ANNEX IX

Seasonal Storage and Renewable Energy in District Heating Systems

- IEA Research Categories:

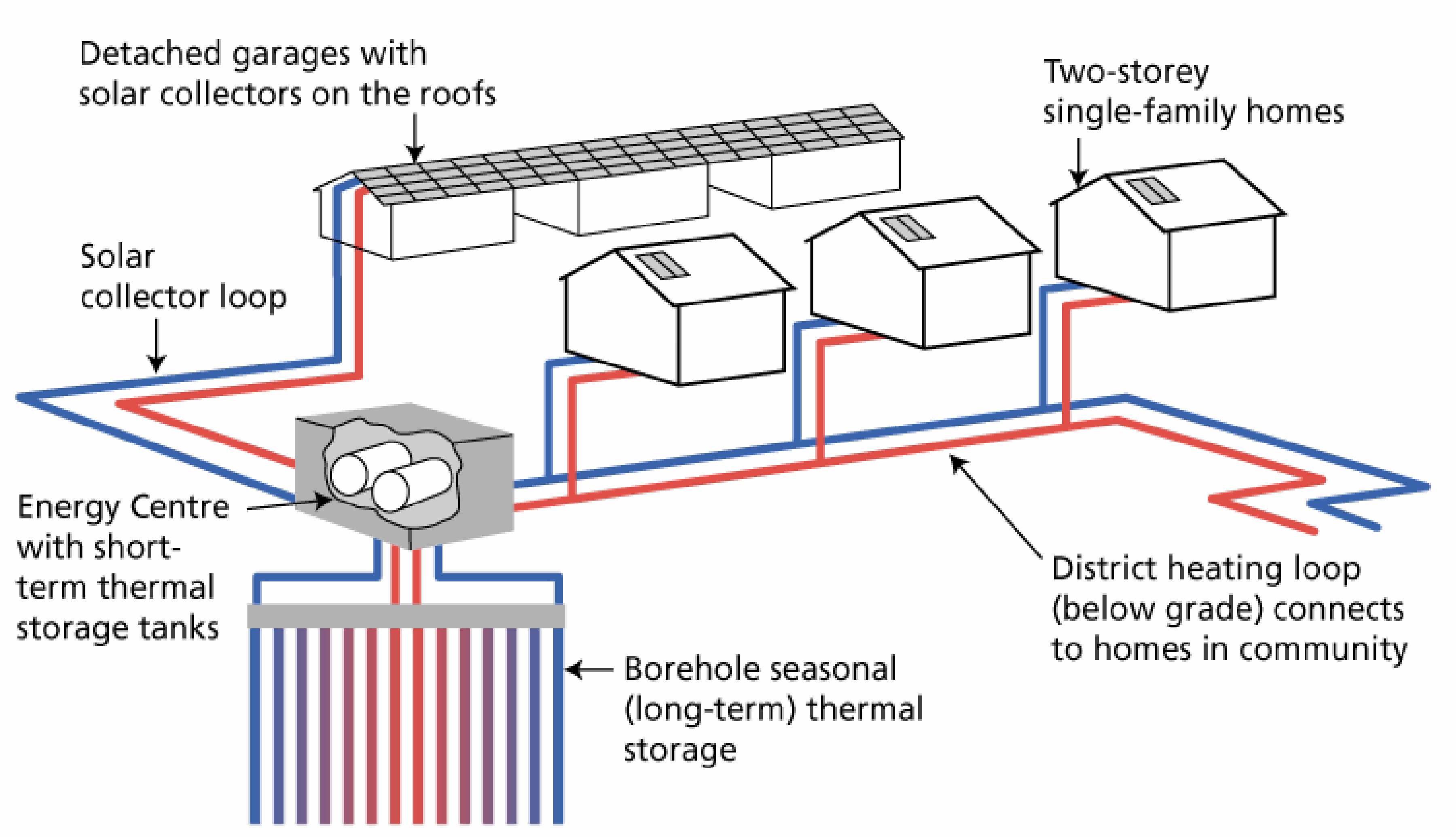
  #6 District Energy in Future Buildings

  #5 Renewable Energy Sources for District Energy Systems

Overview

- Canadian solar seasonal storage project
- Characteristics of in-ground borehole storage system
- Project description
    - System-level analysis
    - Simulations and optimization
    - Distributed solar energy and storage
    - Experimental work in low energy buildings

Simplified Okotoks Schematic



Okotoks Seasonal Solar System (Drake Landing Solar Community)
Source: Natural Resources Canada, CANMET

Okotoks

Source: Natural Resources Canada, CANMET

Okotoks

Source: Natural Resources Canada, CANMET

Okotoks Solar System Costs (CDN)

- Energy Centre (incl. short term tanks) $600K
- Seasonal Storage Borehole Field $620K
- Heating & Solar Collection Loops $1025K
- Solar Collector Supply $710K
- Solar Collector Installation $430K

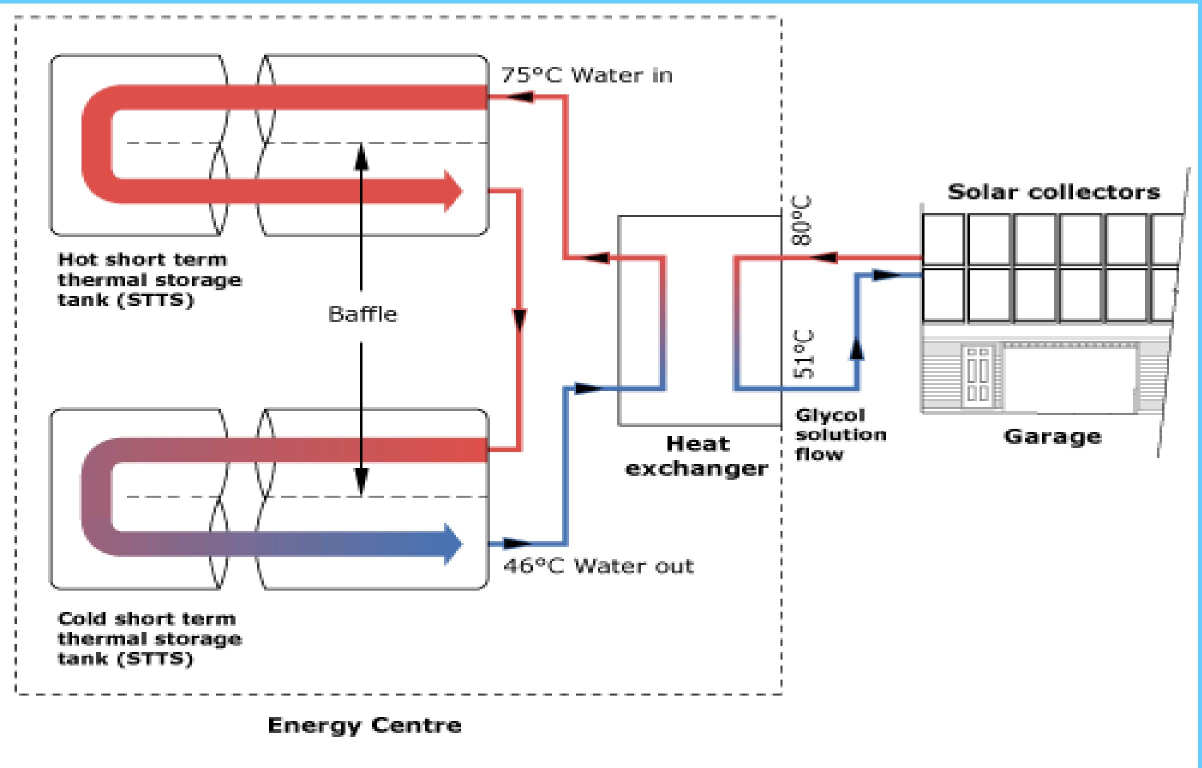
- Solar Energy Life Cycle Cost: $0.13/kWh (40 yr)
  $0.17/kWh (25 yr)

