Can Rooftop PV Meet Europe's Rising Cooling Demand?

Case Study 4

Andrej Bernhard
Hannah Livingston
Lukas Schmidt-Engelbertz
Clara Tillous Oliva
Fiona Turner-Hehlen

ETH zürich

BKW

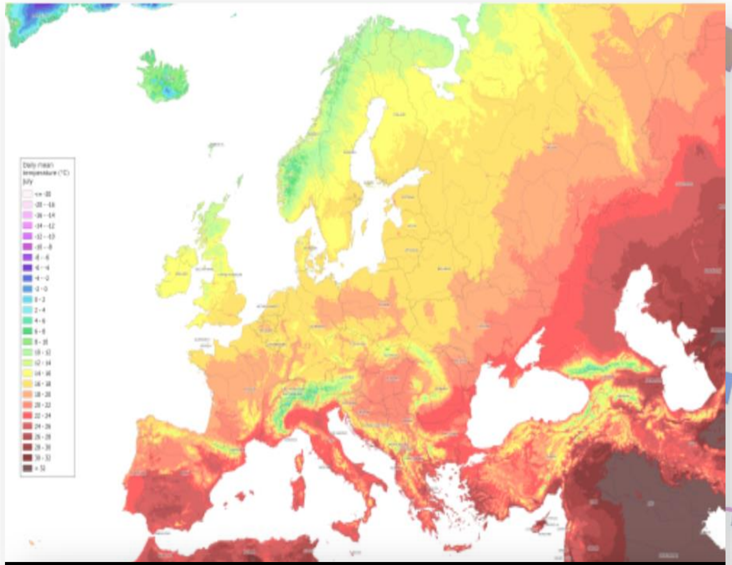
Agenda

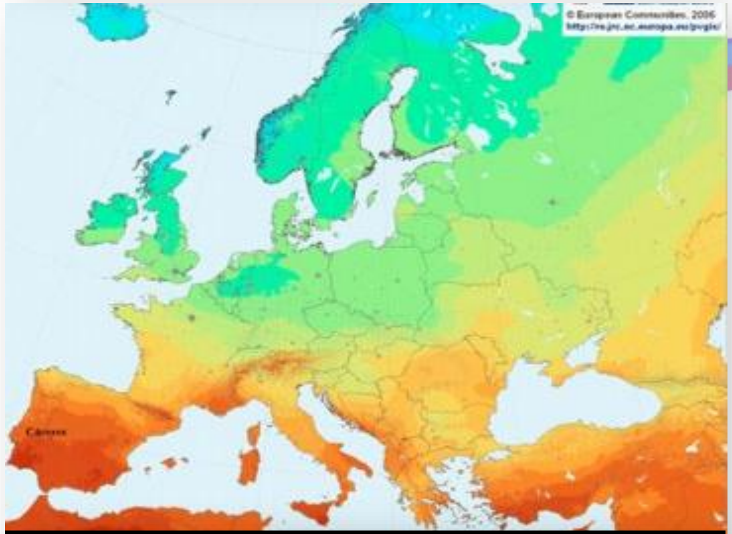
1. Project Background
2. Existing Cooling by PV Models
3. Cooling Demand Model
4. PV Generation Model
5. Work Plan Methodology
6. Project Schedule
7. Conclusion

Background

Motivation:
Determine if PV can be the dominant energy source for residential cooling electricity demand.

- PV generation and cooling demand are co-located.
- Demand for cooling is rising rapidly.
- Demand for cooling represents up to 50% of peak electricity on hot days.


