

Numerical Energy Analysis of PV Modules as Adaptive Building Shading Systems

Master Thesis

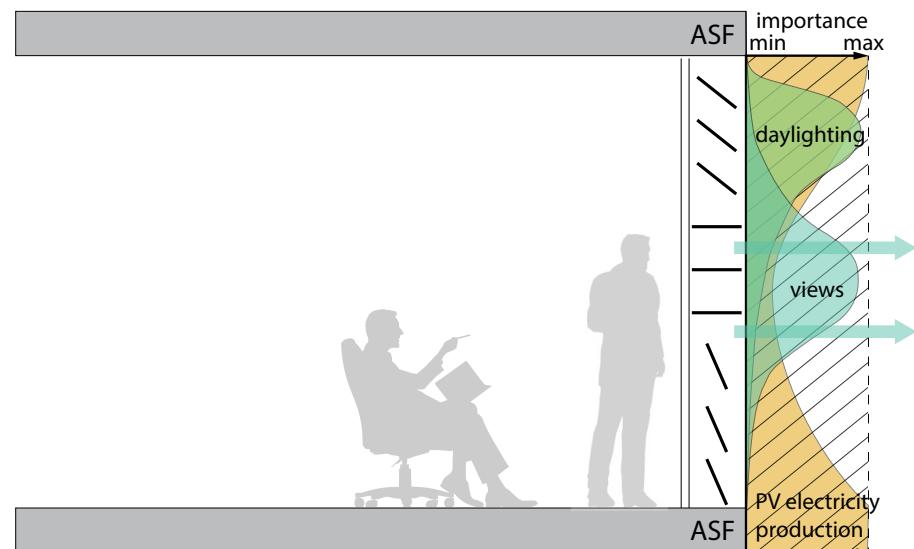
Jeremias Schmidli

Supervisor:
Prageeth Jayathissa



The Adaptive Solar Façade (ASF)

- Individually Actuated Panels
- Combines Dynamic Shading with PV-Electricity Production
- Needs to Be Optimized for Cooling, Heating, Lighting and PV-Electricity Production



Previous Work

Giovanni Bianchi: Single Evaluation of Building Energy Demand



Prageeth Jayathissa: Parametric Thermal Model with Estimated PV

Johannes Hofer: Detailed Model and Evaluation of PV Electricity Production

*Proceedings of the International Conference on Building Envelope Design and Technology, Graz
Advanced Building Skins 2015*

Numerical Simulation of Energy Performance,
and Construction of the Adaptive Solar Façade

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Energy Science & Engineering

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RESEARCH ARTICLE

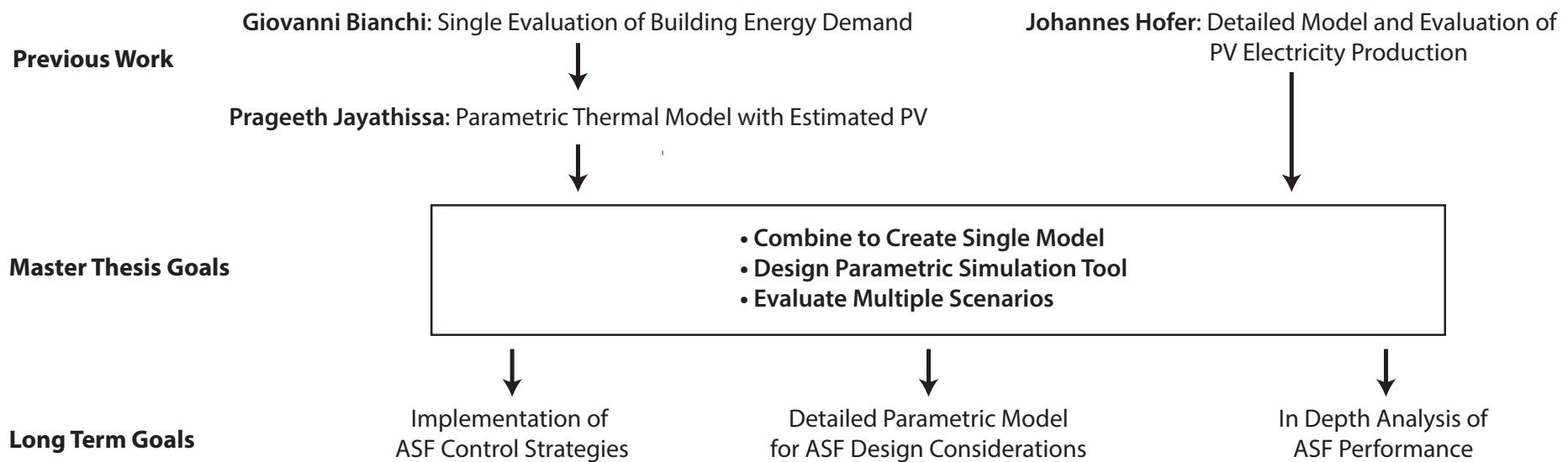
Parametric analysis and systems design of dynamic photovoltaic shading modules

Johannes Hofer¹, Abel Groenewolt², Prageeth Jayathissa¹, Zoltan Nagy¹ & Arno Schlueter¹

¹Architecture and Building Systems, Institute of Technology in Architecture, ETH Zurich, John-von-Neumann Weg 9, 8093 Zürich, Switzerland

²Institute for Computational Design, University of Stuttgart, Keplerstrasse 11, 70174 Stuttgart, Germany

ASF Simulation Goals



Overview

- Introduction
- Problem Description
- Methodology
- Results and Discussion
- Conclusions and Outlook

Problem Description

Optimization Problem

Minimize: $C + H + L - PV$

C = Cooling Electricity Demand

H = Heating Electricity Demand

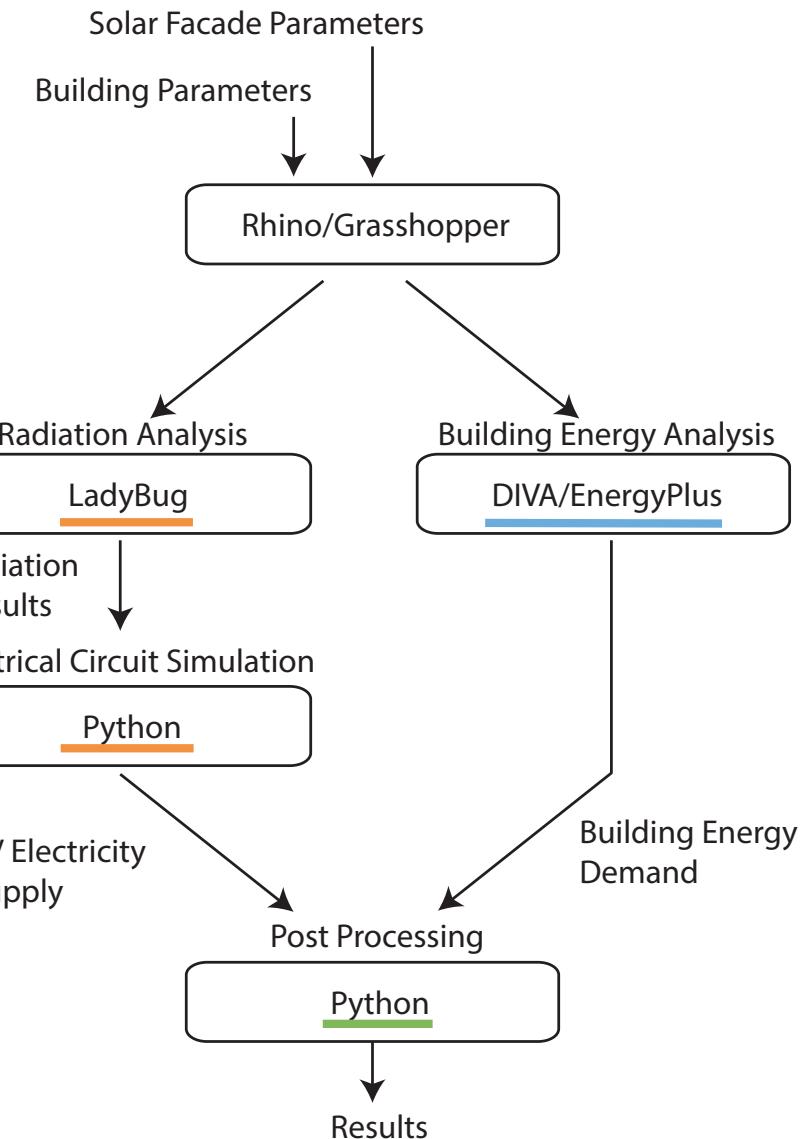
L = Lighting Electricity Demand

PV = Photovoltaic Electricity Supply

Methodology

Combination Of Different Tools To Achieve Optimal Results

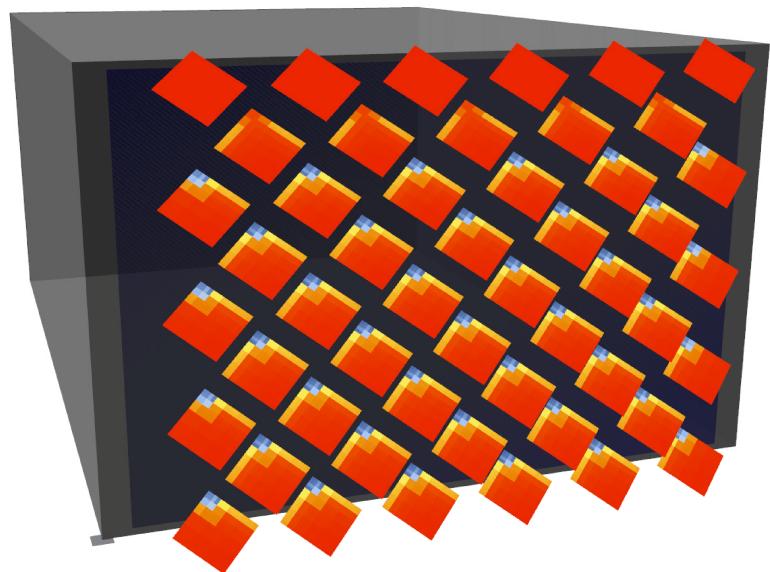
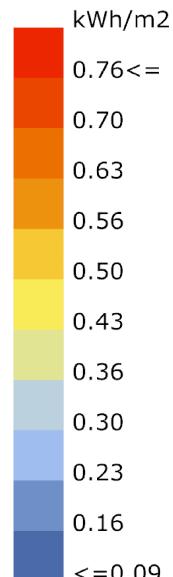
Minimize: C + H + L - PV



Radiation and PV analysis

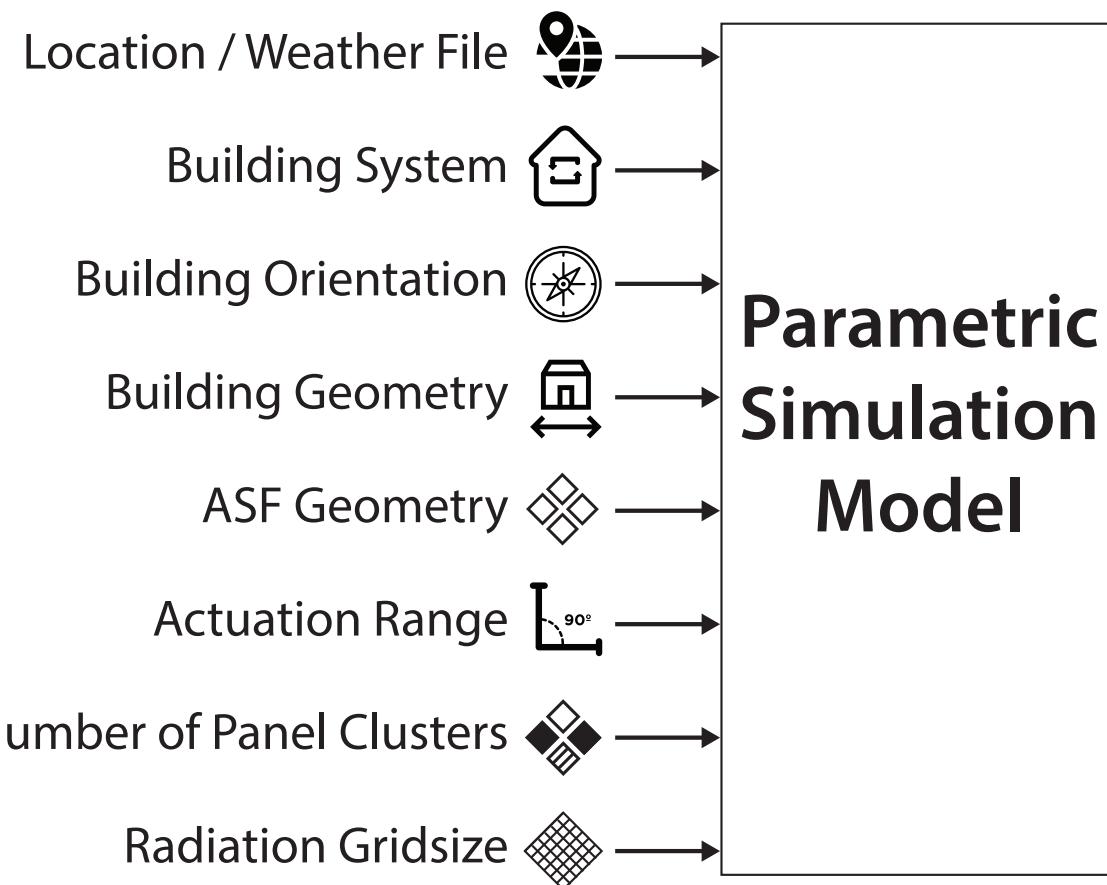
(Collaboration with Johannes)

