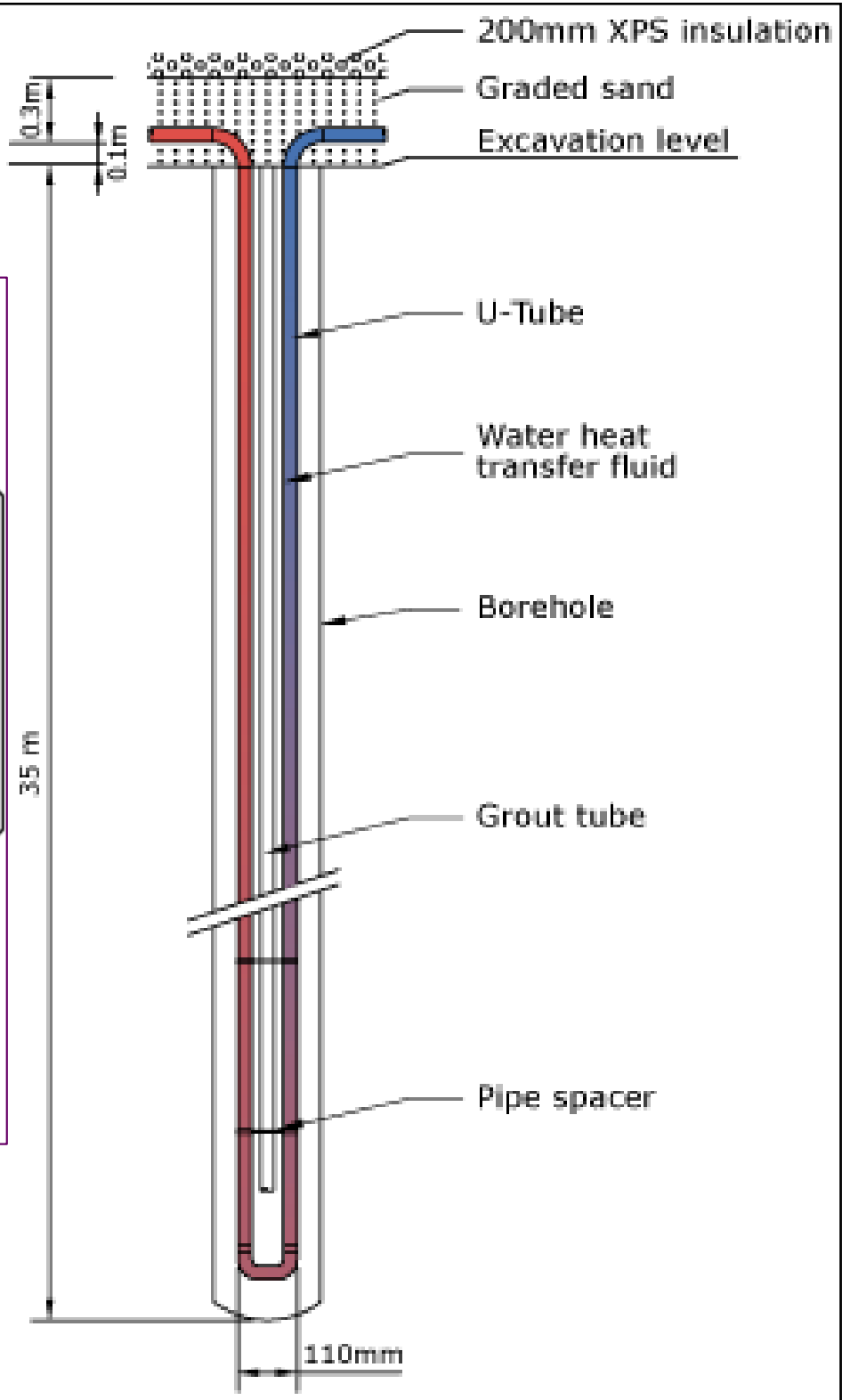
Short-term tanks absorb heat fast, borehole field absorbs slowly.

It is cheaper to build larger short-term storage tanks than a larger borehole field.

