Diseño Innovativo de Techo Solar Adaptable al Entorno, para Calefacción y Refrigeración de Viviendas a Costos Competitivos

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Introduction

- Roof solar collectors: 50 year
  - ☹High investment.
  - ☹Few designs proposing substantial changes to the **basic roof concept**
- Innovative Solar Roof Design
- **Strong Synergies Roof ↔ Collector ➔**
  - ☺ Cost ≅ Conventional roof
  - ☺ Heating & Cooling
  - ☺ Configurable by water redistribution

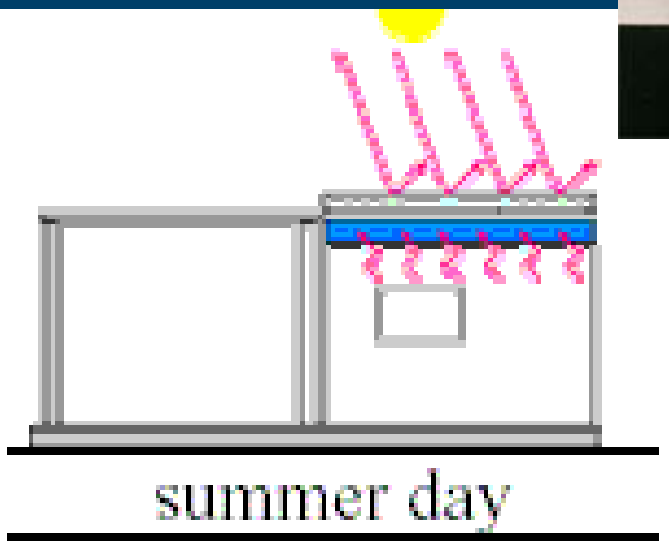
The Conventional Roof Goals…

- **FIXED** roof
- **One Impervious** external layer
- **Many** insulation internal layers
- **ADIABATIC** roof ➔ = Building Design