Average Summer temperature in Europe


PV Potential in Europe

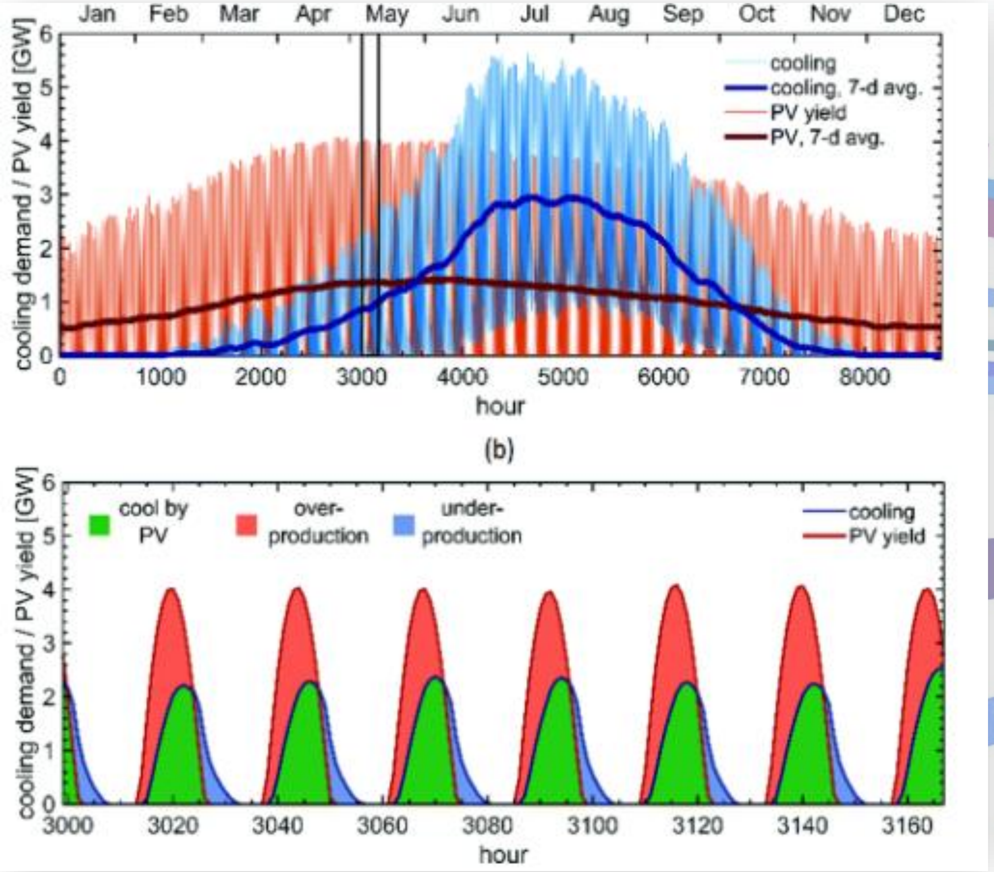
Existing Cooling by PV Models

Key Findings:

- PV system could satisfy 55.5% of the hourly cooling electricity demand (Laine et. Al., 2019)

- Cost of cooling electricity from PV is up to 50% less than traditional electricity
  (Kan et al., 2022)

PV and cooling demand modelling approaches vary widely.

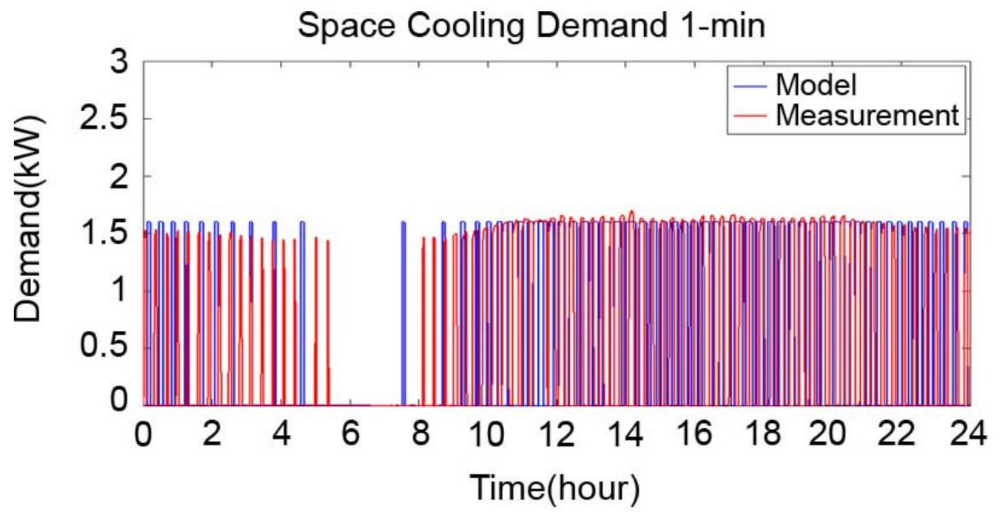


Cooling-Demand Model

Function of

- Desired Indoor temperature
- Hourly outdoor temperature
- Heat gain (irradiance, building parameters)
- Specific heat capacity (volume of household)

