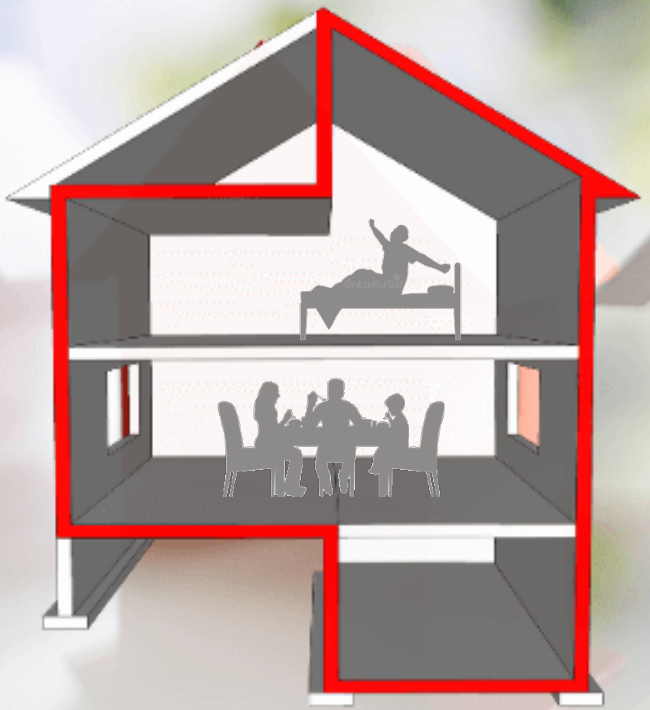
PRACTICE EXERCISES



CIVIL-407 Energy & Comfort in Buiildings

Heating & Cooling Demand in Buildings

Assist. Professor
Dolaana KHOVALYG

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Case Study for Exercises 1-2:

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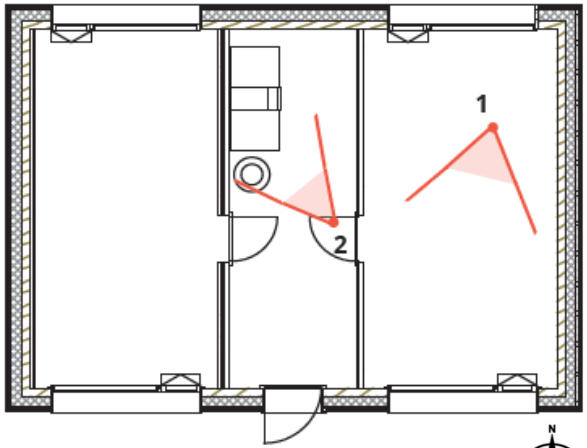
Consider *an air-tight* office building prototype with windows shown in the figure, with its parameters detailed below.

Dimensions:

- Overall outside dimension: 7(w) x 9.6(l) x 4.3(h) m^3
- Internal volume: **163.4 m^3 ,** 6.2(w) x 8.5(l) x 3.1(h) m^3
- Internal surface area: **52.7 m^2,** 6.2(w) x 8.5(l) m^2
- Size of each window: **4.5 m^2** , 2.5 (l) x 1.8 (h) m^2
- Entrance door: **2.4 m^2** , 1.2 (l) x 2.0 (h) m^2



Technical characteristics:

- Building envelope thermal transmittance $[W/(m^2 \cdot K)]$:

Roof	Floor	Walls	Door	Windows
0.16	0.11	0.12	0.5	1.1

- Four double-pane windows, solar heat gain coefficient of windows - 0.64
- Standard fluorescent ceiling lights
- All indoor space is conditioned

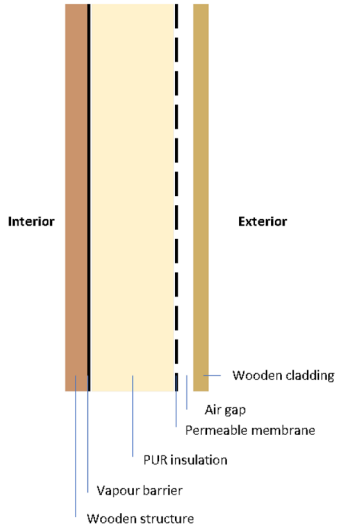
Usage:
- Office space with 2 rooms, each room (20 m^2) for 2 occupants
- Working hours: 8-18h