Source: Natural Resources Canada, CANMET

Okotoks Overall System Costs

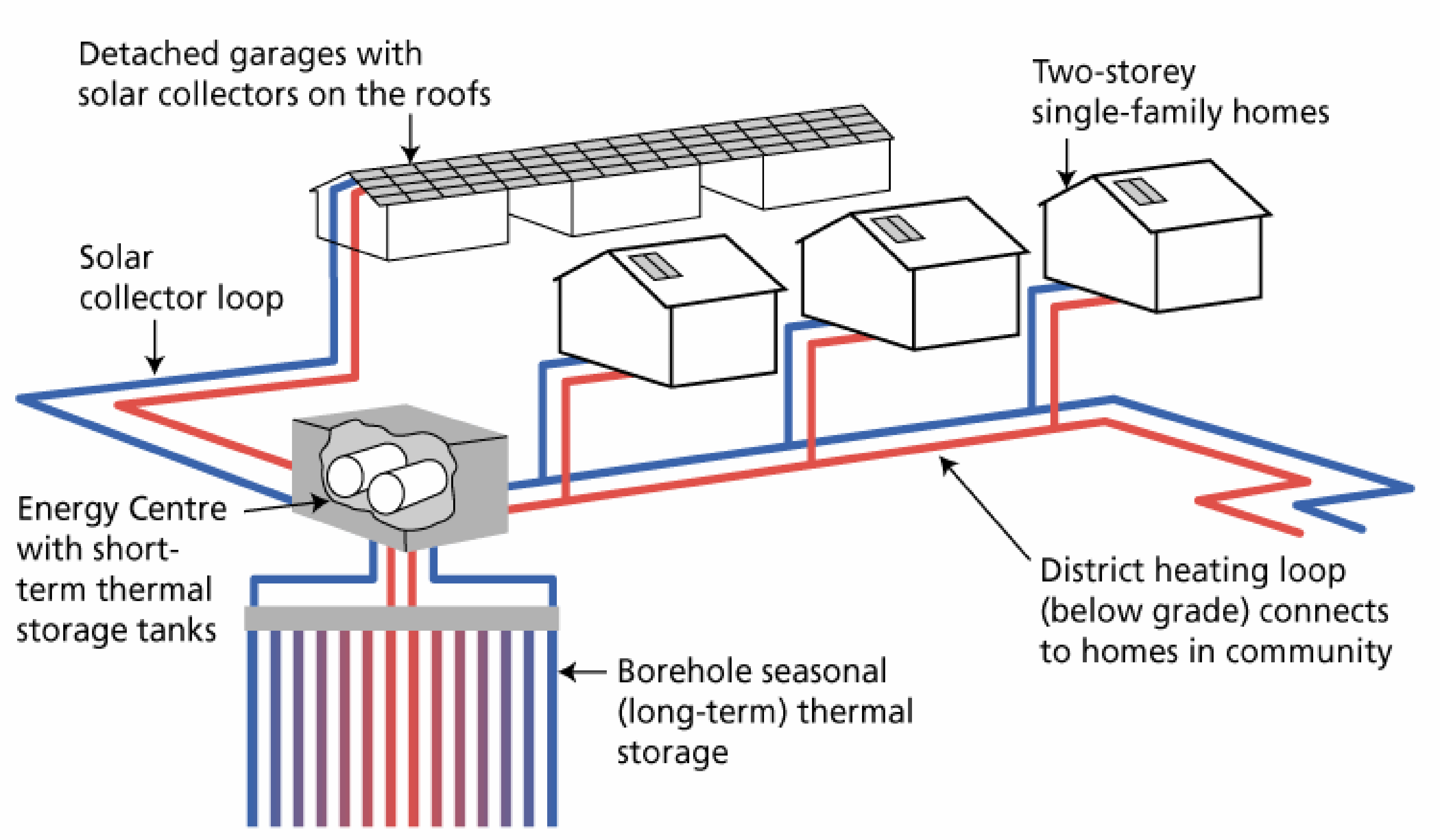
- 52 houses with peak load 11 KW
- Total cost including DH System = $3,385K CDN or 2,227K Euros
- Cost per house = $65,100 CDN or 42,800 Euros

