BUILDING SCIENCE
INSIGHTS
Physics to the Field™

Topics:

1. Igloo Design
2. Air Cavity Ventilation - Walls
3. Air Leakages in Buildings

BUILDING SCIENCE
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Why need WUFI for Igloo Design ?

Achilles Karagiozis

Global Director Building Science, Sustainability

Owens Corning

Acknowledgements

- Mikael Salonvaara
- Marco Schönaich
- Florian Antretter
- Ben Arens

Background

- **Sept. 2012-Launch** of new “Passive House Dynamic Tool” WUFI-Passive by PHIUS-Fraunhofer-Owens Corning
- Impressive Tool by all means (3-D, Comfort, Equipment)
- Joe “A key Note” speaker at Conference
- Joes first words “**Achilles**…You Don’t need **WUFI** to design an **Igloo**”
- Everyone stops breathing !!!
- **It is obvious…. Need to educate..**

Famous PhD Conclusion

2000

- Experimental work determining quasi-steady state interstitial air pressures and leakage regimes could be coupled with enhanced heat, air and moisture (HAM) analytical models enhancing the predictability and accuracy of the analytical models. Linking a network model such as CONTAM96 with a moisture model such as WUFFI or MOIST should be possible. CONTAM96 could be modified to contain a numeric module for apportioning leakage areas (as previously described) and also be configured to address interstitial air pressure fields. In this manner CONTAM96 could be used to provide the inputs of leakage areas and pressures to WUFFI or MOIST.

WUFFI

Value Proposition:
WUFI needed for Design IGLOO

Crashed Dec 25 2013

Crashed in Alaska –

How can I survive the cold?

Answers with **WUFI®Plus**…

Simulation of an **IGLOO** with WUFI®Plus

Geometry

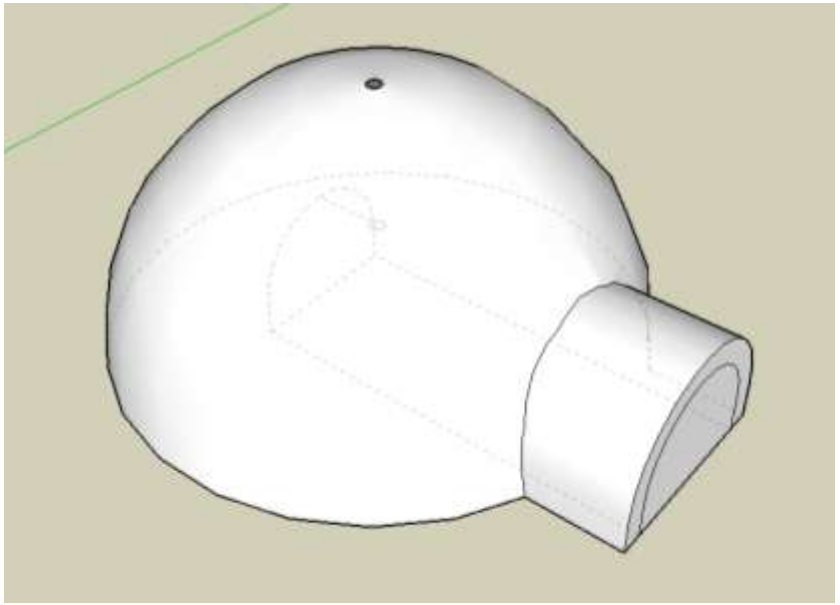
General:

- Floor has to have an inclination to build up an elevated sleeping place and to secure that cold streams going out

- Entrance area is lowered

- Ice boards on the top of the Igloo are a possibility to make some light come in. 0.3 m^2

- Arc radius: 2m
- Thickness of walls: 0.6 m ???