- Our model will use a vapour-compression system.
- Average COP of VC=3.5



$$T_{i+1} = T_i + \Delta t \frac{G_i}{\Delta c} + \Delta t \frac{C_{HVAC}}{\Delta c} w_{AC,i},$$

$$G_i = \left(\frac{A_{\text{wall}}}{R_{\text{wall}}} + \frac{A_{\text{window}}}{R_{\text{window}}} + \frac{A_{\text{ceiling}}}{R_{\text{Ceiling}}} + \frac{11.77\text{BTU}}{°\text{F ft}^3} n_{ac,i} V_{\text{house}} \right) (T_{out,i} - T_i)$$
$$+ SHGC \cdot A_{\text{windowsouth}} \cdot H_{\text{solar}} \frac{3.412 \frac{\text{BTU}}{\text{WH}}}{10.76 \frac{\text{ft}^2}{\text{m}^2}} + H_p.$$

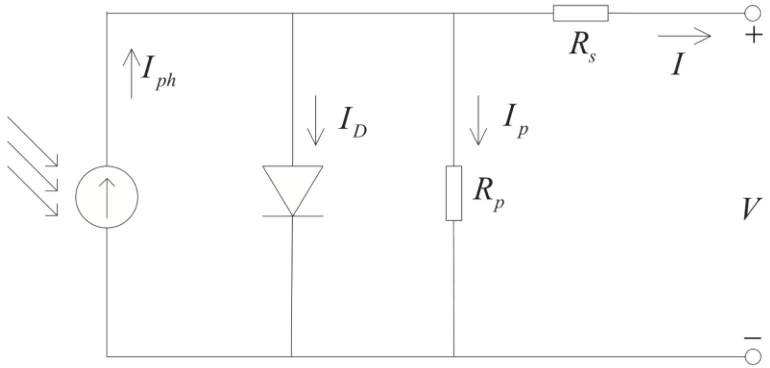
Example Equations of Inputs into Cooling Demand Model