The Okotoks Energy Centre



Source: Natural Resources Canada, CANMET

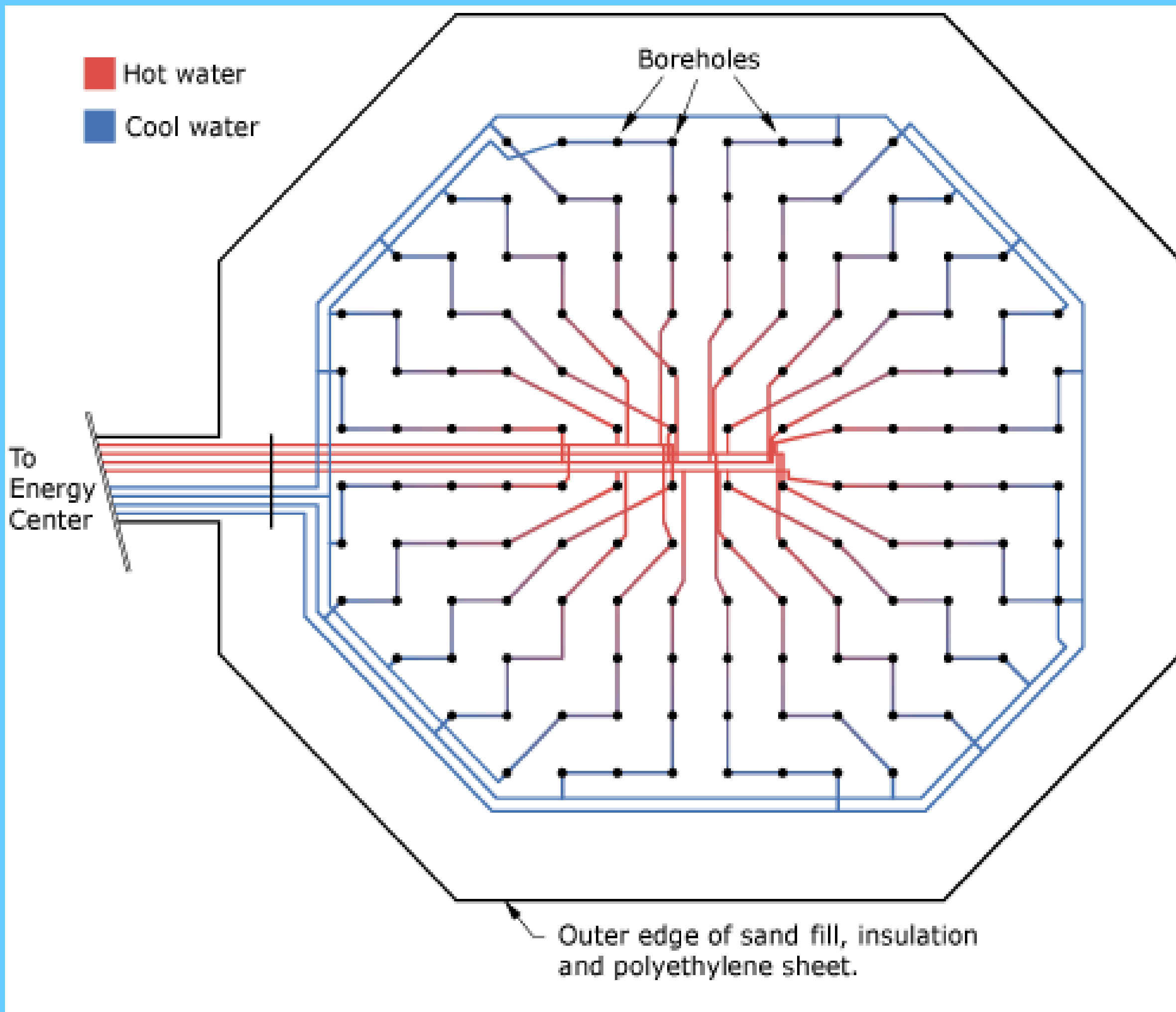
Simplified Okotoks Schematic

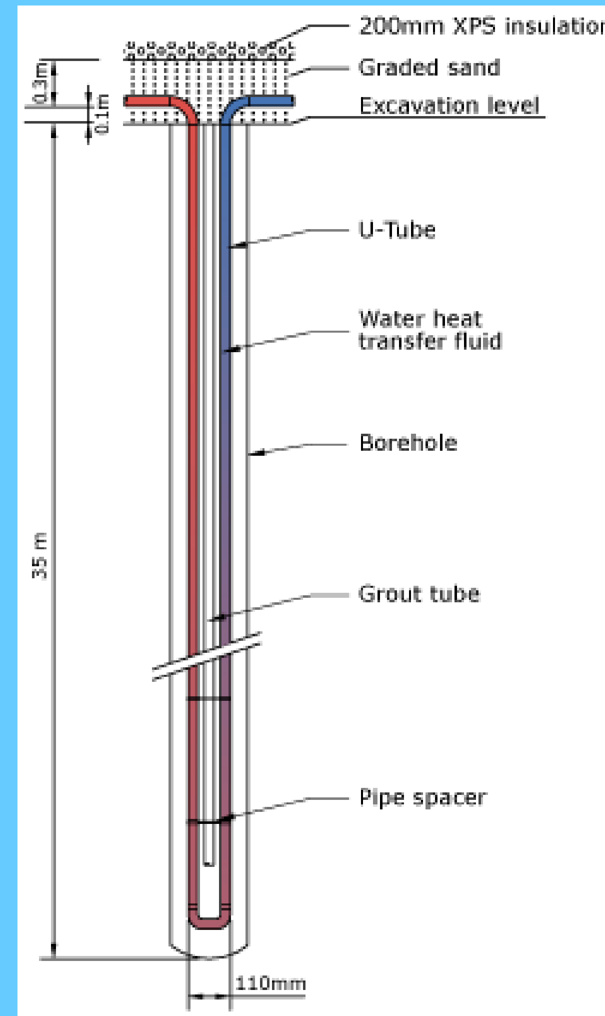


Okotoks Seasonal Solar System (Drake Landing Solar Community)

Source: Natural Resources Canada, CANMET

Borehole Thermal Energy Storage





Source: Natural Resources Canada, CANMET

Okotoks Construction Photos

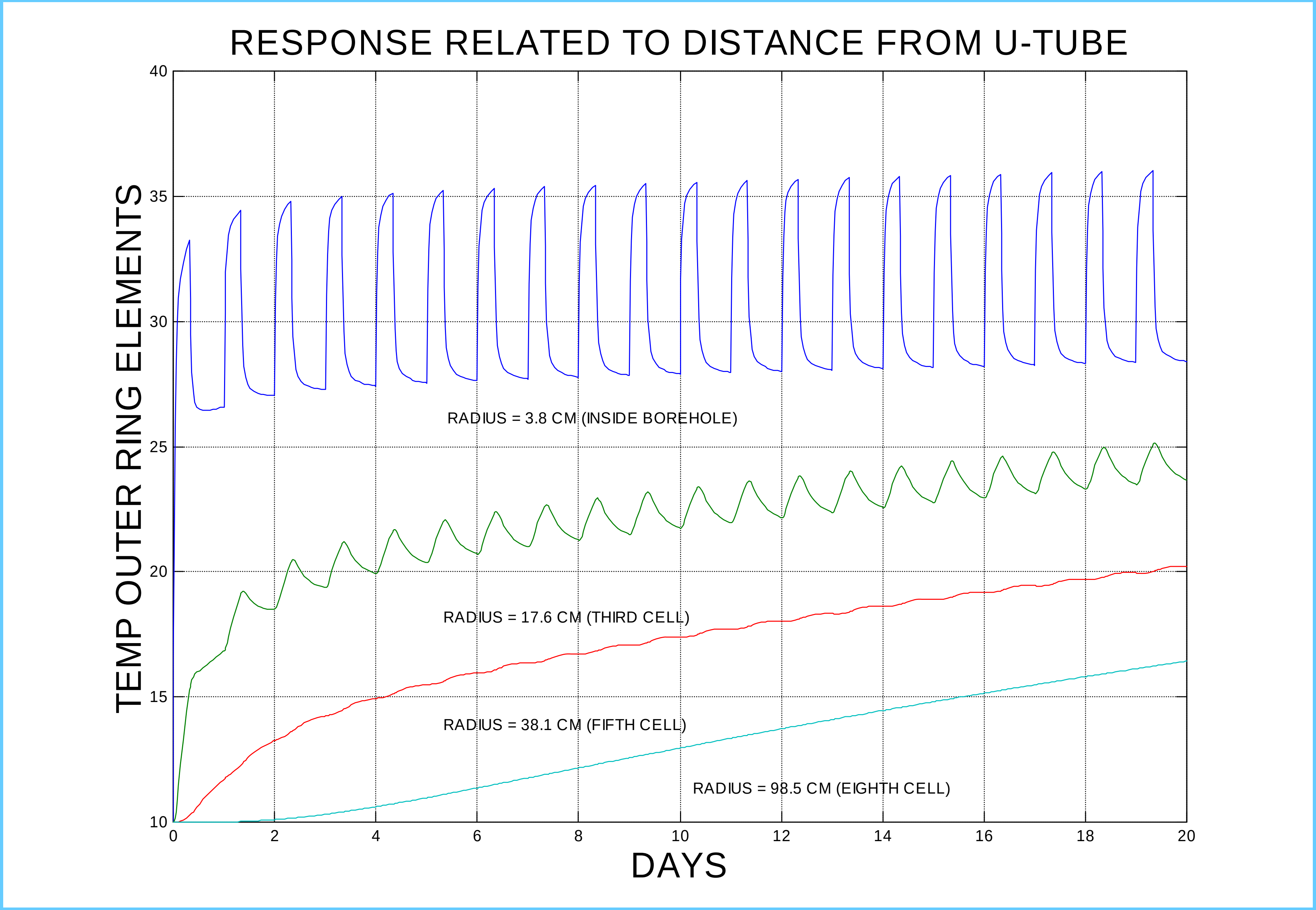
Source: Natural Resources Canada, CANMET

Characteristics of Seasonal Storage

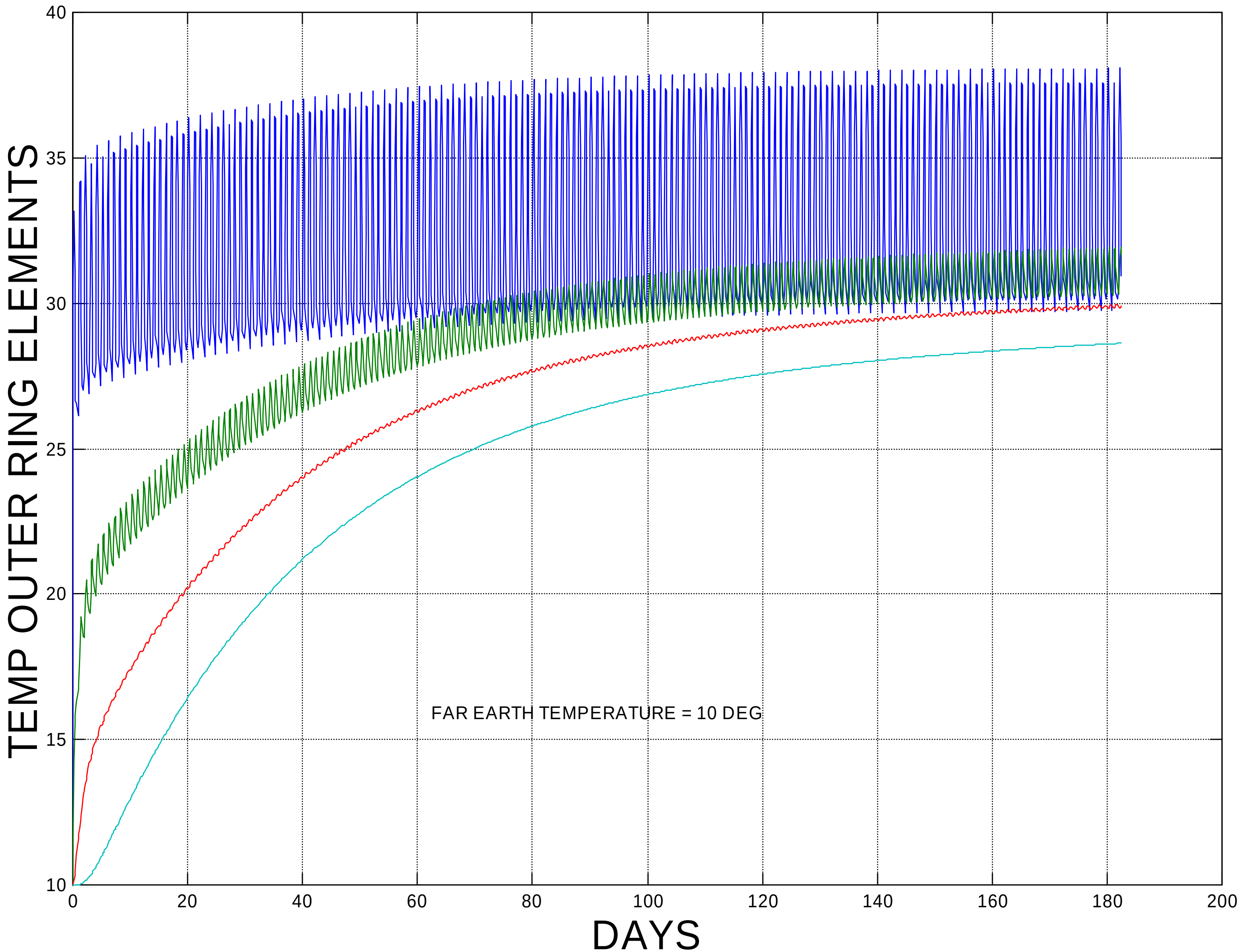
- Combines fast response sections with very slow ones
- Limited heat transfer capacity, 400 KW at Okotoks (Peak solar is 1.6MW)
- Cost of Okotoks buffer water storage is approximately $300,000 USD
- Distributed thermal storage of low energy buildings can replace the large water storage