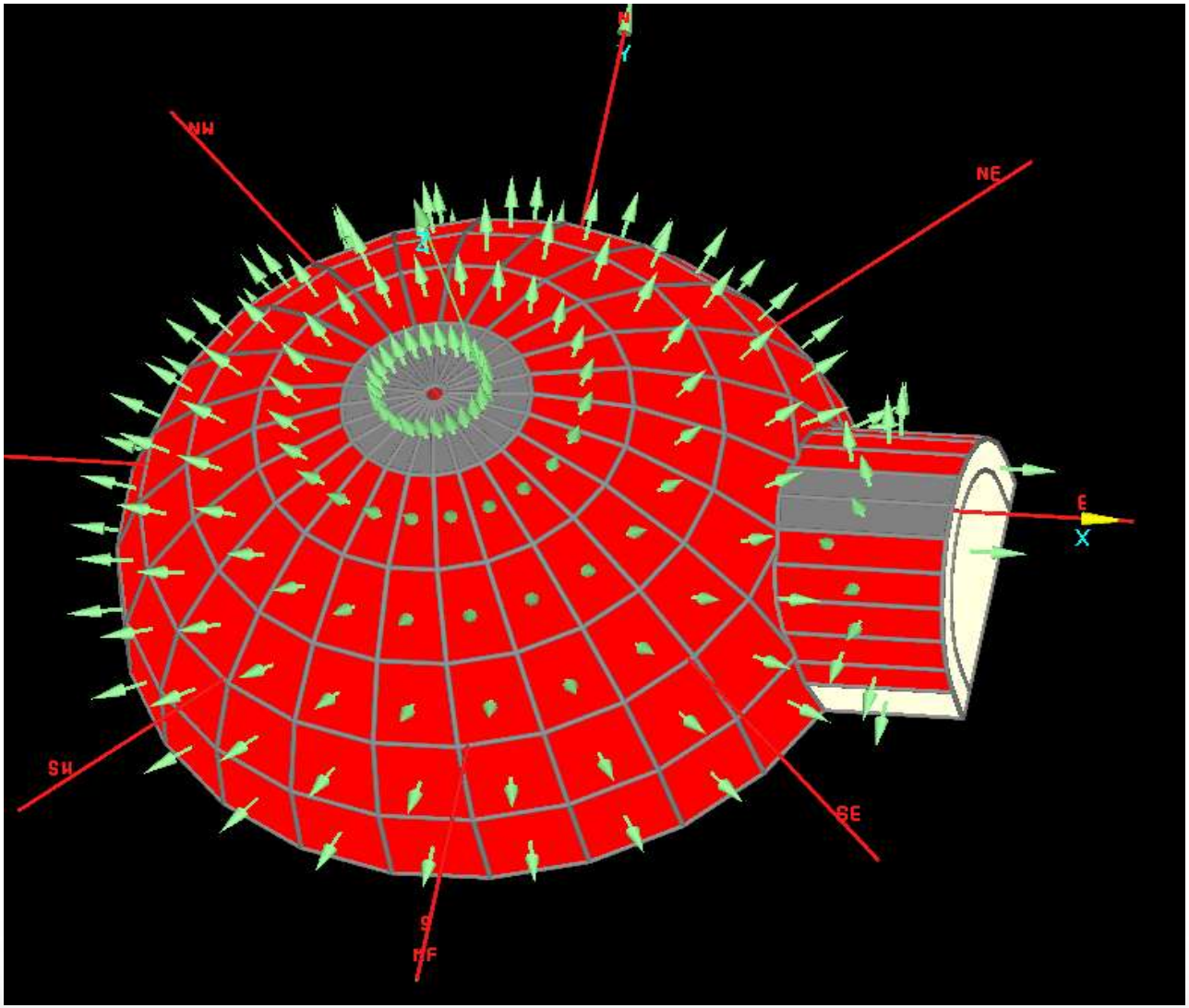


WUFI Plus

Ice skylight
to meet Joe's
preference

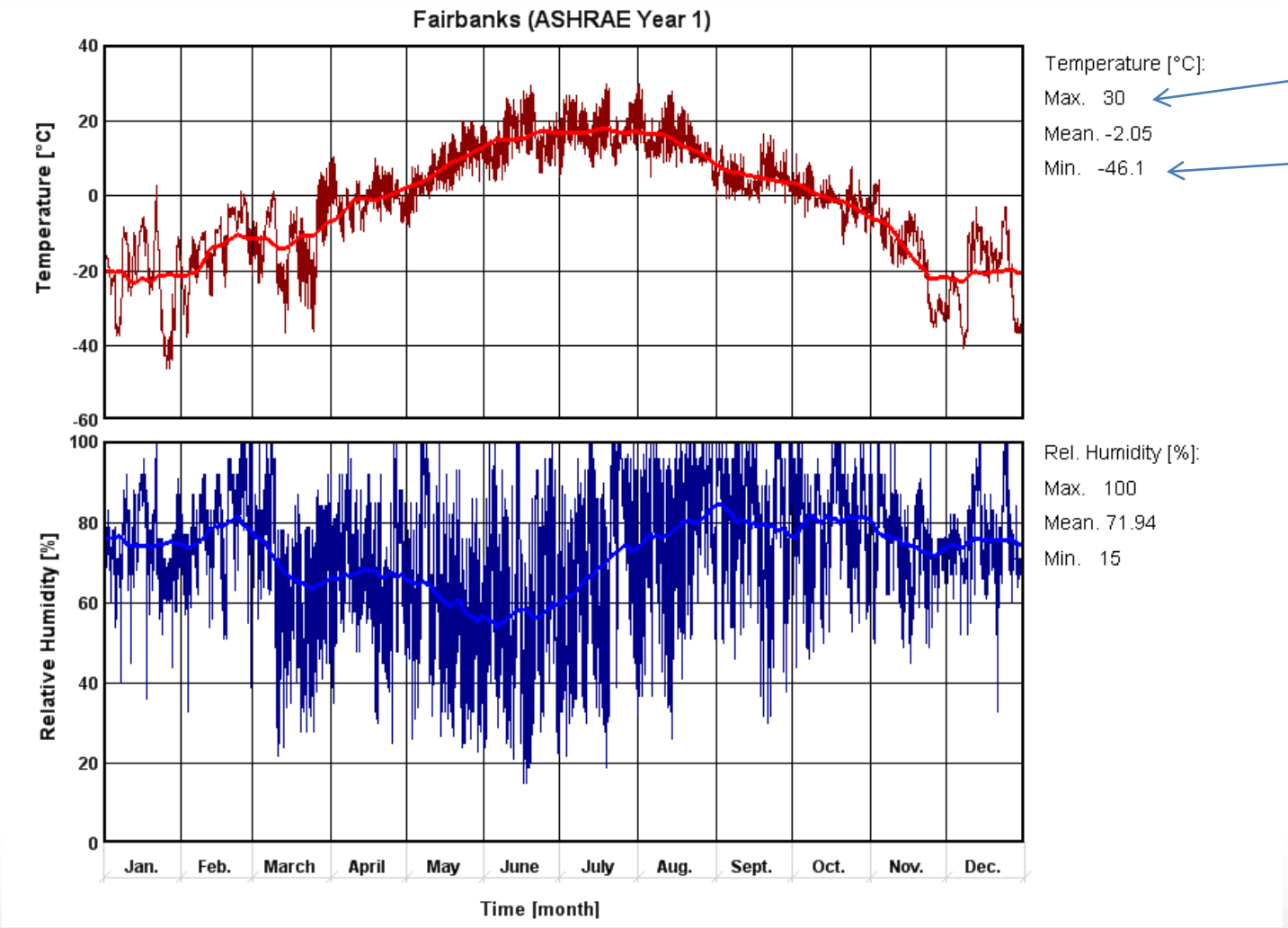
Joe the customer
is
Demanding

Granite – **NO**
Kitchen – **NO**
Plasma TV- **NO**



Location

Location 1: Fairbanks



Physics of snow and ice

Material	Density [kg/m³]	Thermal conductivity [W/m K]	Heat capacaty [j/kg K]	Enthalpies [kJ/kg]	Porosity [-]
Air	1.293	0.0247	1		
Snow	30-800	(rho200)=0.1	2016 (T0)	335 (fusion)	
Ice	800-900	(0.8-)2.5	2016 (T0)	2945 (subl.)	
Water	1000	0.6	4184	2520 (vap.)	