We intend the greatest configurable ➔

most adaptable to the Environment

Configurable Skytherm Design

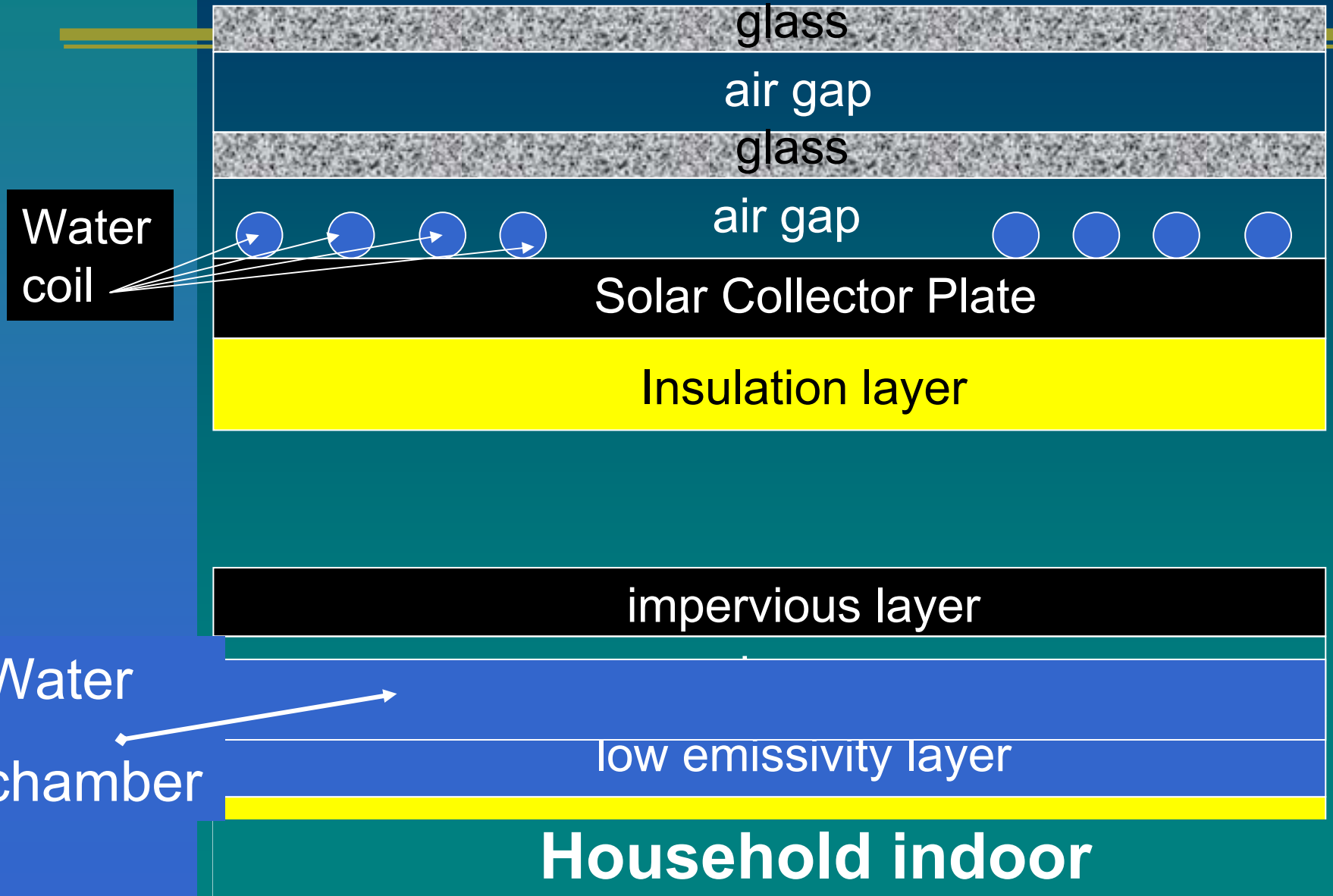


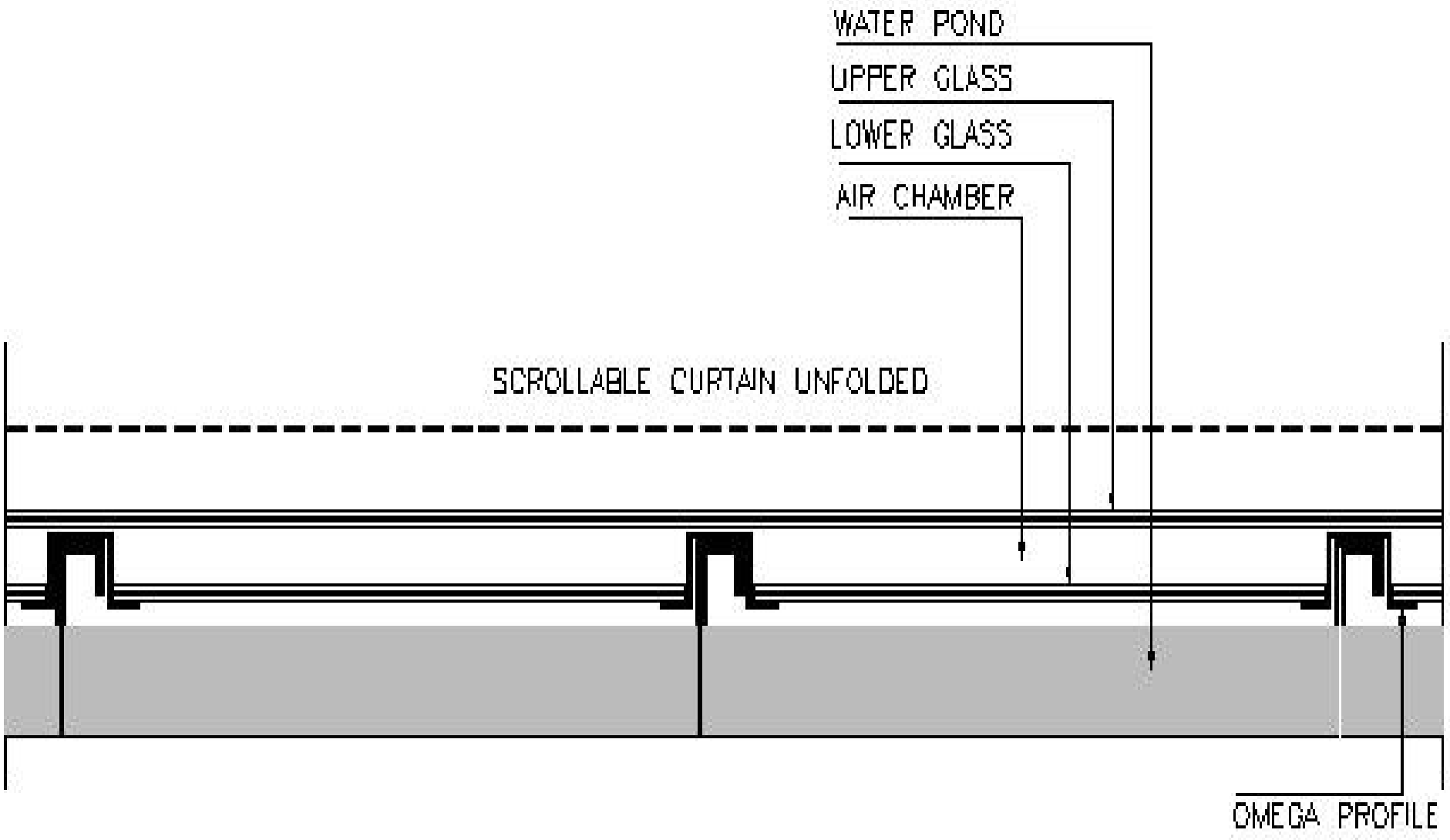
Harold Hay

The New Roof Design

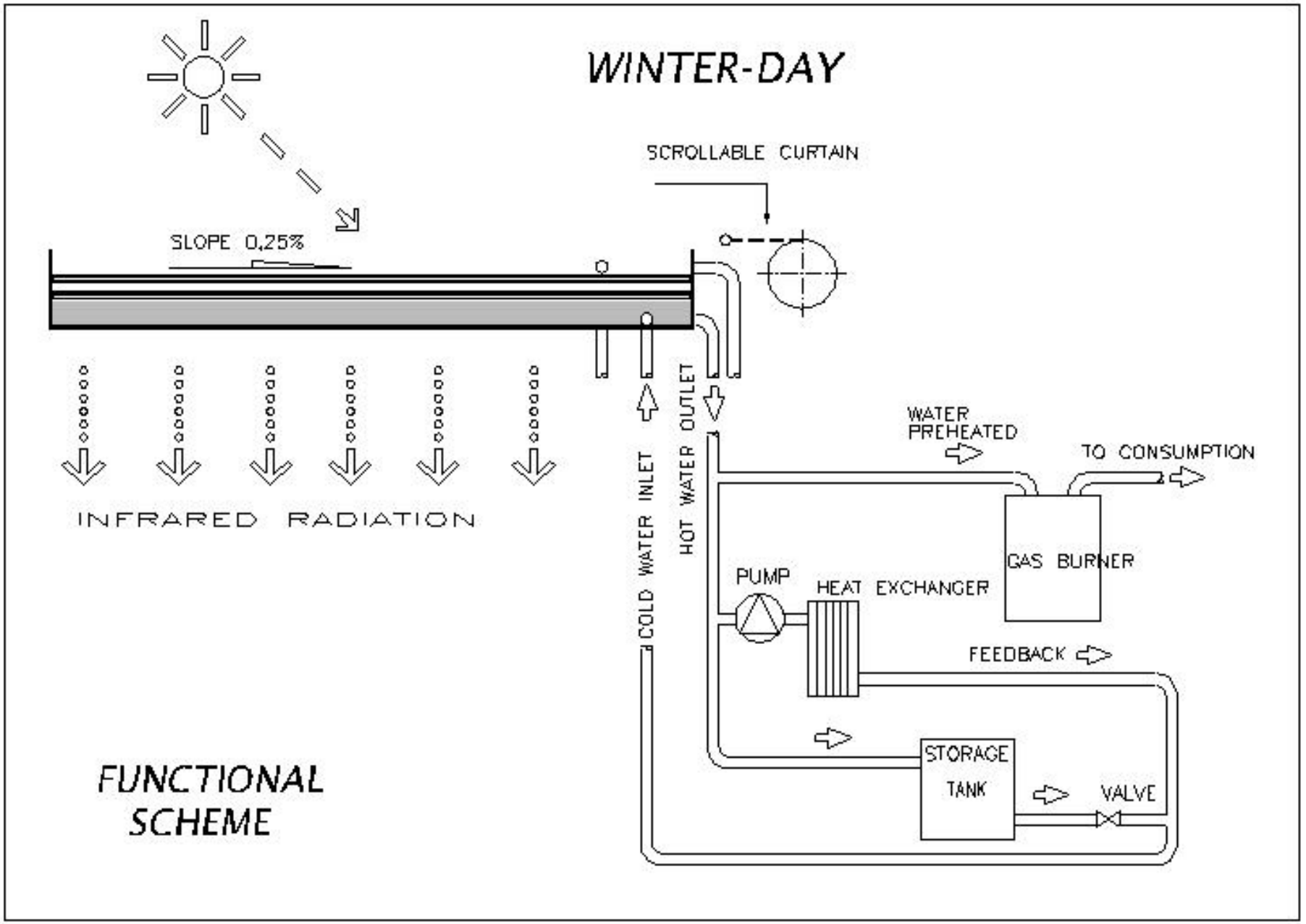
Configurable by water redistribution

Roof + Collector Synergies

