Retrofitting a Multi-Unit Residential Building To Reduce Purchased Energy by a Factor of 10

Chris Richards

MSc Candidate, Mechanical Engineering
University of Saskatchewan
Saskatchewan Research Council

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King Edward Place

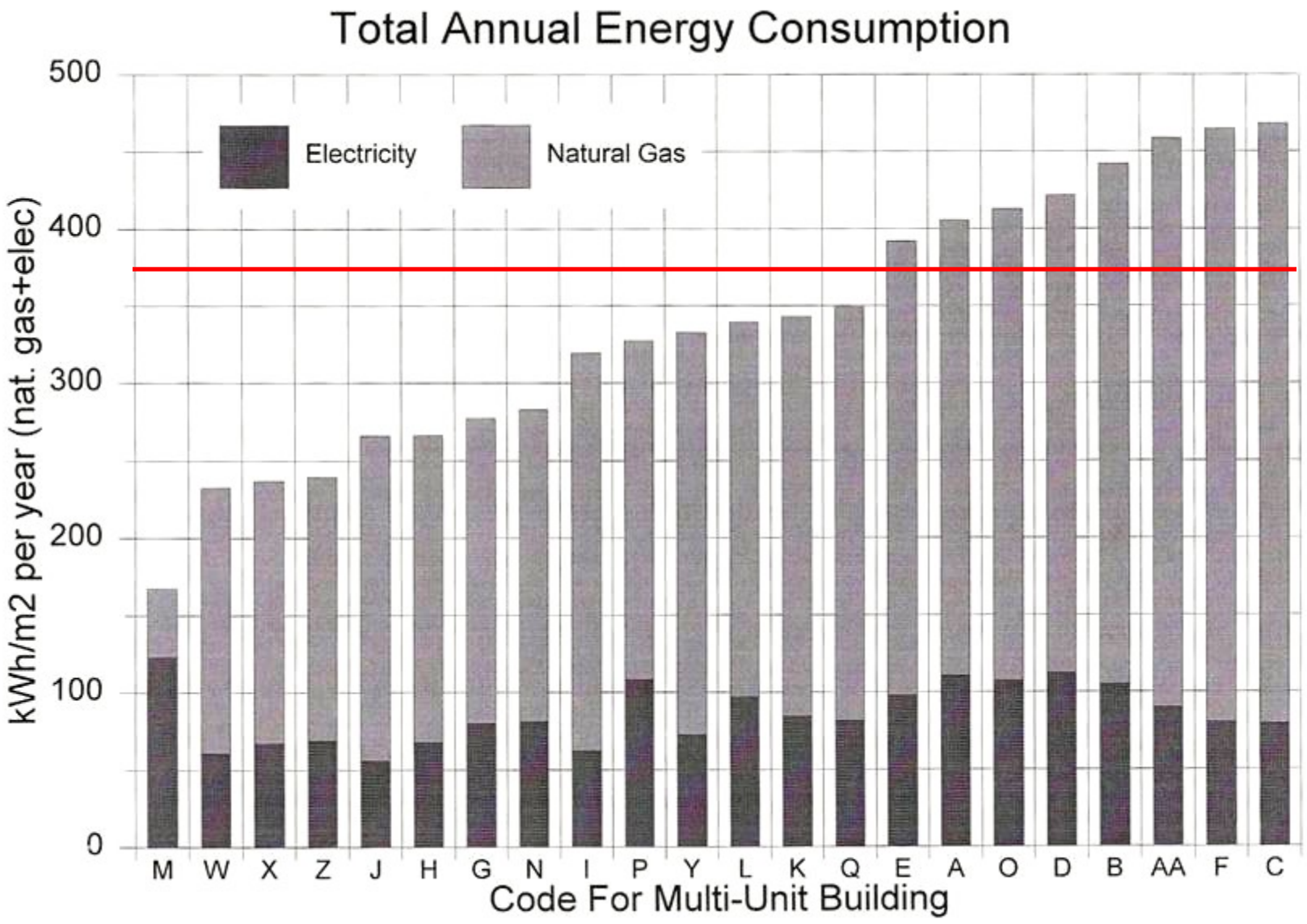
Southern Exposure

Eastern Exposure

King Edward Place

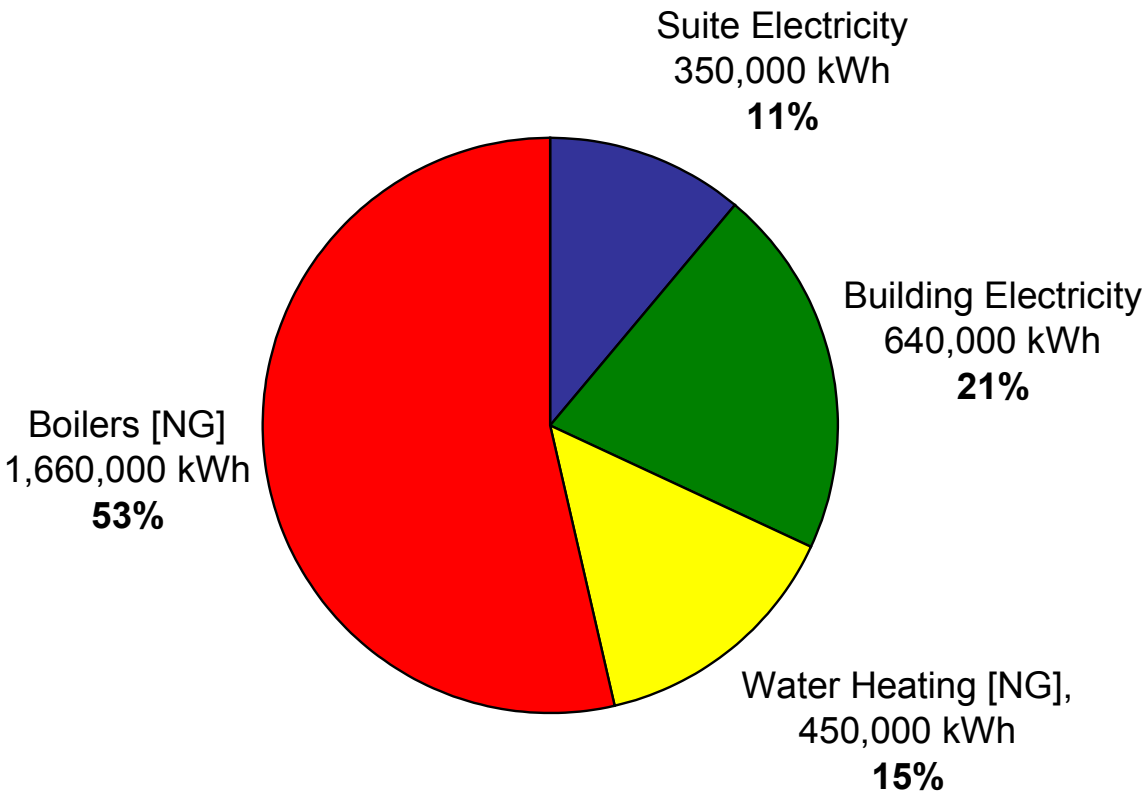
- Owned by the Saskatoon Housing Authority
- Seniors social housing
- 2003 energy use: 3,095 MWh **(371 kWh / m² / yr)**
- Average energy use measured by SRC of seniors multifamily buildings: **367 kWh/m²/yr**
- Factor 10 – **37.1 kWh / m² / yr**
- Reduce water use and greenhouse gas emissions

SRC Building Audit Comparison



Building Energy Use Summary

Annual Energy Use:



Suite Electricity:	$35,000
Building Electricity:	$64,000
Boiler Natural Gas:	$50,000
DHW Natural Gas:	$14,000

Why Factor 10?

The future of energy use for the world to be sustainable.

- **Future population growth: 1.5**

  "In 2000, the world had 6.1 billion human inhabitants. This number could rise to more than 9 billion in the next 50 years. " - Population Reference Bureau

- **Future consumption growth per person: 3.3**

  "To bring 9 billion people up to at least the 1980s material standards enjoyed by western Europeans would require something like 6 or 7 hectares per capita; Earth has less than 2 hectares per capita of productive land and water.If the population were to stabilize at between 10 and 11 billion sometime in the next century, five additional Earths would be needed" – Dr. William E. Rees

- **Required reduction in GHG emissions: 2 *(50%)***

  "If we are ever to win the long-term battle on climate change, global greenhouse gas emissions will have to be cut by more than half by the end of this century." - Government of Canada, Canada and the Kyoto Protocol

1.5 x 3.3 x 2 = Factor 10

King Edward Place

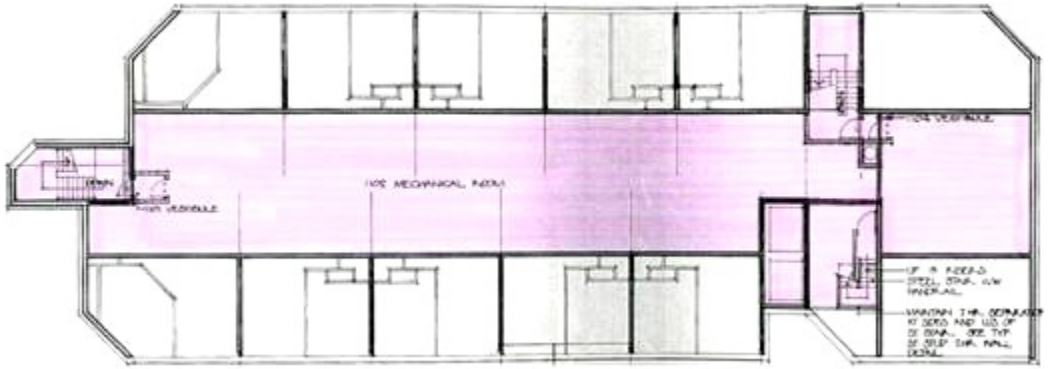
Crawlspace and Penthouse

Crawlspace

- Mechanical / Electrical
- Storage
- Hot Deck with Heat Recovery
- Outdoor Ventilation Air
- Recirculation

- Previous moisture problems

- **More ventilation than a typical floor (315 L/s)**



11th Floor Penthouse

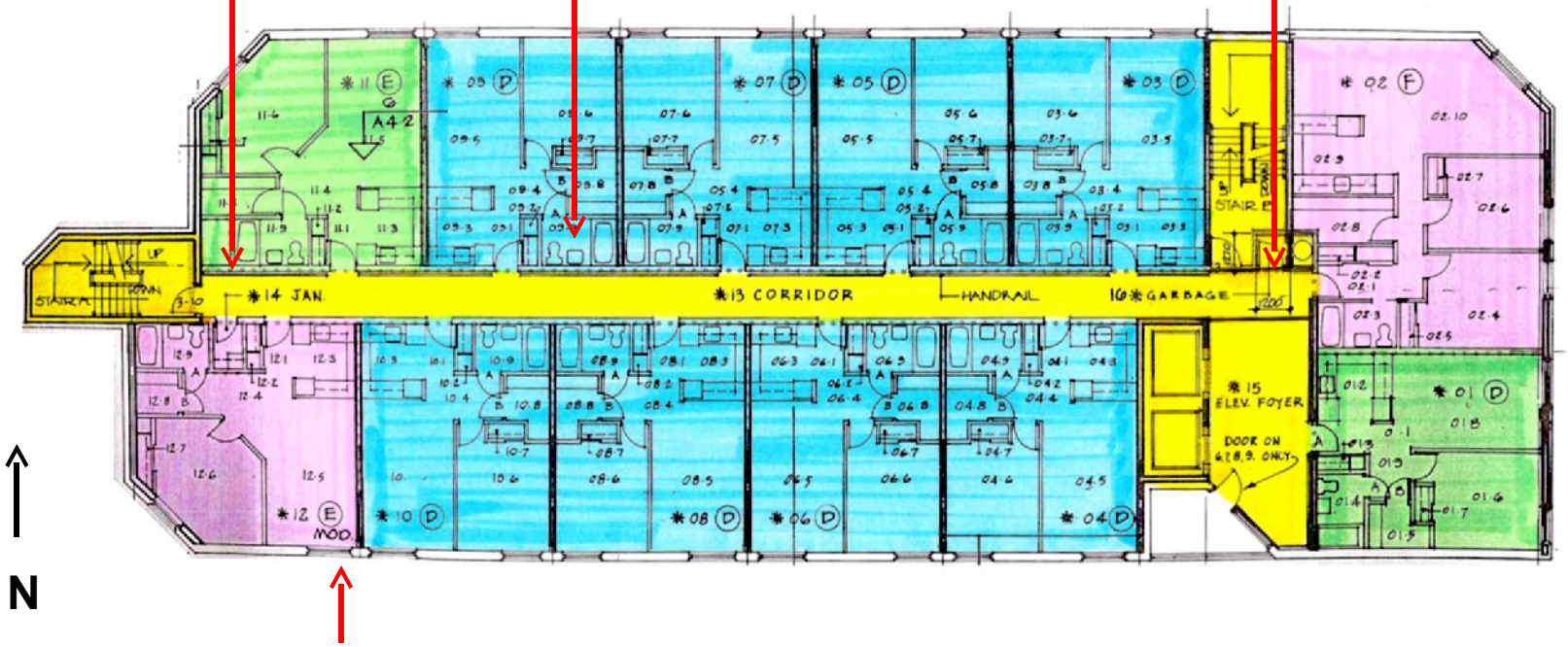
- 20 Boilers
- 3 Hot Water Heaters
- Elevator Equipment
- Heat Recovery