Albedo-values of snow: from 0.2 (dirty) up to 0.9 → average = 0.8-0.9
→ Most of the melting energy comes from the short wave radiation (Albedo important factor for melting)!

Snow reflects short wave radiation (90%) but absorbs long wave radiation(ε=0.01)
→ snow radiates like black body with a maximum amount of energy (316 W/m²) according to max temperature of 273° Kelvin (10µm) → Infrared window (8-13µm)
→ snow can cool down during night time

- http://www.wau.boku.ac.at/uploads/media/SchneePhysik_02.pdf
- http://nsidc.org/cryosphere/seaice/processes/albedo.html
- http://www.slf.ch/ueber/organisation/schnee_permafrost/schneephysik/projekte/index_EN

Layers

Main layer:

2 layers:

- 0.1m fresh fallen snow → λ = 0.8 W/mK
  → After the first day of snowing
- 0.5m old snow → λ = 0.12 W/mK
  → cut out snow blocks
- 0.03m ice layer → λ = 1.6 W/mK
  → after the first heating of the indoor

Phase Change Capability

Edit material data

Name

KLH Massivholz

Basic values

Bulk density [kg/m³]	100
Porosity [-]	0.6
Specific heat capacity [J/kgK]	2106
Thermal conductivity [W/mK]	0.8
Water vapour diffusion resistance factor [-]	300

Additional data

Typical built-in moisture [kg/m³]	60
Thermal conductivity supplement [%/M.-%]	1.3
Color	

Optional data

- Moisture storage function
- Liquid transport coefficient, suction
- Liquid transport coefficient, redistribution
- Thermal conductivity, moisture-dependent
- Thermal conductivity, temperature-dependent
- Water vapour diffusion resistance factor, moisture-dependent
- Enthalpy, temperature-dependent (PCM)

No.	Temperature [°C]	Enthalpy [J/kg]
1	-2	2108
2	-1	4216
3	-0.75	15211.75
4	-0.5	47145
5	-0.25	100015.75
6	0	174342
7	0.25	248668.25

New
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New/Insert:
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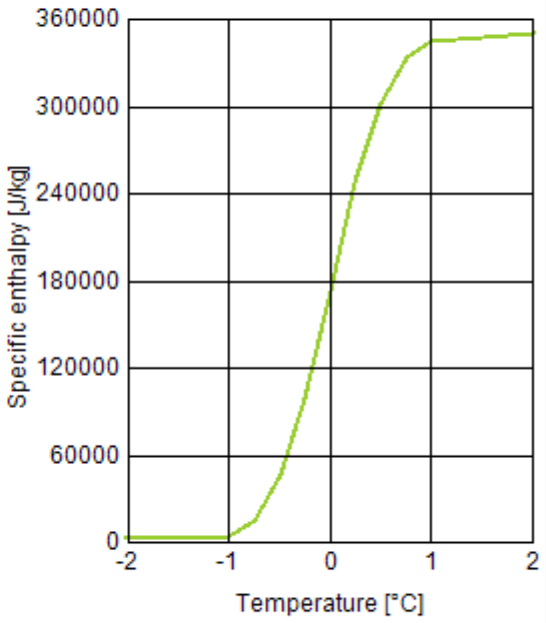