- Radiation Analysis with Ladybug
- Includes Self-Shading
- Detailed PV Simulation with Python
- Electrical Model includes Temperature and Radiation Dependency

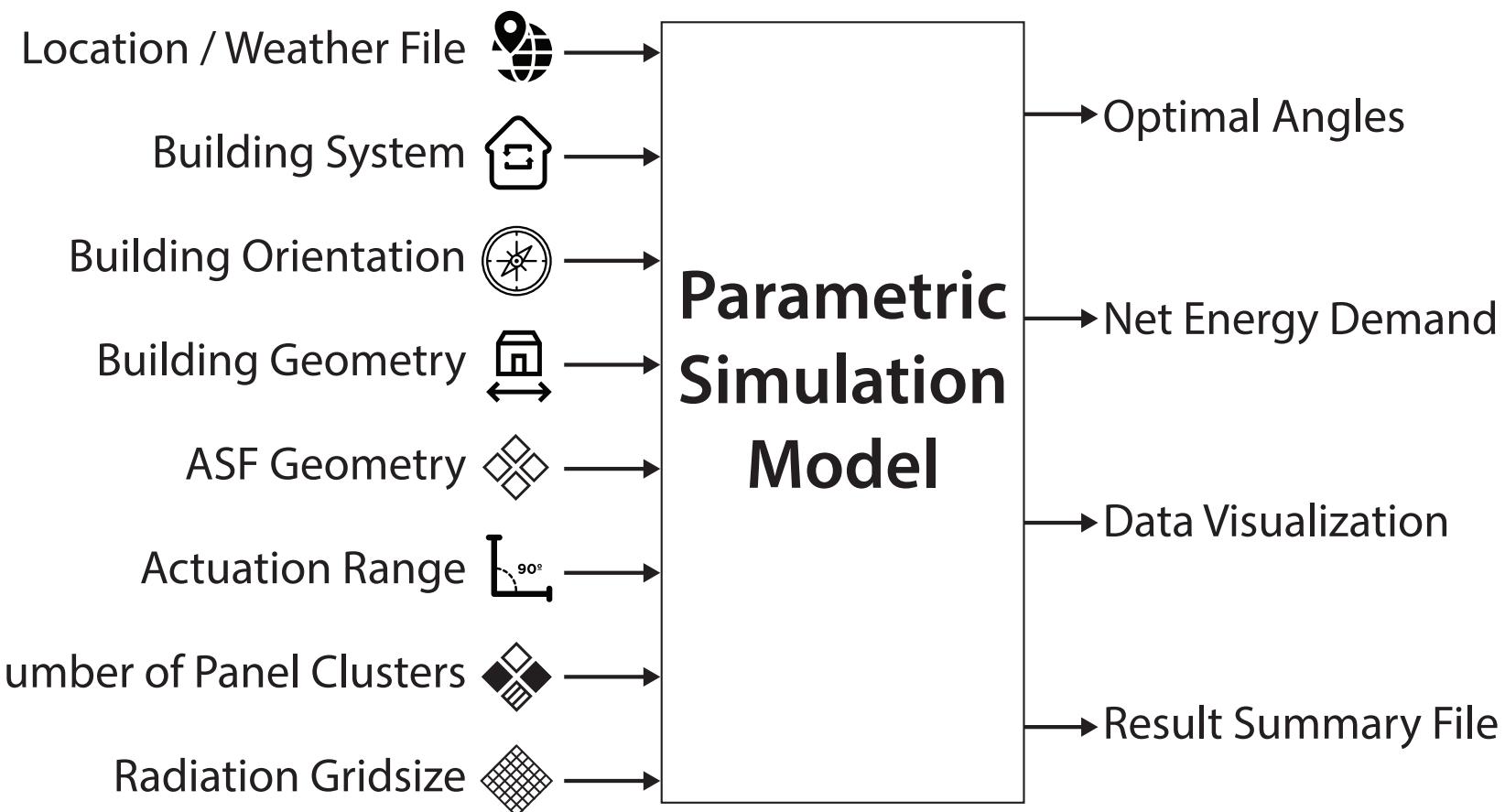


Insolation from 12:00-13:00 on August 11

Parametric Model



Parametric Model

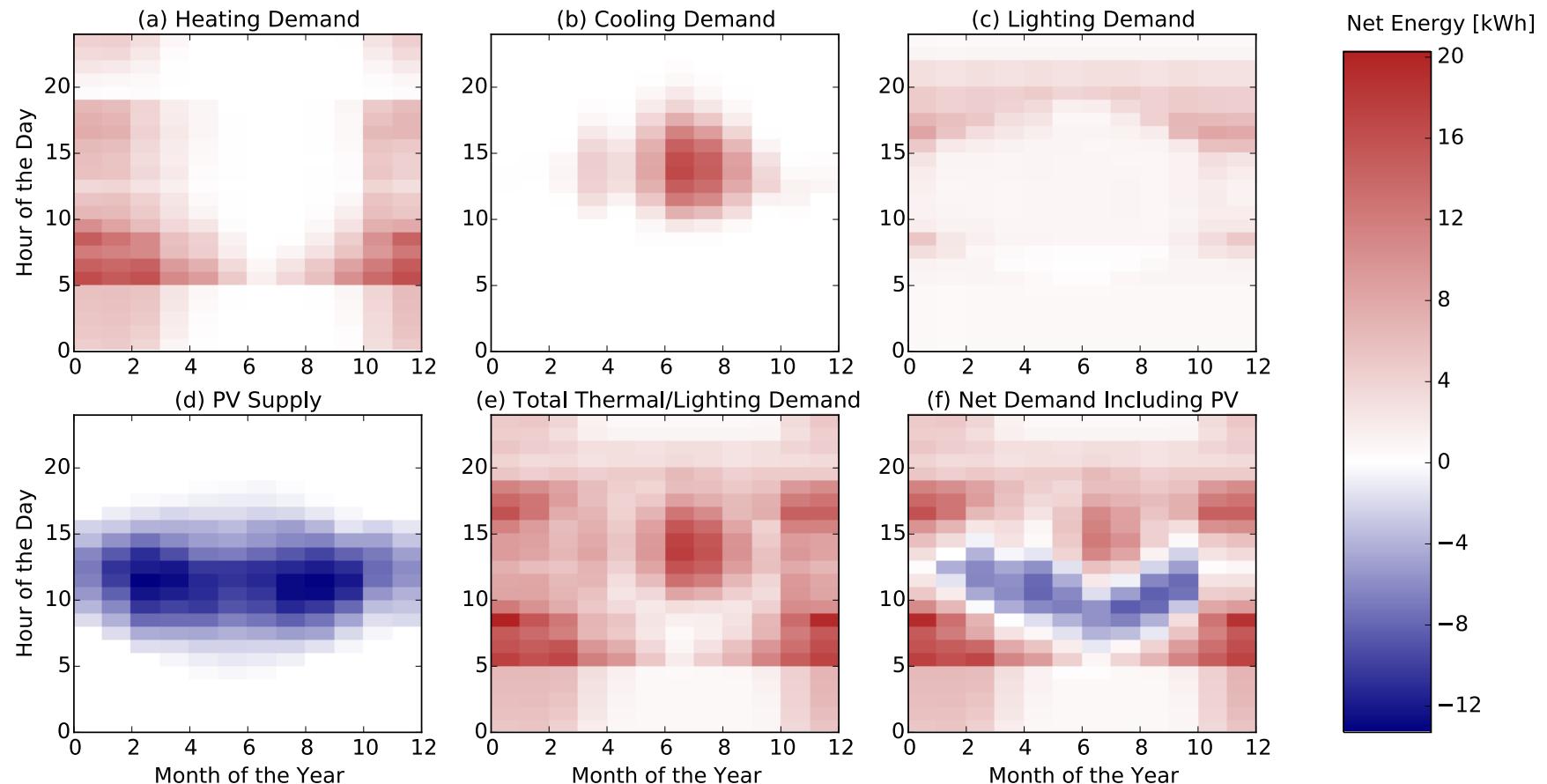


Base Case

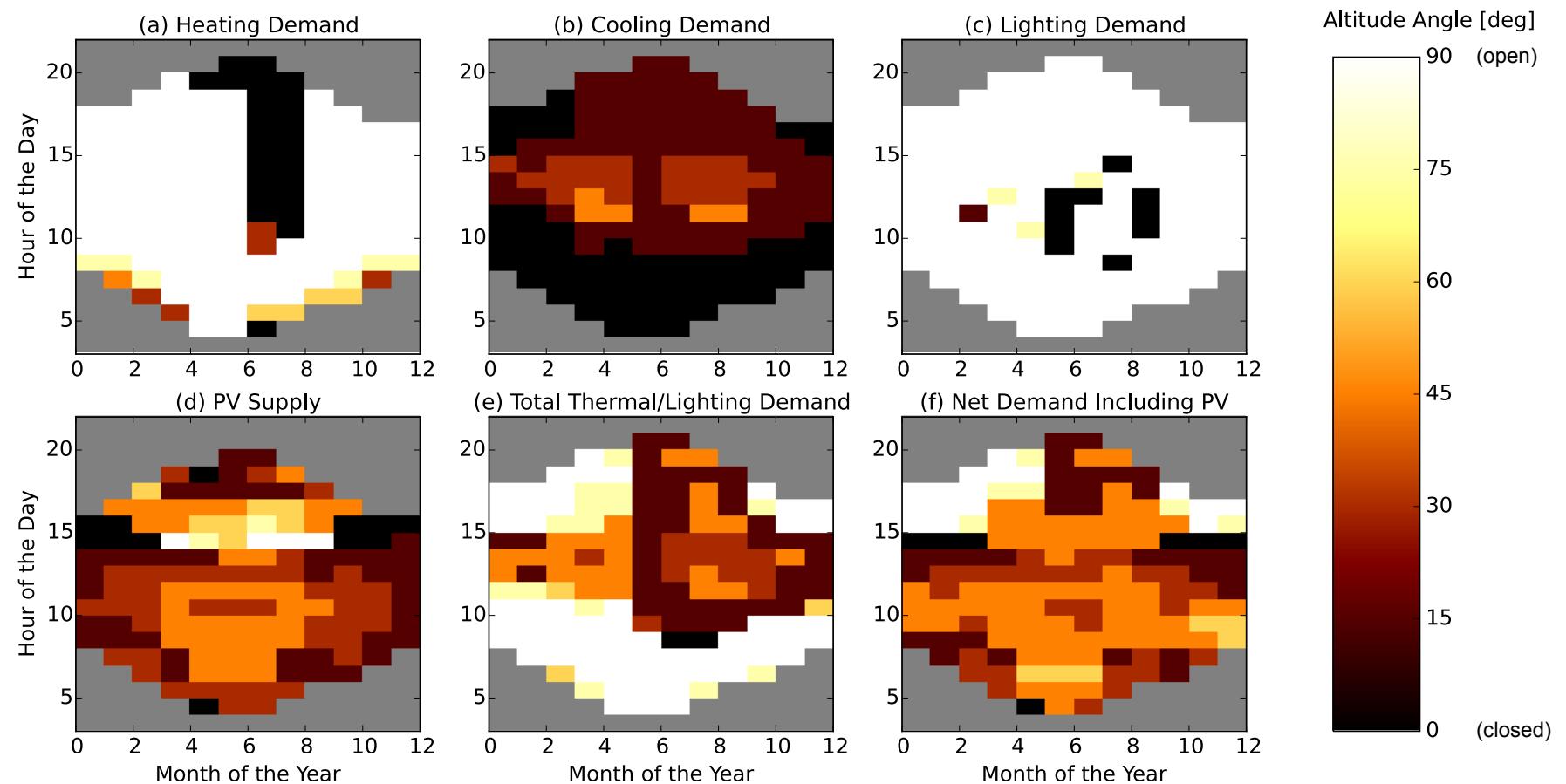
- Single Zone Office
- Simulation for One Year
- Weather File for Kloten-Zurich
- Heating COP: 4
- Cooling COP: 3
- Lighting Load: 11.74 W/m^2
- Infiltration Rate: 1/h
- 50 Panels in a Single Cluster