Exercise 1: Dynamics of the Building Envelope

Assist. Prof. Dolaana Khovalyg

Vertical opaque walls of the building prototype have the following layers and properties:

Material	Thickness (mm)	Conductivity (W/mK)	Density (kg/m^3)	Specific Heat (J/kgK)	Emissivity (thermal absorptance)
Wooden cladding	24	0.15	450	1800	0.84
Ventilated air gap	44	0.21	1.24	1000	0.82
Waterproofing membrane	0.45	0.17	900	1800	0.90
Expanded polystyrene insulation	180	0.031	15	1116	0.90
Vapour barrier	0.22	0.4	500	1800	0.5
Wooden covering	140	0.13	471	1600	0.84



Questions:

For the hourly environmental conditions given in the file "**CIVIL407_2025_L10_Ex1_Data.xlsx**", determine the following:

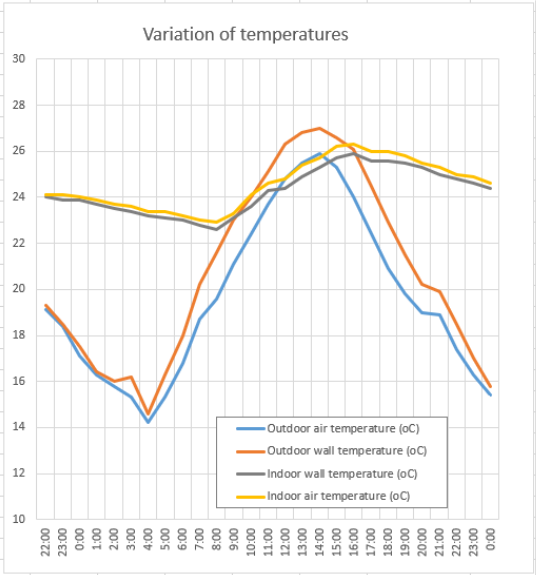
1. Calculate and plot the **hourly outdoor sol-air temperature** for the vertical wall and compare it with the air temperature
2. Determine **time lag** and **decrement factor** of the wall assembly

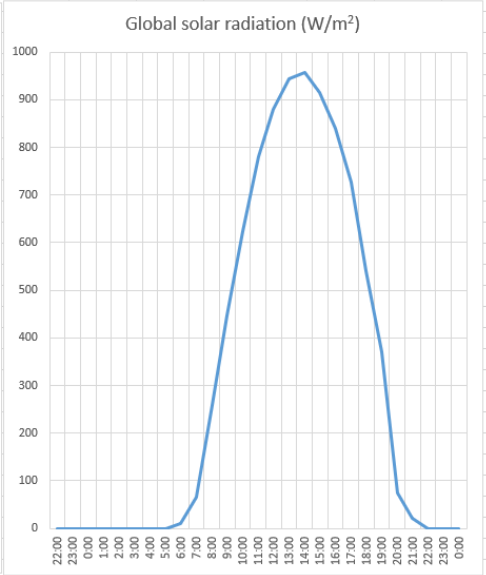
Exercise 1: Dynamics of the Building Envelope

Assist. Prof. Dolaana Khovalyg

Overview of the data provided in the file "**CIVIL407_2025_L10_Ex1_Data.xlsx**":

	Time	Outdoor air temperature (°C)	Outdoor wall temperature (°C)	Indoor wall temperature (°C)	Indoor air temperature (°C)	Global solar radiation (W/m²)
Day -1	22:00	19.1	19.3	24	24.1	0
Day -1	23:00	18.4	18.5	23.9	24.1	0
	0:00	17.1	17.5	23.9	24	0
	1:00	16.3	16.4	23.7	23.9	0
	2:00	15.8	16	23.5	23.7	0
	3:00	15.3	16.2	23.4	23.6	0
	4:00	14.2	14.6	23.2	23.4	0
	5:00	15.3	16.3	23.1	23.4	0
	6:00	16.8	18	23	23.2	10.3
	7:00	18.7	20.2	22.8	23	66.5
	8:00	19.6	21.6	22.6	22.9	258
	9:00	21.1	23	23.1	23.3	446
	10:00	22.4	24	23.6	24.1	622
	11:00	23.7	25.1	24.3	24.6	780
	12:00	24.8	26.3	24.4	24.8	880
	13:00	25.5	26.8	24.9	25.4	944
	14:00	25.9	27	25.3	25.7	957
	15:00	25.3	26.6	25.7	26.2	914
	16:00	24	26.1	25.9	26.3	840
	17:00	22.4	24.5	25.6	26	727
	18:00	20.9	22.9	25.6	26	542
	19:00	19.8	21.5	25.5	25.8	372
	20:00	19	20.2	25.3	25.5	73.9
	21:00	18.9	19.9	25	25.3	20.7
	22:00	17.4	18.5	24.8	25	0
	23:00	16.3	17	24.6	24.9	0
	0:00	15.4	15.8	24.4	24.6	0