Typical Floor

Hallway Ventilation Supply

Washroom Exhausts **(No Kitchen Exhaust)**

Thermostat



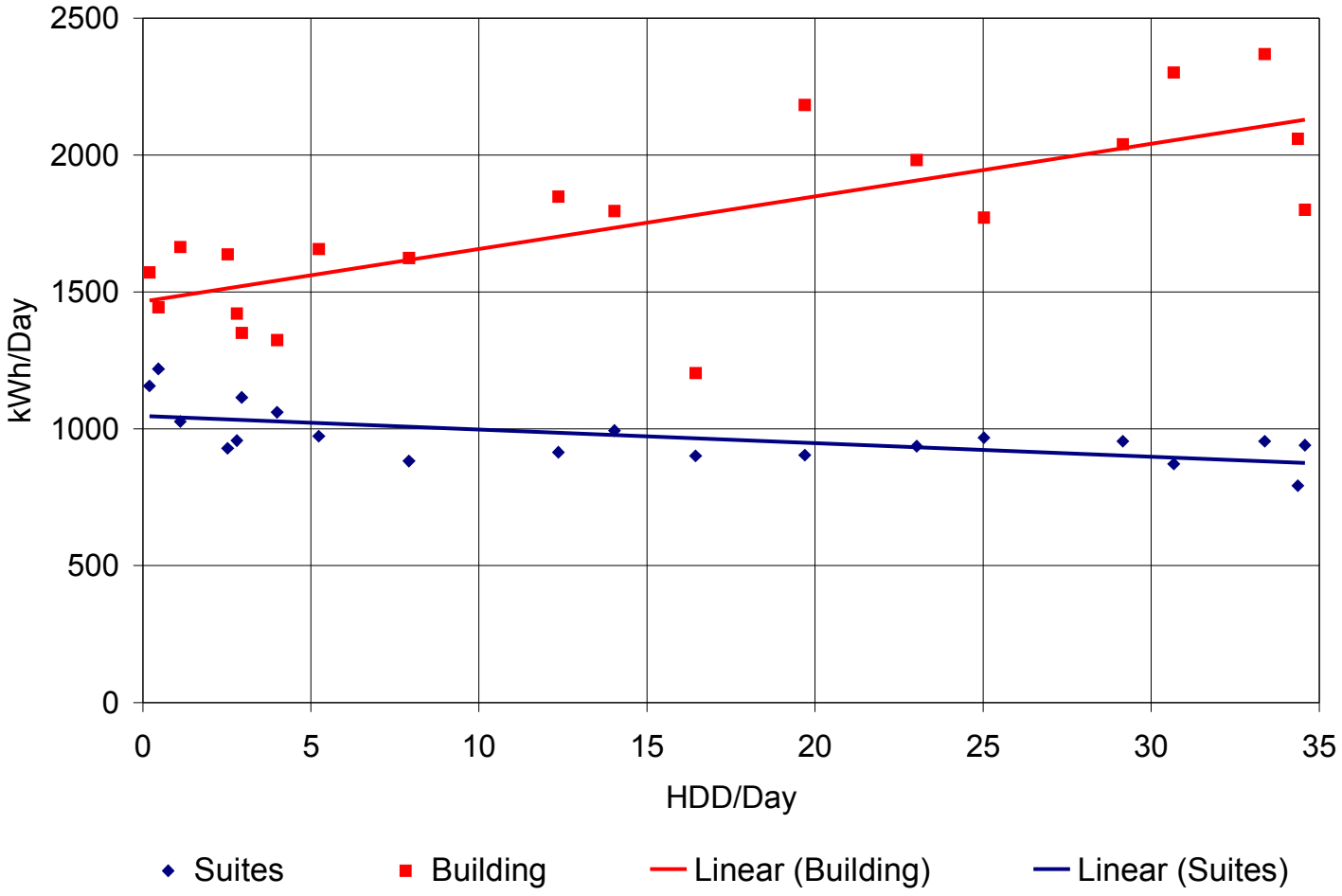
26 Window Air Conditioning Units

Total Floor Area: 746 m²

Approximate Floor Area Per Suite: 50 m²

Electrical Consumption

There is both a suite and a building meter.



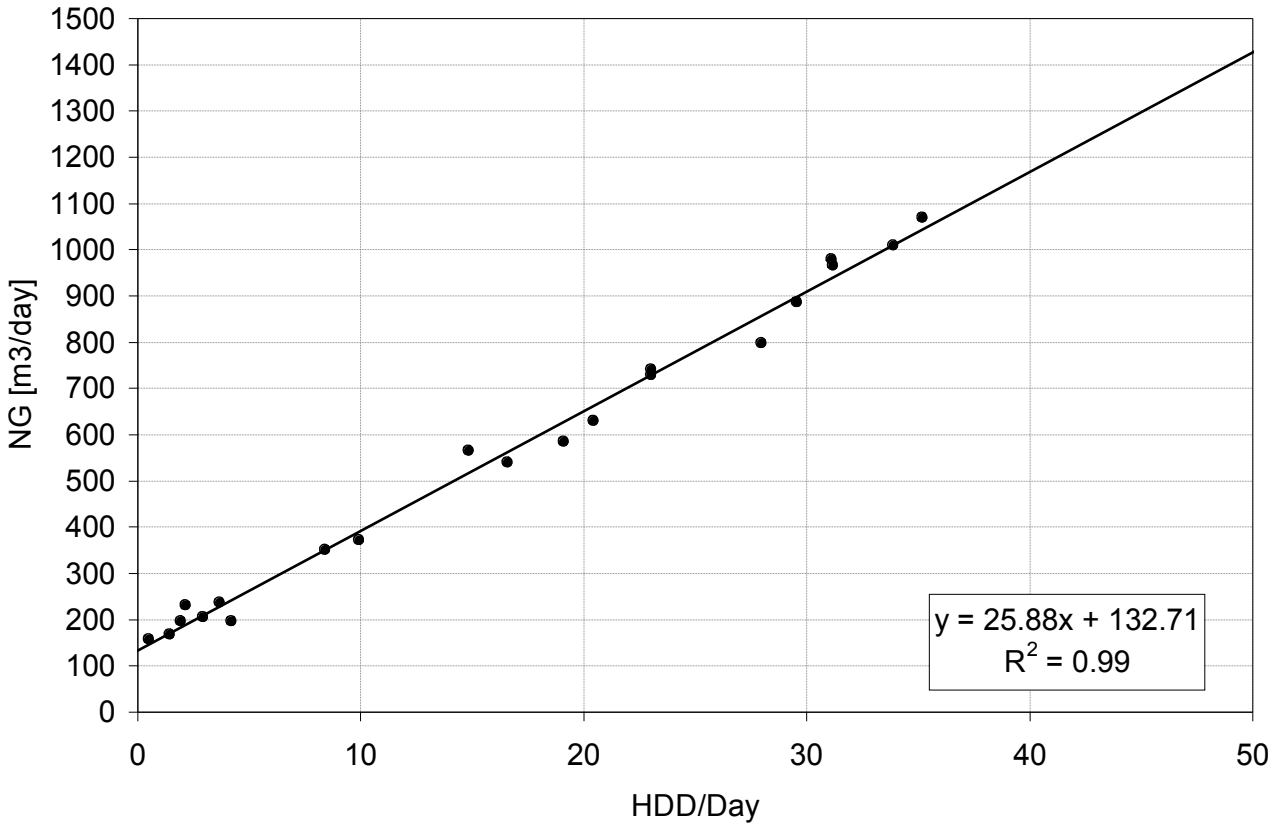
HDD/Day = 18 – Average Daily Temperature Therefore: -35ºC = 53 HDD/Day

Boiler Room

- 20 Boilers
- Maximum Capacity: 4,100 m^3/day (natural gas consumption), (6,000,000 Btu/hr)
- Water baseboard convection heaters in each suite and throughout building
- Hot deck coil for ventilation air

Natural Gas Consumption (2002 & 2003)

Consumption prior to SRC low cost retrofit.



HDD/Day = 18 – Average Daily Temperature

Therefore: -35ºC = 53 HDD/Day

Max possible consumption: 1,500 m3/day

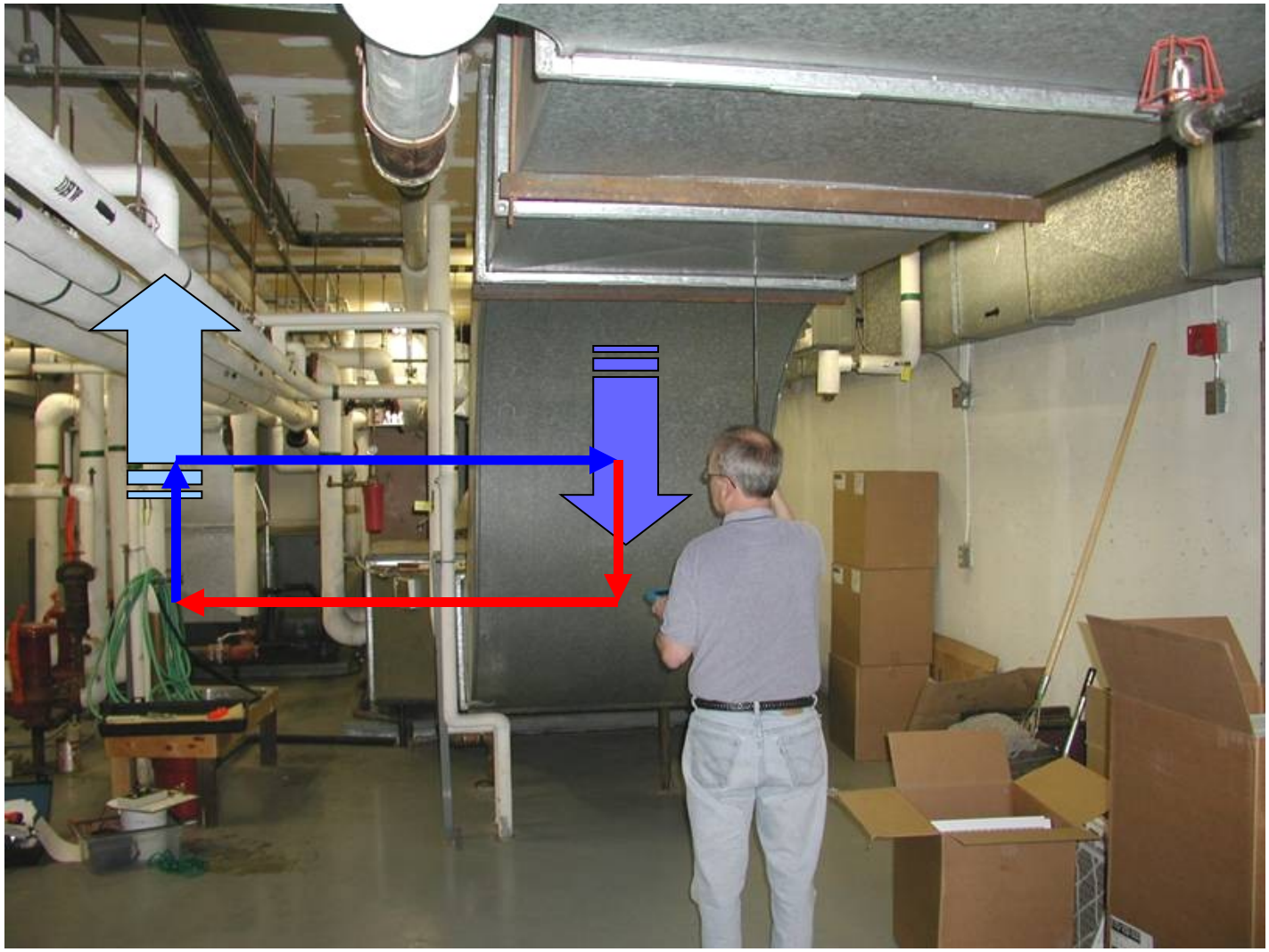
Actual capacity: 4,100 m3/day **(2.7x)**

Boiler Room

20 Boilers + 3 Hot Water Heaters

- Directly vented to the atmosphere (no stack dampers)
- Chimney open area: 1.41 m^2 (no air sealing on vents)
- 23 pilot lights ($77/year each, $1771/year total)

Hot Deck / Heat Recovery



No Air Sealing on Supply or Exhaust Ducts – Leakage is Apparent

Hallway Supply

Hallway Ventilation

Suite Exhaust (bathrooms, not kitchens)

Hallway Supply

"Much of the air delivered to the corridor system bypasses apartments, exiting the building via shafts, stairwells, and other leakage points.

- CMHC, 2003

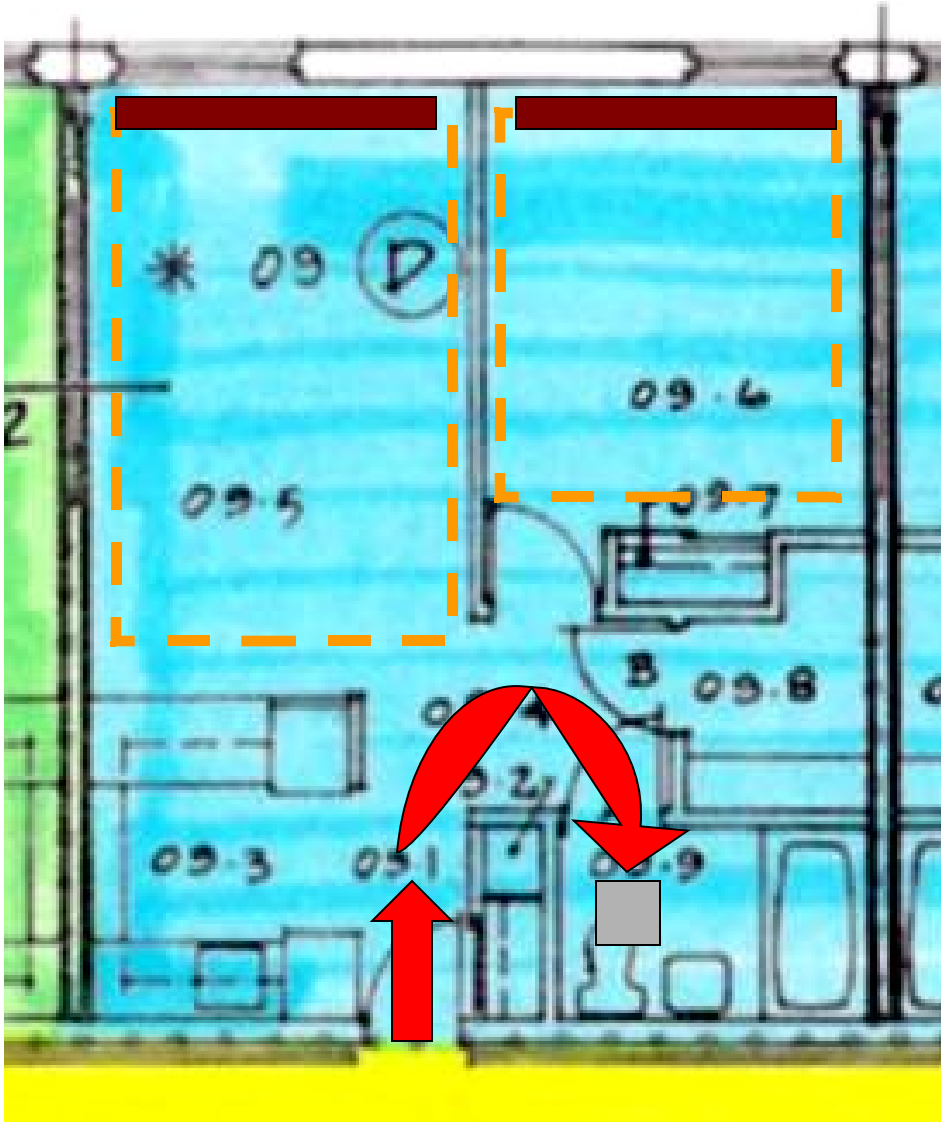
Ventilation

- Minimum outdoor air per suite (ASHRAE Standard 62): **22 L/s**

- Actual approximate outdoor air per suite: **25.2 L/s**

"Conventional corridor air supply and bathroom-kitchen exhaust systems do not, and cannot, ventilate individual apartments."