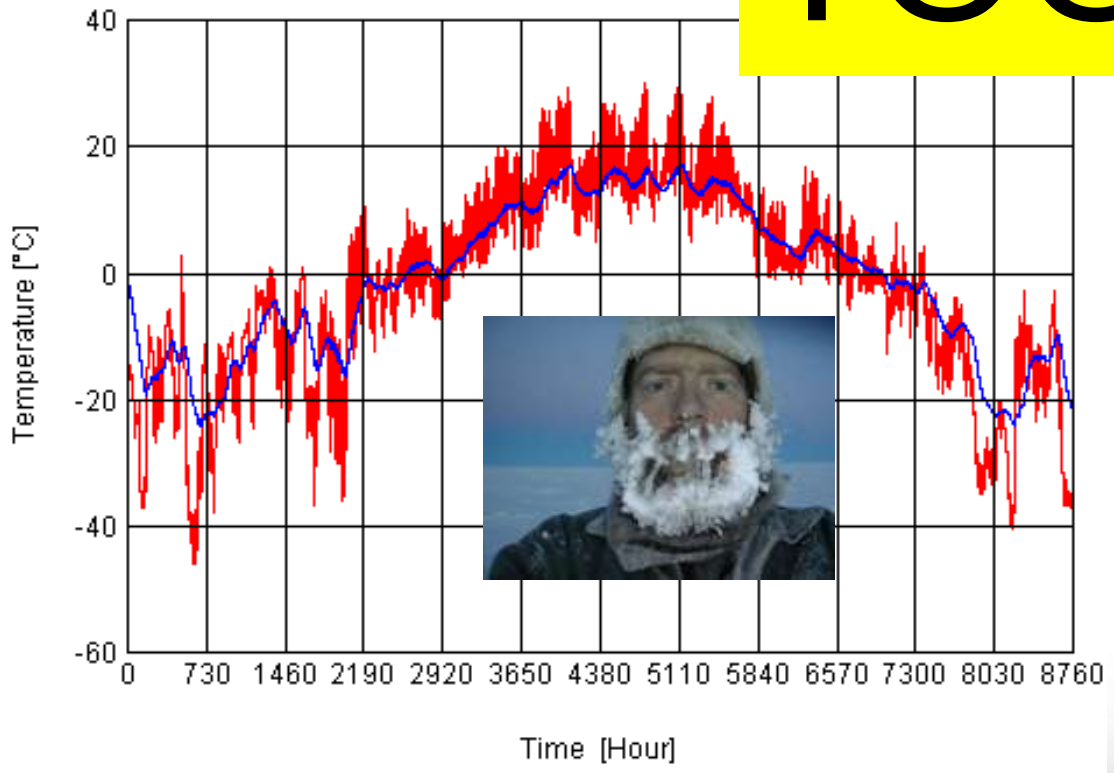
Save in database
OK
Cancel
Help

Indoor climate in the empty Igloo…???

Cases:

- **Case passive climate :**
  - Without inner sources → **passive indoor climate** calculation
  - Air change rate: 0.5 [1/h

TOO Cold



Blue = indoor

Too cold!

How can I achieve the warmest indoor climate possible without melting my Igloo…???

→ max. temperature

0°C long-term

up to 6°C short-term

Cases: Interior Loads

Sports… Joe push-ups

- No inner sources just 1 person exercising (bathing suit):
- Push-ups: aprox.: 5met = 290W/m² → human skin = 1.7m²

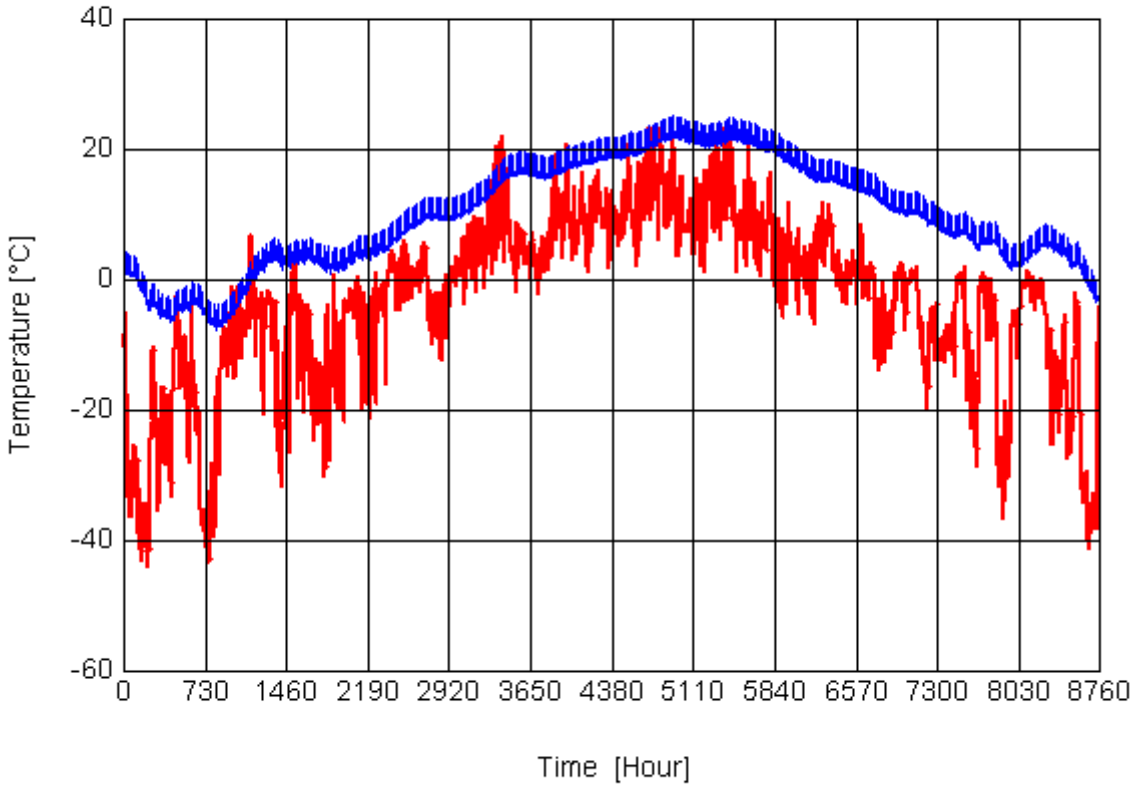
→ 5met = 290W/m² * 1.7m² = 493W

→ 120 push-ups in 1 hour to keep the body at aprox. 500W for 1 hour

?

WUFI for Igloos

- Case Sports : Joe's push-ups Bad… too powerful !!