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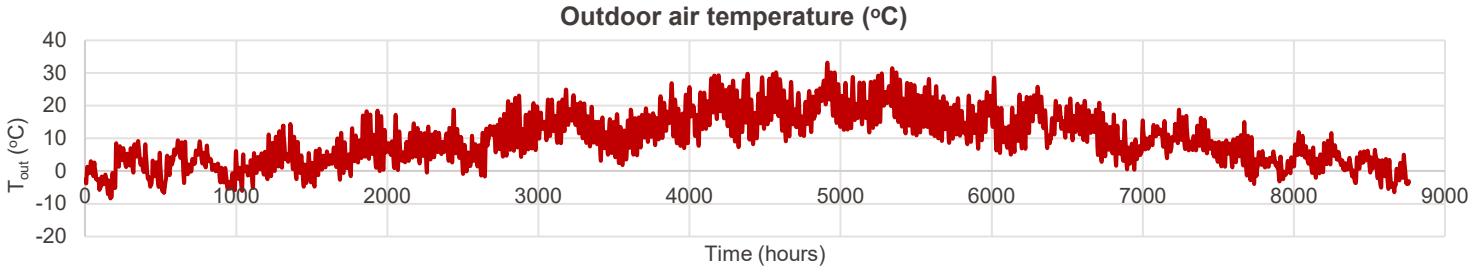
Exercise 2: Annual Heating/Cooling Demand

Assume that **the office building prototype** locates **in Geneva,** and the **hourly outdoor weather parameters** over *the entire year* correspond to the data provided in the file "**CIVIL407_2025_L10_Ex2_Data.xlsx".**



Questions:

1. Determine the **heating degree days** (**HDD**) and **cooling degree days** (**CDD**) for the given location
2. Estimate **annual heating** and **cooling demand** using the *degree days*
3. Estimate **limiting value for annual heating demand** per SIA 380-1 standard
4. **Compare** the **calculated annual heating demands** in **(2)** and **(3)**, and discuss *possible reasons* for *any discrepancies*

Note: Make reasonable assumptions for any parameters not explicitly provided, and justify your choices.

Exercise 3: Hourly Cooling Demand

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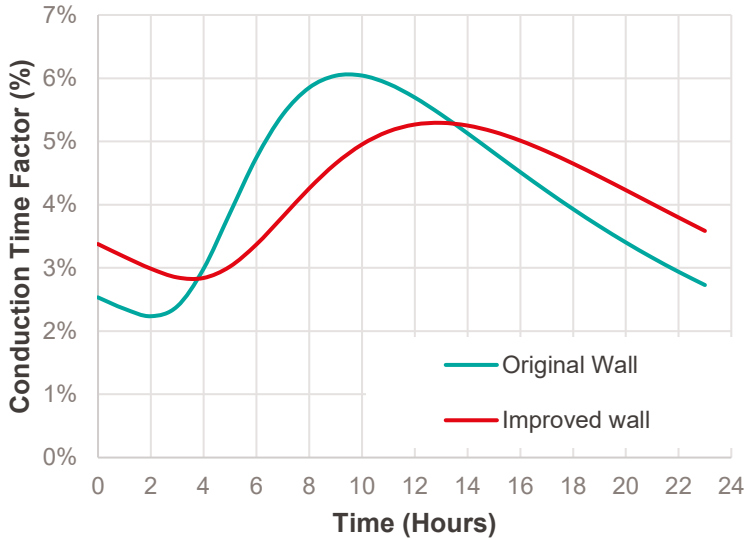
Consider the wall from **Exercise 1** in **Lecture 09**. The original wall included **150 mm** of **rockwool insulation**, which must be increased to **220 mm** to meet *the requirements for new buildings*. The plot below illustrates the **conduction time factors (CTFs)** for both wall configurations.