- CMHC, 2003



One Tenants Response to Inadequate Ventilation

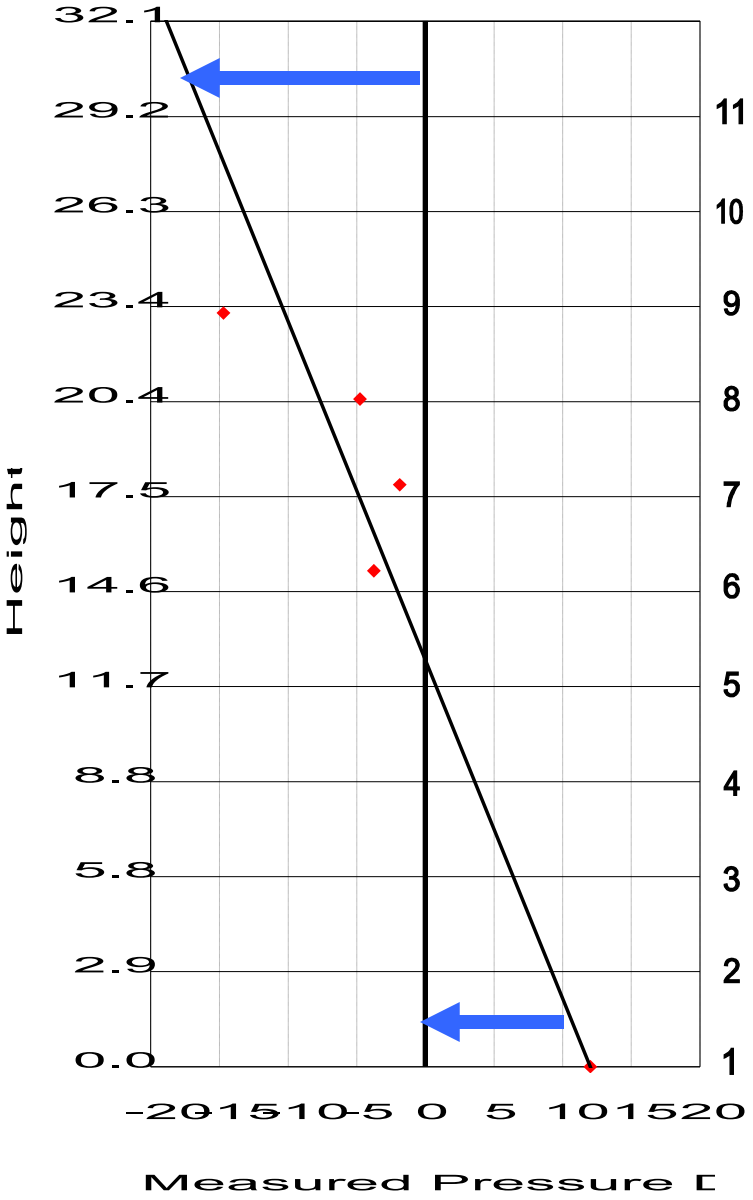
- 8th Floor, South Facing Suite
- 16 hours per day, everyday.

Tenant stated that he would operate the fan and keep the windows open 24 hours per day but the noise from the traffic below disturbed him.

Impact of individual suite monitoring??

Measurements

Neutral Pressure Plane



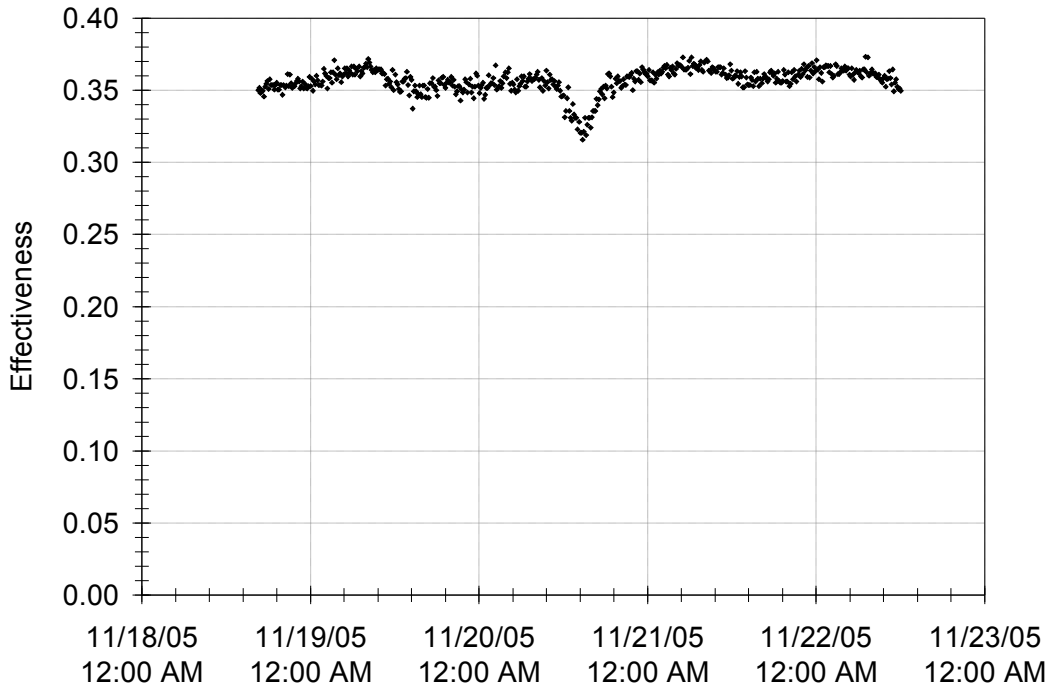
Measured from the corridors to the outdoors.

Indoor hallway temperature: 24ºC

Outdoor temperature: -12ºC

Average wind speed: 7 km/hr

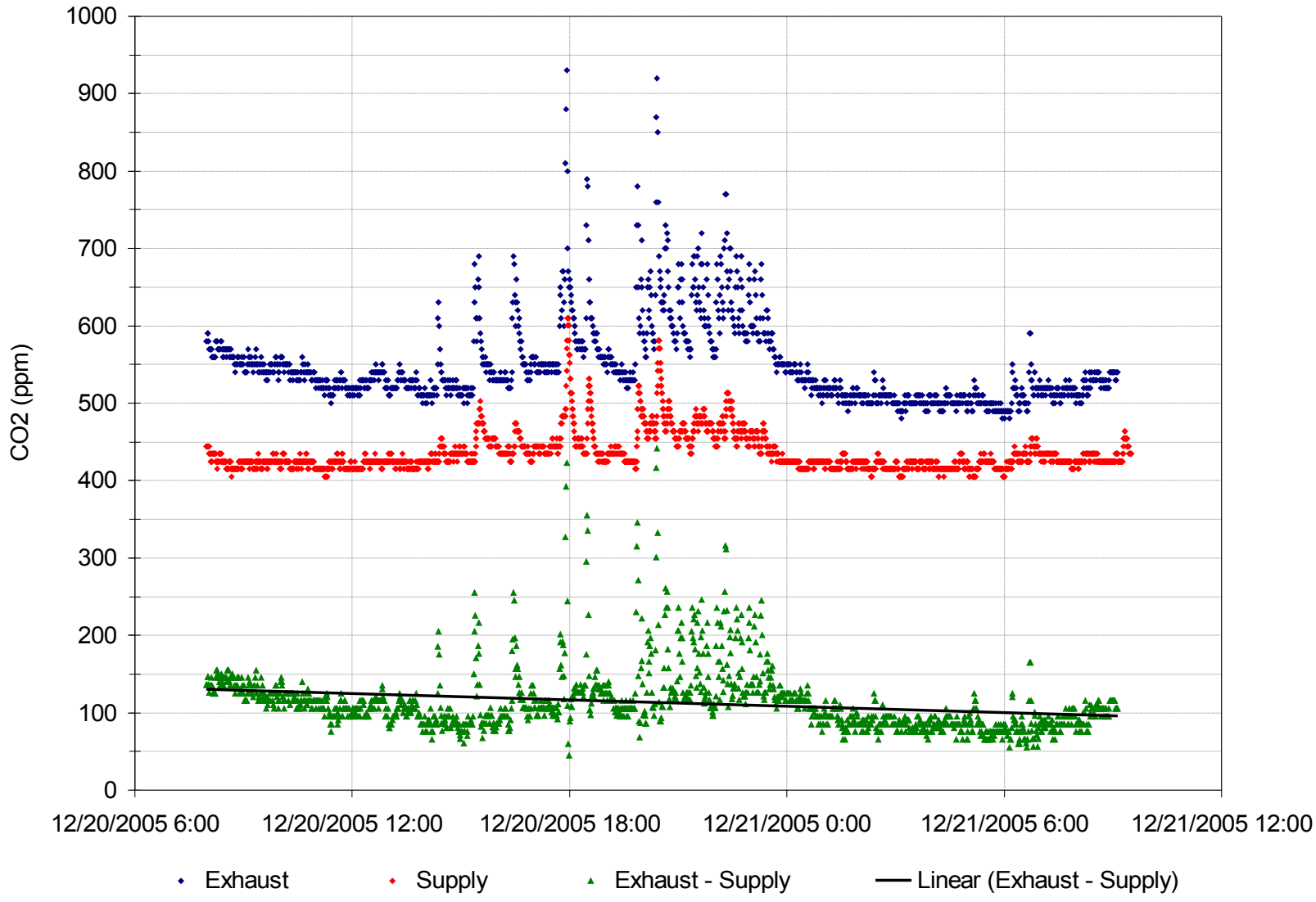
Measured Heat Recovery Effectiveness



Average measured heat recovery effectiveness: 36%

Most systems are typically 60% or higher.

CO2


1000
900
800
700
600
500
400
300
200
100
0
CO2 (ppm)
12/20/2005 6:00
12/20/2005 12:00
12/20/2005 18:00
12/21/2005 0:00
12/21/2005 6:00
12/21/2005 12:00
Exhaust
Supply
Exhaust - Supply
Linear (Exhaust - Supply)

CO_2

$$C_{EXHAUST} = C_{SUPPLY} + N / kV$$

- Average exhaust level of CO_2: 578.9 ppm
- Average supply level of CO_2: 460.3 ppm.
- Average difference in CO_2: 118.6 ppm.

Adults breath out 700 mg/min of CO2 during regular respiration, 120 tenants in KEP

Thus infiltration rate per square meter of exterior wall area is **0.68 L/s/m²**

EE4 default value for a new building is 0.25 L/s/m² **(2.7x)**

Initial Retrofit Options

Key Changes to Achieve Factor 10

Space Heating

- Properly sized condensing boilers
- More efficient heat recovery
- Wall and window retrofit, combined with air tightening

Lighting

- Energy efficient fixtures

Domestic Hot Water

- Solar water heating with wastewater heat recovery

Ventilation

- Solar air heating
- Reduce ventilation and change suite ventilation method

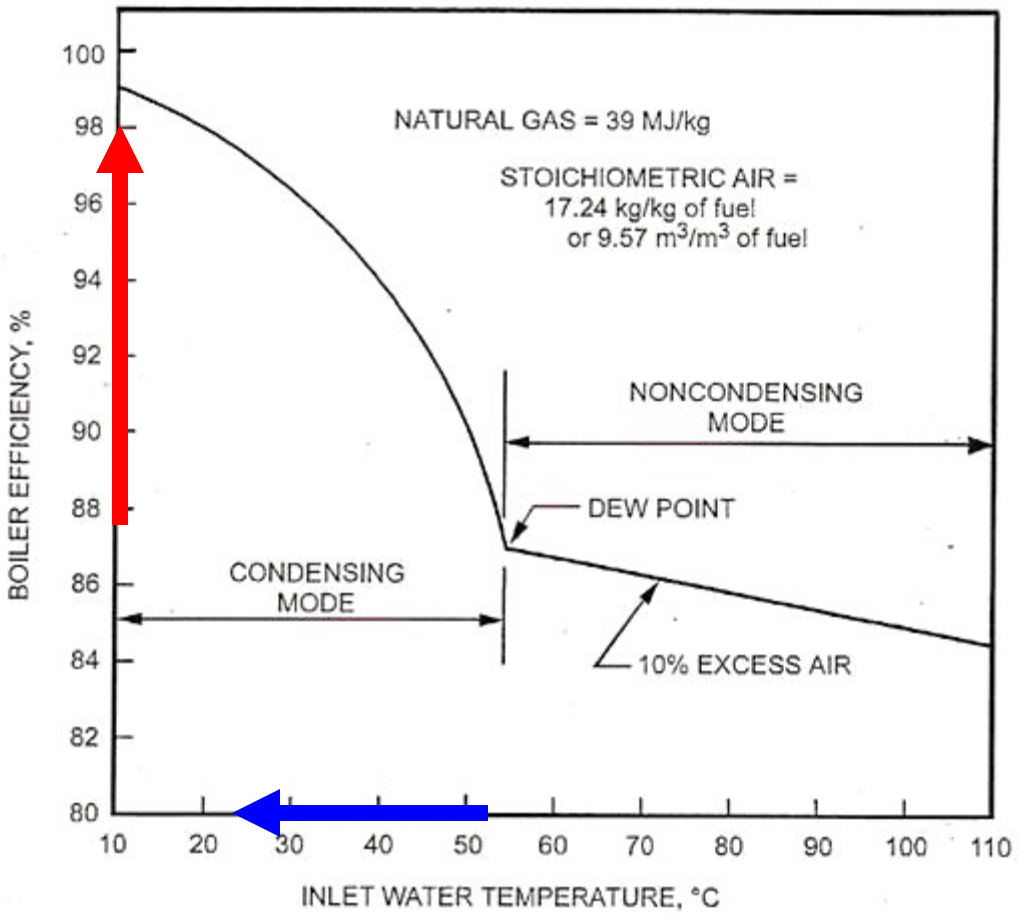
Control Systems and Charging Each Suite Individually