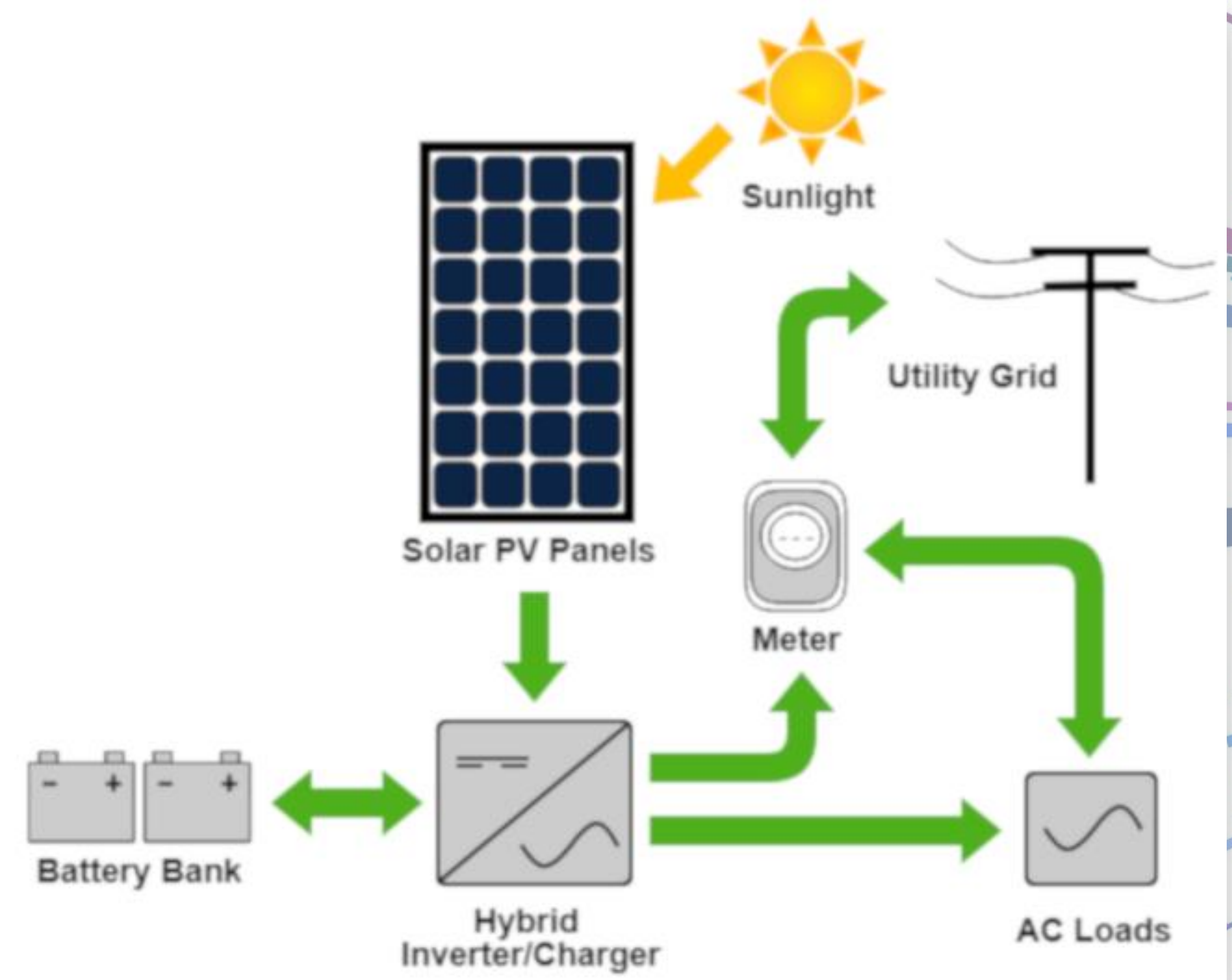
Photovoltaic Generation Model

- Generation: P = V*I
  Efficiency: $\eta \propto$ P / (Irradiance * Area)
  Average efficiency of 20%