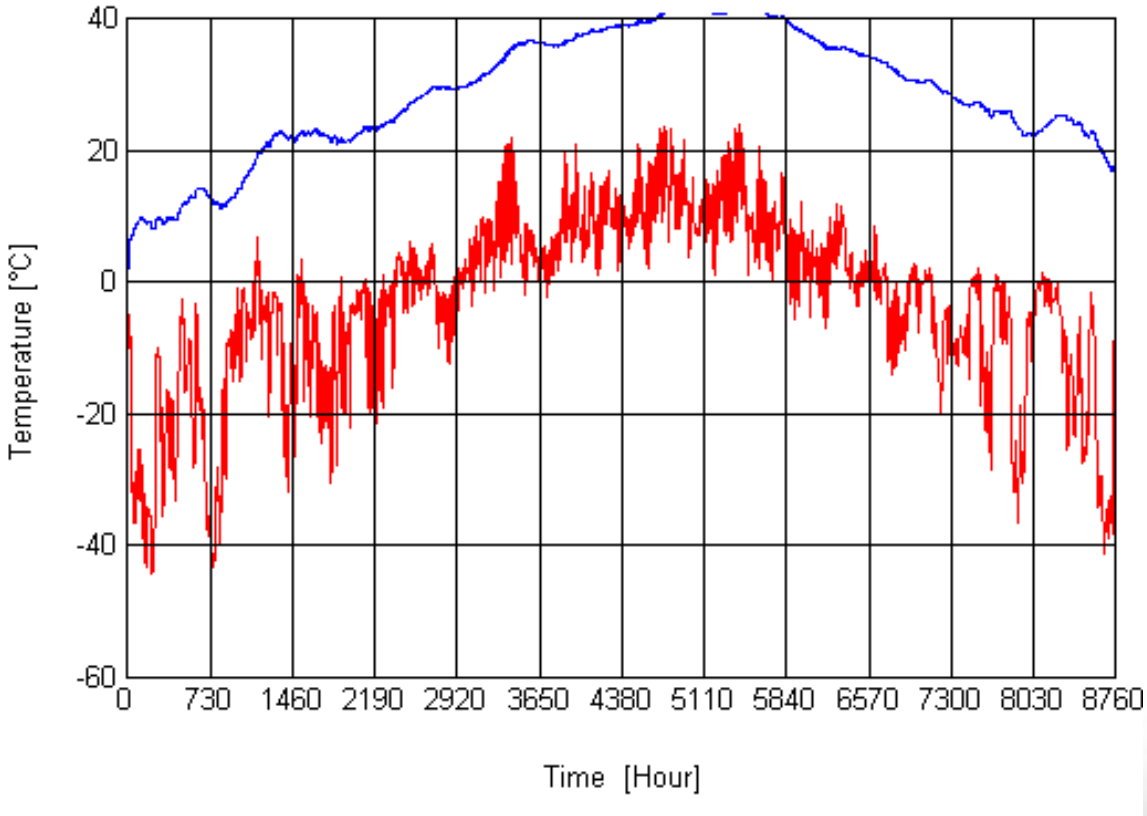
Not appropriate !

Cases:

- **Case People…**
  - No inner sources just 3 persons staying the whole day in the igloo…
  - 80W * 3 persons = **240W**

Interior

- **Case People :**
  - No inner sources just three persons who are the whole day in the igloo:



Too warm!

Other solutions...

?

Available heat sources:

- **Human body:**
  - 80 – 100W (seating) → Igloo
  - >100W (activity)

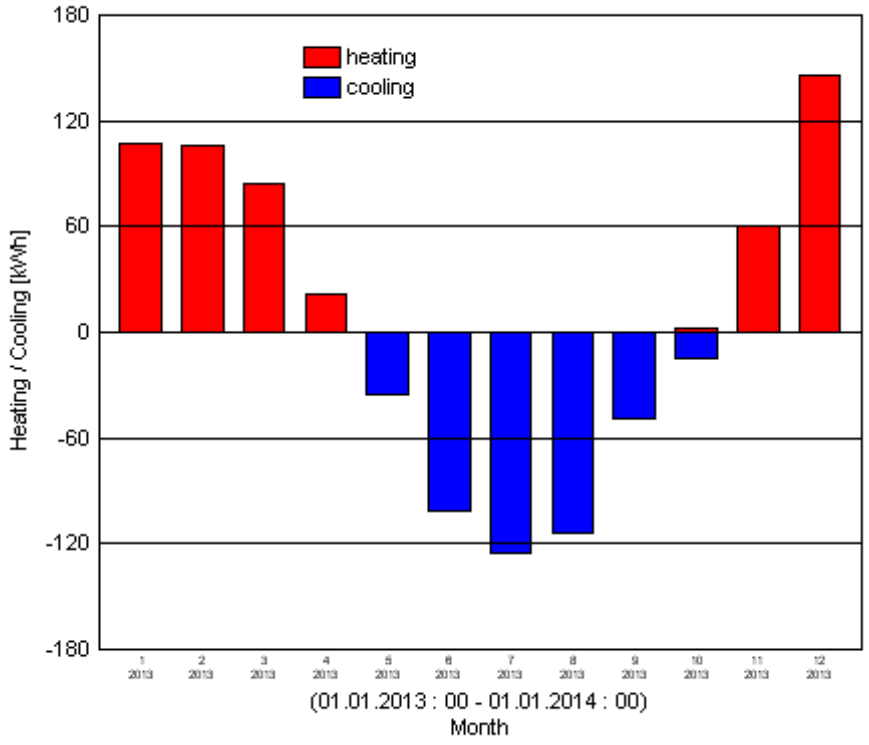
- **Candle:**
  - Heat of combustion of Paraffin: 12.5 kWh/kg
  - Weight of small candle: 15g @ 5h burning time
    → Power = **37.5W**
    → Energy = **0.19kWh**
  - Weight of medium size candle: 450g @ 43h burning time
    → Power = **130.8 W**
    → Energy = **5.63 kWh**