Boiler Sizing and Stack Dampers

- Current pre-dilution measured *combustion efficiency* is 78%
- However the *seasonal efficiency* may be as low as 65%
- Oversized equipment is inefficient
- Stack dampers stop the continuous venting of heated air to the atmosphere (1.41 m^2)

Condensing Boilers

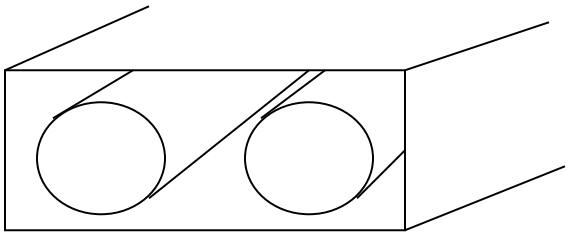
2000 ASHRAE Systems and Equipment Handbook (SI)



Effect of Inlet Water Temperature on Efficiency of Condensing Boilers

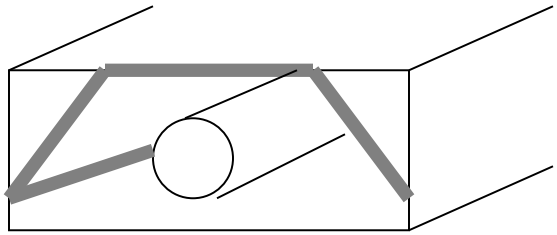
Energy Efficient Lighting

- Compact fluorescents for all incandescent bulbs
- De-lamping over-lit areas
- Electronic ballasts and T8 lights
- Retrofitting two bulb fixtures with silver reflectors
  - 8.6% of the total energy is lighting: 120,000 kWh/yr (building 4%, suites 5%)
  - The building owners engaged in a lighting retrofit prior to 2003. The buildings pre-retrofit energy use for lights is estimated to be 190,000 kWh (**savings of 37%**)



Two lamp T12

81 W



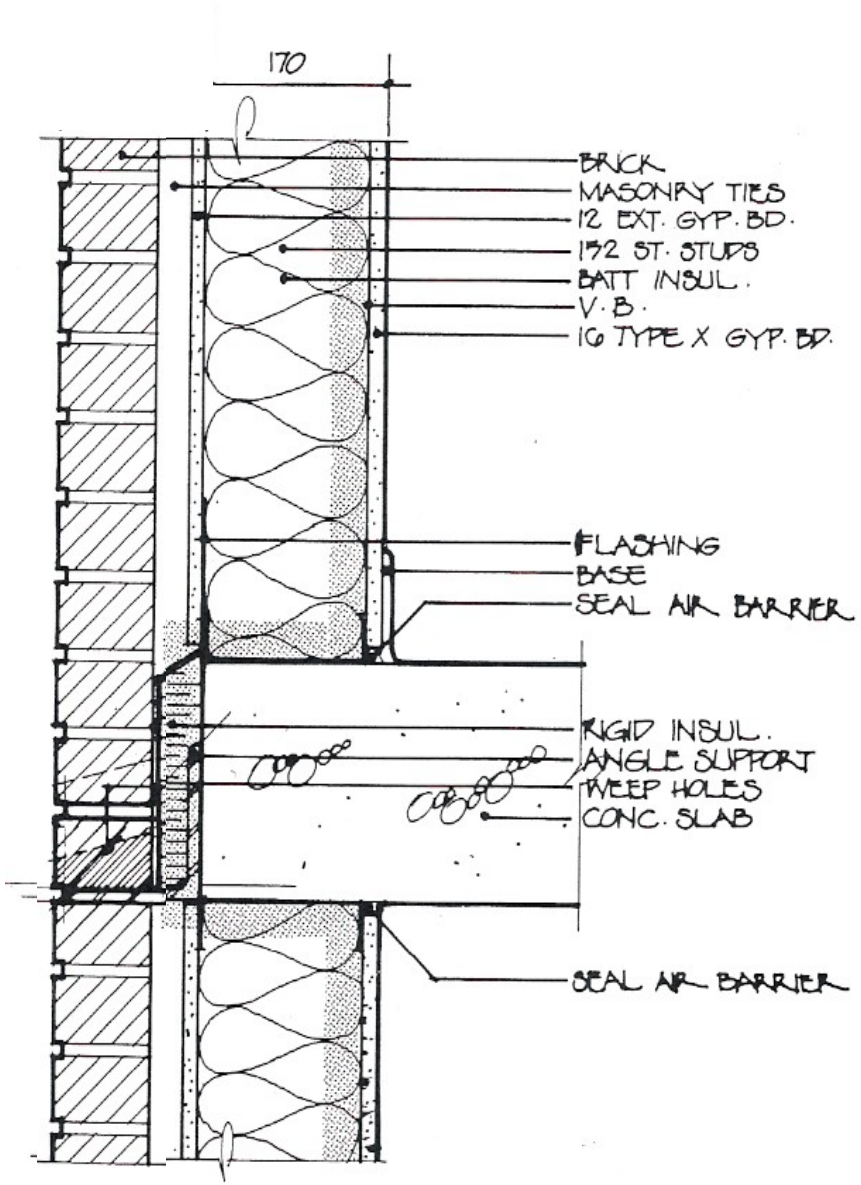
Single Lamp T8 w/Reflector

30 W

Air Tightening

- Minimize stack effect through compartmentalization of floors
- Reduce cost of heating incoming air
- SRC low-cost no cost retrofit reduced natural gas consumption by approximately 3.5%
  - Weather-stripping stairwell and outside doors (not suite doors!)
  - Elevator and other vertical shafts (pipe chases, internet cables, etc)
  - Garbage chutes
- Much higher savings possible
  - Wall/window retrofit
  - Occupants kept windows closed

Existing Wall



R20 insulating batts.

Effective R Value: ***12.9***

Air seal and increase insulation levels using either internally or using an EIFS (Exterior Insulation Finish System).

Water Damage

Window Retrofit

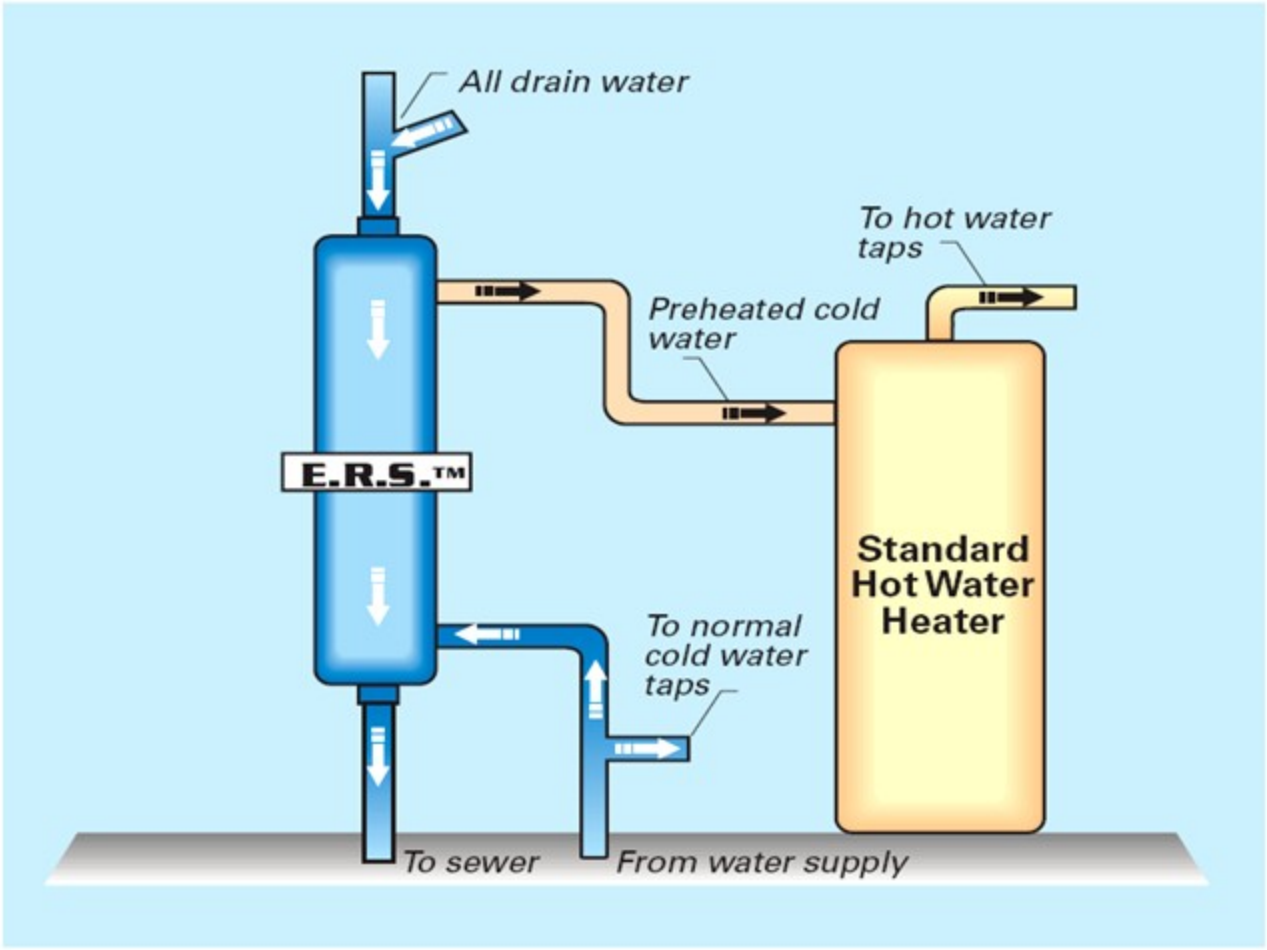
Existing windows are clear, double pane, with metal spacers, and a wood frame.

Weather-stripping the windows has been attempted but with little success.