- Maximum Power Point tracking, using different algorithms

- Simulation: use parameters to estimate I and V

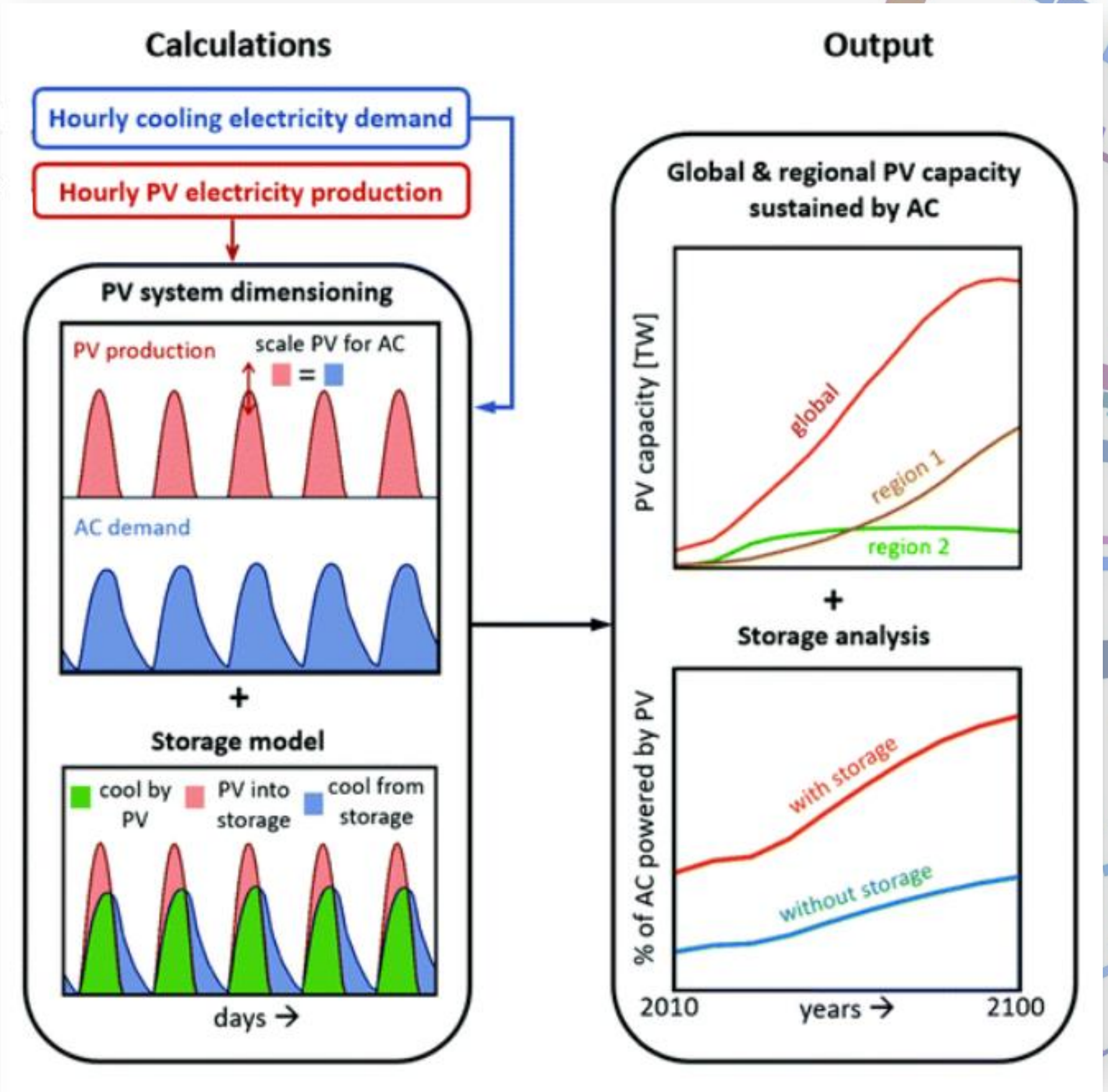




PV System Set-Up

Work Plan Methodology

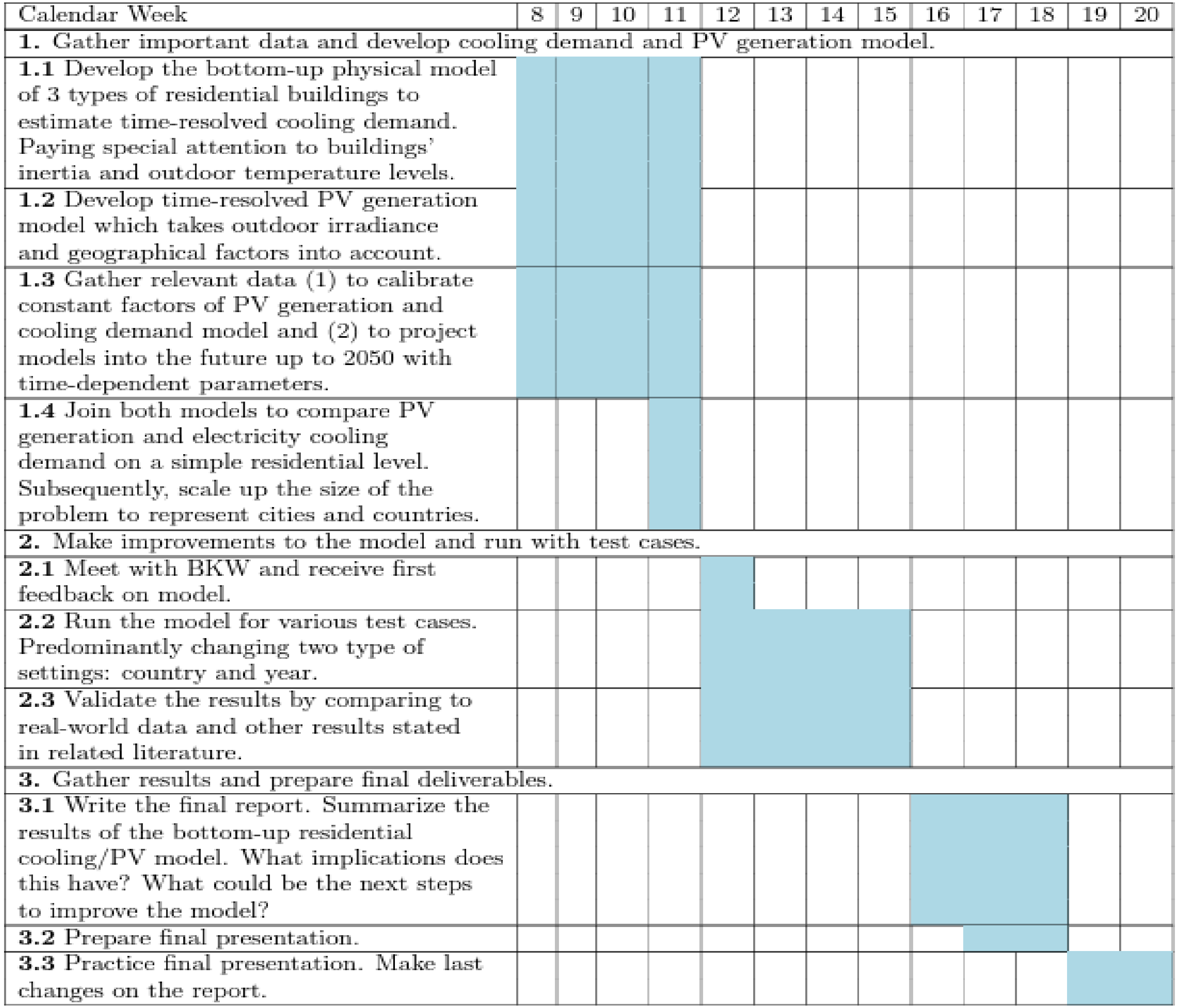
1. Gather and clean up relevant data.
2. Generate hourly PV production model (kW)
3. Generate cooling demand model (kW)
4. Compare hourly outputs
5. Extend model to different countries, change parameters



Project Schedule

Key Points:

- Simultaneously develop both models
- Time allotted to make model improvements from feedback
- Ample time is allotted to ensure quality of final report



Calendar Week	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Gather important data and develop cooling demand and PV generation model.													
1.1 Develop the bottom-up physical model of 3 types of residential buildings to estimate time-resolved cooling demand. Paying special attention to buildings' inertia and outdoor temperature levels.													
1.2 Develop time-resolved PV generation model which takes outdoor irradiance and geographical factors into account.													
1.3 Gather relevant data (1) to calibrate constant factors of PV generation and cooling demand model and (2) to project models into the future up to 2050 with time-dependent parameters.													
1.4 Join both models to compare PV generation and electricity cooling demand on a simple residential level. Subsequently, scale up the size of the problem to represent cities and countries.													
2. Make improvements to the model and run with test cases.													
2.1 Meet with BKW and receive first feedback on model.													
2.2 Run the model for various test cases. Predominantly changing two type of settings: country and year.													
2.3 Validate the results by comparing to real-world data and other results stated in related literature.													
3. Gather results and prepare final deliverables.													
3.1 Write the final report. Summarize the results of the bottom-up residential cooling/PV model. What implications does this have? What could be the next steps to improve the model?													
3.2 Prepare final presentation.													
3.3 Practice final presentation. Make last changes on the report.													