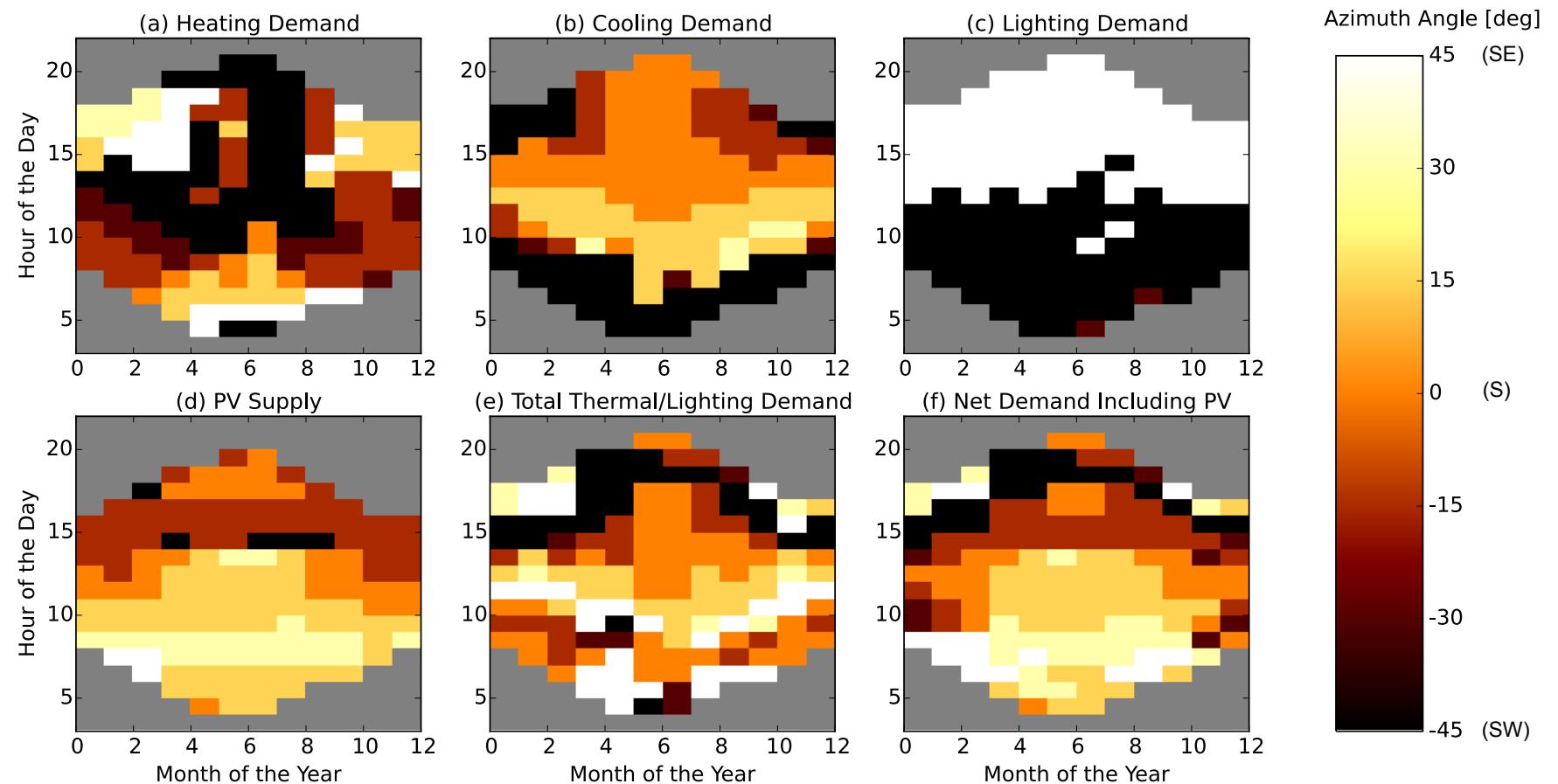
Net Energy Demand at Optimum Panel Angles



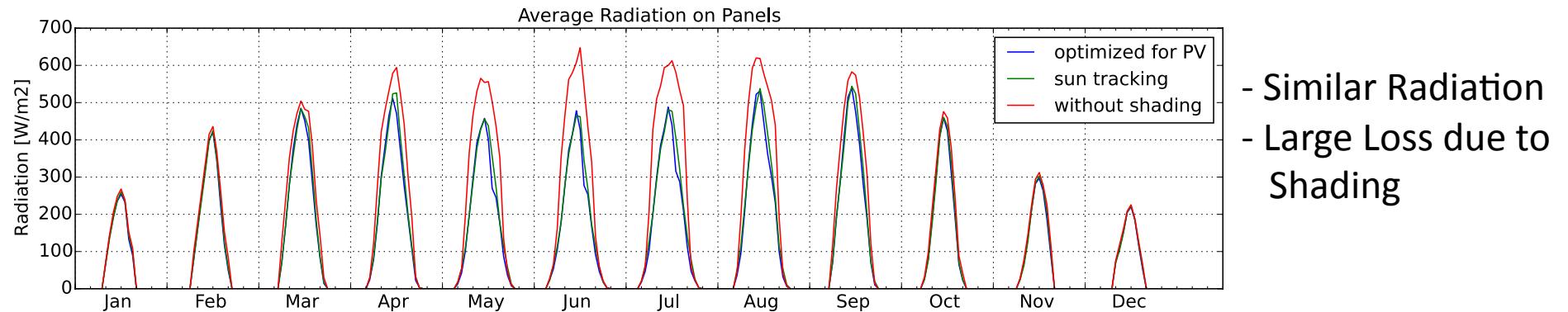
Optimum Altitude Angles of Panels



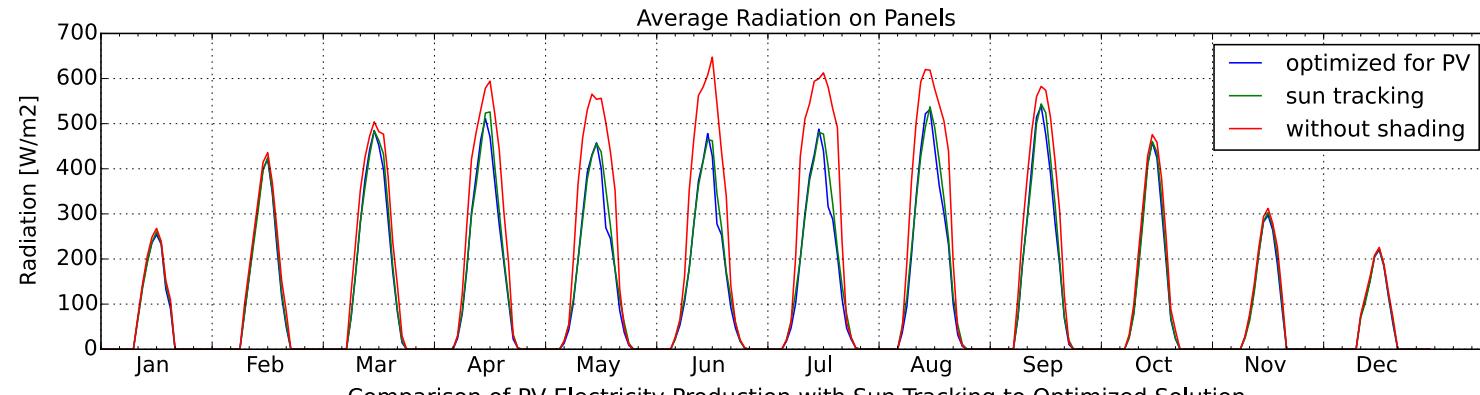
Optimum Azimuth Angles of Panels



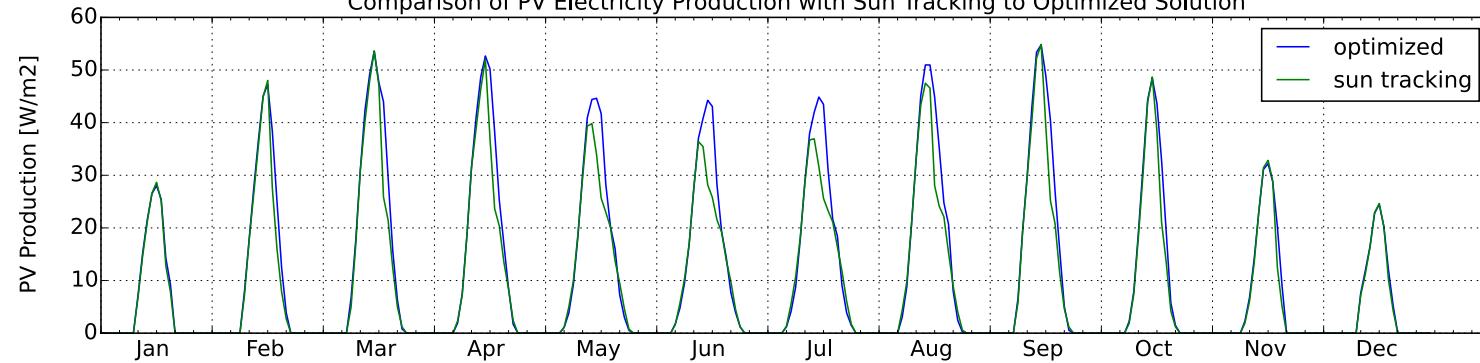
PV: Sun-Tracking vs. PV Optimization



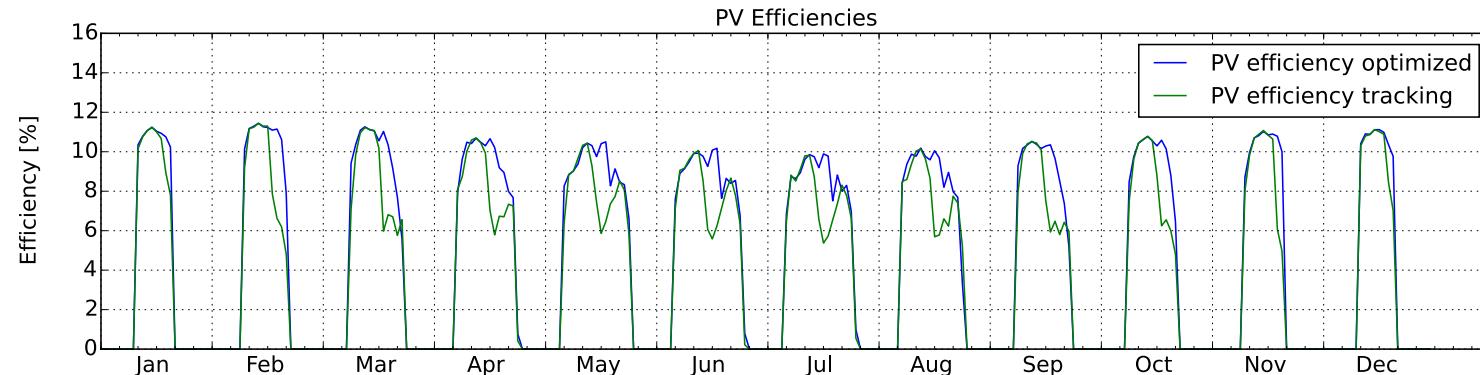
PV: Sun-Tracking vs. PV Optimization



- Similar Radiation
- Large Loss due to Shading



- Higher Electricity Production for Optimized Solution



- Higher Efficiency with Optimized Solution

Parameter Variations

Performance Evaluation in Dependence of:



Building Orientation



Location / Weather File

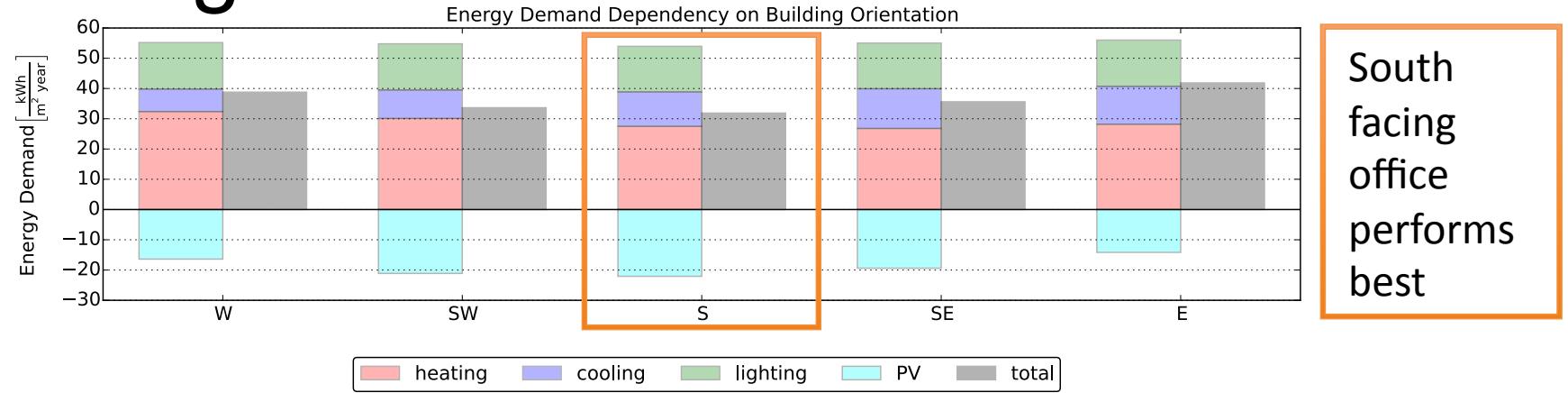


Building System

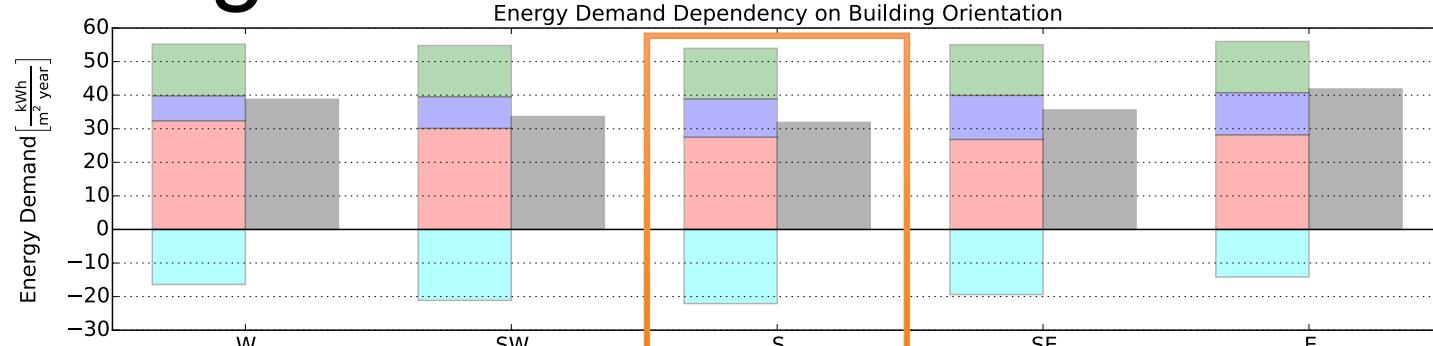


Number of Panel Clusters

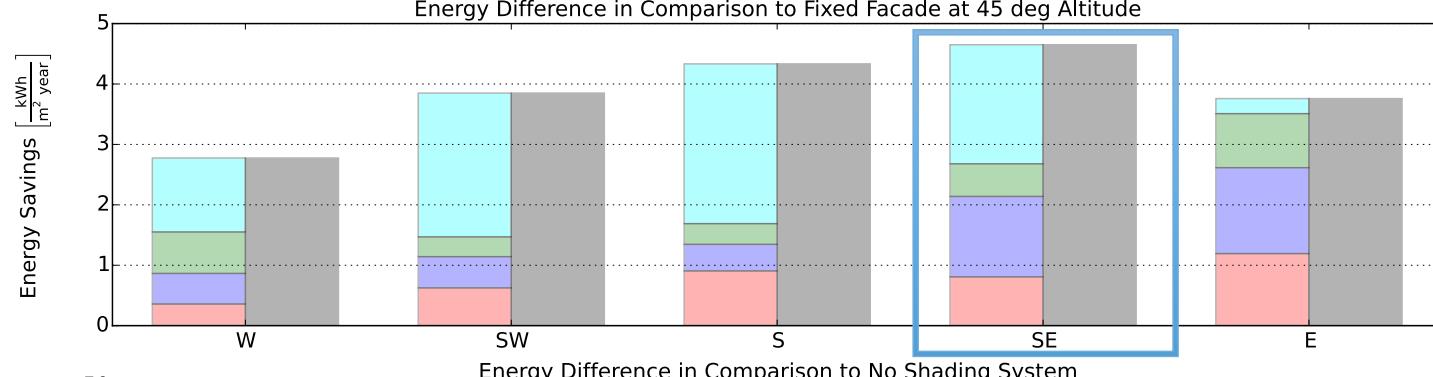
Building Orientation Performance



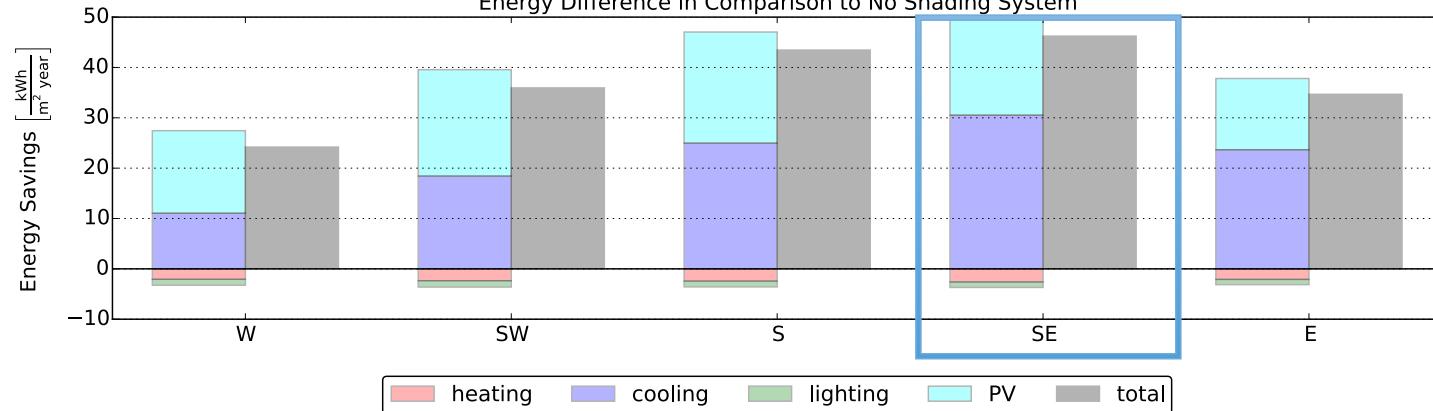
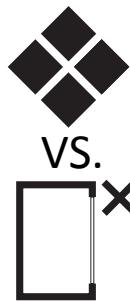
Building Orientation Performance



South facing office performs best

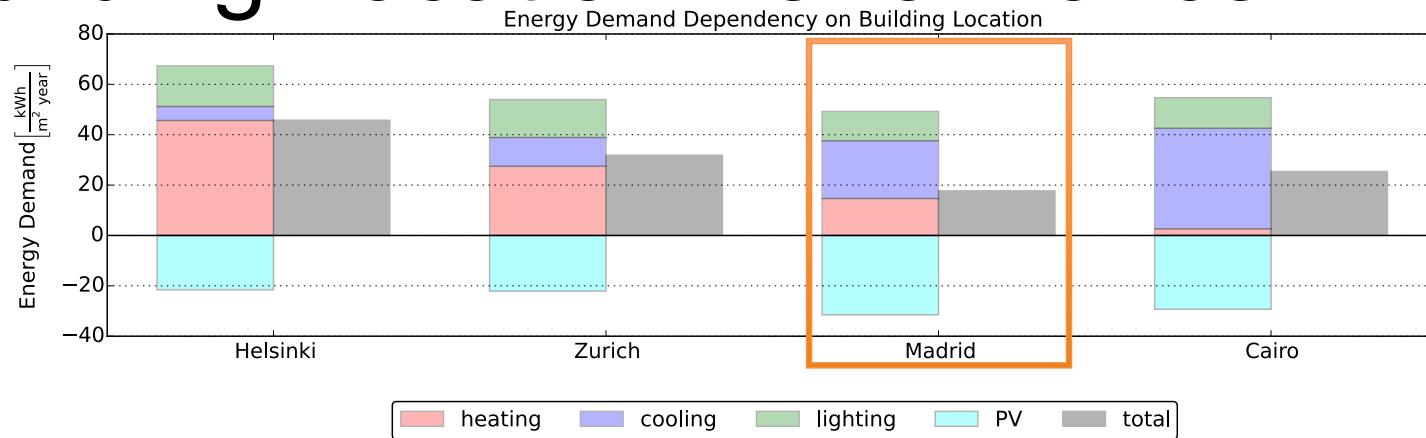


Highest benefit from ASF for south-east facing facade due to cooling



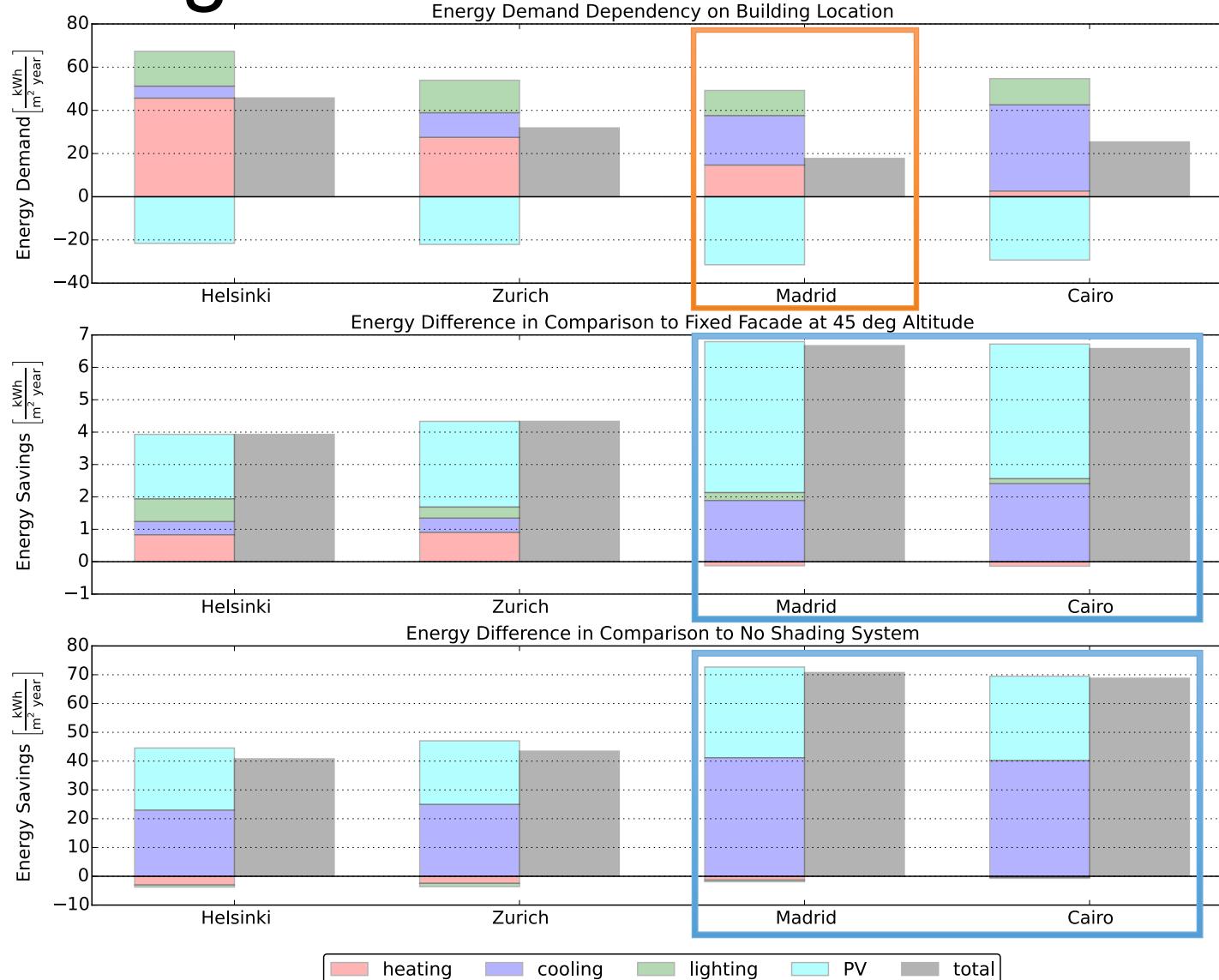
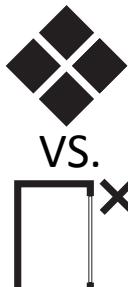
heating cooling lighting PV total