Estimated average window U value: 3.2 W/m^2K

Estimated average window SHGC: 0.67

Wastewater Heat Recovery



Solar Water Heating

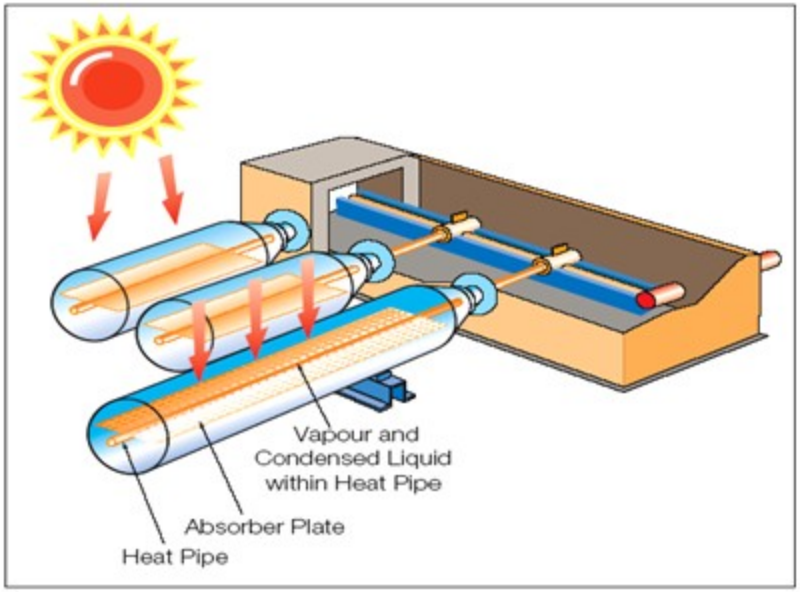


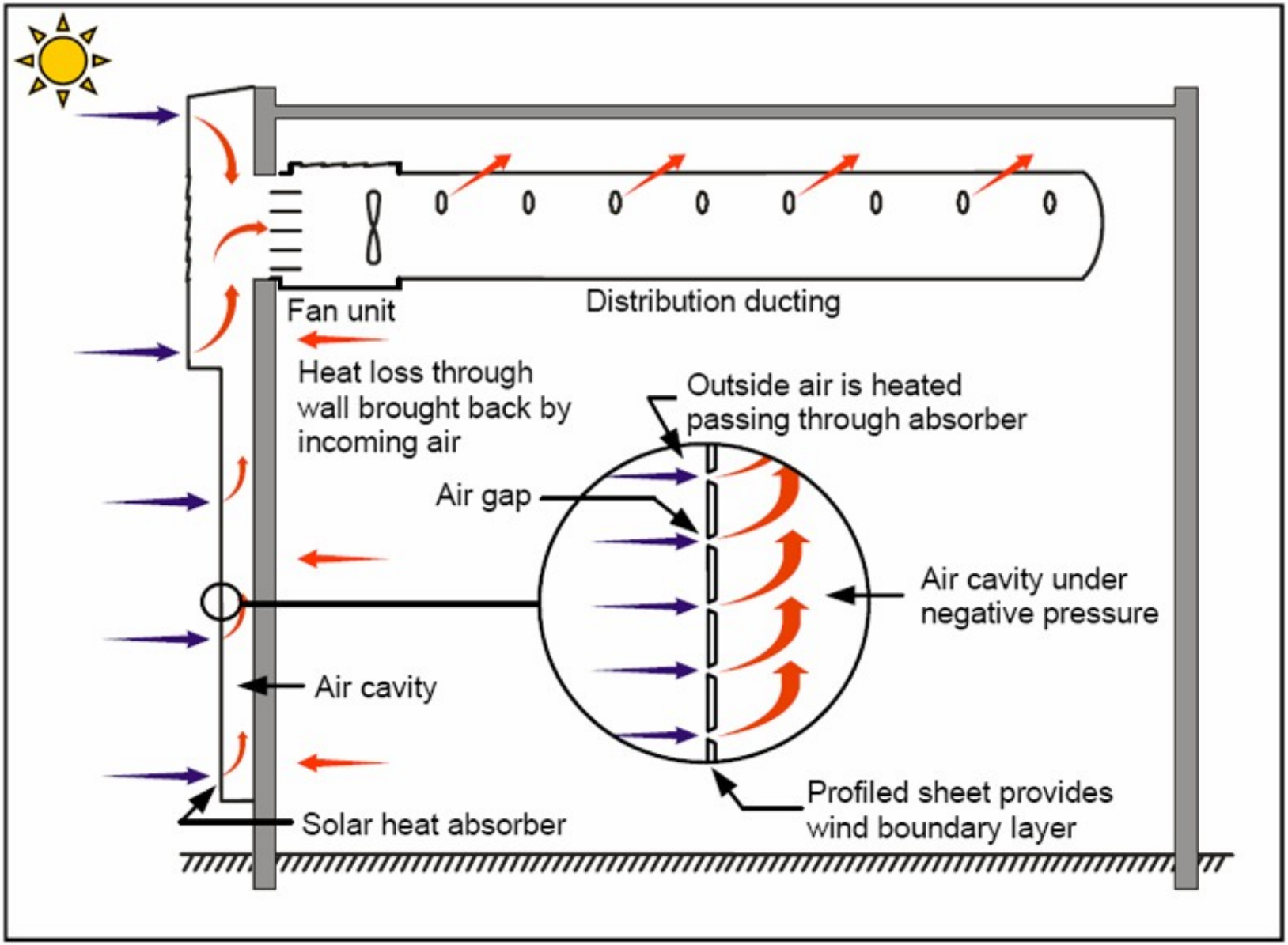
Figure 1:
Evacuated Tube Solar Collector in Tibet, China.

Photo Credit:
Alexandre Monarque

Evacuated Vacuum Tube Solar Collectors

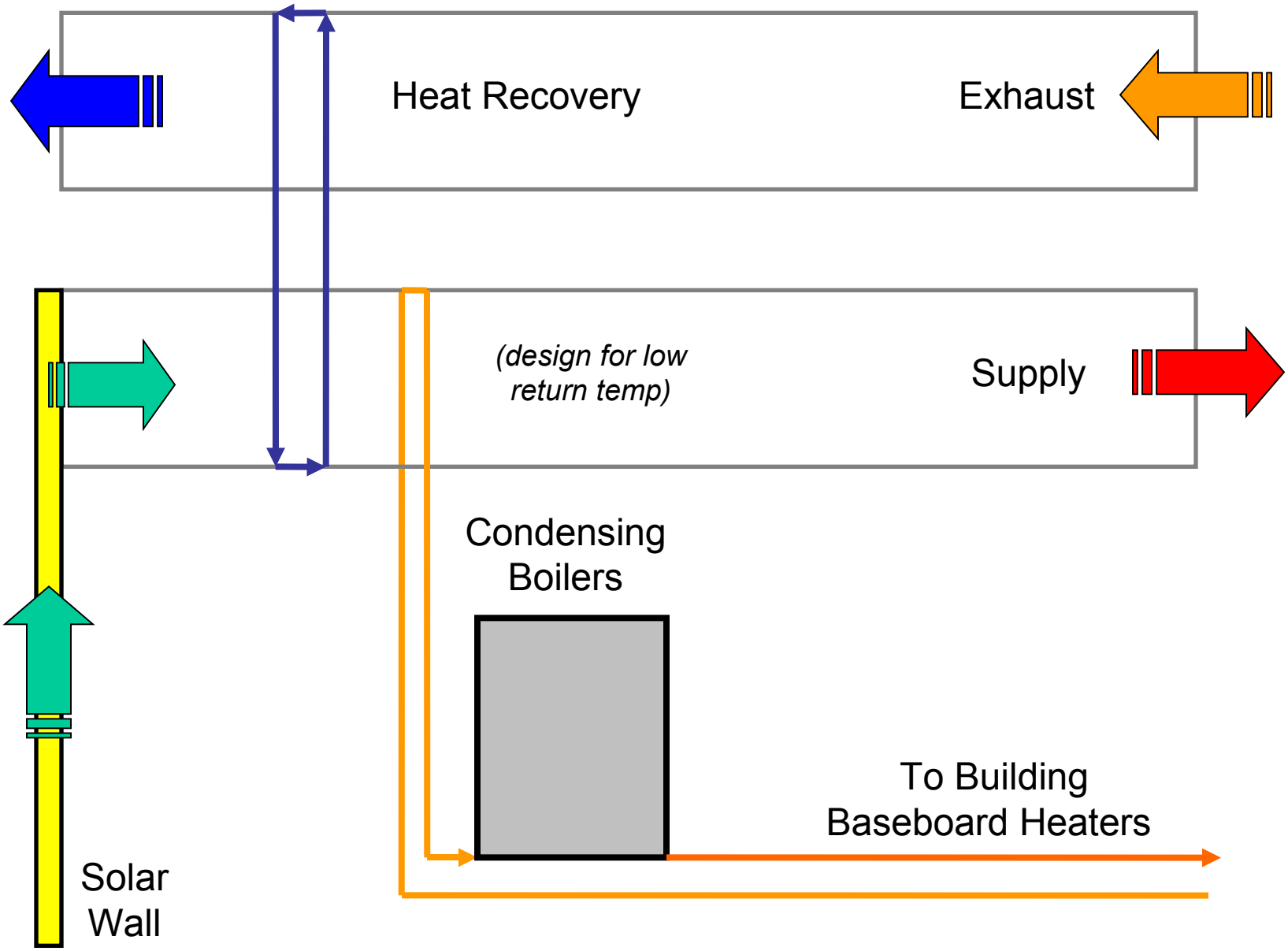
- Extremely low thermal losses to the environment
- Domestic hot water and space heating
- Typically produce water at 60°C to 80°C
- Particularly well suited for cold climates.

Solar Air Heating (SolarWall)

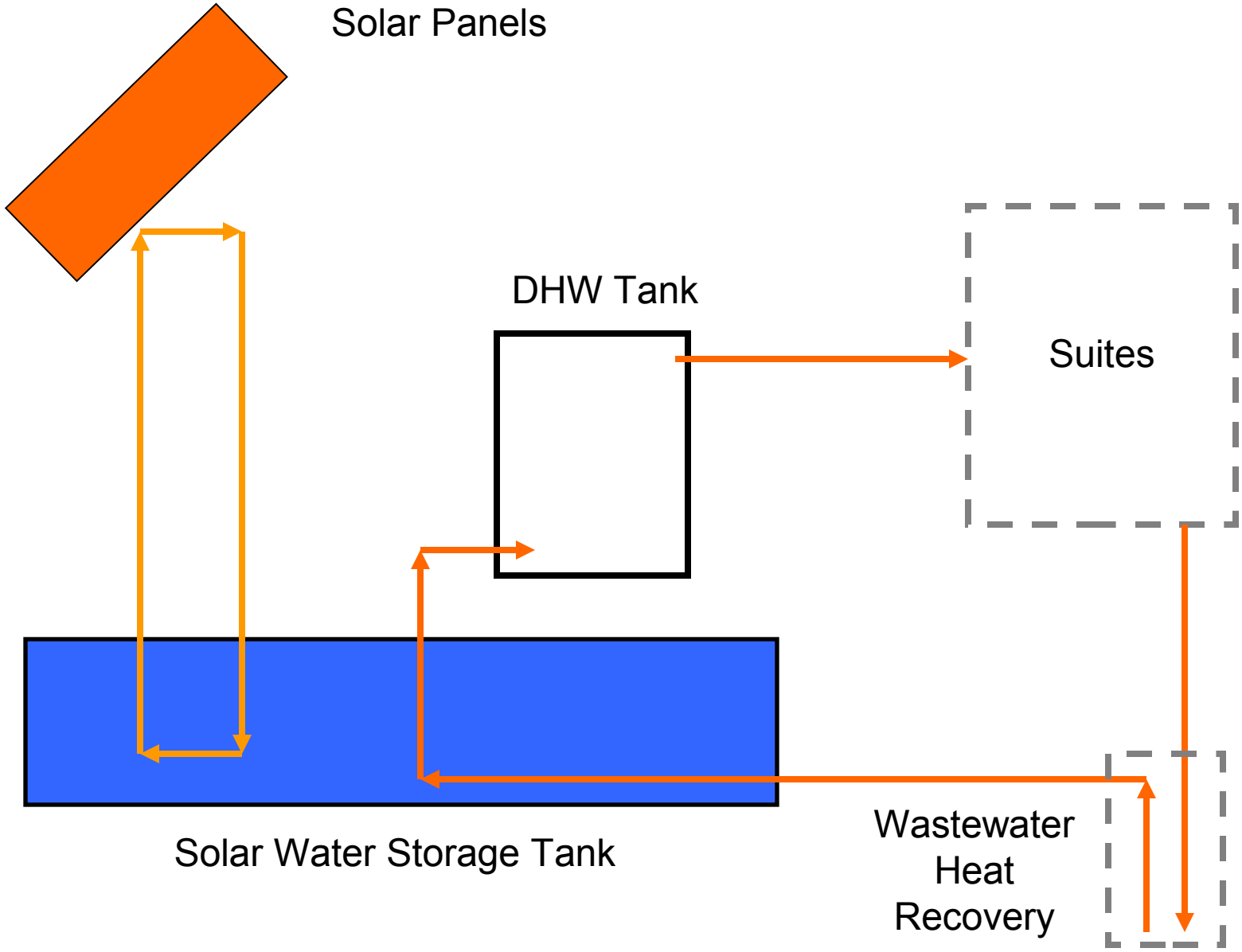


Proposed Design

HVAC


Heat Recovery
Exhaust
(design for low return temp)
Supply
Condensing Boilers
To Building Baseboard Heaters
Solar Wall

Domestic Hot Water



Other Potential Energy Savings

Space Conditioning

- **The building is too hot!** (improve building operation, thermostats are too high)
- Hot water recirculation controls (wastes energy in the summer and contributes to overheating building)

Electrical

- Block heater control
- Replacement of building appliances (washers, dryers, vending machines, kitchen fridges, etc)
- Replacing motors (elevator, fans, pumps, etc)
- Photovoltaic panels
- **Demand metering (currently no incentive to conserve)**

Water

- Reduce water consumption

Ventilation

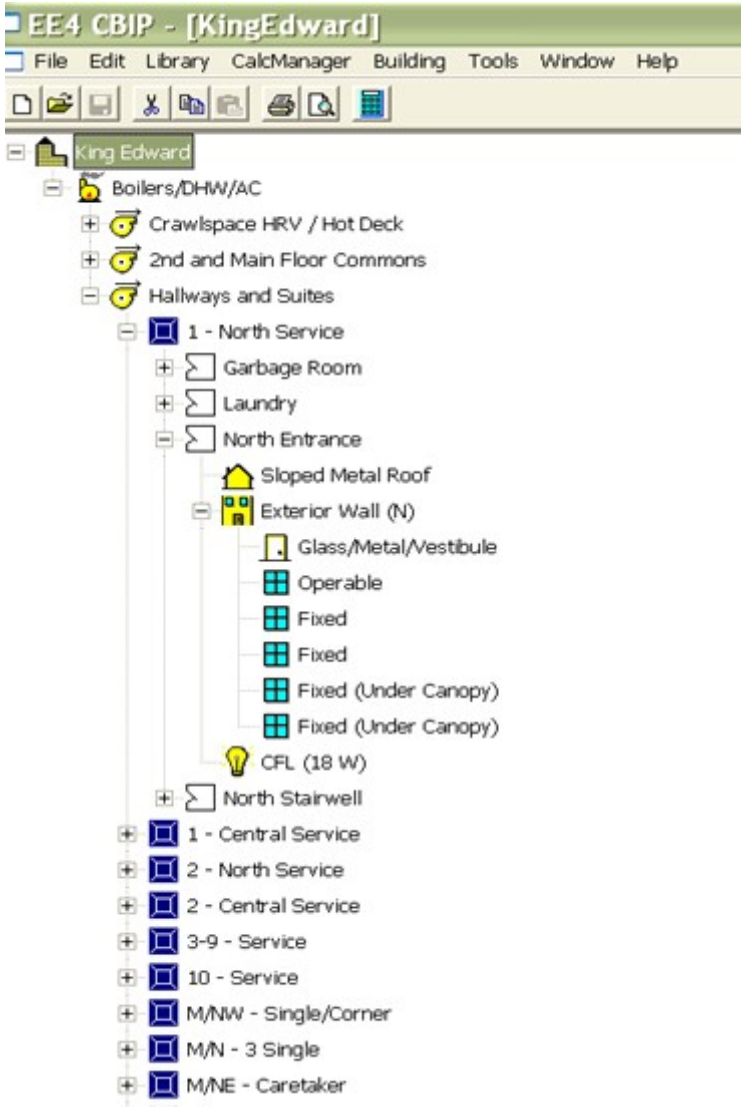
- Alternative methods of ventilating the suites

Computer Modeling

Methodology

- Create EE4 model of building (monthly results)
- Use DOE2 to generate hourly building loads from EE4 DOE file
- Create TRNSYS model of the mechanical system
  - TRNSYS model will use the hourly loads generated by the DOE2 engine
  - Convert monthly RETScreen results into hourly TRNSYS inputs
- Optimize system to achieve significant energy savings
- If Factor 10 is not reached, explore alternative energy savings

EE4



roger21NOV - DOE

Calculation	Electricity	Natural Gas	Propane	Oil	Total	Energy Cost
Proposed	1 411 472	4 463 220	0	0	5 874 692	$ 28 530
Reference	2 777 159	5 883 808	0	0	8 660 967	$ 54 811