Simulations of Borehole Outer Ring

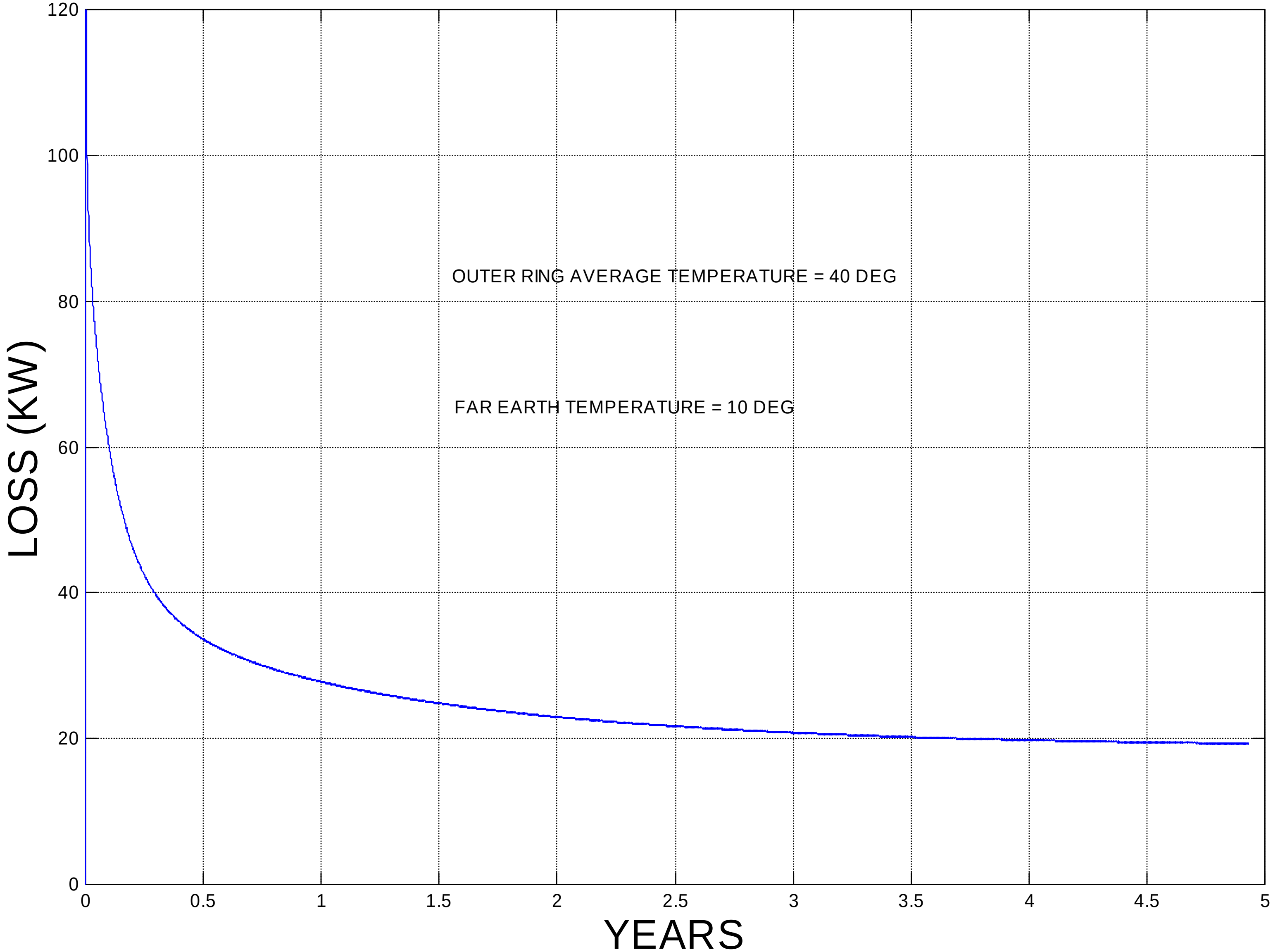
- “Coarse finite element” approach, using SIMULINK ™, enabling complete DH system simulation at high speed
- 24 cells around the outer ring
- 8 hour temperature pulse, 30-40 deg C
- Start at ground temperature = 10 deg C