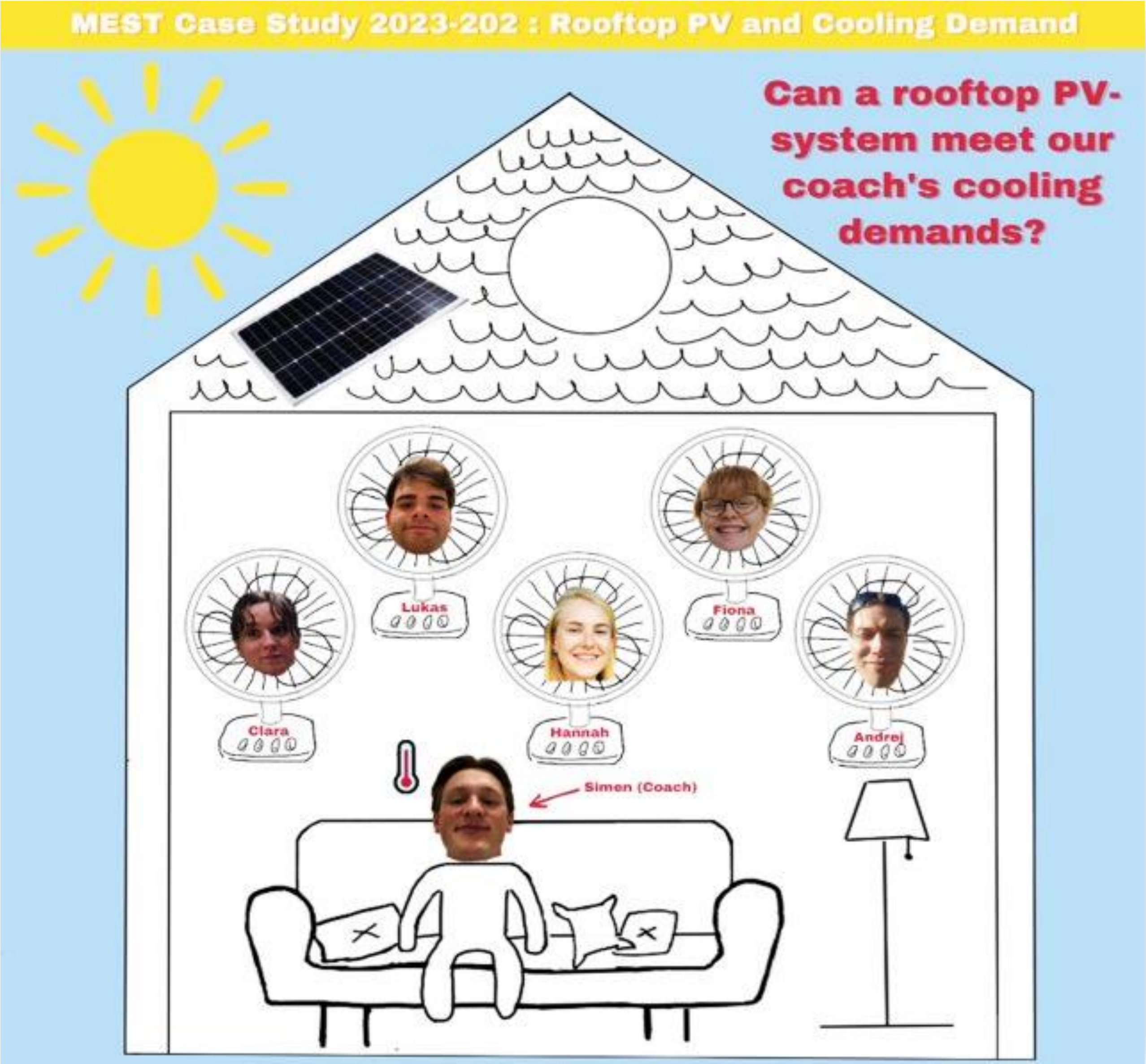
Conclusion

- Modelling approaches vary
  - Utilize standard approaches from literature

- Current and historical data is widely available, future data is not

- Difficult for companies like BKW to determine future energy needs
  - Large uncertainty exists when using model to project to 2050

Thank You!



MEST Case Study 2023-202 : Rooftop PV and Cooling Demand
Can a rooftop PV-system meet our coach's cooling demands?
Lukas
Fiona
Clara
Hannah
Andrej
Simen (Coach)