* Values listed are in MJ

roger21NOV - Loads

System/Zone	Heating	Sensible	Latent	Airflow
System - AHU 1	392.8	191.0	32.2	22328
Zone - corridors	2.0	59.5	30.3	11224
Zone - Res. Zone 5	16.8	19.3	0.3	1621
Zone - Res Zone 2	25.5	34.5	0.5	2903
Zone - Res. Zone 1	30.5	26.5	0.5	2232
Zone - Res Zone 3	3.7	4.5	0.0	375
Zone - Res Zone 4	5.0	5.7	0.1	480
Zone - Res Zone 6	14.6	16.6	0.2	1398
Zone - Res Zone 7	2.3	2.3	0.0	195
Zone - Res Zone 8	3.1	3.0	0.0	249
Zone - Res Zone 9	3.4	3.6	0.0	302
Zone - Res Zone 10	2.3	2.5	0.0	211
Zone - Res Zone 11	3.1	2.8	0.0	236
Zone - Res Zone 12	2.9	2.9	0.0	247
Zone - Res Zone 13	1.9	2.5	0.0	211
Zone - Res Zone 14	2.6	3.0	0.0	248
Zone - Comm Zone 17	0.7	0.7	0.0	103

* Heating and Cooling values are in kW * Airflows are in L/s

RETScreen

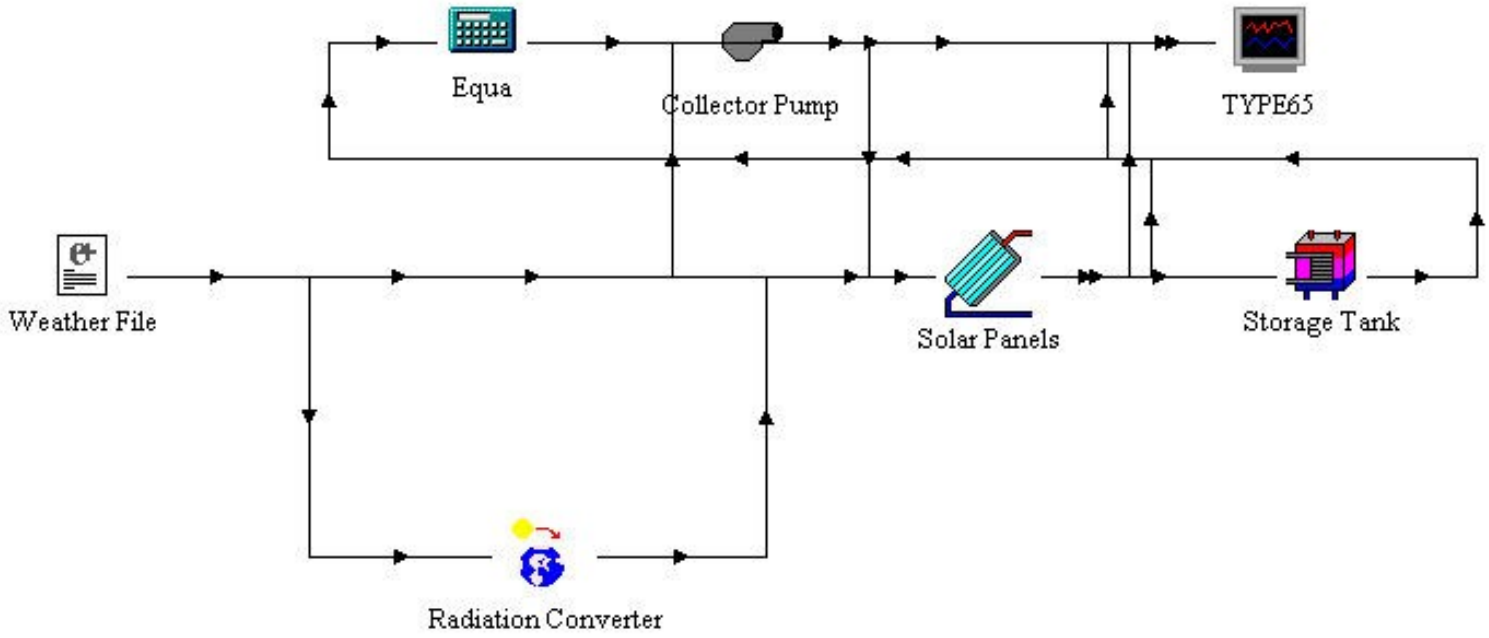
RETScreen® Energy Model - Solar Water Heating Project

Training & Support

Site Conditions		Estimate	Notes/Range
Project name		DHW	See Online Manual
Project location		Saskatoon, SK	
Nearest location for weather data		Saskatoon, SK	Complete SR&HL sheet
Annual solar radiation (tilted surface)	MWh/m²	1.77	
Annual average temperature	°C	2.0	-20.0 to 30.0
Annual average wind speed	m/s	4.6	
Desired load temperature	°C	55	
Hot water use	L/d	20,000	
Number of months analysed	month	3.50	
Energy demand for months analysed	MWh	121.38	

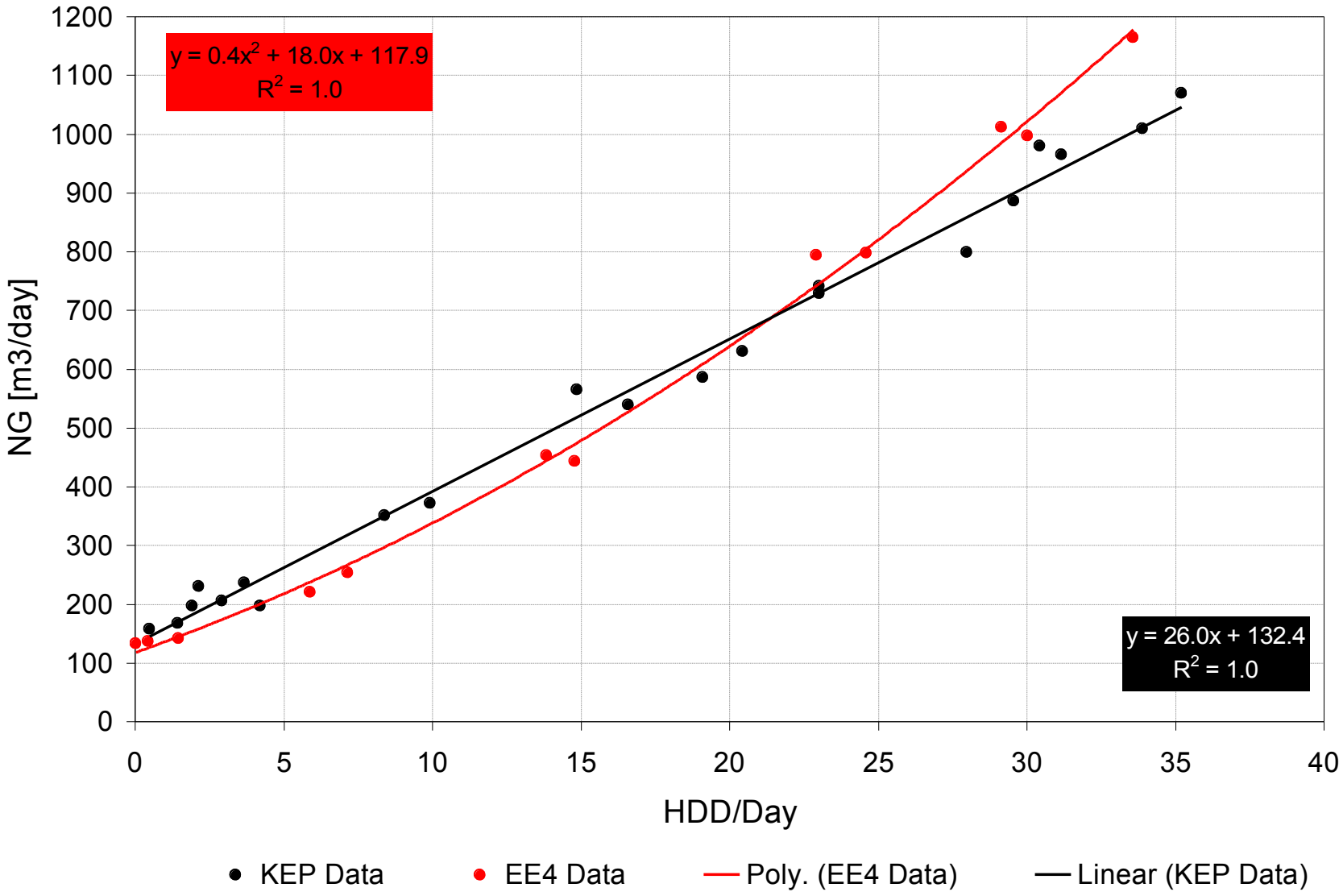
System Characteristics		Estimate	Notes/Range
Application type		Service hot water (with storage)	
Base Case Water Heating System			
Heating fuel type	-	Natural gas - m³	
Heating system seasonal efficiency	%	70%	55% to 350%
Solar Collector			
Collector type	-	Glazed	See Technical Note 1
Solar water heating collector manufacturer		ABC S.A.	See Product Database
Solar water heating collector model		model XYZ	
Area per collector	m²	4.00	1.00 to 5.00
Fr (tau alpha) coefficient	-	0.85	0.50 to 0.90
Fr UL coefficient	(W/m²)/°C	11.56	3.50 to 6.00
Suggested number of collectors		56	
Number of collectors		56	
Total collector area	m²	224.0	
Storage			
Ratio of storage capacity to coll. area	L/m²	50.0	37.5 to 100.0
Storage capacity	L	11,200	

TRNSYS Simulation of Solar Water Heating



Model Matching (EE4)

EE4 Model and Actual Natural Gas Consumption

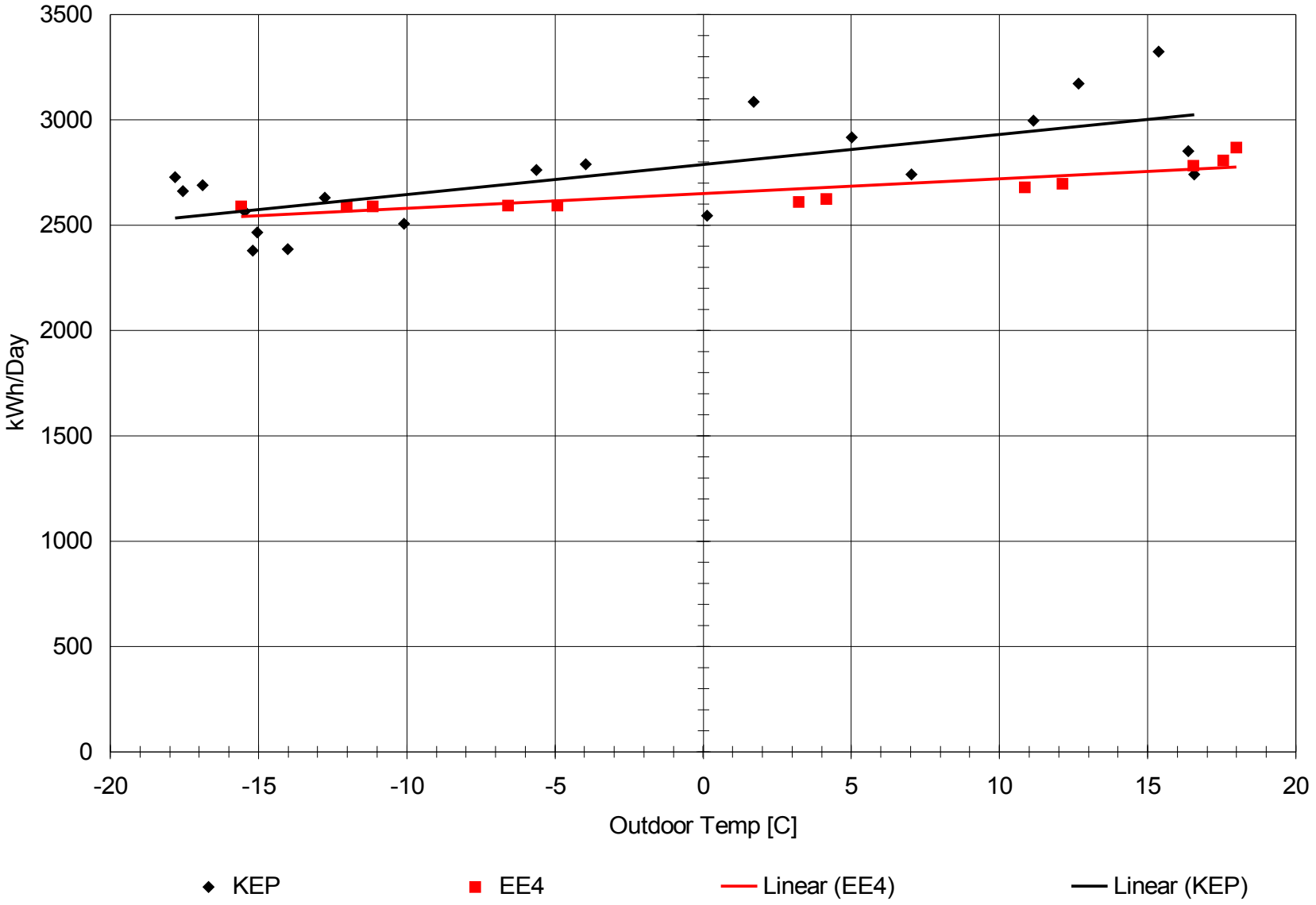


Note: ***Boiler Efficiency is constant in EE4. In reality it will decrease during low HDD and increase during high HDD.***