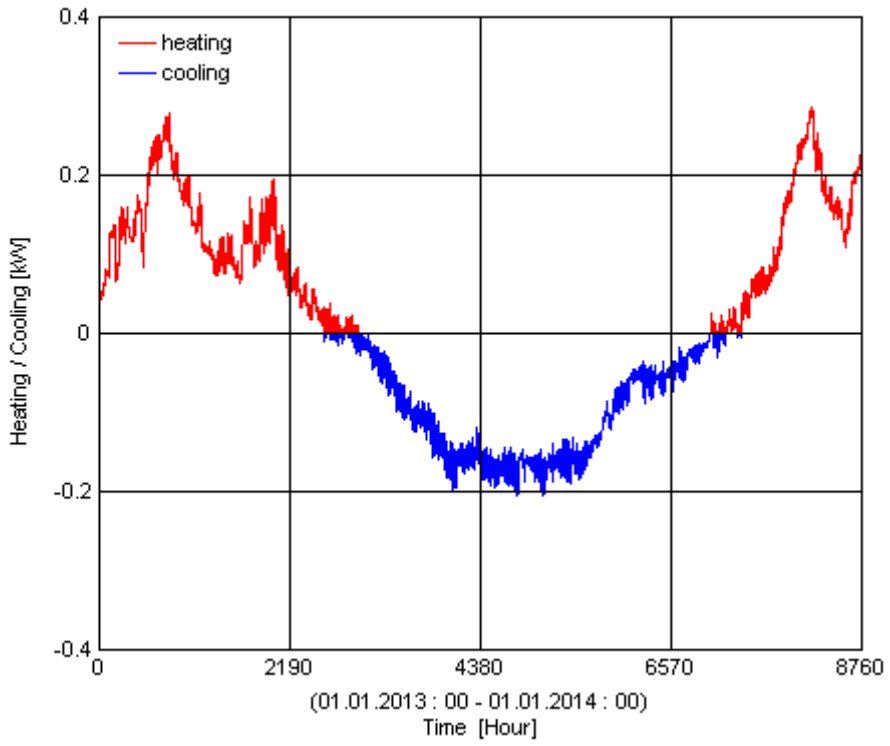
Ventilation = 0.9 ACH (portal)… Joe's schedule

- **Case Handmade heating system → set up heat sources**
  - **Calculation of inner climate with appropriate inner sources**
  - Inner sources:
    - One person (relaxed 70W) during one month = 50kWh
    - Heat source candle during heating period (September-April)
      - **Necessary**:
      - January, February: max total Power needed = 250W
        → 1 big & 1 small candle & 1 persons
        Energy needed = 100kWh
        → 1 Person (50kWh) + **9 big candles** (50kWh)
      - March : max Power needed = 180W
        → 1 big candle & 1 person
        Energy needed = 80kWh → **7 big candles** (40kWh)
      - November, December: max Power needed = 250W
        →1 big & 1 small candle & 1 person
        Energy needed = 150kWh → **13 big candles** (70kWh)

Cases:

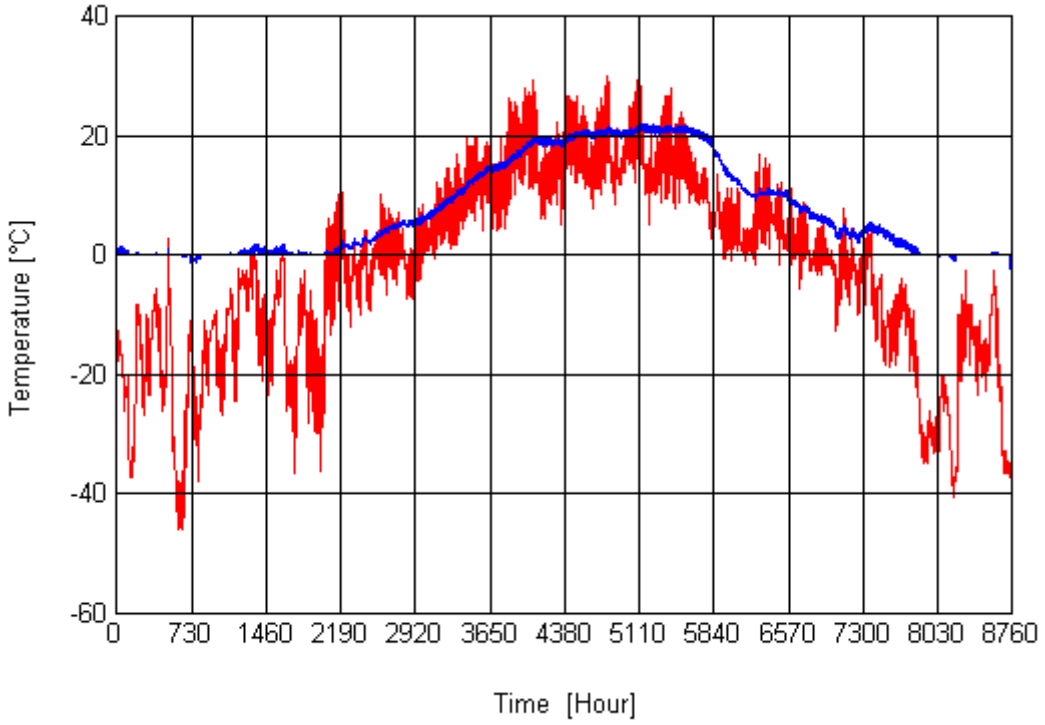
- **Case Dimensioning → Preparing a handmade heating system – calculation of loads & energy**
  - Calculation to dimension a HVAC system:
  - with PCM-effect of snow





Cases:

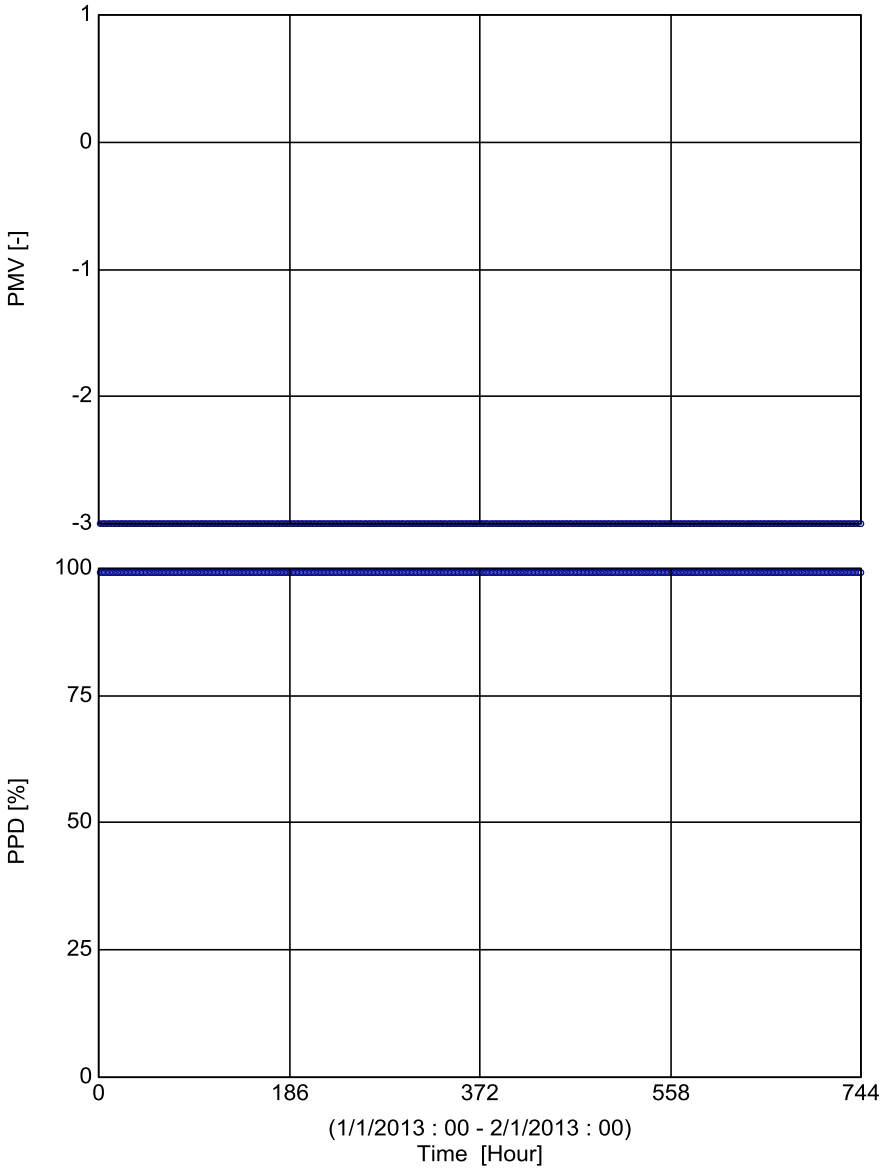
- **Case Handmade heating system → indoor climate**
  - Calculation of inner climate with inner sources (with PCM-effect)
  - One person