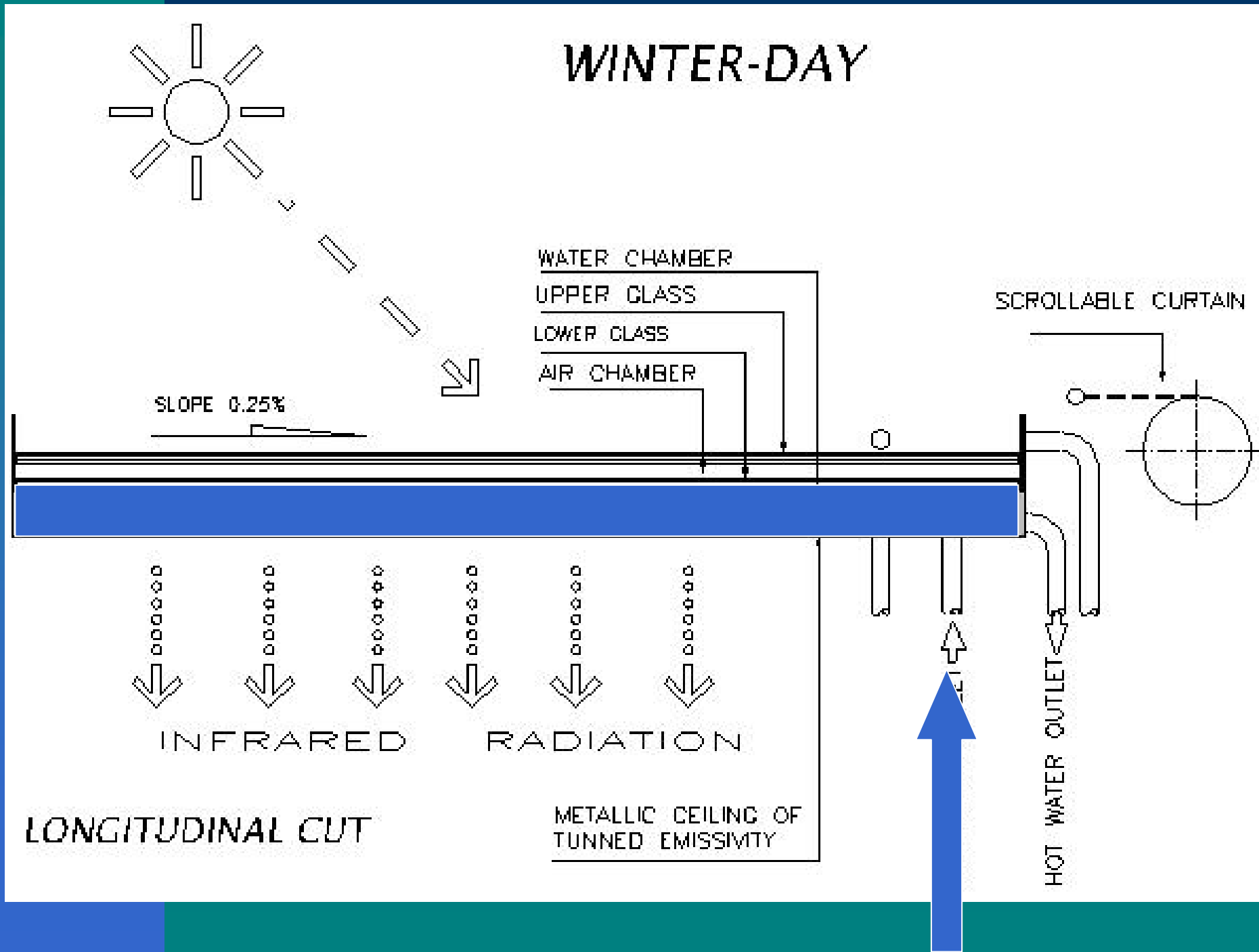


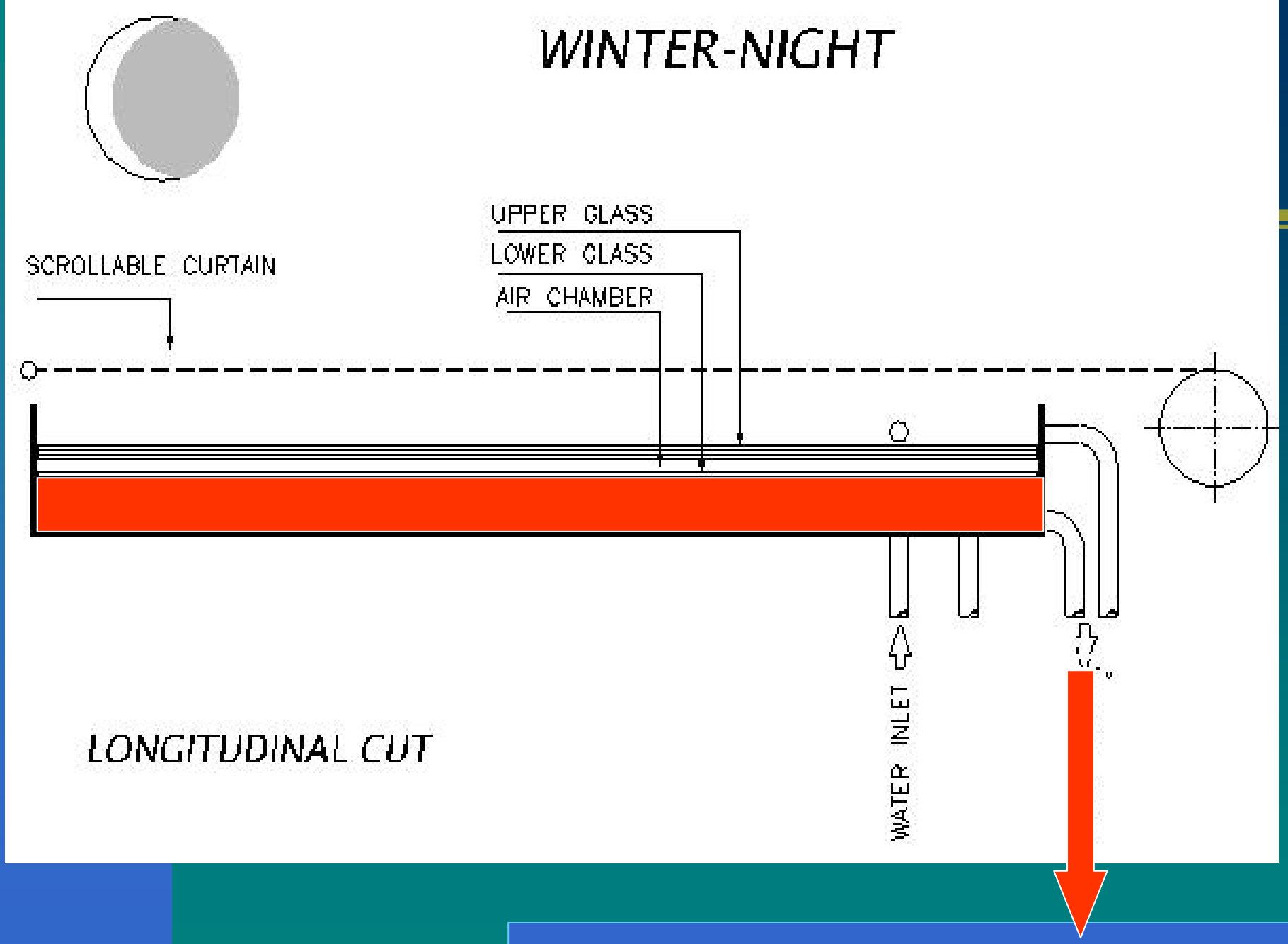


TRANSVERSAL CUT


WINTER-DAY
SCROLLABLE CURTAIN
SLOPE 0,25%
INFRARED RADIATION
COLD WATER INLET
HOT WATER OUTLET
WATER PREHEATED
TO CONSUMPTION
GAS BURNER
PUMP
HEAT EXCHANGER
FEEDBACK
STORAGE TANK
VALVE
FUNCTIONAL SCHEME