Total Consumption

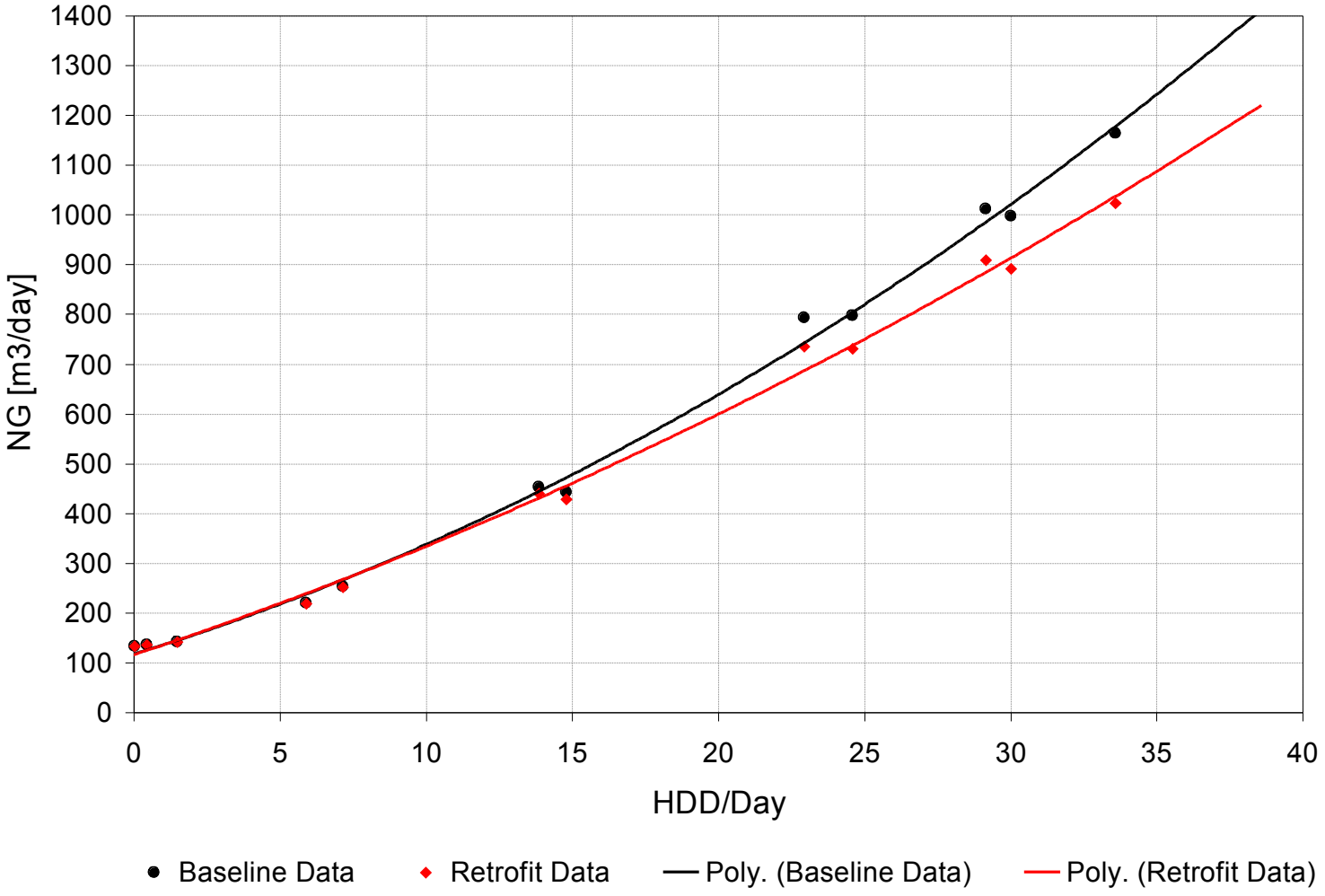
HDD in 2002:	6,045 HDD/Yr
2002 Actual Consumption:	208,000 m^3
HDD in 2003:	5,789 HDD/Yr
2003 Actual Consumption:	197,000 m^3
HDD in EE4 Weather:	**5,646 HDD/Yr**
EE4 Total Consumption:	**198,000 m^3**

Model Matching (EE4) - Electricity



Preliminary Results

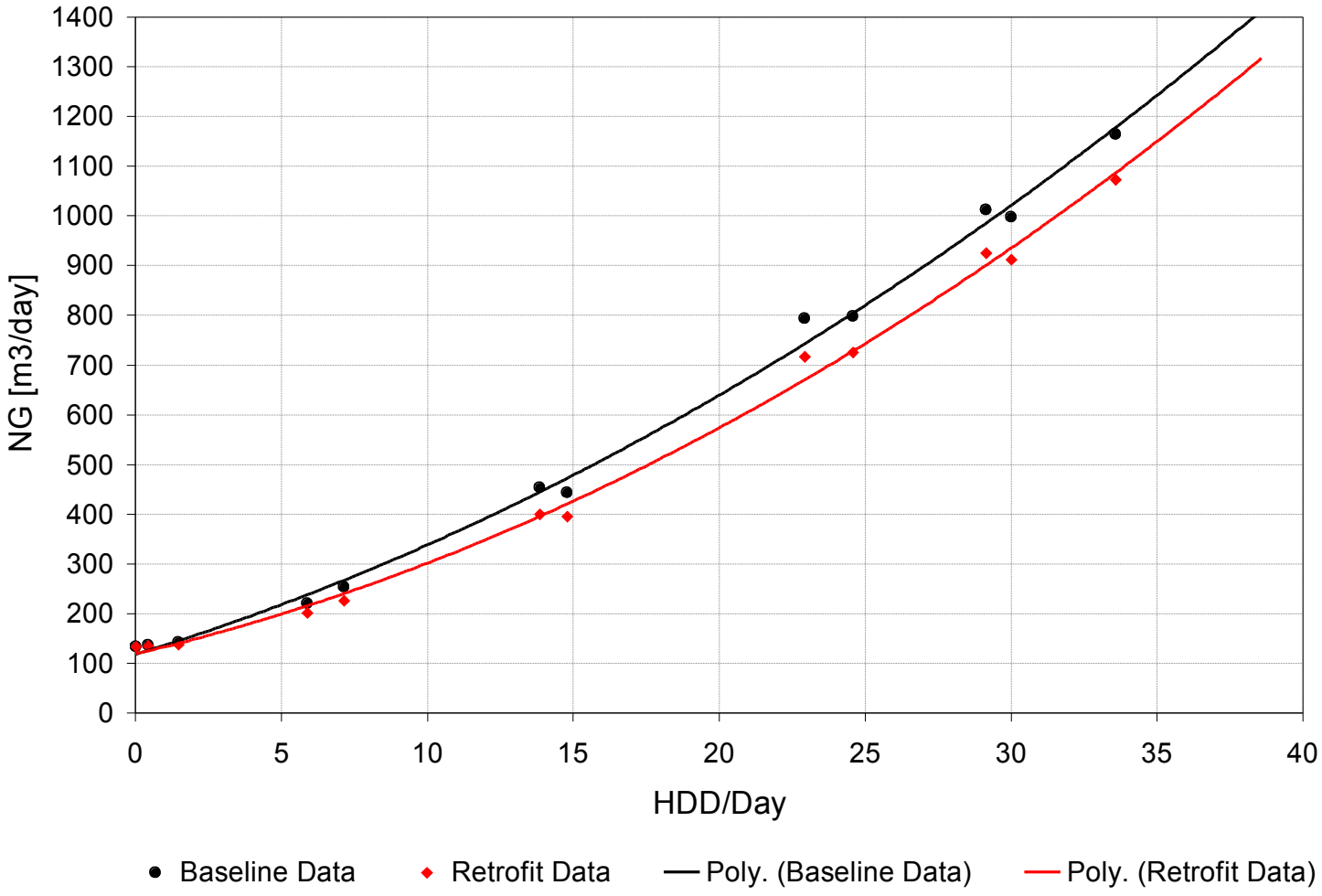
85% Effective Heat Recovery



7.6% Decrease in Natural Gas Consumption

Add R12 to Exterior Walls

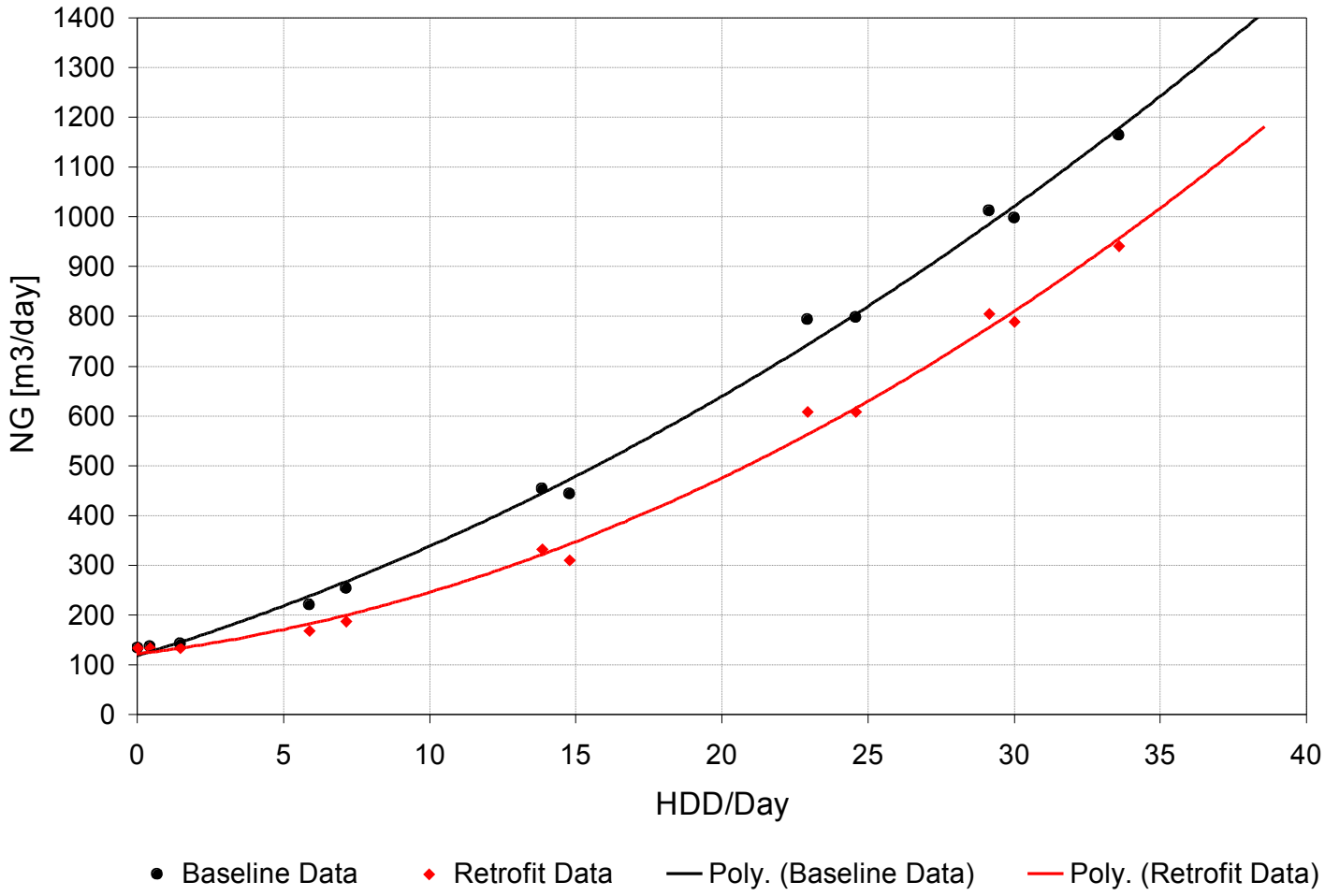
Total Wall Value: R25 (RSI 4.4)



8.6% Decrease in Natural Gas Consumption

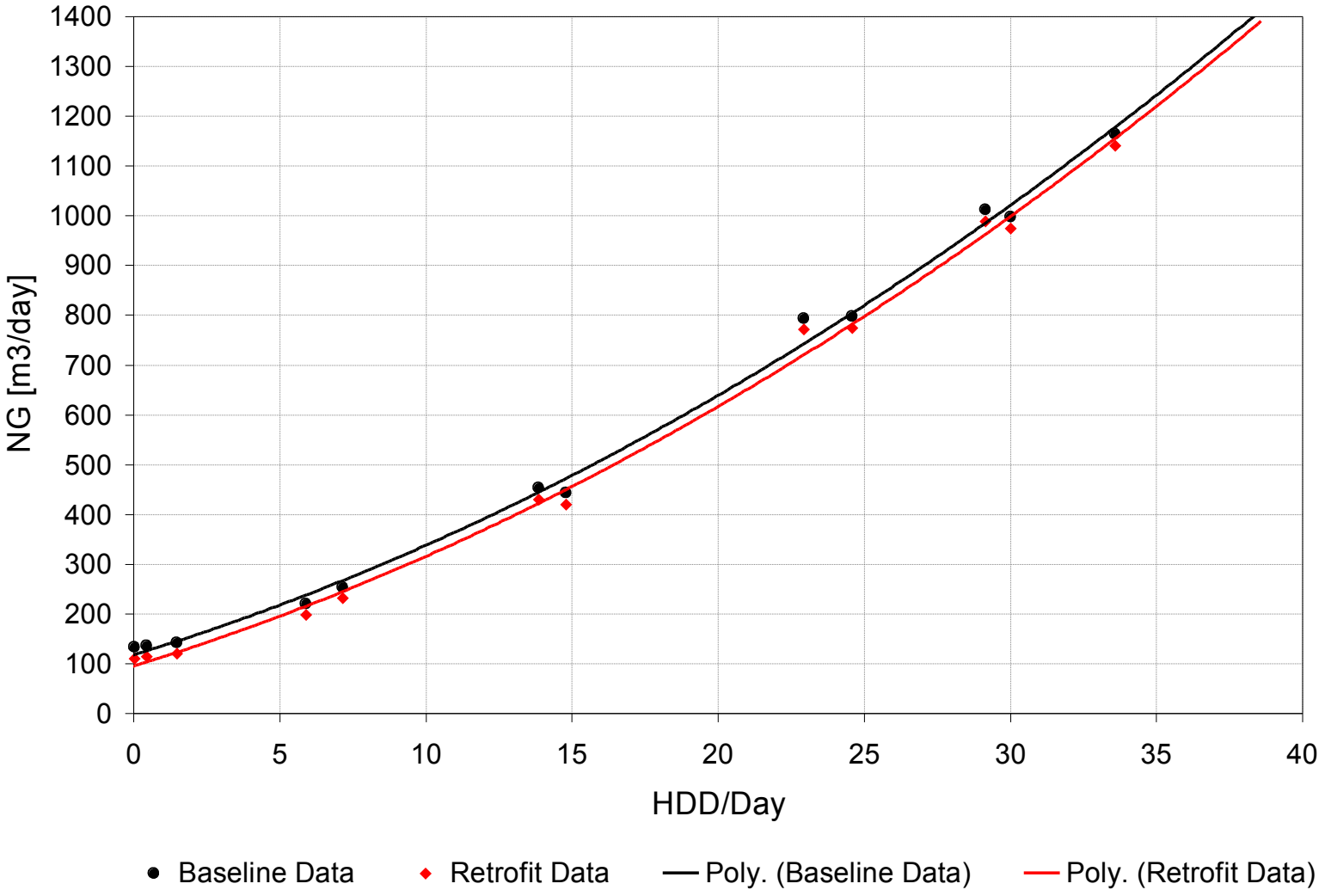
Reduce Infiltration to 0.35 L/s/m²

½ Current infiltration but still not as tight as new construction (0.25 L/s/m²)