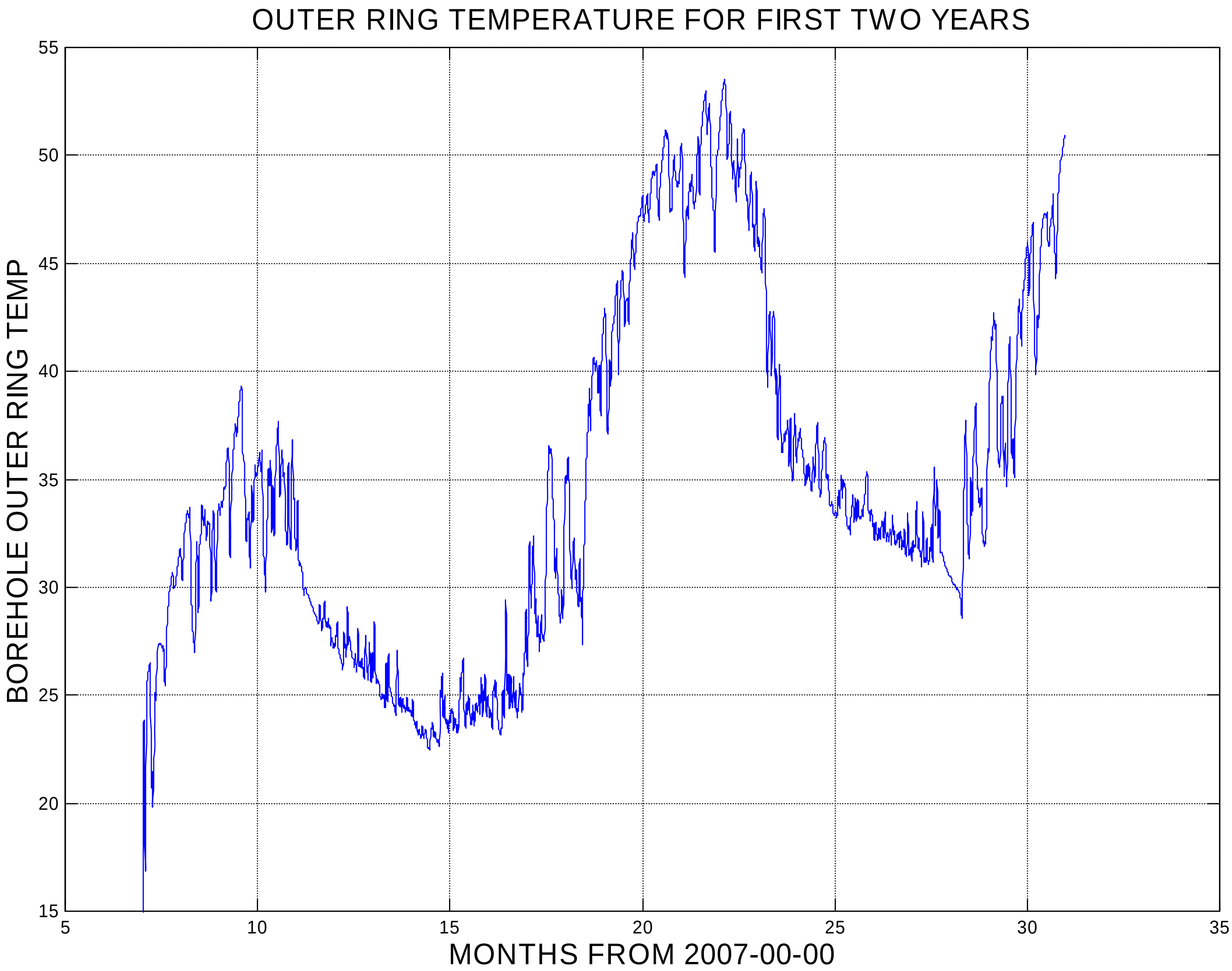

RESPONSE RELATED TO DISTANCE FROM U-TUBE
TEMP OUTER RING ELEMENTS
DAYS
RADIUS = 3.8 CM (INSIDE BOREHOLE)
RADIUS = 17.6 CM (THIRD CELL)
RADIUS = 38.1 CM (FIFTH CELL)
RADIUS = 98.5 CM (EIGHTH CELL)
40
35
30
25
20
15
10
0
2
4
6
8
10
12
14
16
18
20