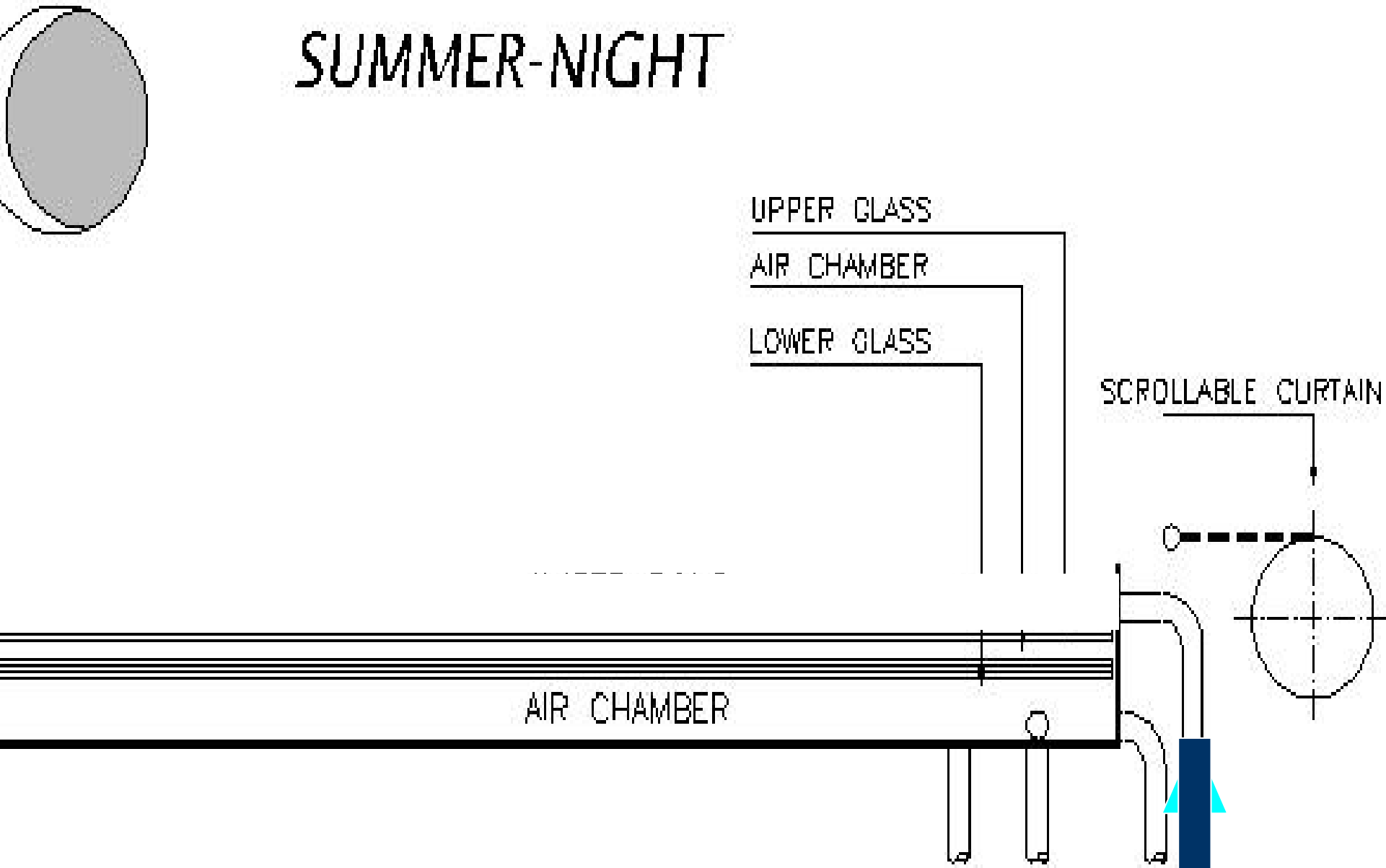
Roof Configurations


WINTER-DAY
WATER CHAMBER
UPPER GLASS
LOWER GLASS
AIR CHAMBER
SCROLLABLE CURTAIN
SLOPE 0.25%
INFRARED
RADIATION
HOT WATER OUTLET
LONGITUDINAL CUT
METALLIC CEILING OF
TUNNED EMISSIVITY

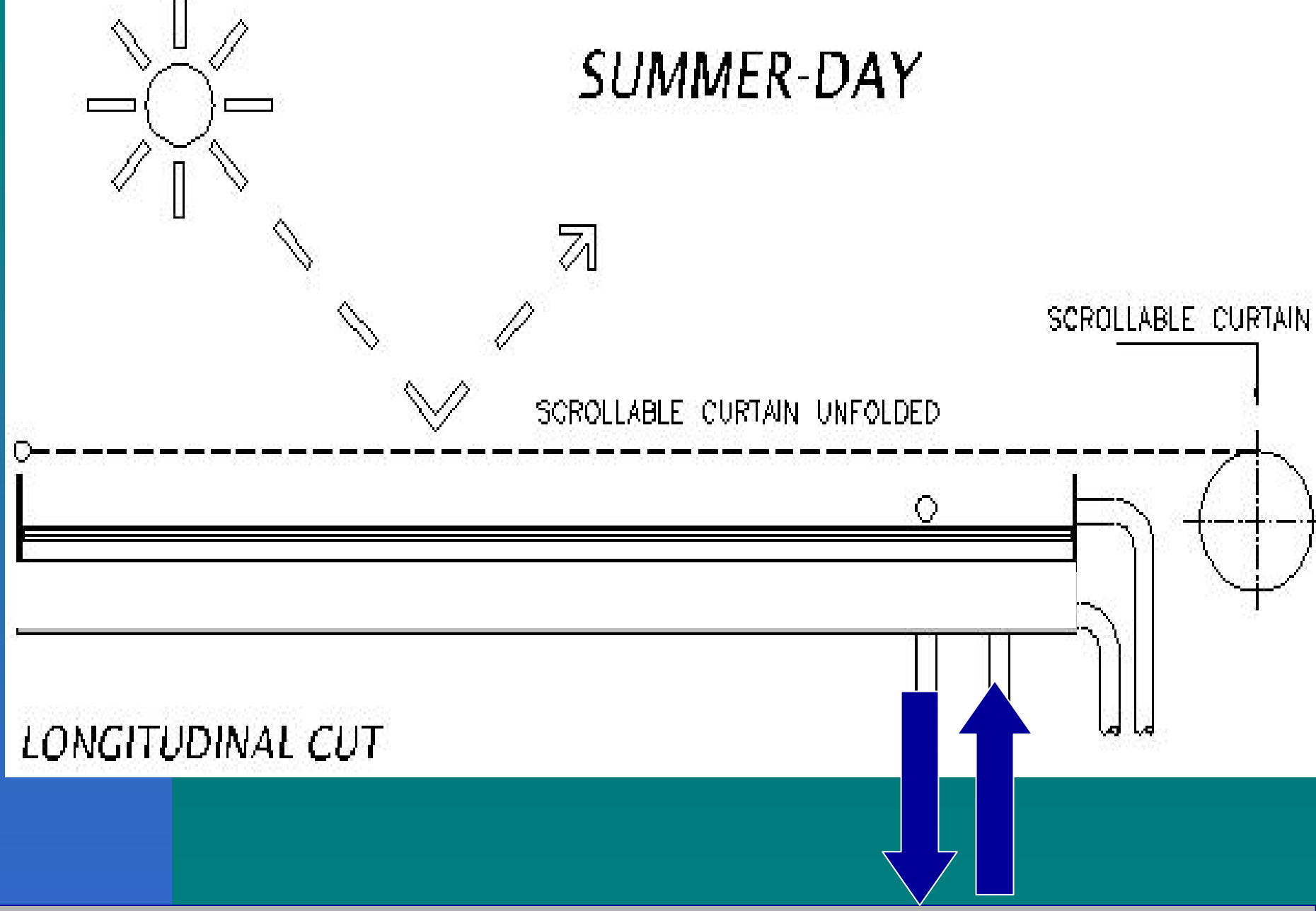


heating infloor system

SUMMER-NIGHT



LONGITUDINAL CUT



Recirculing by heating infloor system

Winter Performance (38° N)