Building Location Performance



Office in
Madrid
performs
best

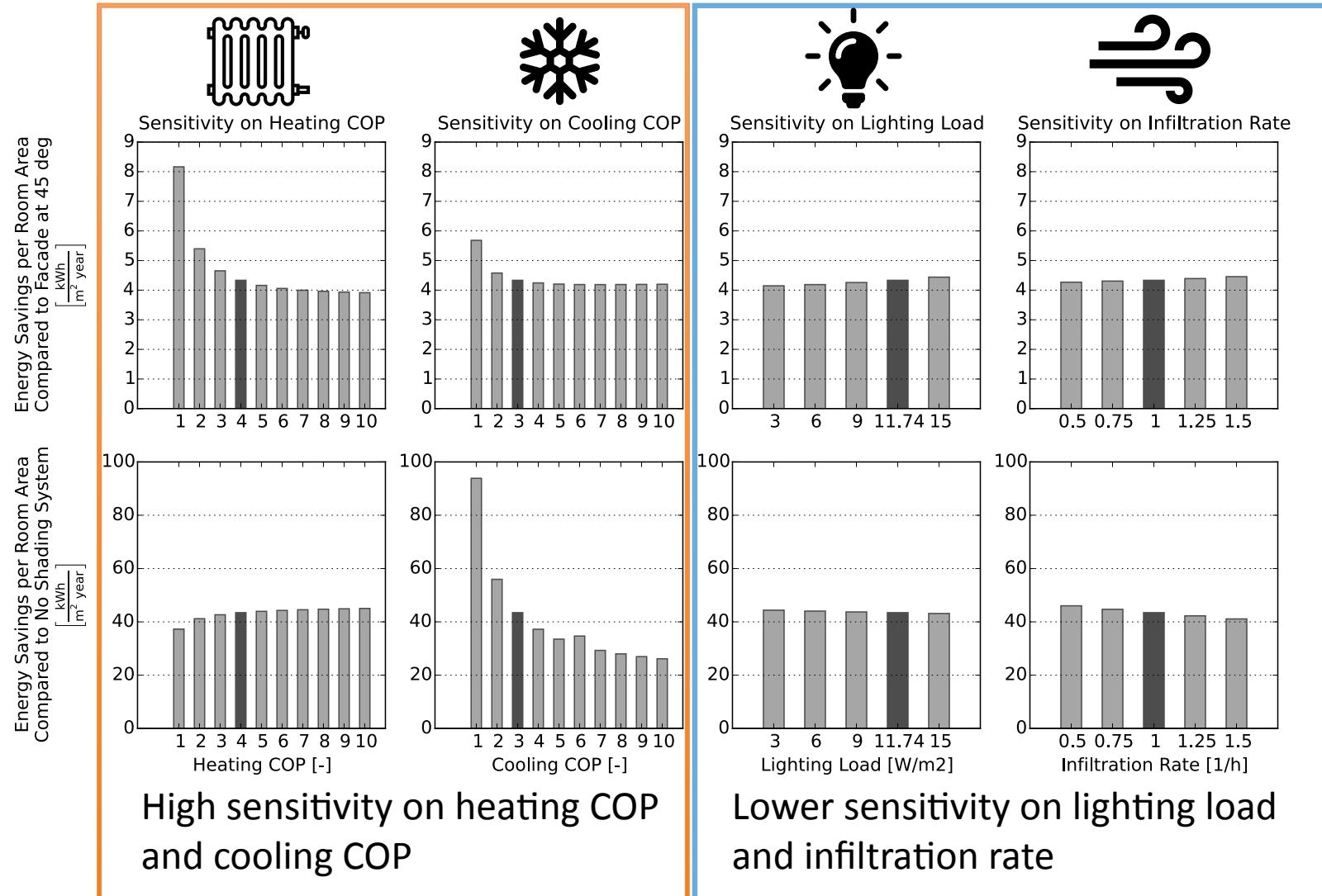
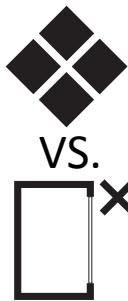
Building Location Performance