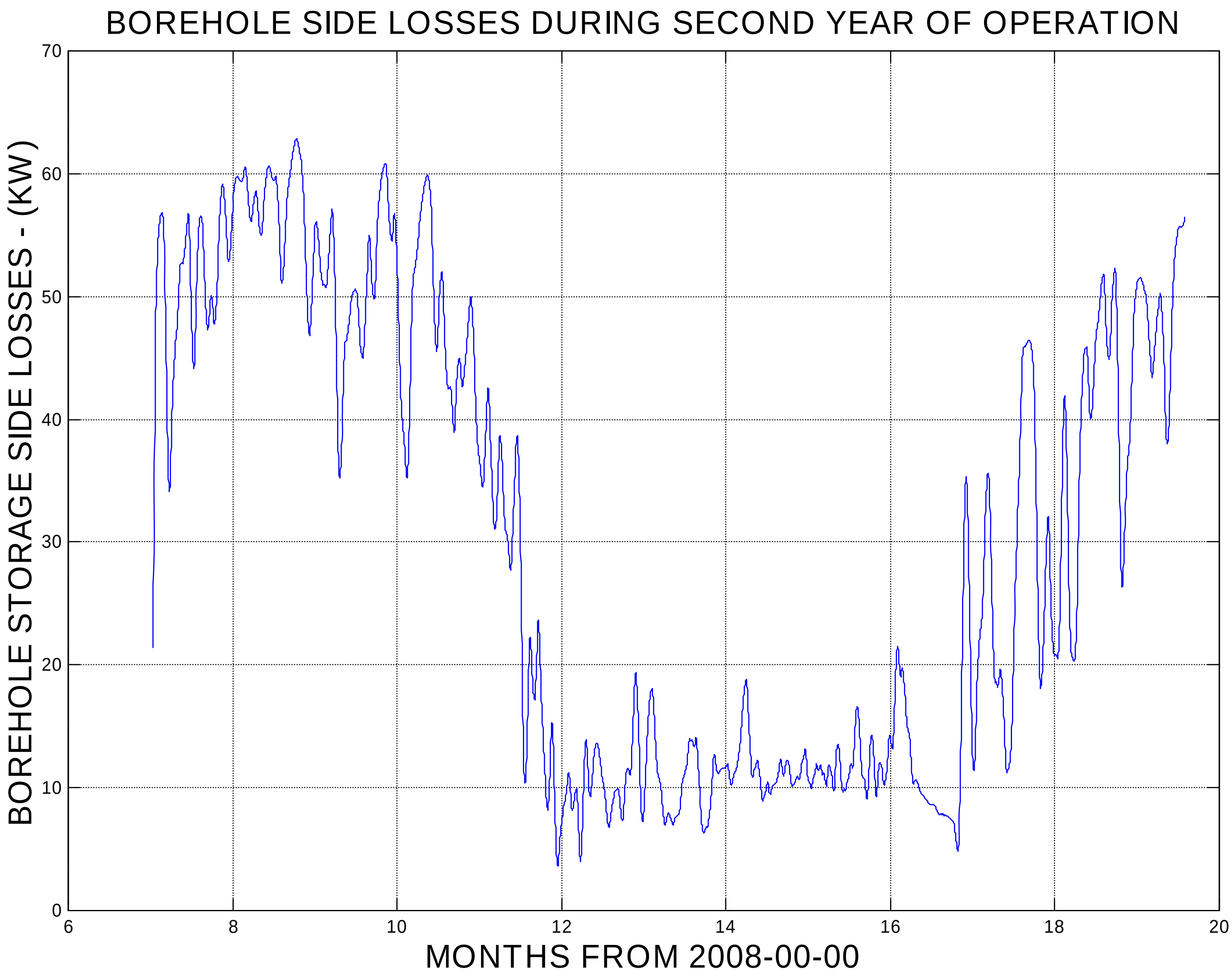
RESPONSE AS A FUNCTION OF DISTANCE FROM U-TUBE



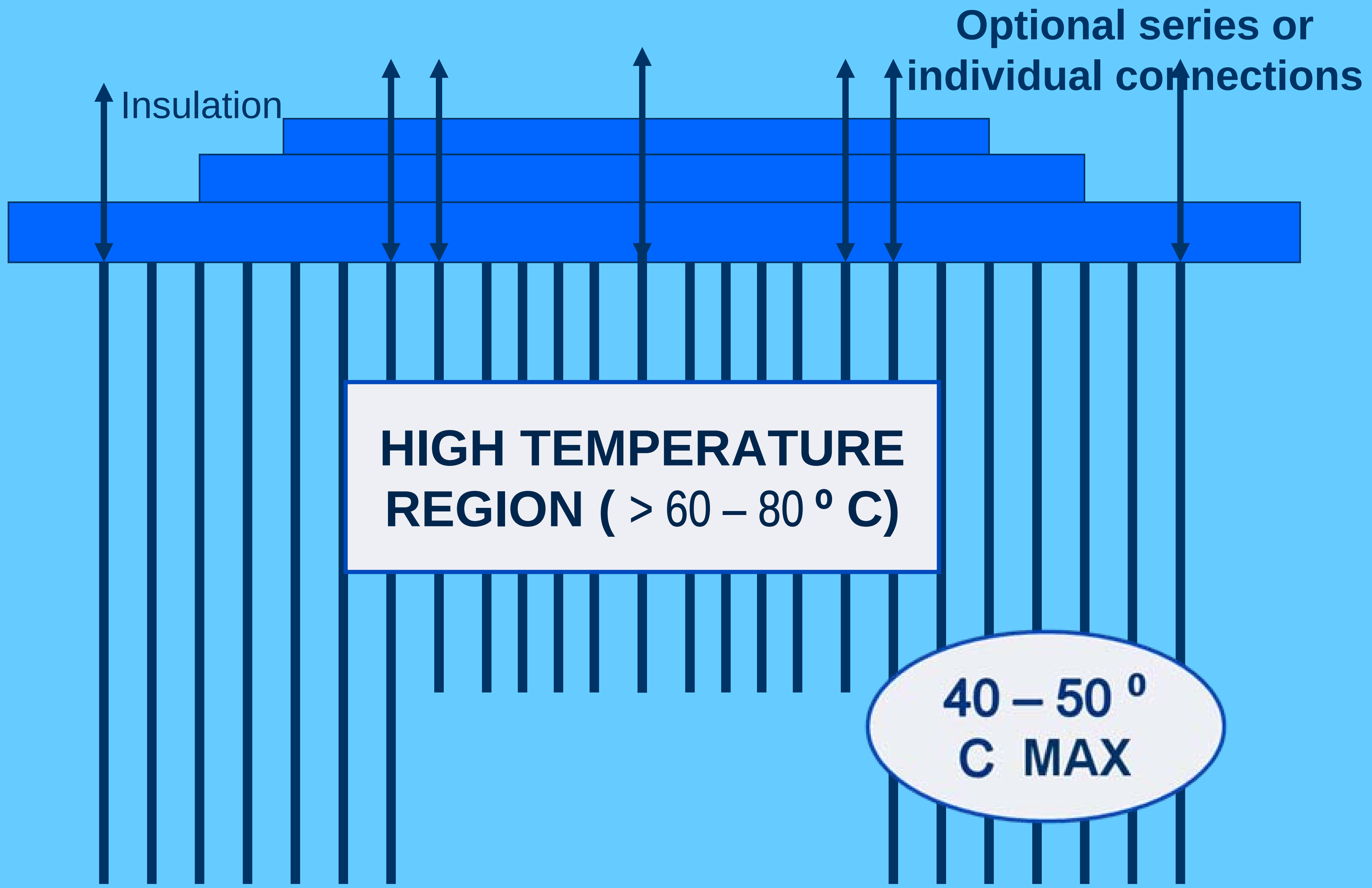
BOREHOLE STORAGE LOSSES VS. TIME




OUTER RING TEMPERATURE FOR FIRST TWO YEARS
BOREHOLE OUTER RING TEMP
MONTHS FROM 2007-00-00
55
50
45
40
35
30
25
20
15
5
10
15
20
25
30
35

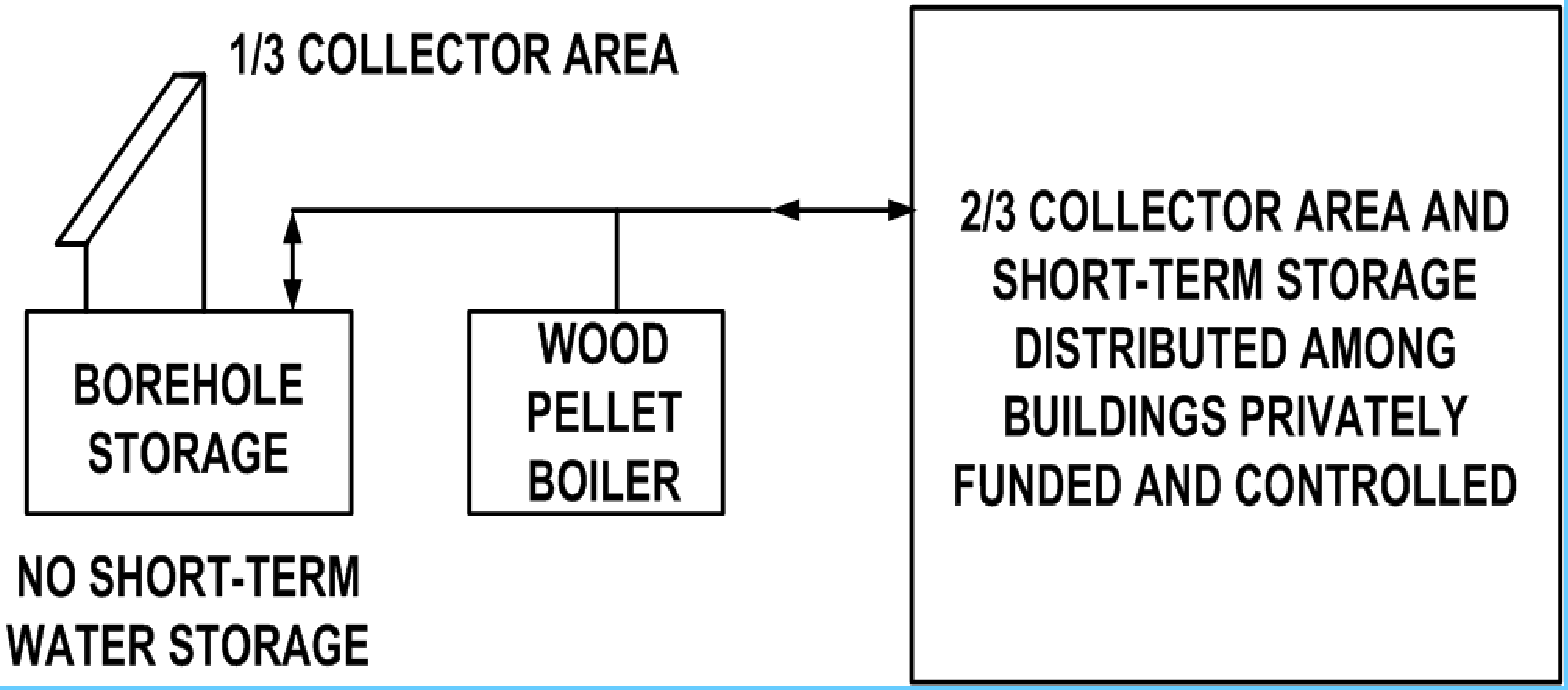

BOREHOLE SIDE LOSSES DURING SECOND YEAR OF OPERATION
BOREHOLE STORAGE SIDE LOSSES - (KW)
70
60
50
40
30
20
10
0
6
8
10
12
14
16
18
20
MONTHS FROM 2008-00-00