Borehole Thermal Energy Storage Field



Expected to reach 80°C by end of summer



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The Borehole Field


2005 June

Drilling the Borehole Field

2005 August-September

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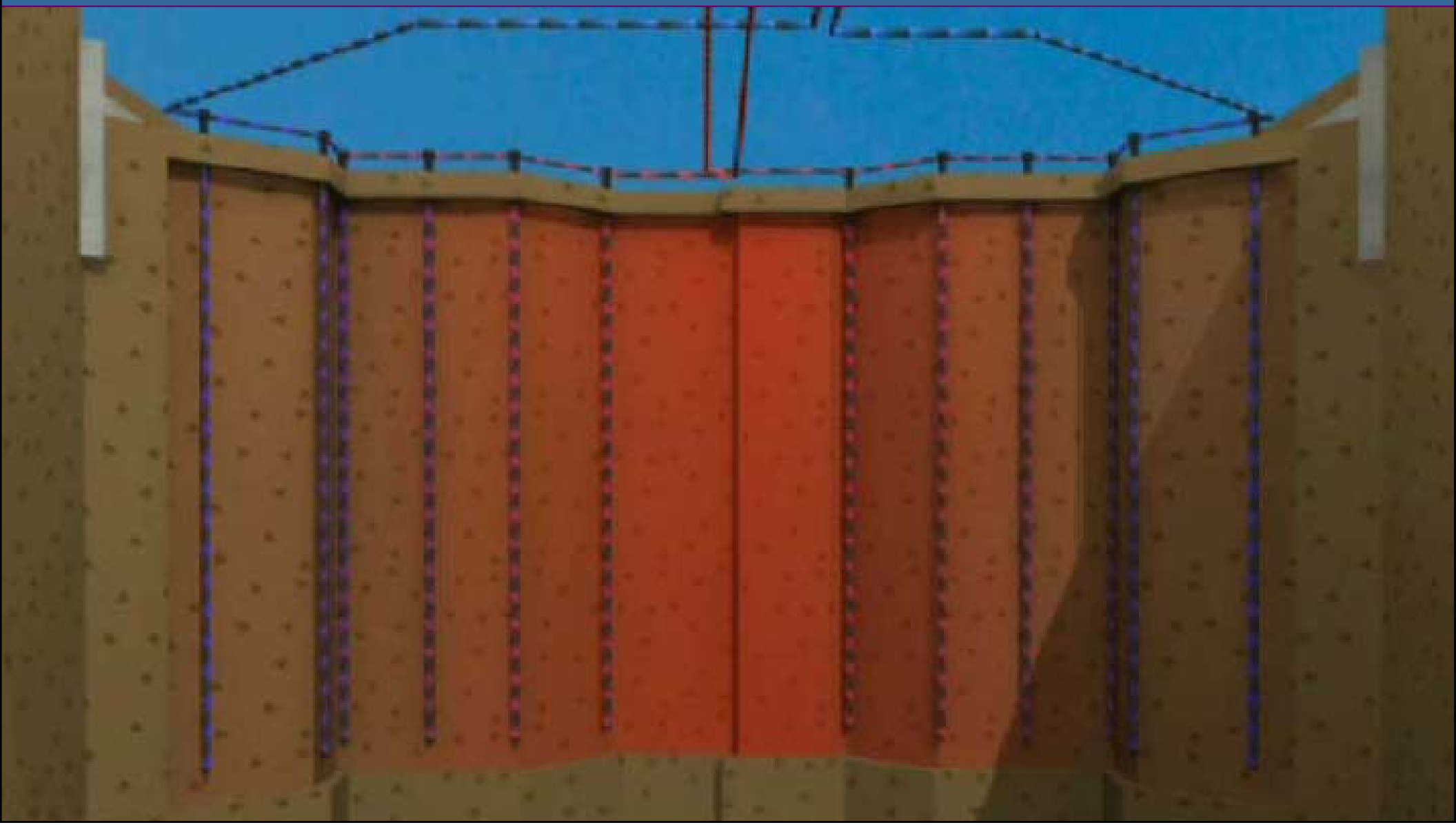
Laying Out The Borehole Field


2005 November

Borehole Storage Stratification



Storage System Controls

SUMMER

- Charge the borehole field as long as heat is available
- Ensure tanks fully depleted by morning to accept full day of charging

WINTER

- Charge the borehole field only if excess heat is available
- Use solar heat directly to the houses if possible
- Have tanks fully charged in the evening to provide a full night of heating