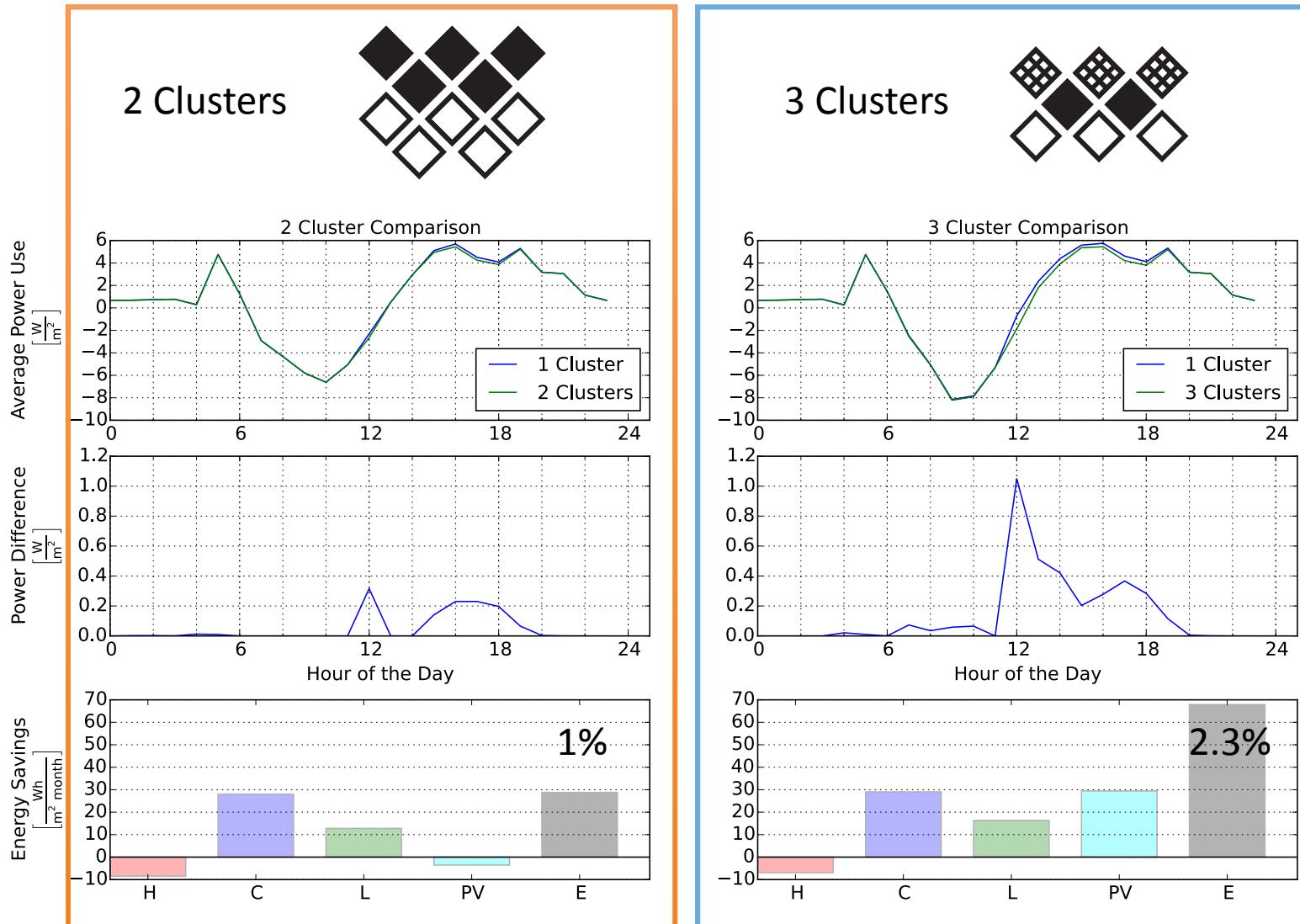
Office in Madrid performs best

Highest benefit from ASF for warm regions

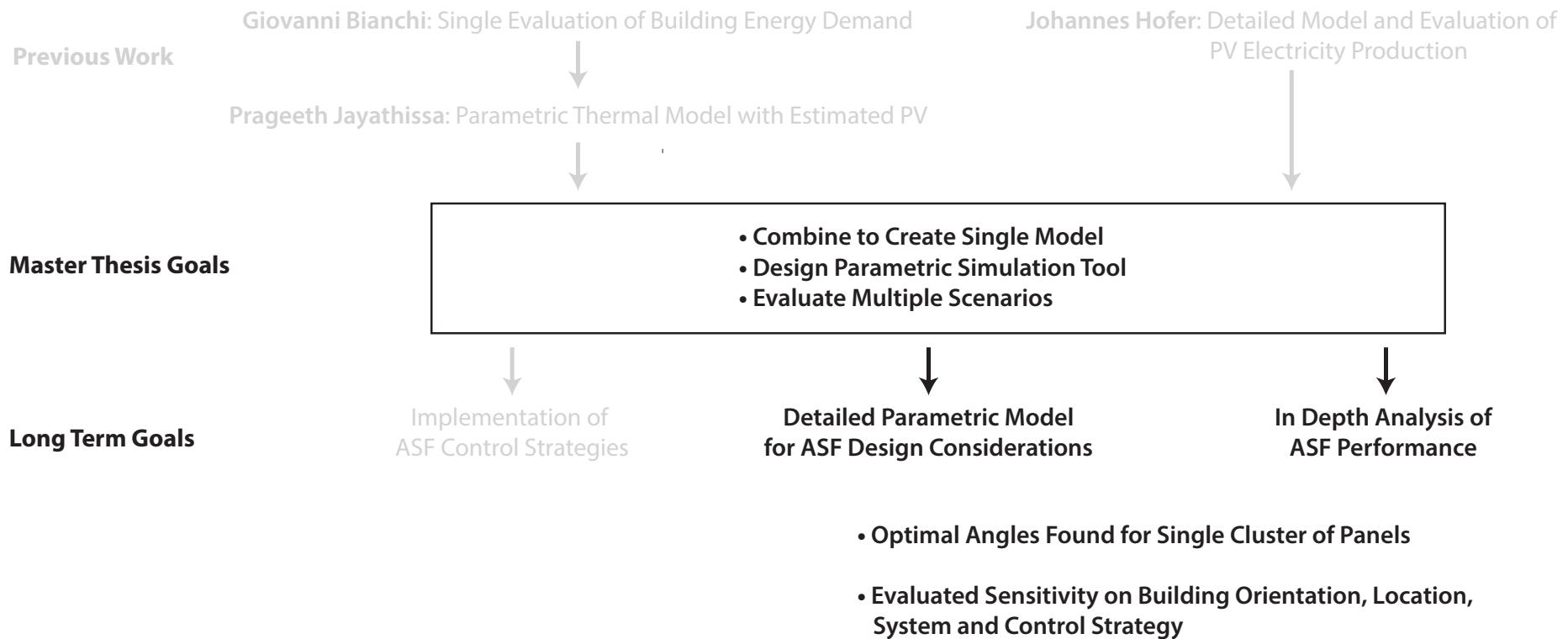
Building System Sensitivity



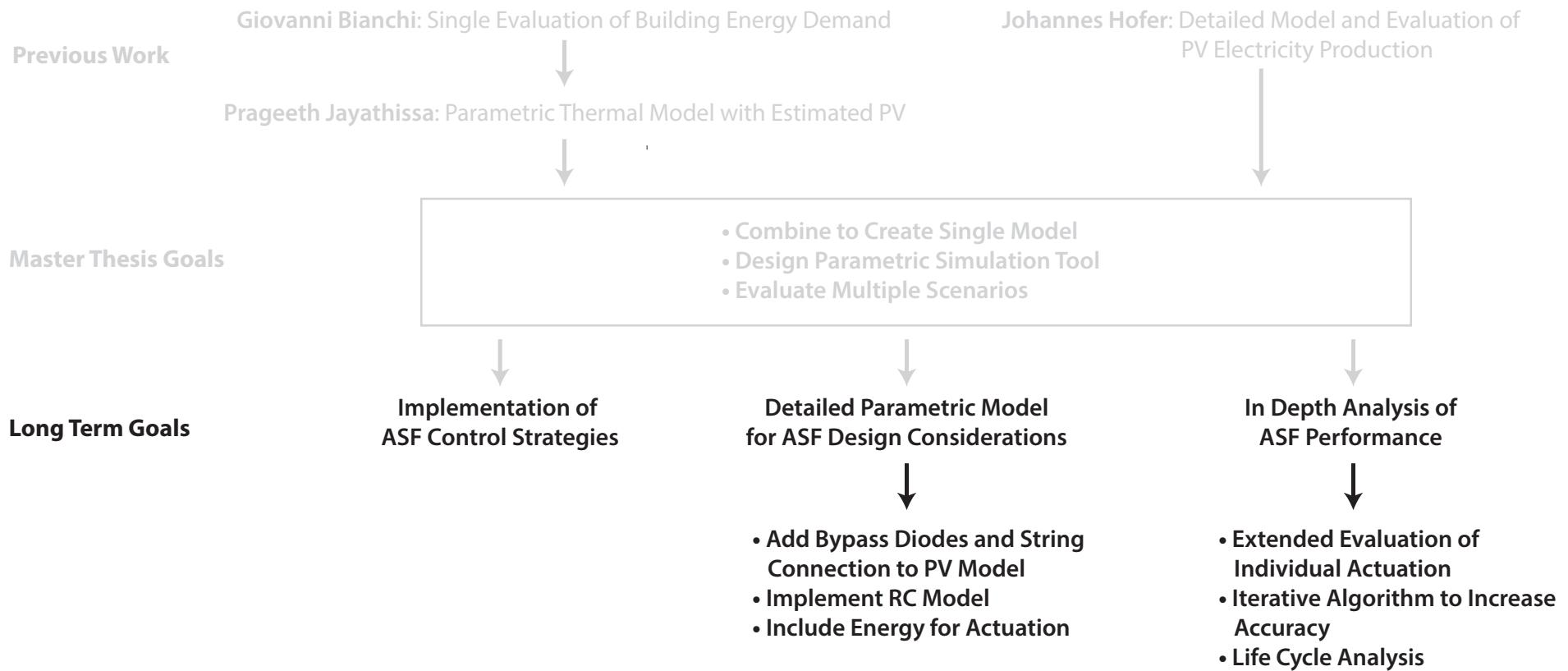
Cluster Analysis



Conclusions



Outlook

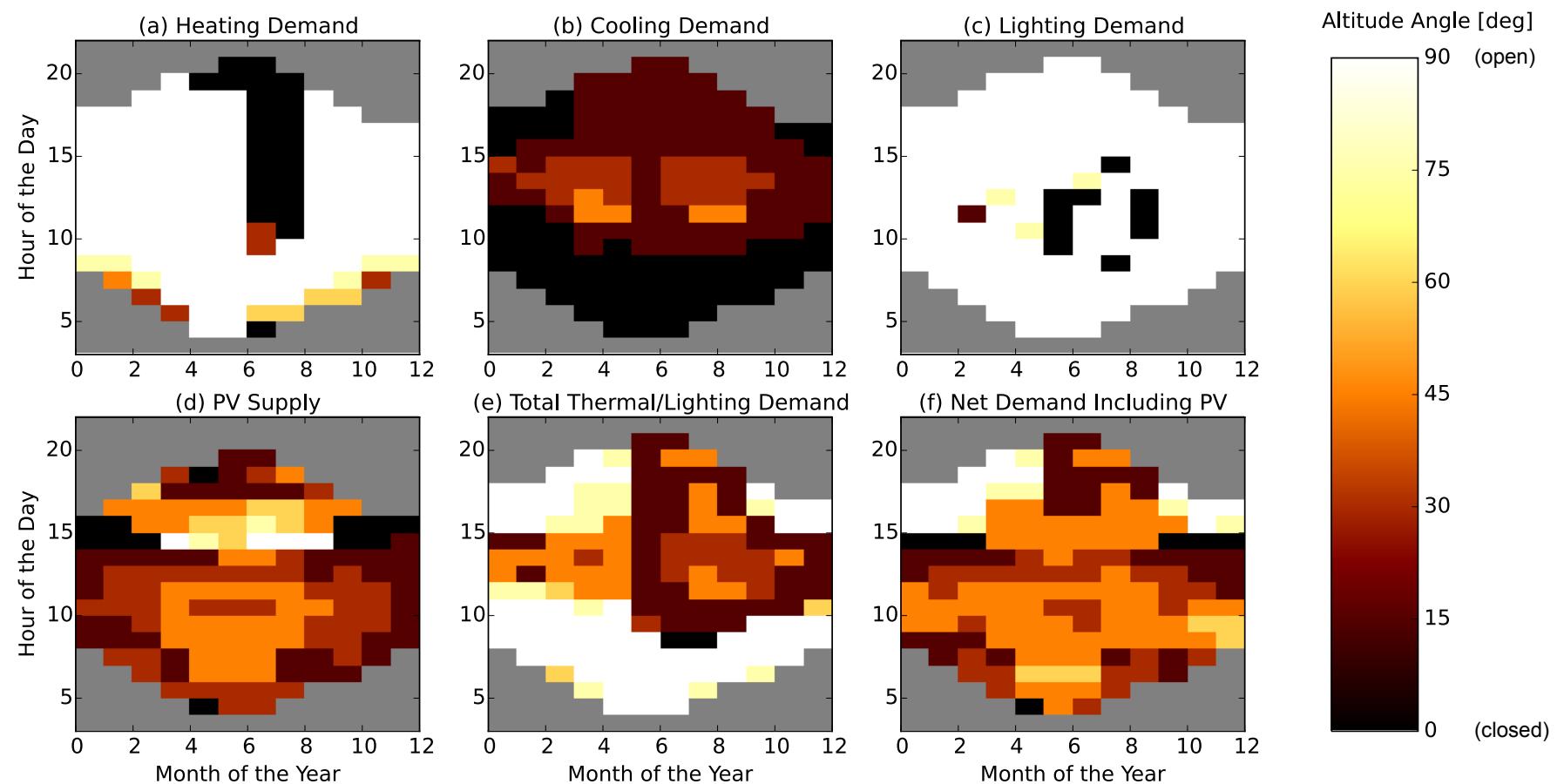


Questions?