Borehole Reference Configuration

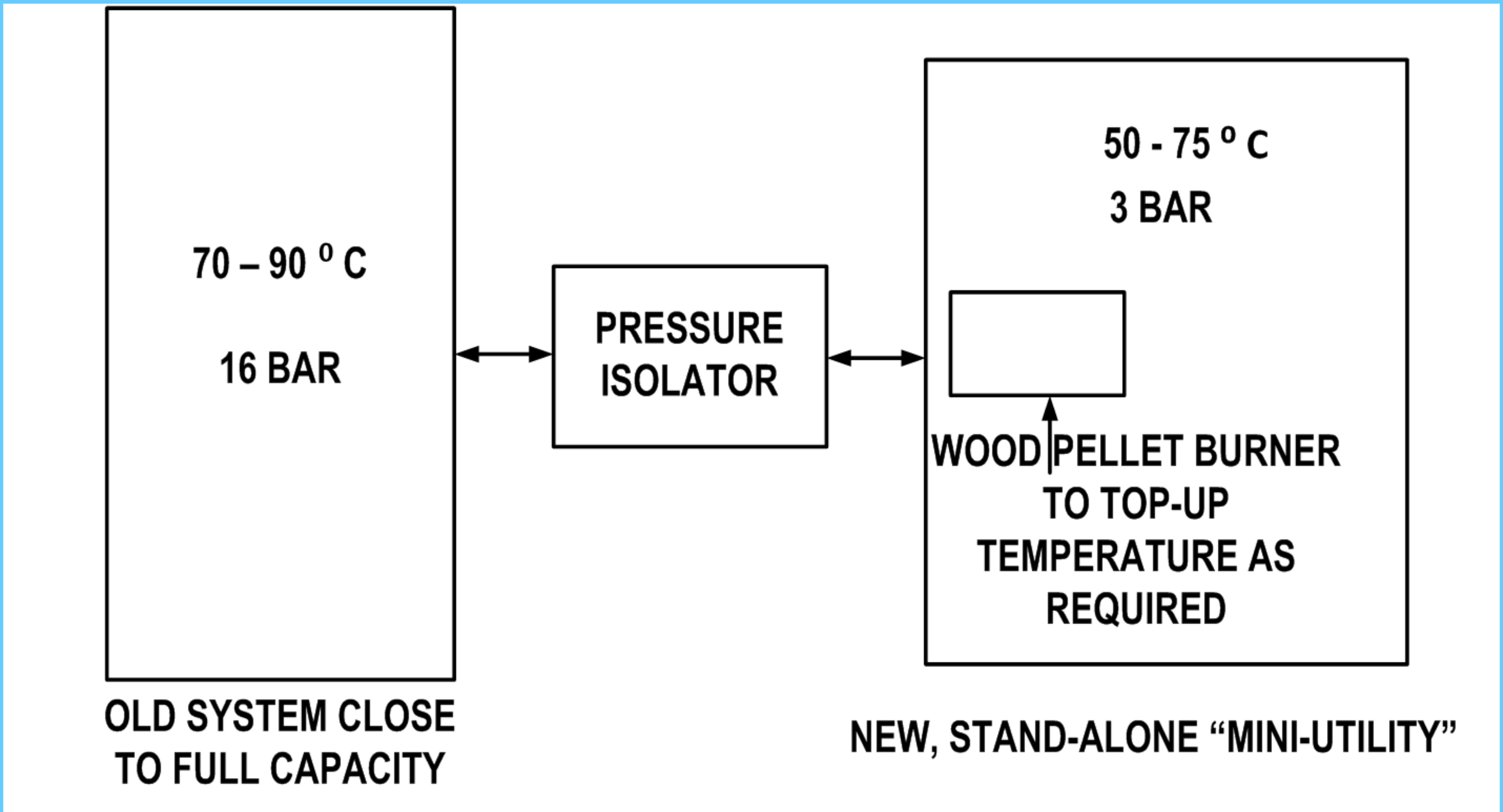


Proposed "Mini-Utility" System

With Two-Stage Borehole Storage To Accommodate Peak Solar Input Temperatures



Interface Between Large DH Utility and Stand-Alone "Mini-Utility" with Seasonal Storage and Solar/Biomass Energy

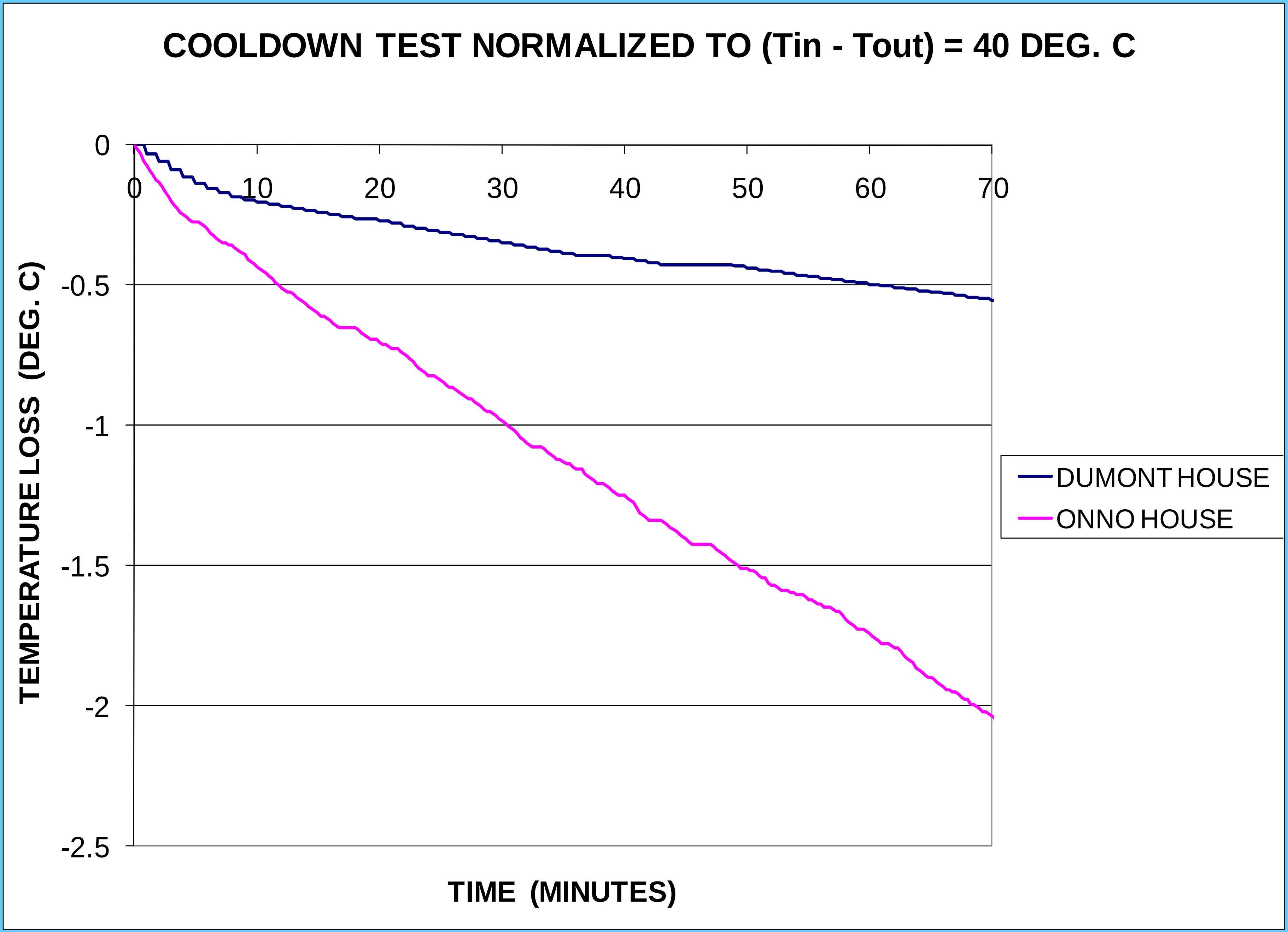


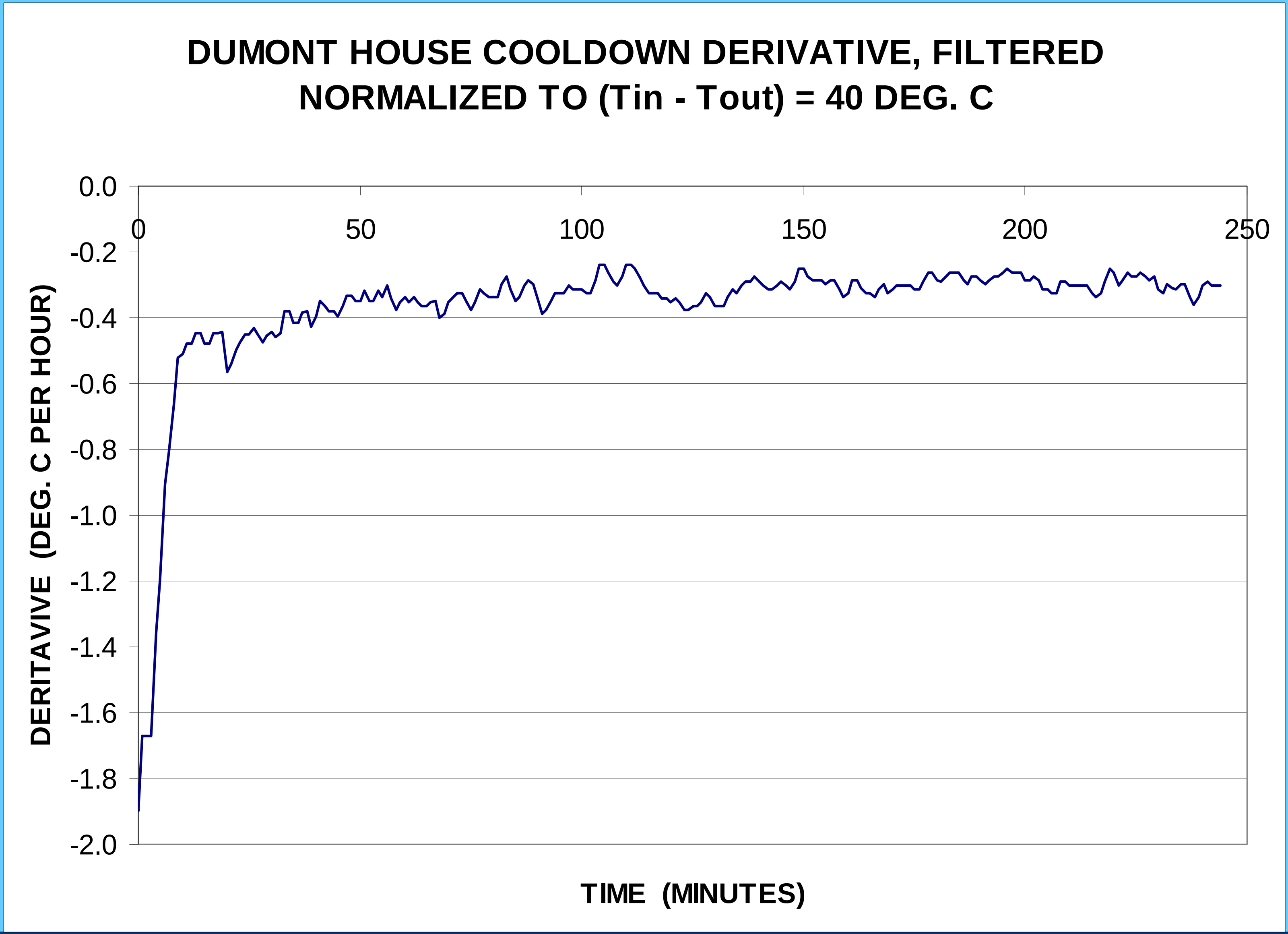
Low-Energy Buildings Can Avoid Peak Loads on DH Systems