Red = outdoor
Blue = indoor

Perfect temperature to not melt the igloo

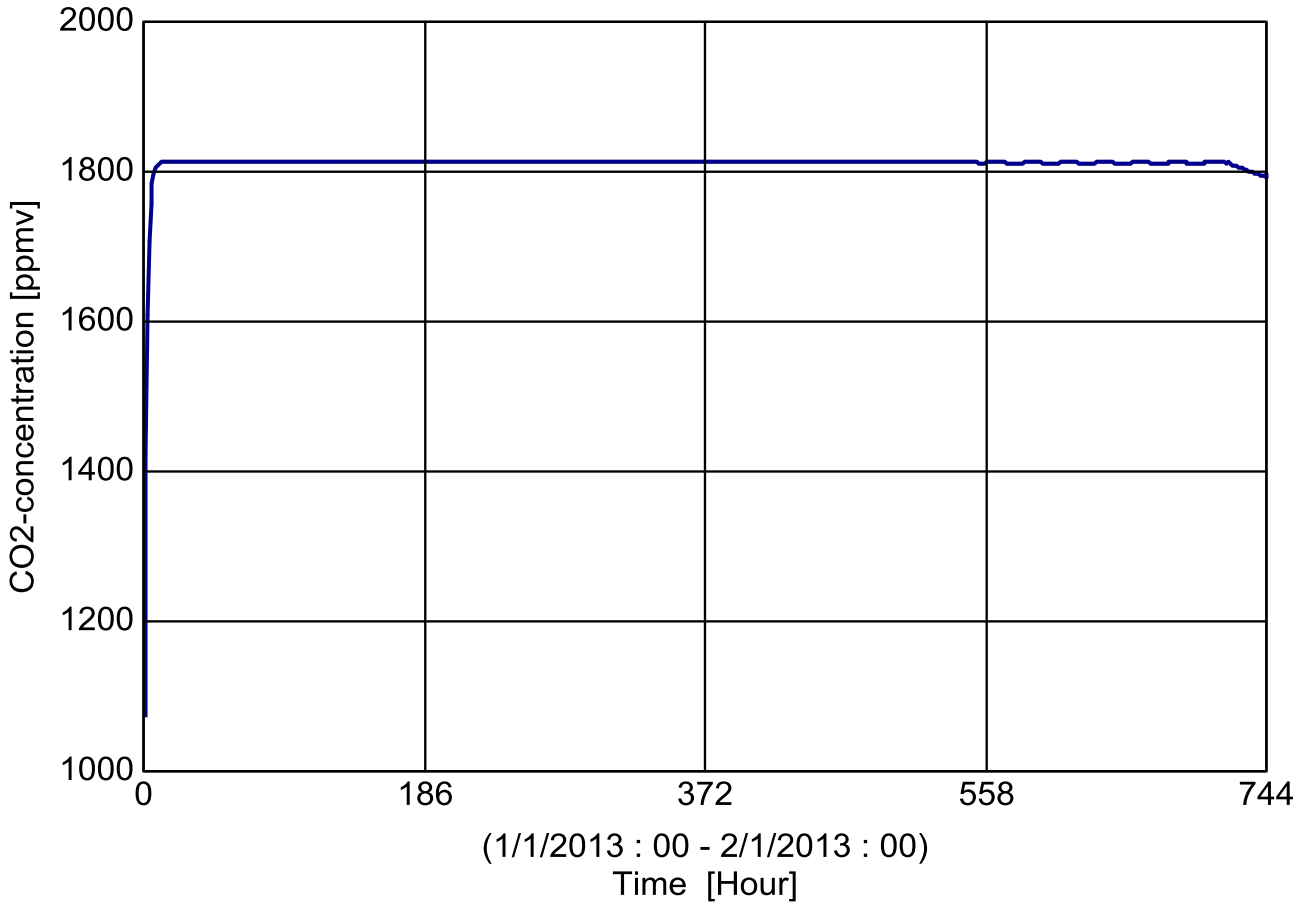
Comfort



PMV: Predictive Mean Vote- Joe will be Dissatisfied….

CO2

Healthy or not ?
About a classroom



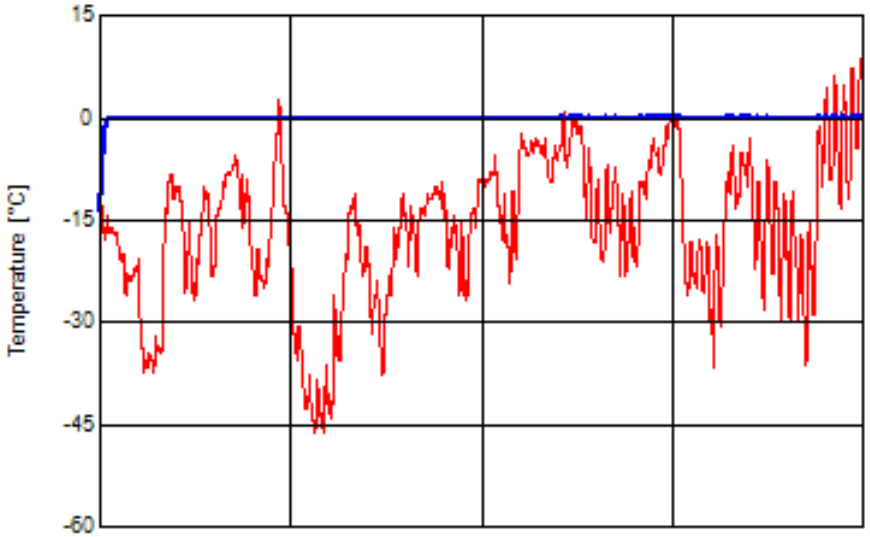
Possible to survive the cold
with **25** candles and an Igloo

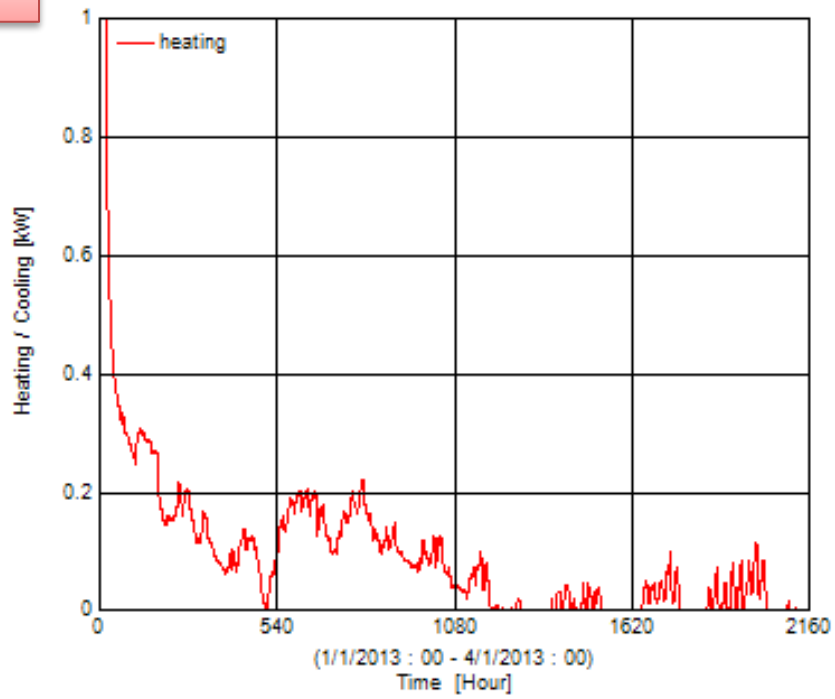
Also don't Freeze initially

- **Case: Heating demand→ -4F to indoor climate 32F**
  - Calculation of inner climate with heating (with PCM-effect)
  - How much heating is needed to get indoor temperature to 32F fast?

Red = outdoor
Blue = indoor

Burn more candles initially!





Be always prepared with WUFI®Plus

…

Joe Personal Survival Rating (PSR) Assessment has jumped to 9.4/10 with WUFI ..

Initial PSR of Joe was -40…Without WUFI you will be top sirloin meat.

Joe..Next Time be careful when talking about WUFI..

Naked and Afraid : Discovery Channel