- G''_{solar} = 140 kWh/m², A=100m², V_{water} = 5000 L
- T_{water} ➔ 70 ºC (ΔT_{water} = 33ºC), E_{day} = 0.7 GJ
- Q_{roof} ➔ 5 kW (Convection) + 35 kW (Radiation)
- U_{night} = **0.8 W/m²K**
  - 3rd Mylar layer ➔ **0.6 W/m²K**
- **Controlling T by water! :** (T_{roof} = 20ºC) ➔ Q_{loss}=1.5kW ➔26 Kg/h water

Summer Performance

- NO-Convective layout (heating from top) ➔
  - U_{day} = 0.15 W/m^{2}K ➔
  - Q_{loss} = 6 kWh/day
- Awning: sun blockage ➔ ↓ 50% heat load
- Q_{roof} (cooling) = 6 kW ➔ O.K.

Comparison of Costs

- Present good roof (U = 0.4 W/m²K, A = 100m²)
  - + Cooling System ➔ 20 U$/m²
  - + Inclination (30º) ➔ + 15%
  - ➢ Total Cost: **120 to 140 U$/m²**
- New Collector + Roof:
  - – Metallic roof: 30 U$/m²
  - – 2 Glazing: 50 U$/m²
  - – Rolling Awning: 40 U$/m²
  - ➢ Total Cost: **140 U$/m²….. ➔ 100 U$/m²**

Energy Saving

- Present house in Stockholm:
  - Annual Heating: 15,000 kWh = USD 3,000
  - No Cooling
  - Total annual: **USD 3,000**
- Present house in Madrid:
  - Annual Heating: 7,000 kWh = USD 1,200
  - Annual Cooling: 1,500 kWh = USD 300
  - Total annual: **USD 1,500**
- 1,000M houses (OCDE) ➔ **2,000 MUSD/y**

Conclusions

- **Huge Saving in Heating and Cooling**
- **Low Investment**
- **Standard Technologies**
- New Buildings Paradigm: ***Configurable!!***
  - New Synergies (≠ Collector Efficiency)
  - Inclined roof → High latitude locations

A New Design of A Low-Cost Configurable Awning for Roof Thermal Gain

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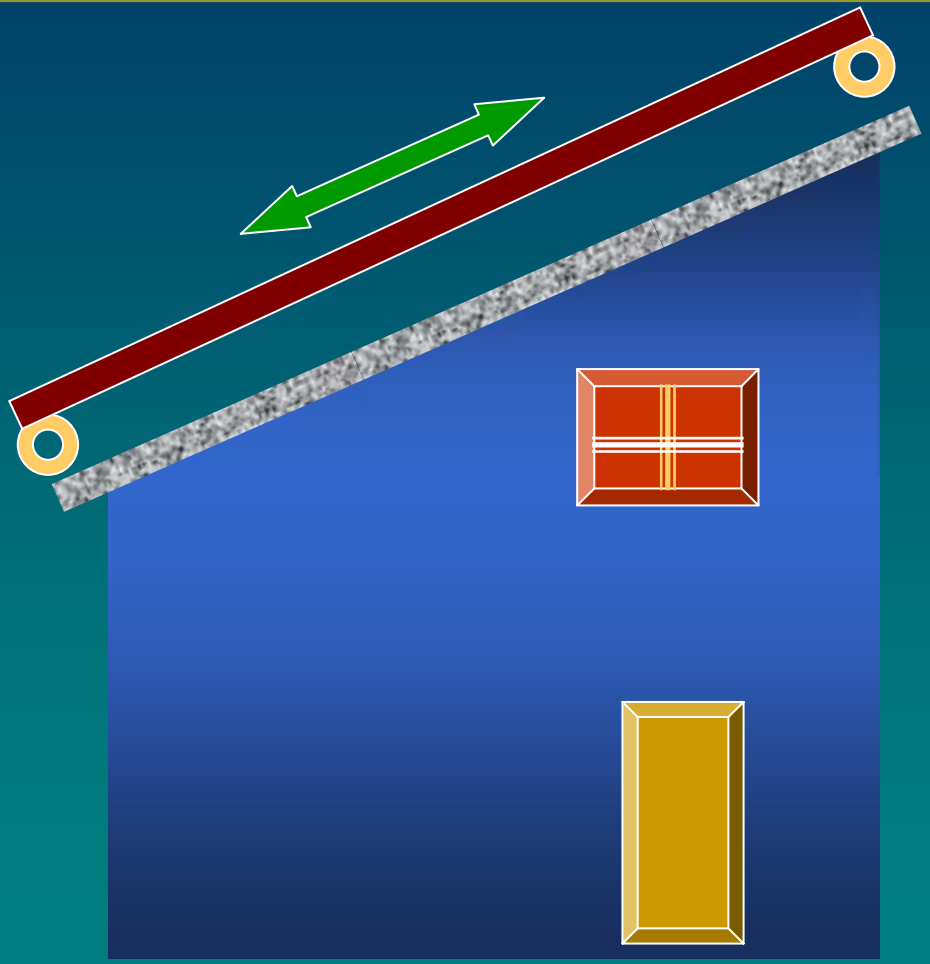
Introduction

- A universal scrollable awning design ➔
- Transform any roof in a new configurable:
  - ☺ Dealing with summer heating
  - ☺ Dealing with winter cooling
  - ☺ Dealing with snow
- Thermal gain obtained was simulated ➔
- Significant improvements were found.

Discuss of present Rolling Awning Design

- Are complex, Expensive or Unreliable
  - Rack and pinion systems with guides
  - Blind system with adjustable fins
- Unfold path fails → System fails →
- Present (FIXED) roofs comes from centuries.
- Fixed roofs cannot deal with snow:
  - ☹ Snow has very poor solar absortivity
  - ☹ Causes a high heat loss
  - ☹ Causes a weight load
  - ☹ Higher slopes → higher investments.