Original wall parameters:

	Layer Name	Thickness mm	Conductivity W/(m-K)	Density kg/m^3	Specific Heat kJ/(kg-K)
1	Cement mortar	20.000	1.400	2000.000	1.000
2	Hollow brick	190.000	0.520	1940.000	0.840
3	Rock wool	150.000	0.041	160.000	0.840
4	Facade mortar	20.000	0.700	1700.000	0.900

Improved wall parameters:

	Layer Name	Thickness mm	Conductivity W/(m-K)	Density kg/m^3	Specific Heat kJ/(kg-K)
1	Cement mortar	20.000	1.400	2000.000	1.000
2	Hollow brick	190.000	0.520	1940.000	0.840
3	Rock wool	220.000	0.041	160.000	0.840
4	Facade mortar	20.000	0.700	1700.000	0.900



Question:

- Evaluate the **CTF results** for both walls and discuss **how a thicker insulation layer** *may* **influence the hourly cooling load**

Exercise 4: Domestic Hot Water Demand

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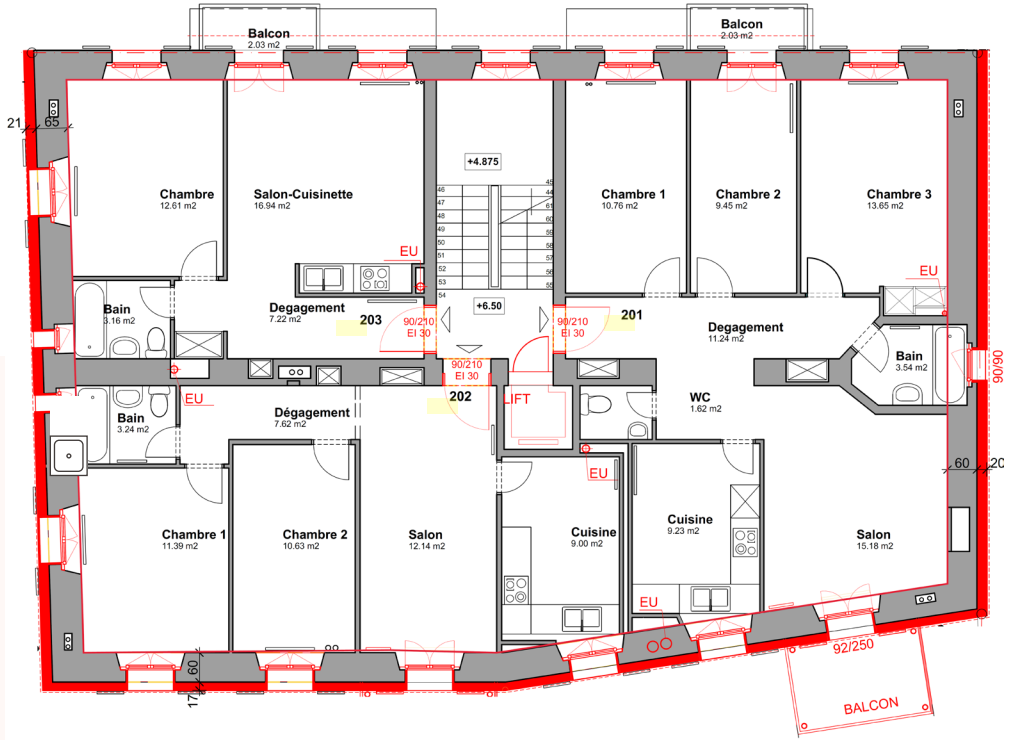
Consider a floor plan of the multi-family building with 3 apartments:

- **201**: 3BR (2 adults + 2 children)
- **202:** 2BR (2 adults + 1 child)
- **203:** 1BR (1 adult)



Questions:

1. What is the possible **average hourly demand of hot water** (L/h) for each apartment?
2. What **factors** contribute to **uncertainty** in the **Average Hourly Demand method**?