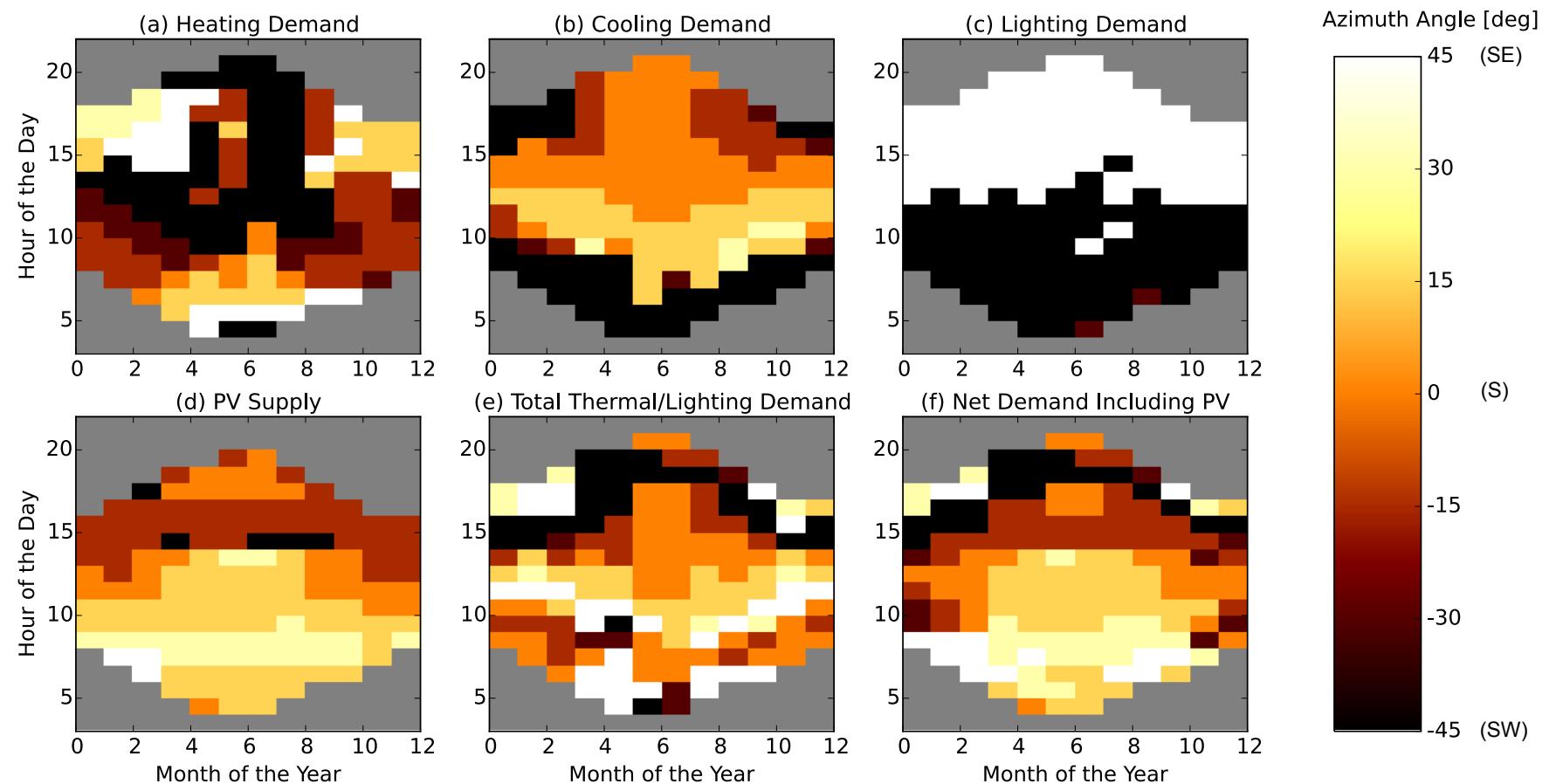


https://github.com/architecture-building-systems/ASF_Simulation

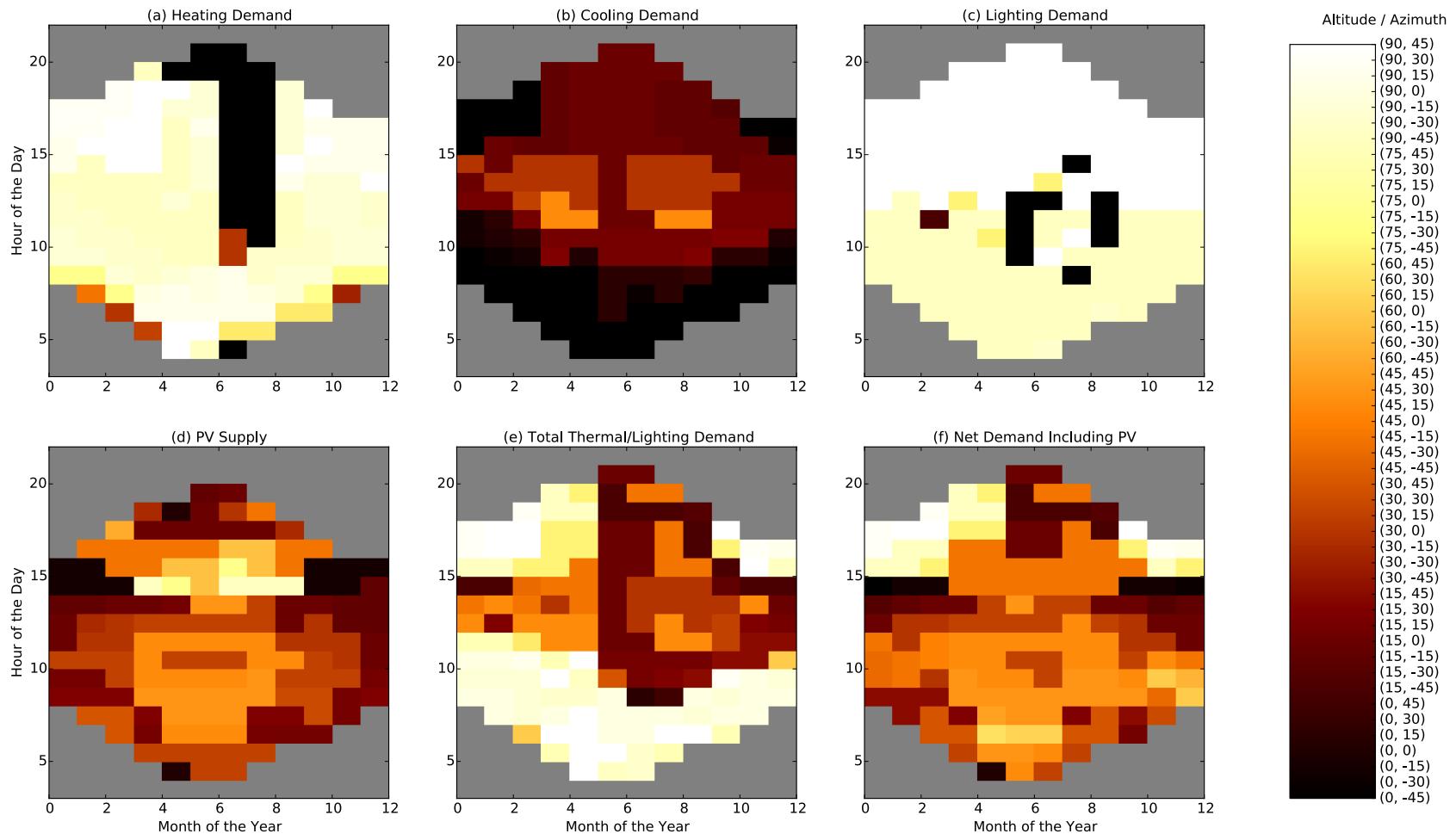
Optimum Altitude Angles of Panels



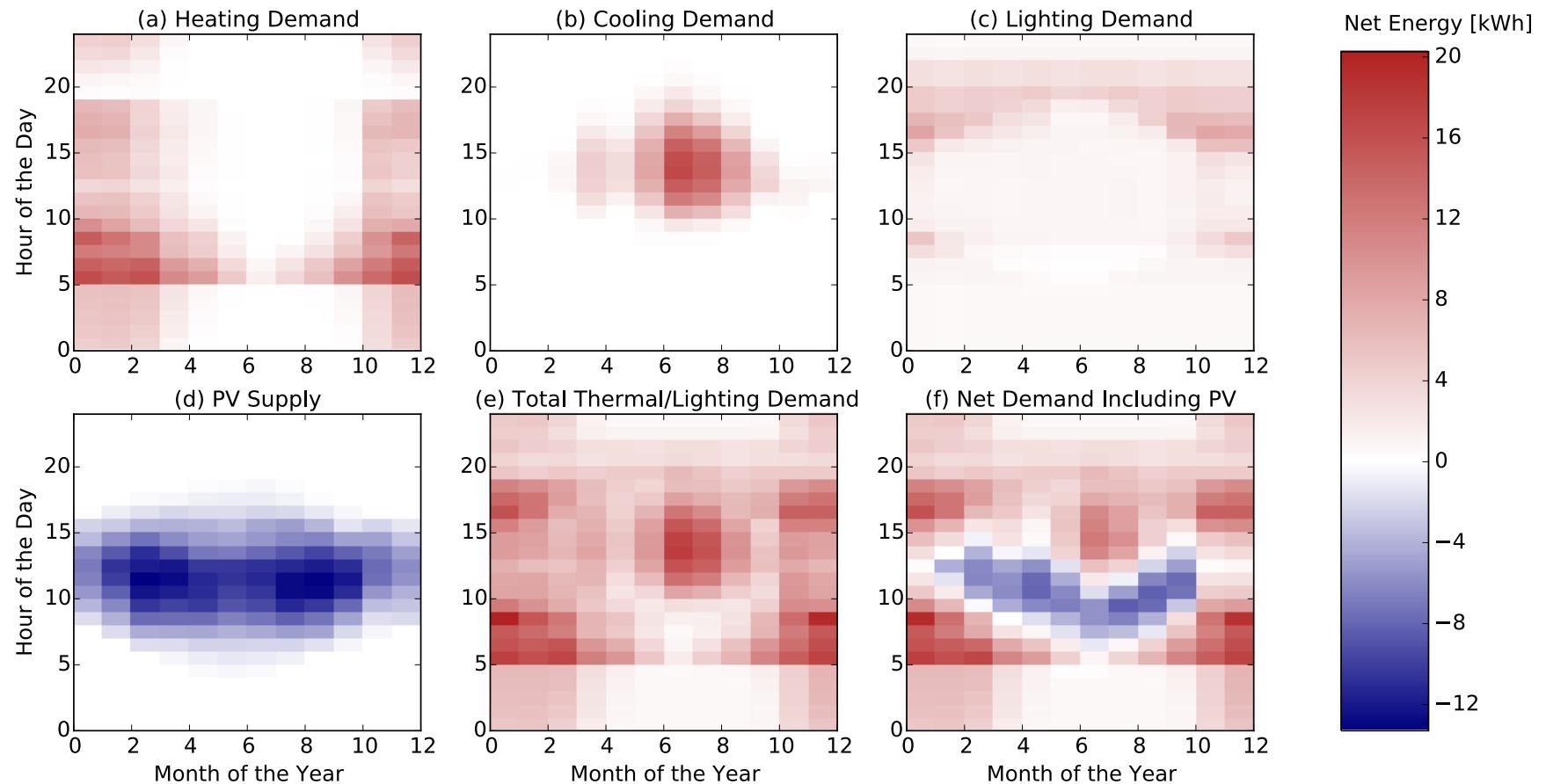
Optimum Azimuth Angles of Panels



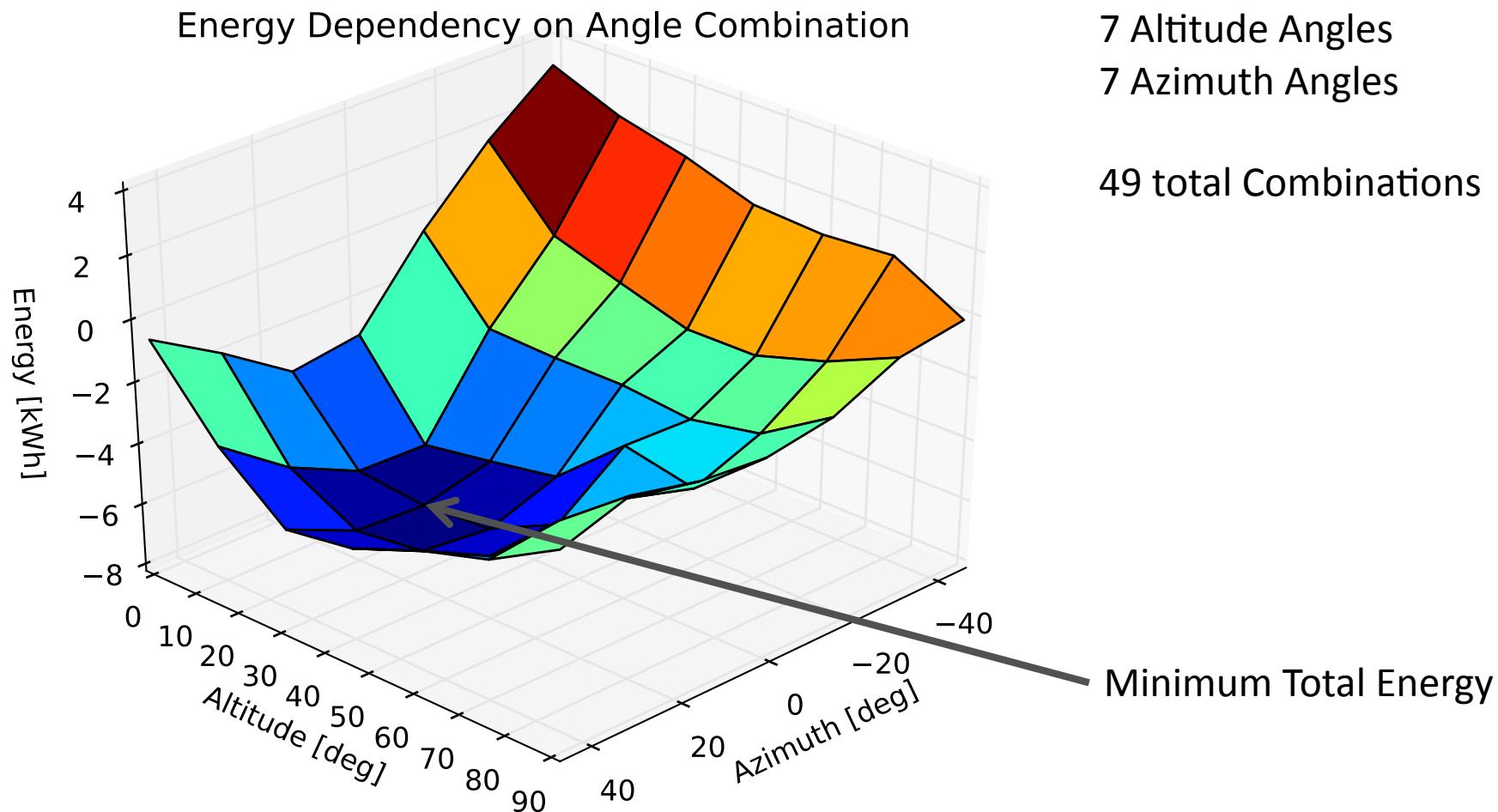
Optimum Angle Combinations of Panels



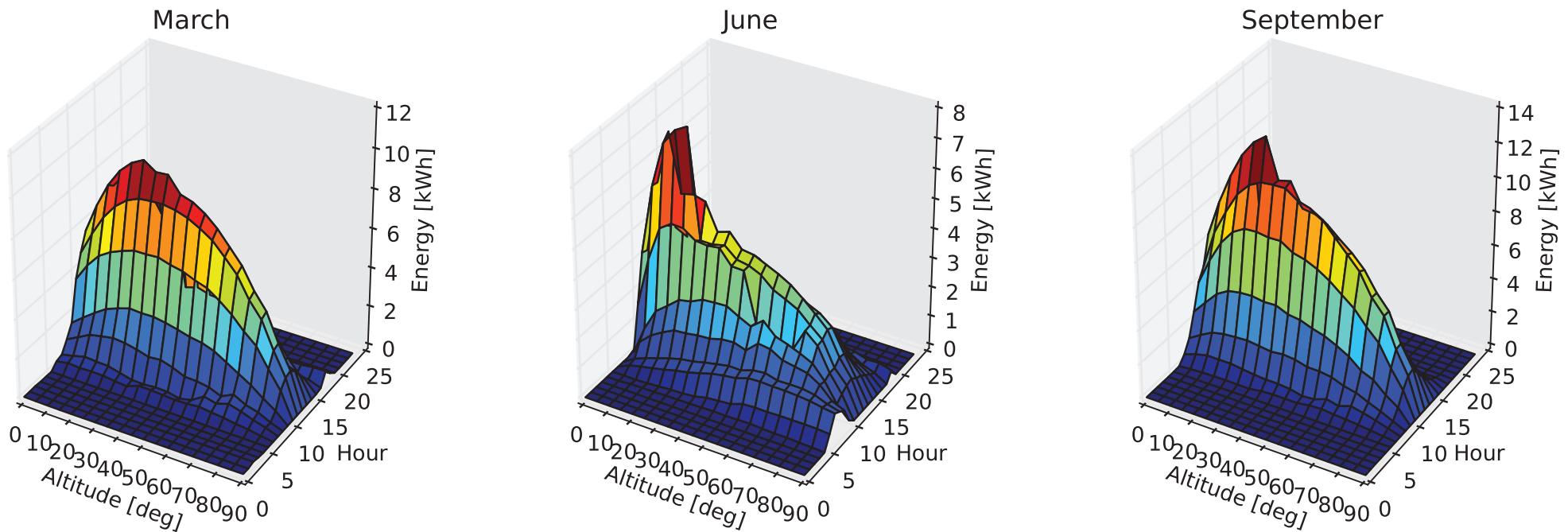
Net Energy Demand at Optimum Panel Angles