The New Rolling Awning



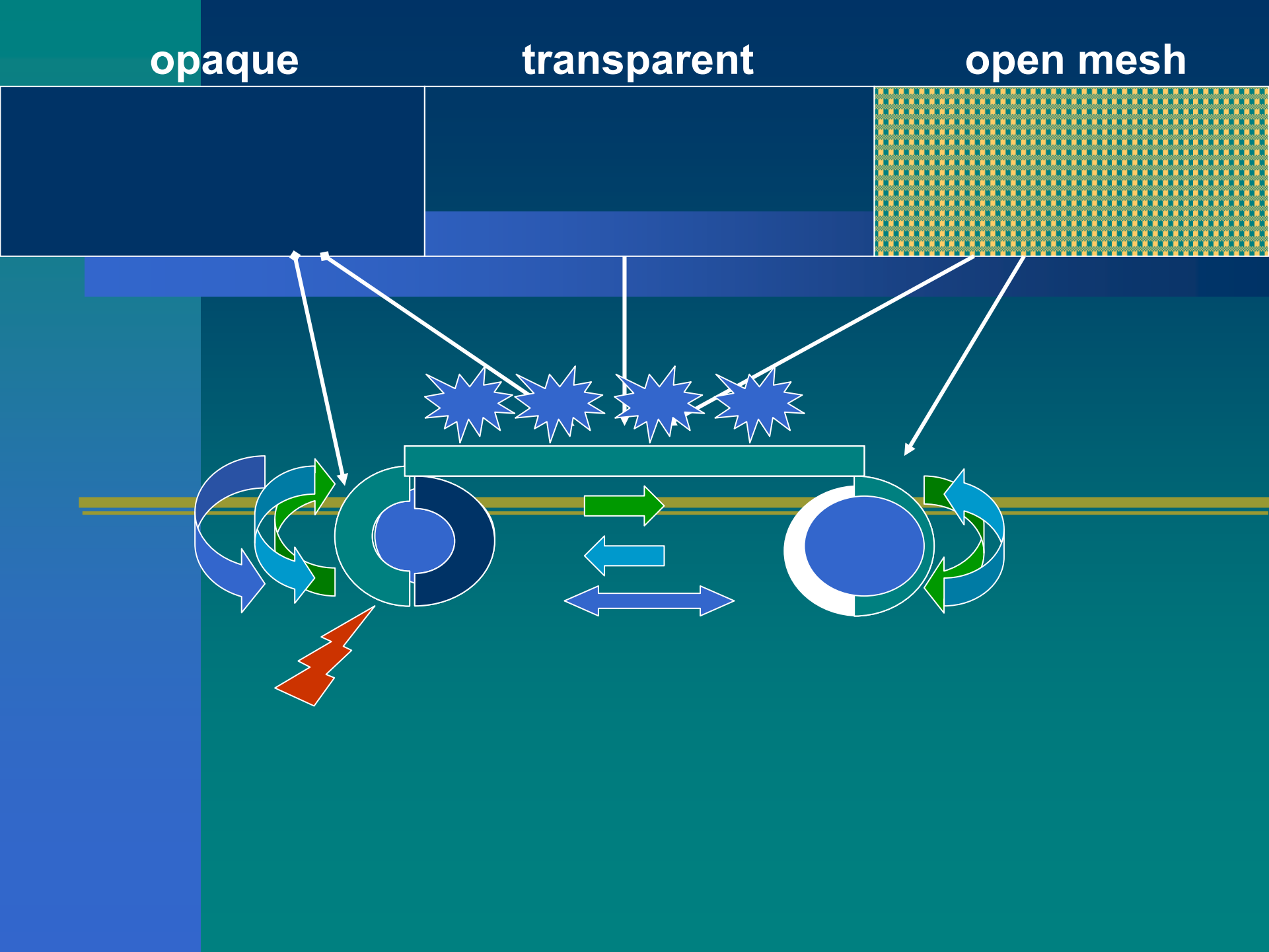
A rolling (non-foldable!) curtain…

Many covers ➔ single curtain with different kind of covers, one unfolded and the others rolled

- **Opaque**, high Reflectivity
- **Transparent**, high Transmissivity (V), low (IR)
- **Open mesh**

It is Always unfolded ➔ A simple tool for Snow:

Rejecting the snow immediately after it falls onto the awning, by means of periodical, intermittent rolling actions


opaque
transparent
open mesh

Awning Configurations

- Summer-Day: OPAQUE
- Summer-Night: OPEN MESH
- Winter-Day: TRANSPARENT
- Winter-Night: OPAQUE

Thermal Model Simulation

- **lumped capacity model**: Transient daily cycle

Bi = h /(*k* L) < 0.1 ➔ **T(x,y,z,*t*) ≈ T(*t*)** ➔

$$M\,c\,(DT / Dt) = A\,(q''_{gain}(t) - q''_{loss}(t))$$

➔ Numerical explicit scheme F.D. of 1 step (Δt):

$$(DT/Dt)_n \approx (T_{n+1} - T_n) / \Delta t$$

Model Parameters

$q''_{gain}(t) = \alpha_s q''_s(t)$

$q''_{losses}(t) = h(T(t) - T_a(t)) - \varepsilon\sigma(T(t)^4 - T^4_{sky})$

$A = 100\ m^2$, Concrete Roof (t = 8 cm)

$\alpha_s = \varepsilon = 0.95$. **Snow:** $\alpha_s = 0.28$

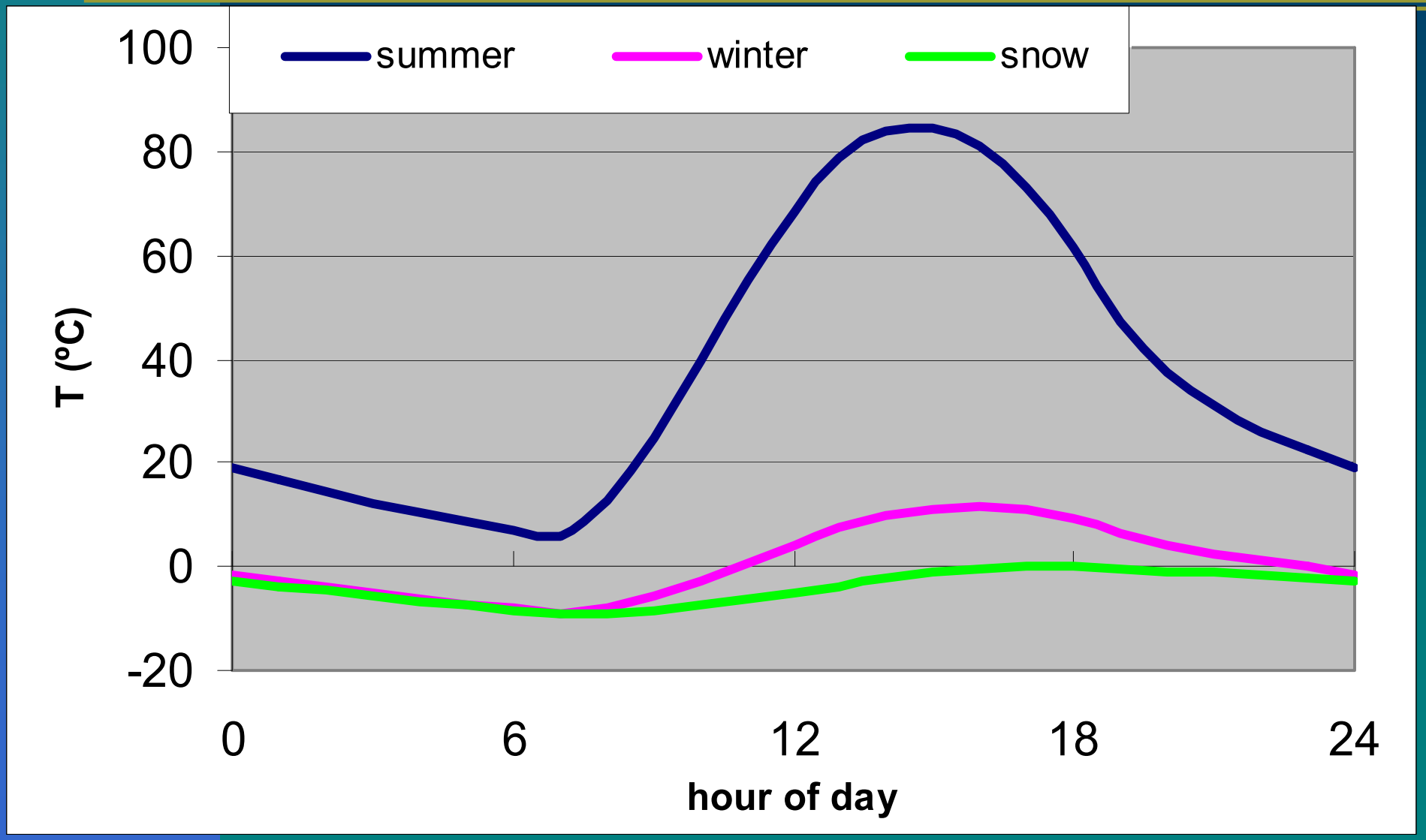
$G''_s = 7.5$ or $1.5\ kWh/m^2day$ (Summer/ Winter)