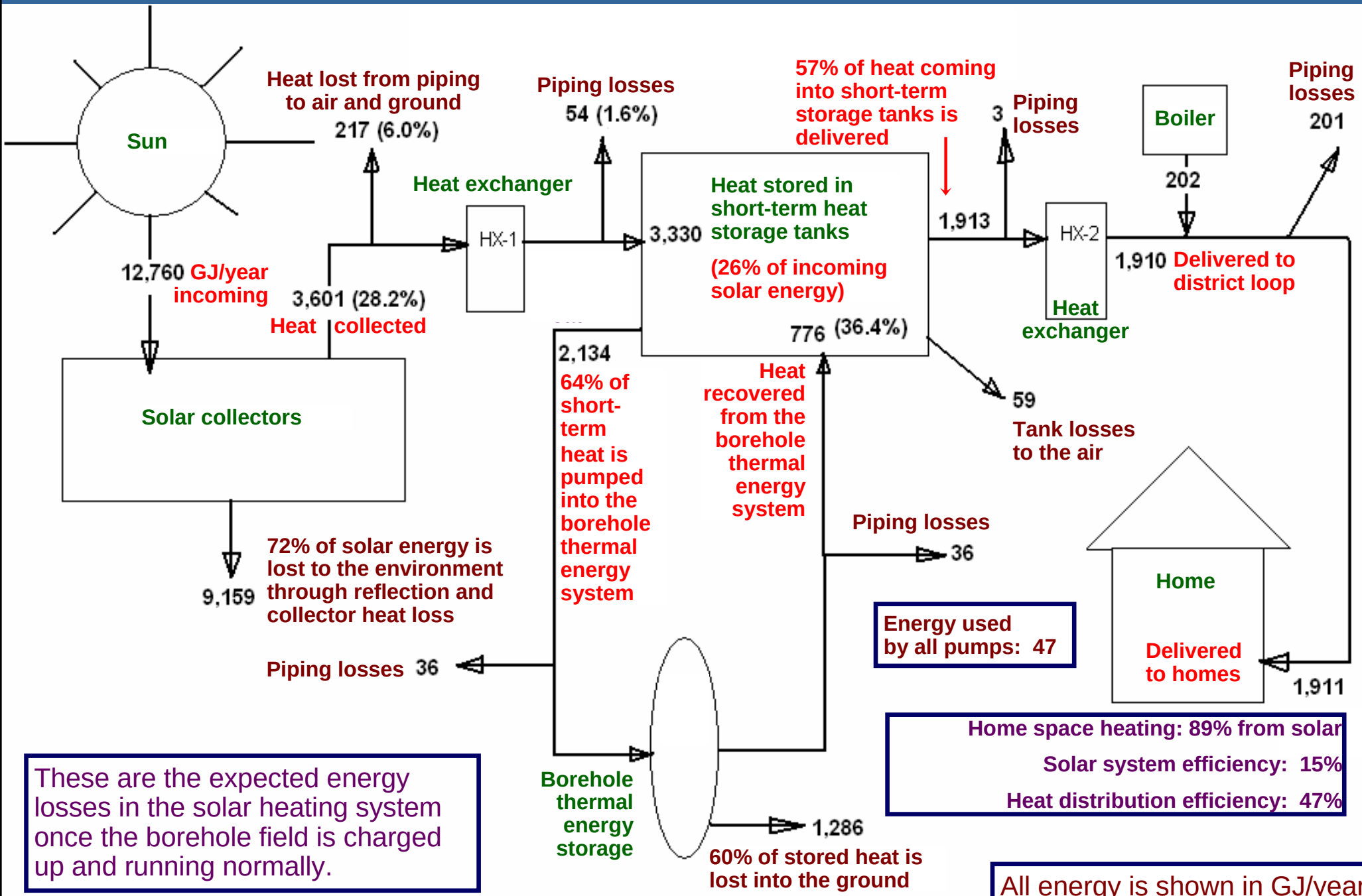
SPRING & AUTUMN

- Keep short-term storage tanks partially charged (about ½ charged)
  - This allows them to
    - supply heat to the house if required
    - and absorb heat from the solar collectors if available