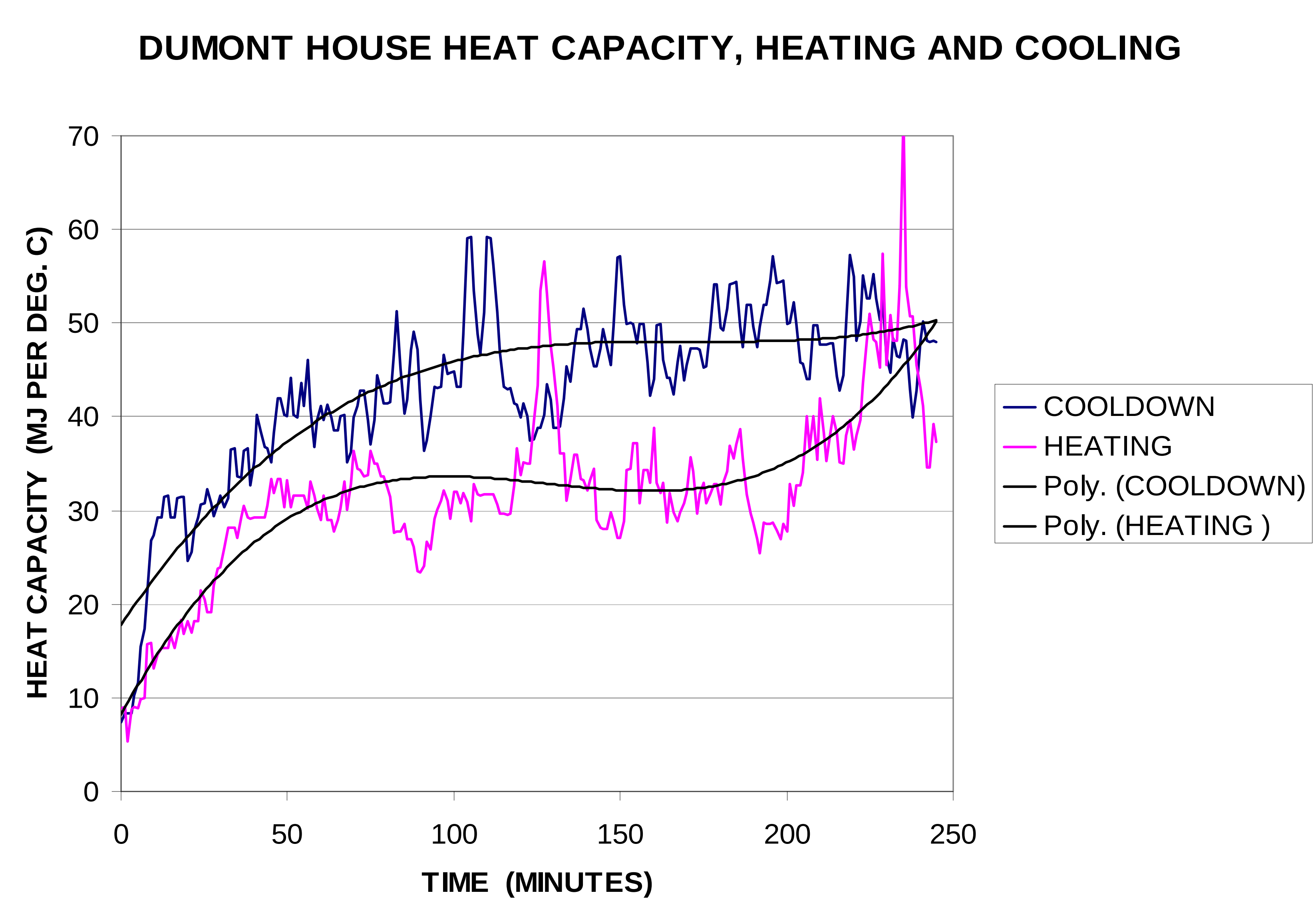
- Future buildings will have low heat loss factor
- Utilize thermal energy storage enabling load shedding and off-peak charging of storage
- Independent production of thermal energy
- Sophisticated control systems

Interface Low - Energy Buildings to DH System

- Dumont House:
  - Heat loss factor 109 watts per °C, 5.5 KW at -30°
  - Passive gain: 11.6 square meters south windows
  - Active solar: 15.6 square meters of collectors
  - 3000 liters water storage


COOLDOWN TEST NORMALIZED TO (Tin - Tout) = 40 DEG. C
0
-0.5
-1
-1.5
-2
-2.5
0
10
20
30
40
50
60
70
TEMPERATURE LOSS (DEG. C)
TIME (MINUTES)
DUMONT HOUSE
ONNO HOUSE


DUMONT HOUSE COOLDOWN DERIVATIVE, FILTERED
NORMALIZED TO (Tin - Tout) = 40 DEG. C
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
0
50
100
150
200
250
DERITAVIVE (DEG. C PER HOUR)
TIME (MINUTES)


DUMONT HOUSE HEAT CAPACITY, HEATING AND COOLING
HEAT CAPACITY (MJ PER DEG. C)
70
60
50
40
30
20
10
0
0
50
100
150
200
250
TIME (MINUTES)
COOLDOWN
HEATING
Poly. (COOLDOWN)
Poly. (HEATING)

Conclusions

- Seasonal storage shows promise but cost too high – need to reduce losses; concentrate on lowering operating temp
- Utilities have concerns that connecting low-energy buildings to DH system will have insufficient payback
- Future buildings will often have distributed solar and thermal storage

Applications to European Coastal Climate

- Since solar gain will be lower than Calgary in January, February minimizing losses in seasonal storage is important
- Relative magnitude of diffuse radiation is larger – collectors should have good response to this input
- Simulations will be done with this climate

Net Benefits to the Utility of Low Energy Buildings

- Load shedding
- Distributed storage can buffer borehole and enable off-peak energy accumulation
- Distributed generation of renewable energy gives direct supply to nearby buildings plus surplus into seasonal storage

IEA Project Activity

- Model optimized borehole configuration
- Model complete DH system with seasonal storage
- Incorporate automatic weather prediction software for optimized control
- Experimental work
  - Interface Dumont house to simulated DH system
  - Develop more efficient heating system matched to low energy buildings