$Q_{indoor} = A\ U\ (T(t) - 22\ ºC)$

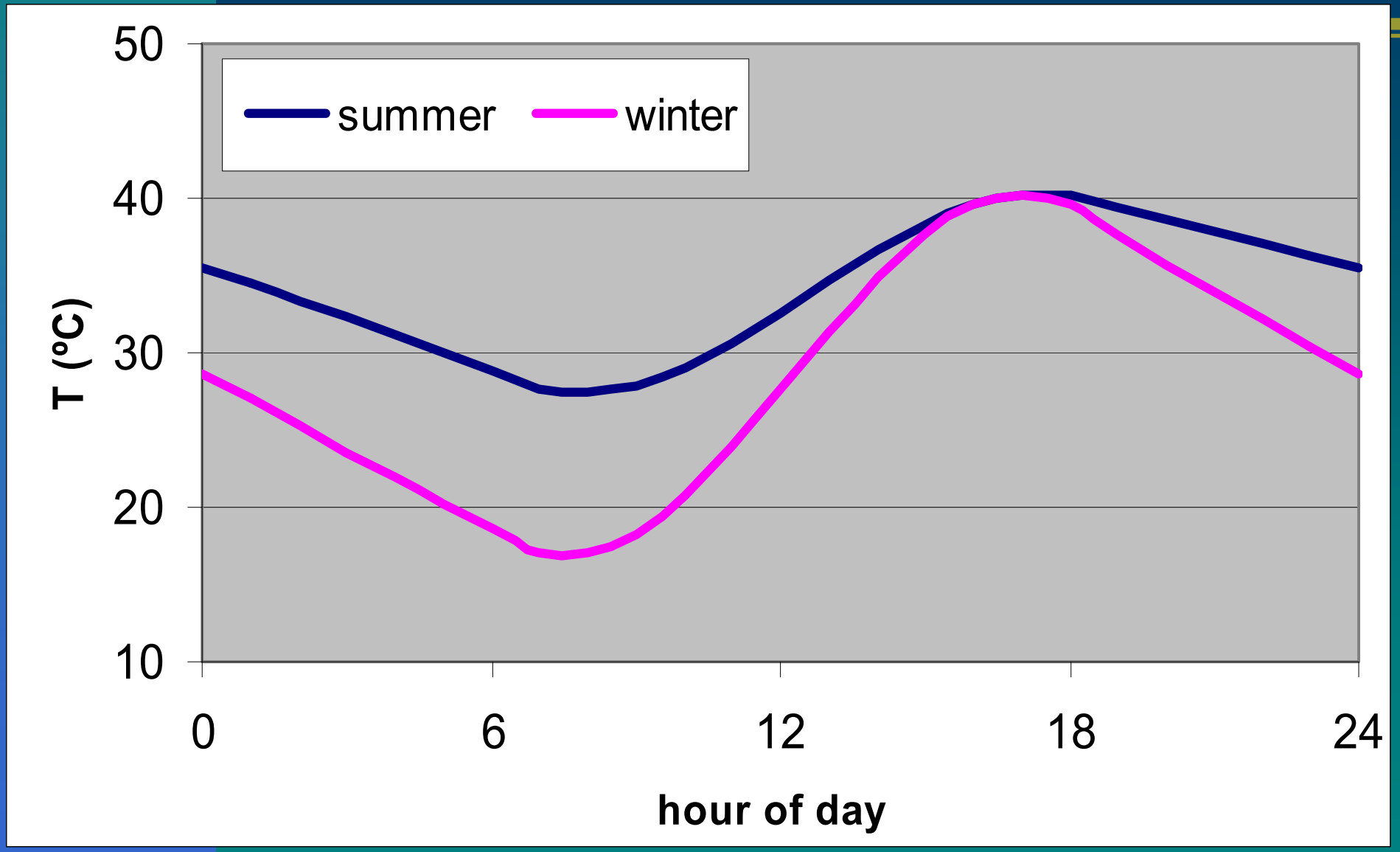
$U = 0.5\ W/m^2K$

Modeling Results

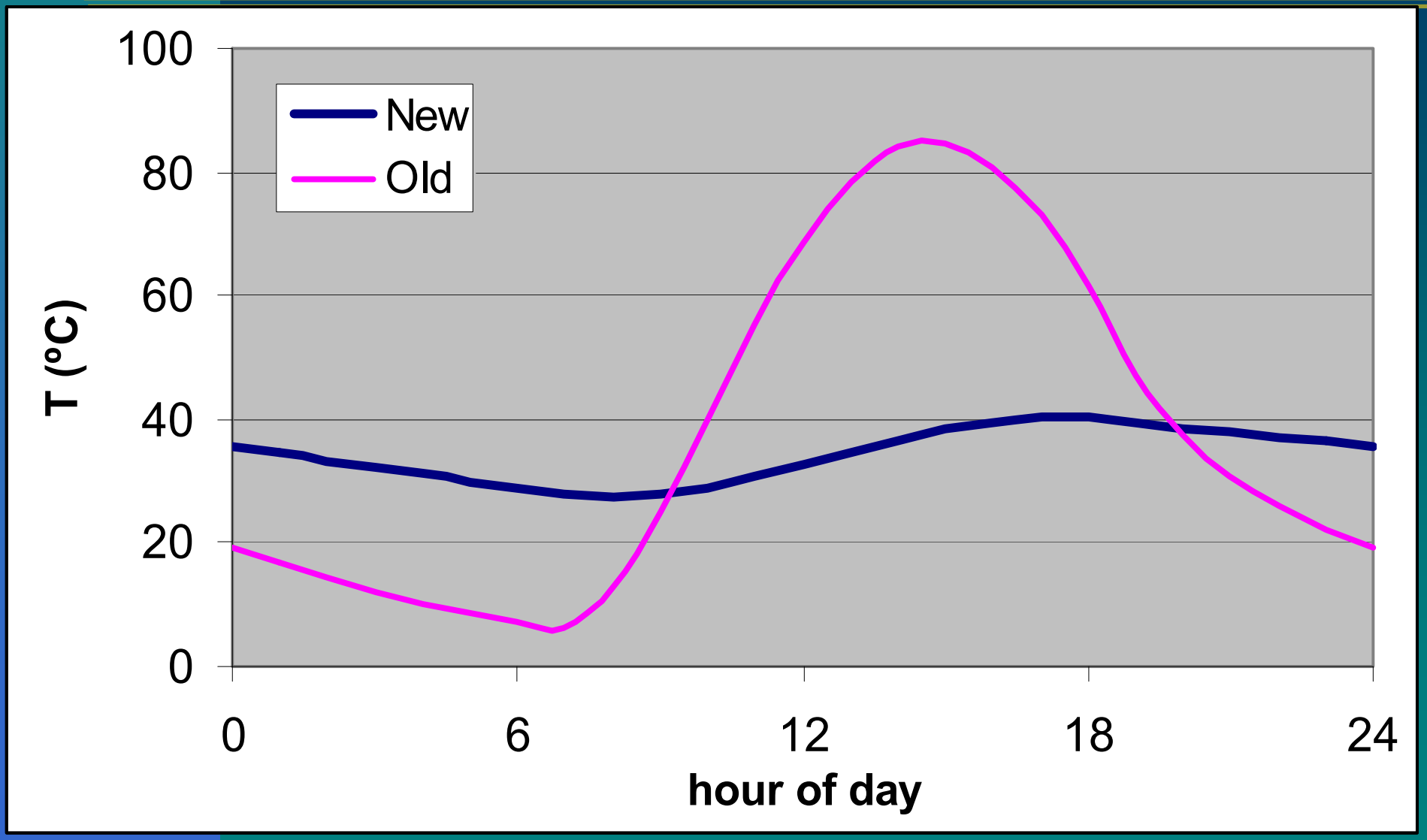
Old Roof



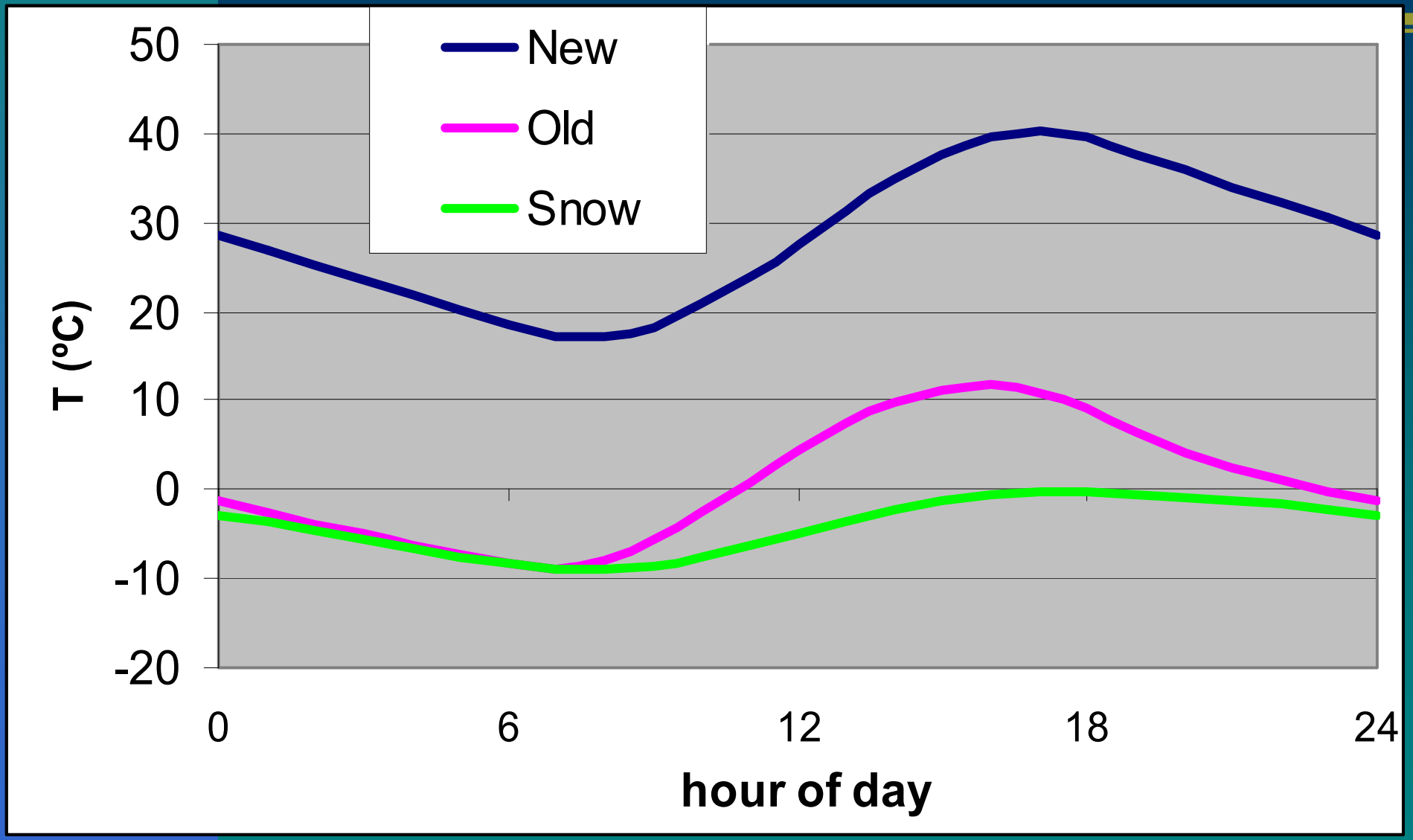
New Roof (+ Rolling Awning)



Roof Comparison for **Summer**



Roof Comparison for **Winter**



Daily Indoor Thermal Loads

	Summer	Winter	Snow
Old roof (kWh)	24	27	33
New roof (kWh)	15	1	1

Equivalent U-factors

	Summer	Winter	Snow
Old roof (W/m^2K)	0.3	0.018	0.015
New roof (W/m^2K)	0.8	13	16

Conclusions

- *A universal scrollable awning design*
- *It can transform any conventional roof in a new configurable ➔ Adaptable to Environmental cycle (≠ Adiabatic Goal)*
- *Improves the roof PVs generation*
- *Thermal gain significant !!*
- *U-traditional roof: great insulation!!*

$$(U_{equivalent} = 0.015\ W/m^2K)$$

More Conclusions

- ***Current design criterion for zero-energy houses (➔adiabatic goal)*** **is wrong ➔**
- **U-factor for Building reflects this criterion**
- ***Why use U-factor?:*** **q" under ΔT steady state**
- **Nature lives along cycles ➔ = on Buildings**

  ➔ Why to use a stationary factor ?
- **Fixed roofs: + insulations ➔ ↓ U-factor…**

  ➔ A day-integrated Gain Parameter

I am proposing to further develop a new architecture design current, based on "environment friendly" buildings. As pioneers (like Harold Hay) has shown, it is possible to obtain very good results by means of configurable designs adaptable to the Environment➔ These 2 New Configurable Designs could help us to modify the deeply-rooted paradigm of the classic roof and building.

Finally…

Present Design current for Buildings (strong, adiabatic) came to us from the Medieval Age…..

….Maybe we must to find the Design Inspiration for Next Buildings in Nature?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Thank you for your attention

Luis E. Juanicó