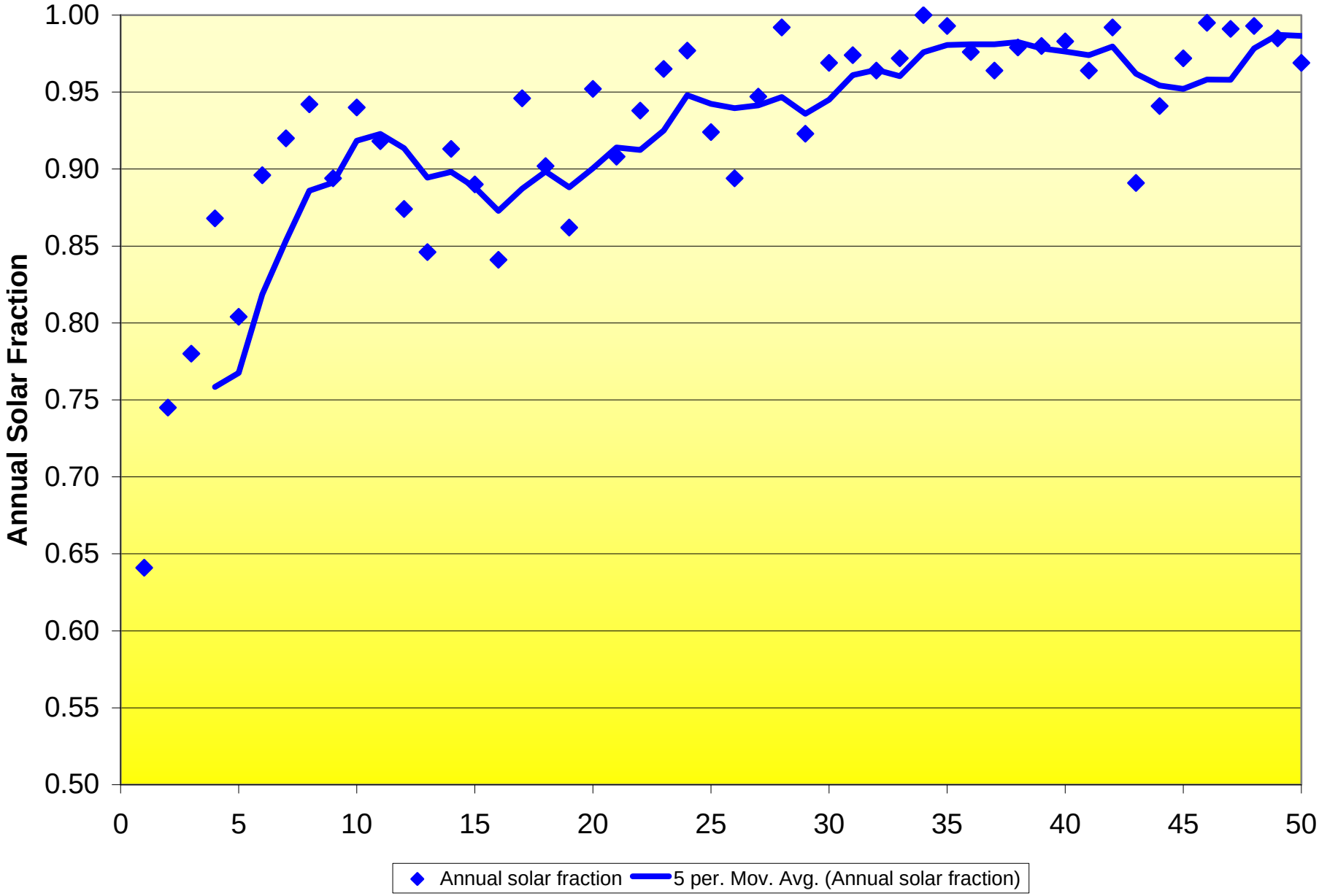
DESIGN CHALLENGES

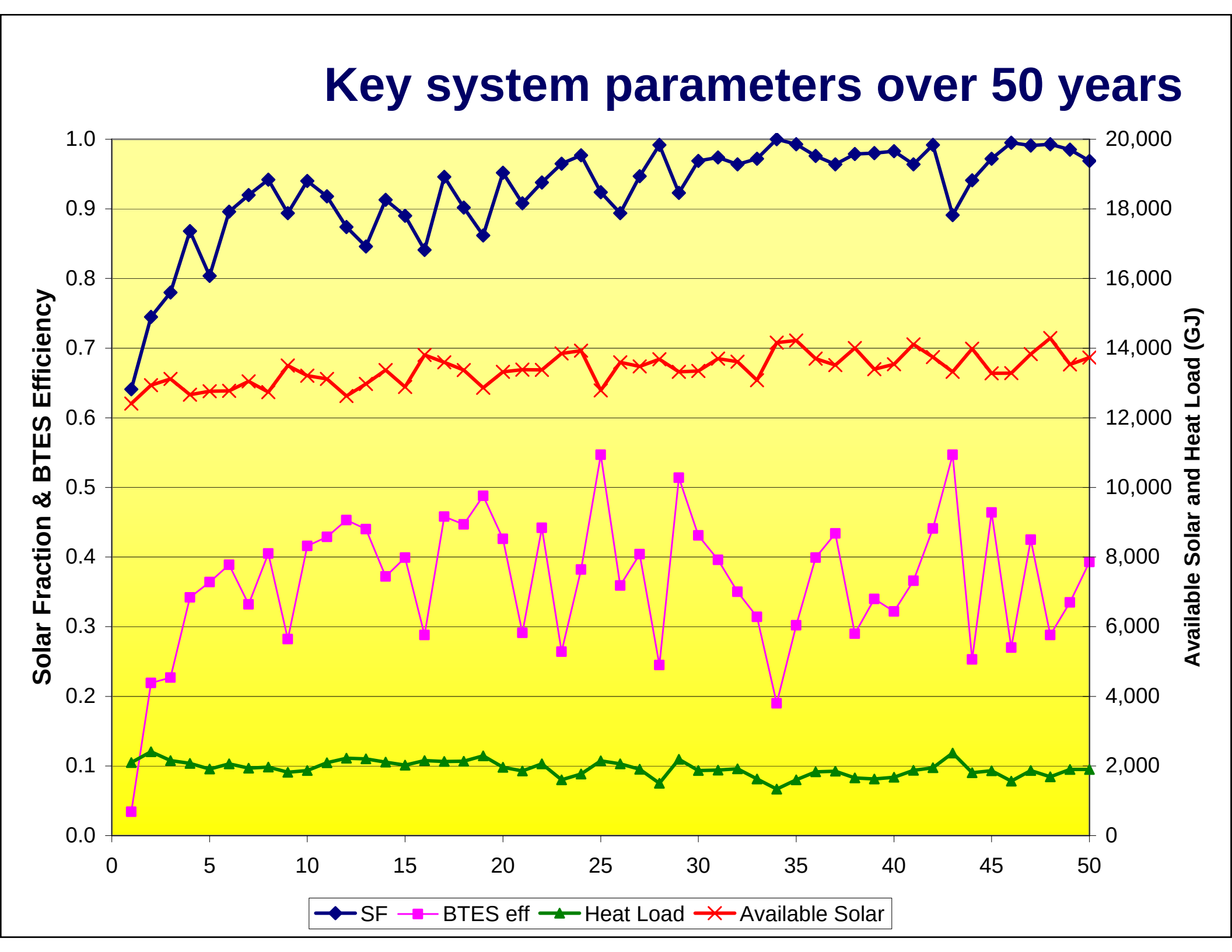
- What is the optimum control strategy to maximize system efficiency?
- How to use predictive control in the spring/autumn for charging/discharging?

System Energy Flow in Year 5



Expected Annual Variation in Solar Fraction




Key system parameters over 50 years
Solar Fraction & BTES Efficiency
Available Solar and Heat Load (GJ)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
5
10
15
20
25
30
35
40
45
50
SF
BTES eff
Heat Load
Available Solar

Solar Utility Bill

- $60 per month (= $720 per year)
- Pays for:
  - Staff to monitor and maintain the solar utility
  - Electricity to run pumps and controls in solar, district heating, and borehole loops
  - Natural gas for boilers to provide the additional 10% heating in winter
- Bill is adjusted up or down
  - depending on how much heat a house uses compared to the average of the Drake Landing Solar Houses

Component Costs

- Energy efficiency upgrades: $6,400 per house
- Solar collector system: $14,800 per house
- Garage upgrades: $4,000 per house
- Short term storage system: $6,000 per house
- District loop: $6,000 per house

- Borehole thermal energy system: $12,000 per house

- Total additional equipment cost $50,000 per house

- Design and modelling: ~$3,500,000
- Construction issues: ~$1,000,000

Project Costs

- $ 7 million from project funders = $134 000 per house
- $13 million for standard house construction including lots
- $20 million total

- Funding money covered:
  - R-2000 upgrades, solar domestic water heater and air-handler, most of the garage costs
  - Solar space heating system, district energy system, borehole field
  - Construction increases due to cold weather, collector installation details, flooding of the trenches, truckers strike, technical details

Learning Process

- Great project from which to learn many things about implementing solar heating systems:
  - **Relationships** – with developers, municipalities, homebuilders, homebuyers, utility companies, solar system suppliers
  - **Costs** – design, modelling, approvals, marketing, utility, components, operation, construction details
  - **New technology developed** – fan coil, learning to work with this technology
  - **Performance** of the whole system as all the components and controls interact
  - **Risk of failure** – system, marketing, uptake from purchasers

Public Outreach

- The energy performance of the project will be monitored for many years.
- Web site is www.dlsc.ca
  - will have performance data displayed on it for analysis and public access
- Tours
  - Technical people coming from around the world

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