21.3% Decrease in Natural Gas Consumption

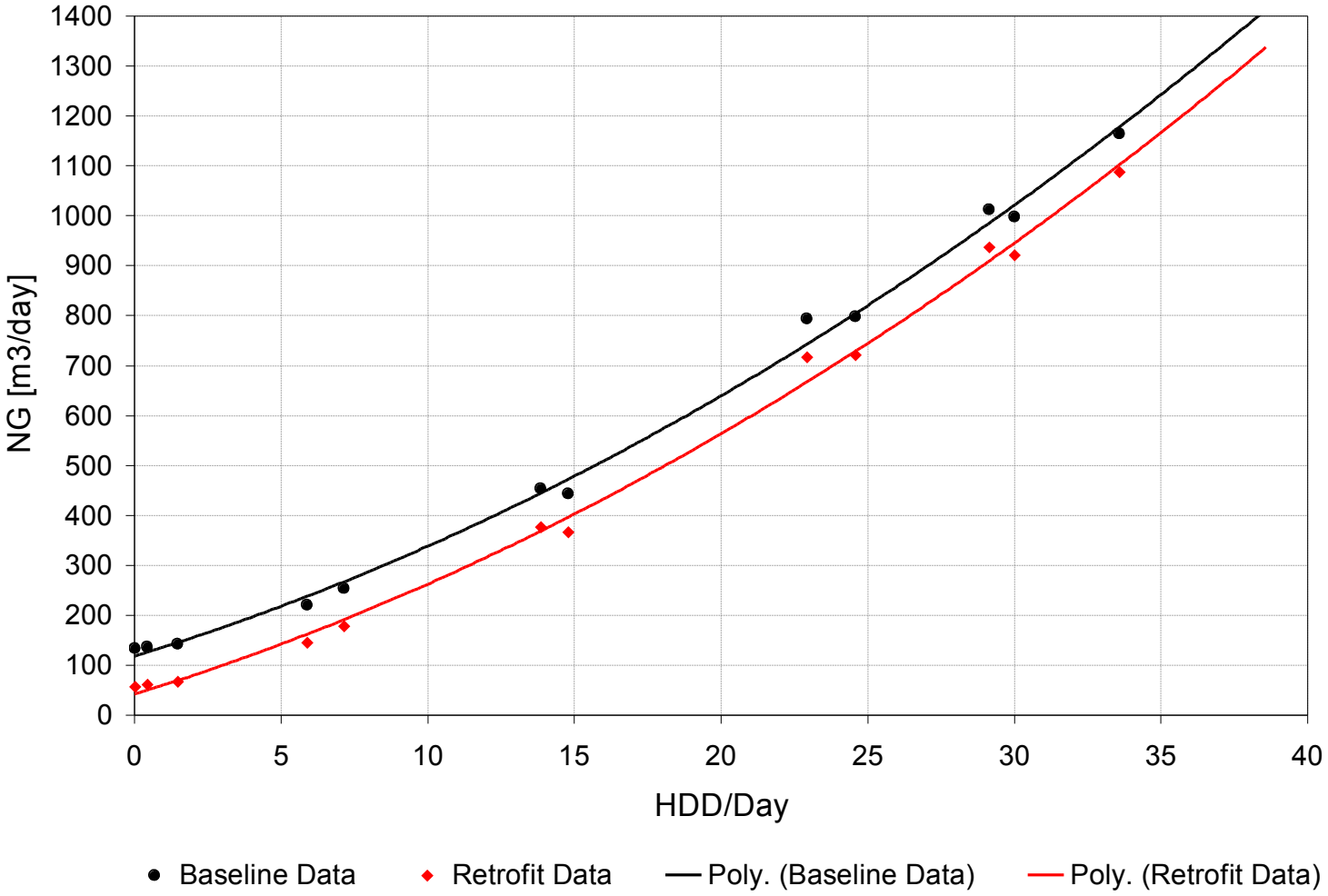
Condensing Water Heaters, 85% Efficient



4.1% Decrease in Natural Gas Consumption

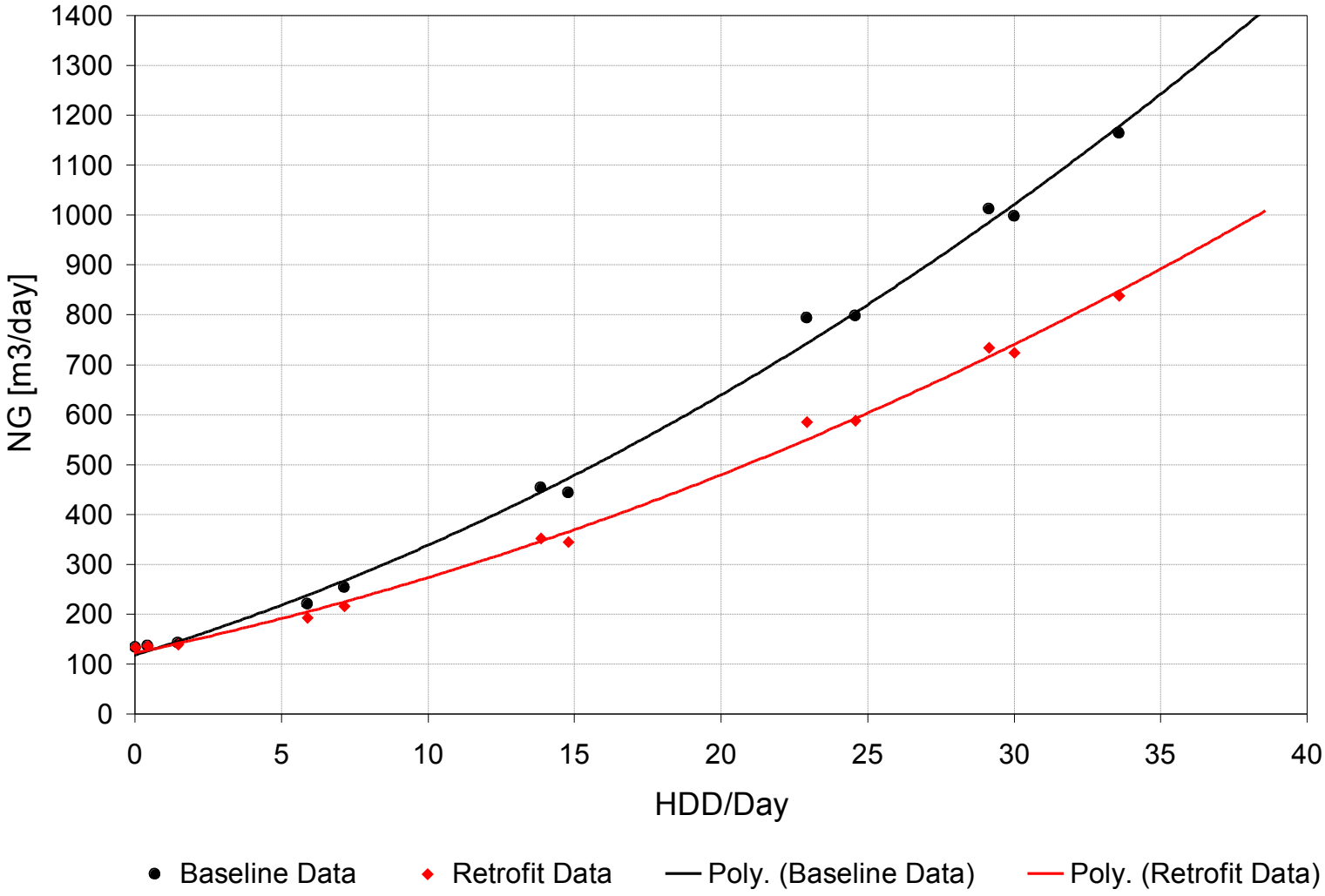
Reduce DHW Load by 80%

Combination of solar water heating, wastewater heat recovery, and water conservation.



14.0% Decrease in Natural Gas Consumption

Condensing Boilers, 95% Efficient

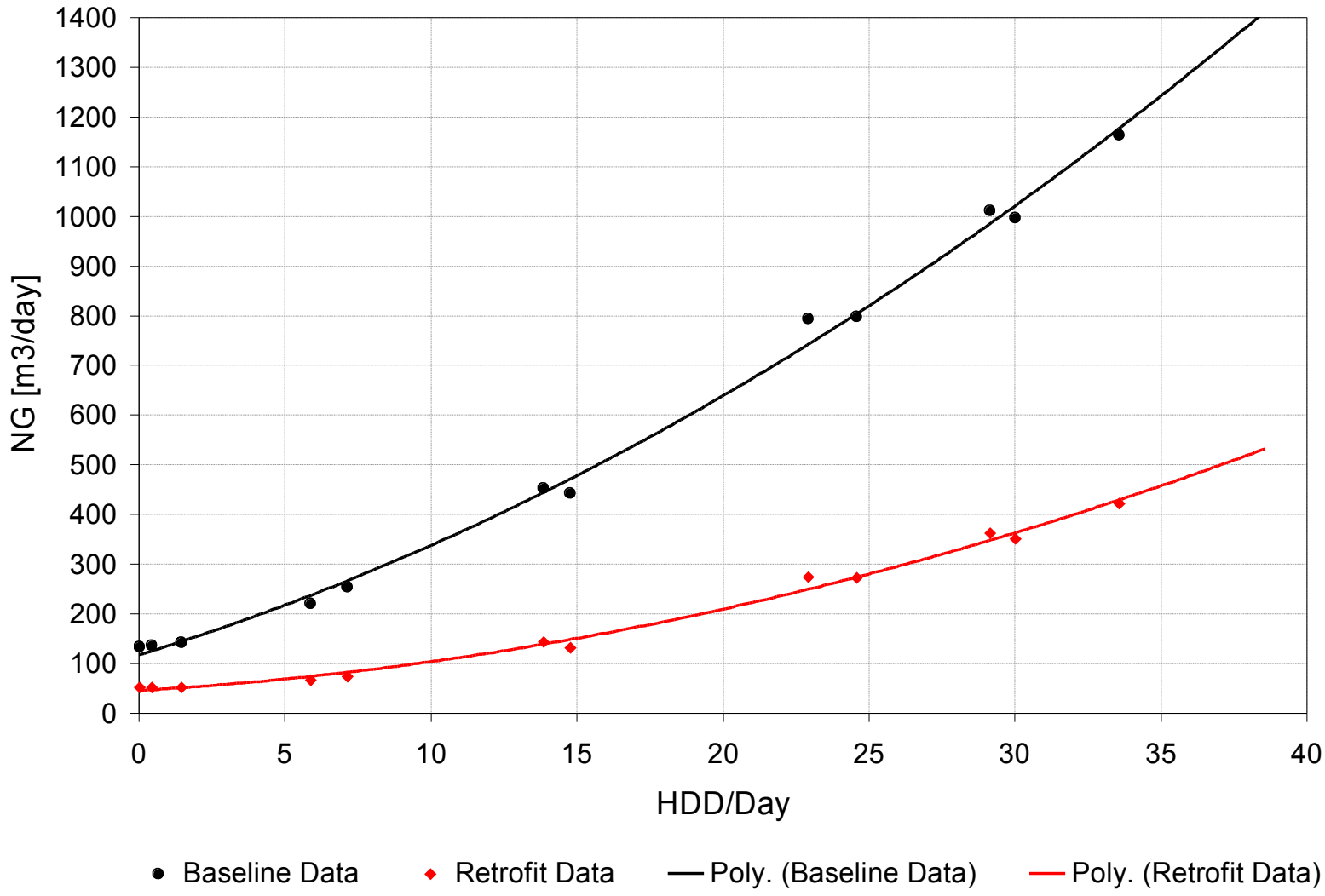


23.9% Decrease in Natural Gas Consumption

Summary:

85% effective heat recovery	7.6%
Additional R12	8.6%
Infiltration of 0.35 L/s/m^2	21.3%
Condensing Water Heaters 85%	4.1%
80% reduction in DHW load	14.0%
95% efficient boilers	23.9%
Sum:	79.5%

Total



65% Decrease in Natural Gas Consumption **44% Decrease in Total Energy Consumption**

Economics

Is it Possible?

- Natural gas rates increased 40% this winter
- Goldman Sachs Group Inc raised its oil forecast for 2006 from $45/barrel to $68 **(34%)** (Aug 17, 05)
- The most conservative estimates for peak oil is 2020 (most believe it has already occurred)

How does one plan for a 10, 20, 50 year payback period without knowing the future price of energy?

- Global sulfur dioxide trade is $7 Billion
- The global carbon trade has just begun and is already over $6 Billion (EU and USA)

Annual Savings and Income

Current annual GHG emissions: 1,344 tonnes

Factor 10 annual GHG emissions: 134 tonnes

At current energy prices & if carbon dioxide was valued at $60/tonne:

- **Carbon Trading Value: $72,550 /yr**
- **Energy Savings: $145,857 /yr**

- Total: $218,407 /yr

- Annual Rent: ~ $552,000/yr (*40%*)

Factor 10?

- Canada has stated it will reduce its greenhouse gas emissions to 6% below 1990 levels

- The City of Saskatoon has committed to a community target of 6% below 1990 levels

- GHG emissions increased 24% between 1990 and 2003

Smog Above Saskatoon?

Retrofitting a Multi-Unit Residential Building To Reduce Purchased Energy by a ***Factor of 10***

Questions?