Discrete Optimization

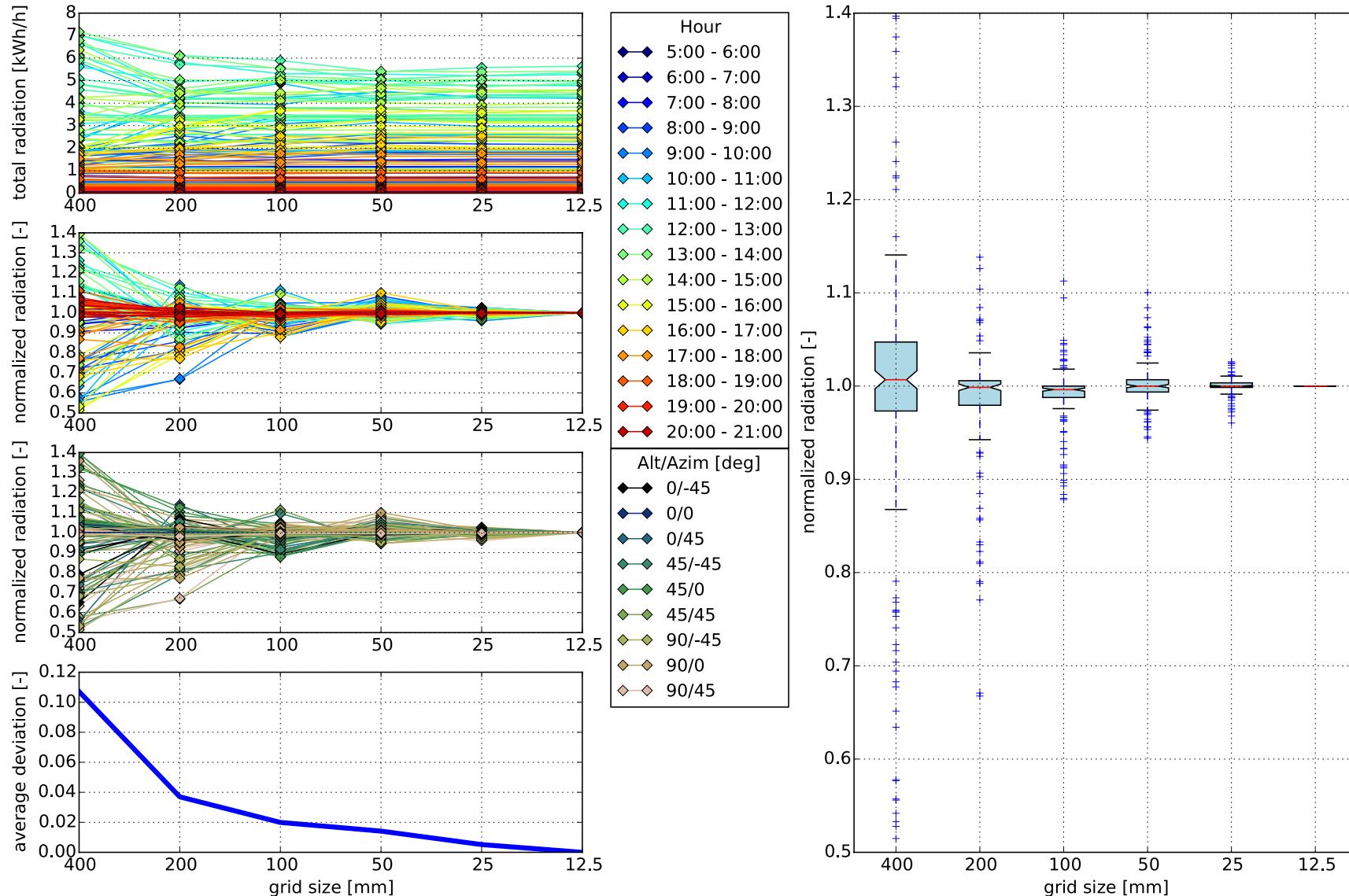


Influence of Actuation

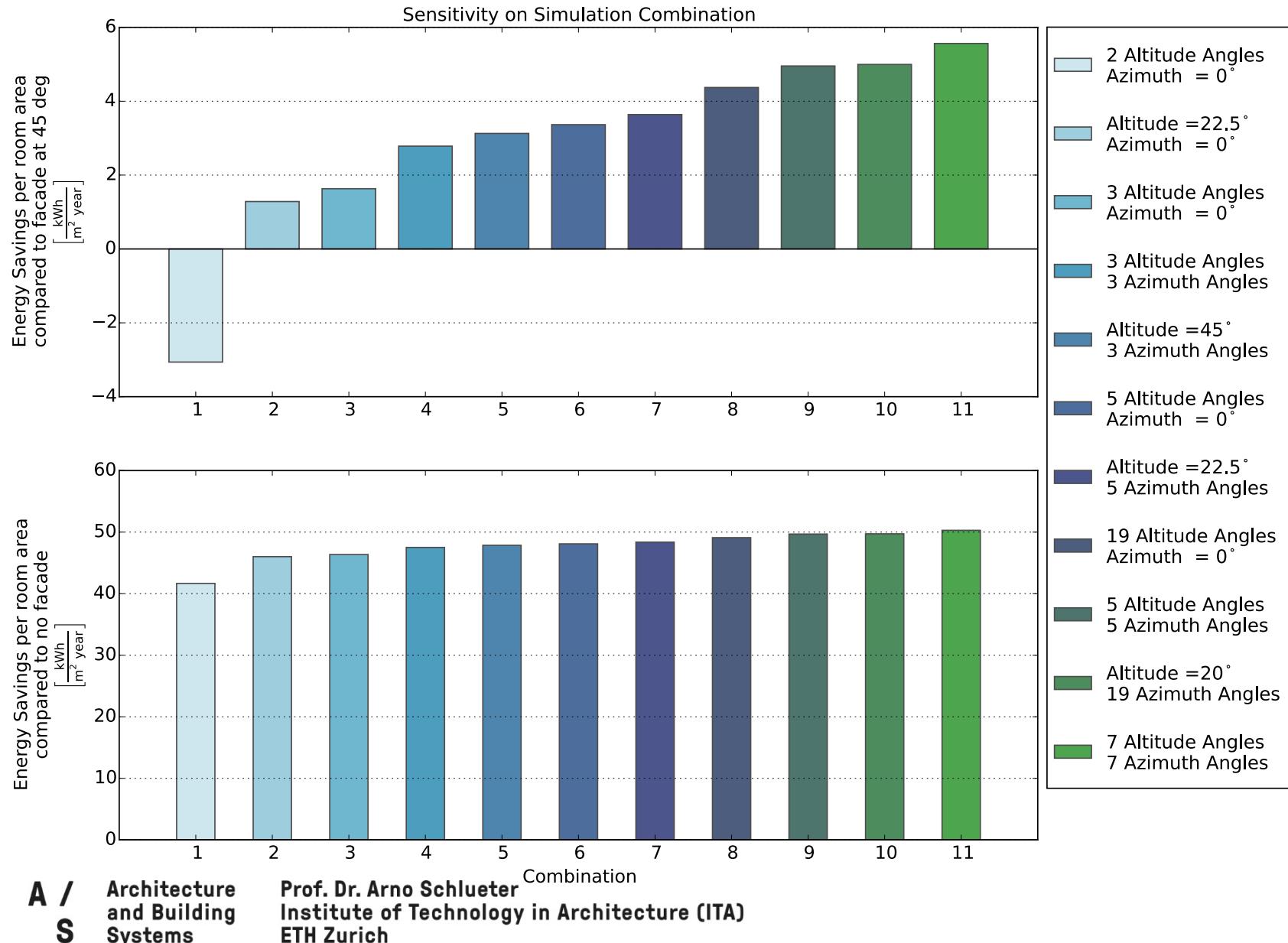


Strongest Influence at Noon
Optimizing for Cooling and PV (closed positions)

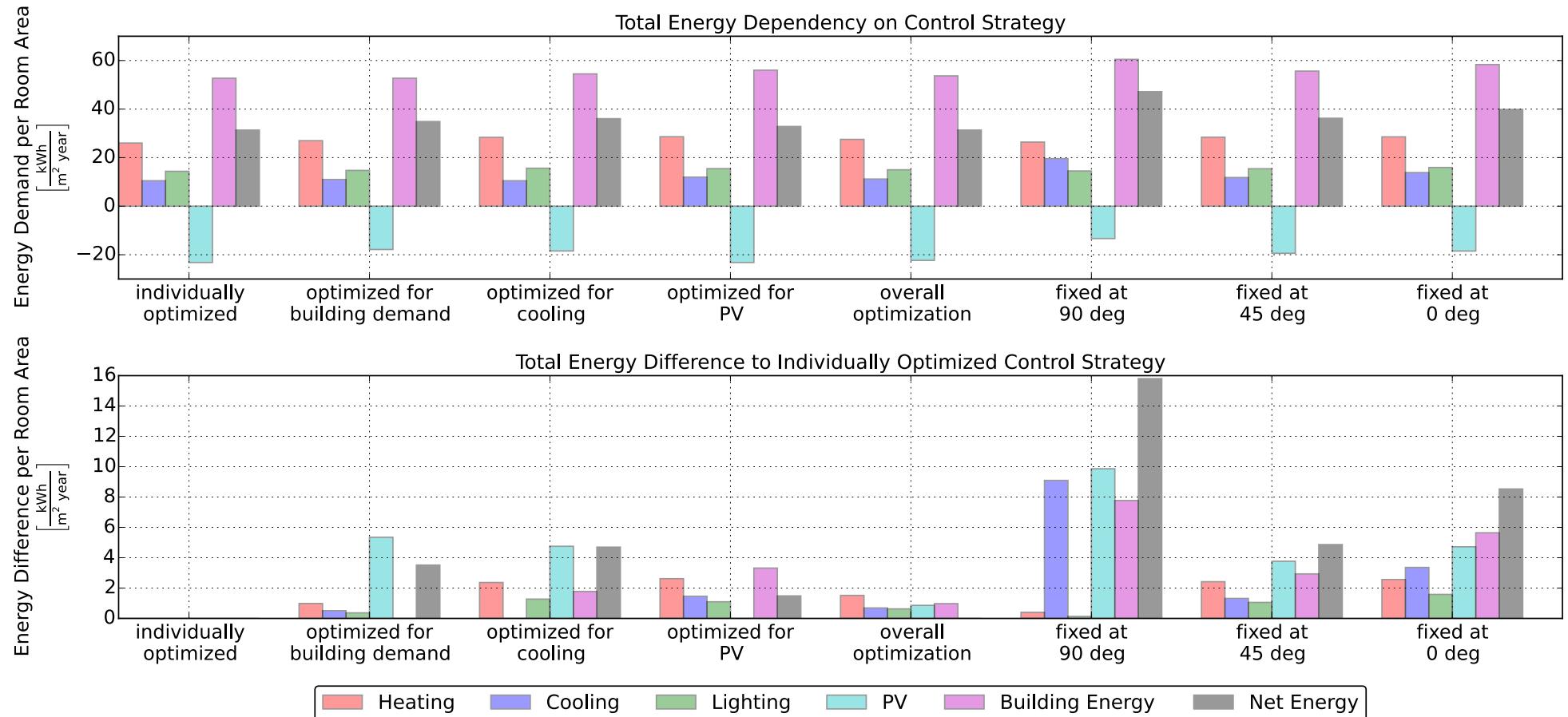
Grid Convergence Study



Sensitivity on Simulation Combination



Energy Dependency on Control Strategy



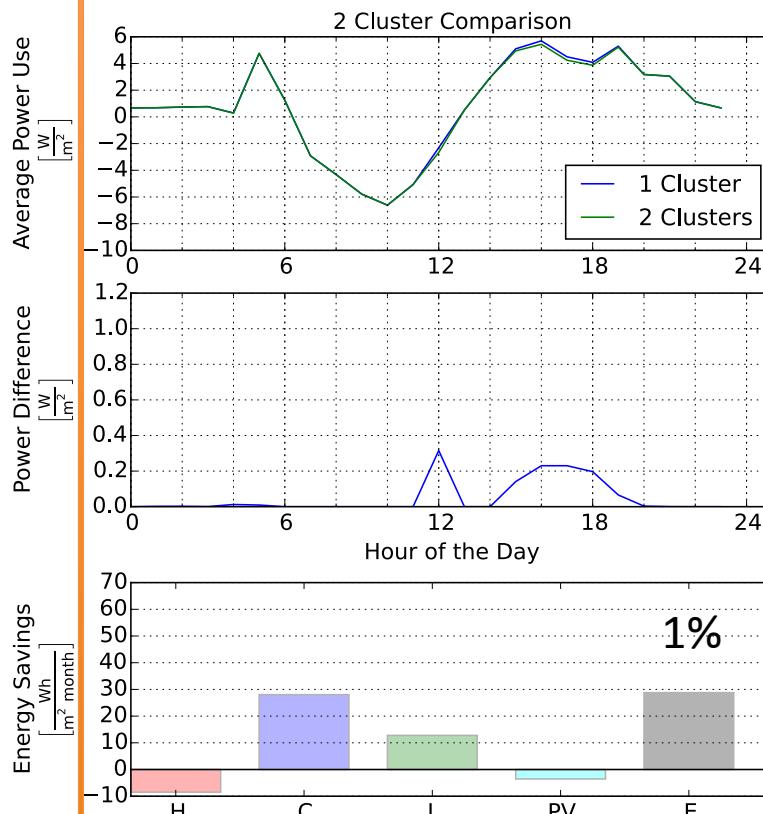
Results for 7 Azimuth and 7 Altitude Angles

Cluster Analysis

2 Clusters

10 Panels for Radiation

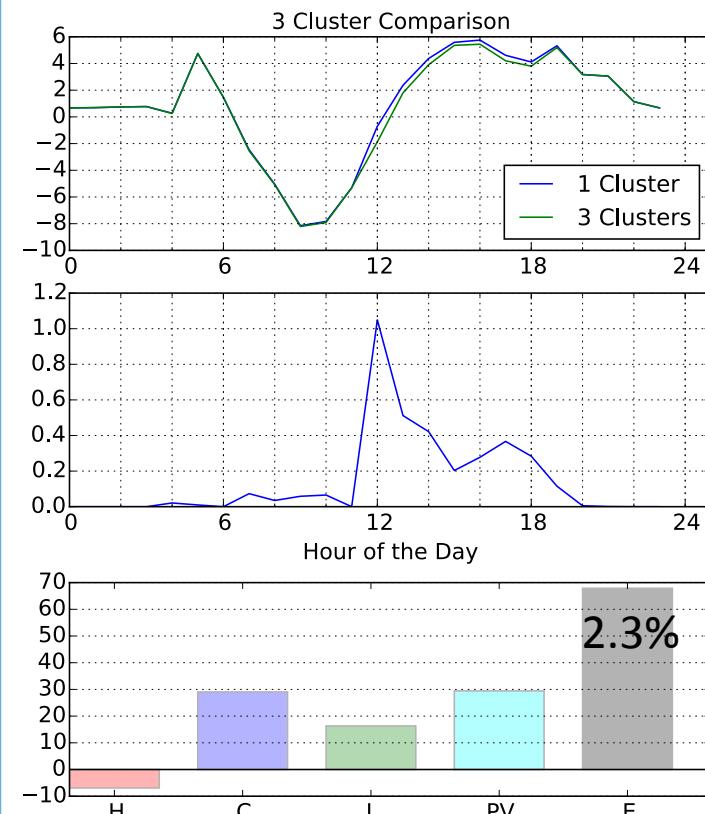
5 Azimuth / 5 Altitude Angles



3 Clusters

8 Panels for Radiation

1 Azimuth / 5 Altitude Angles



June

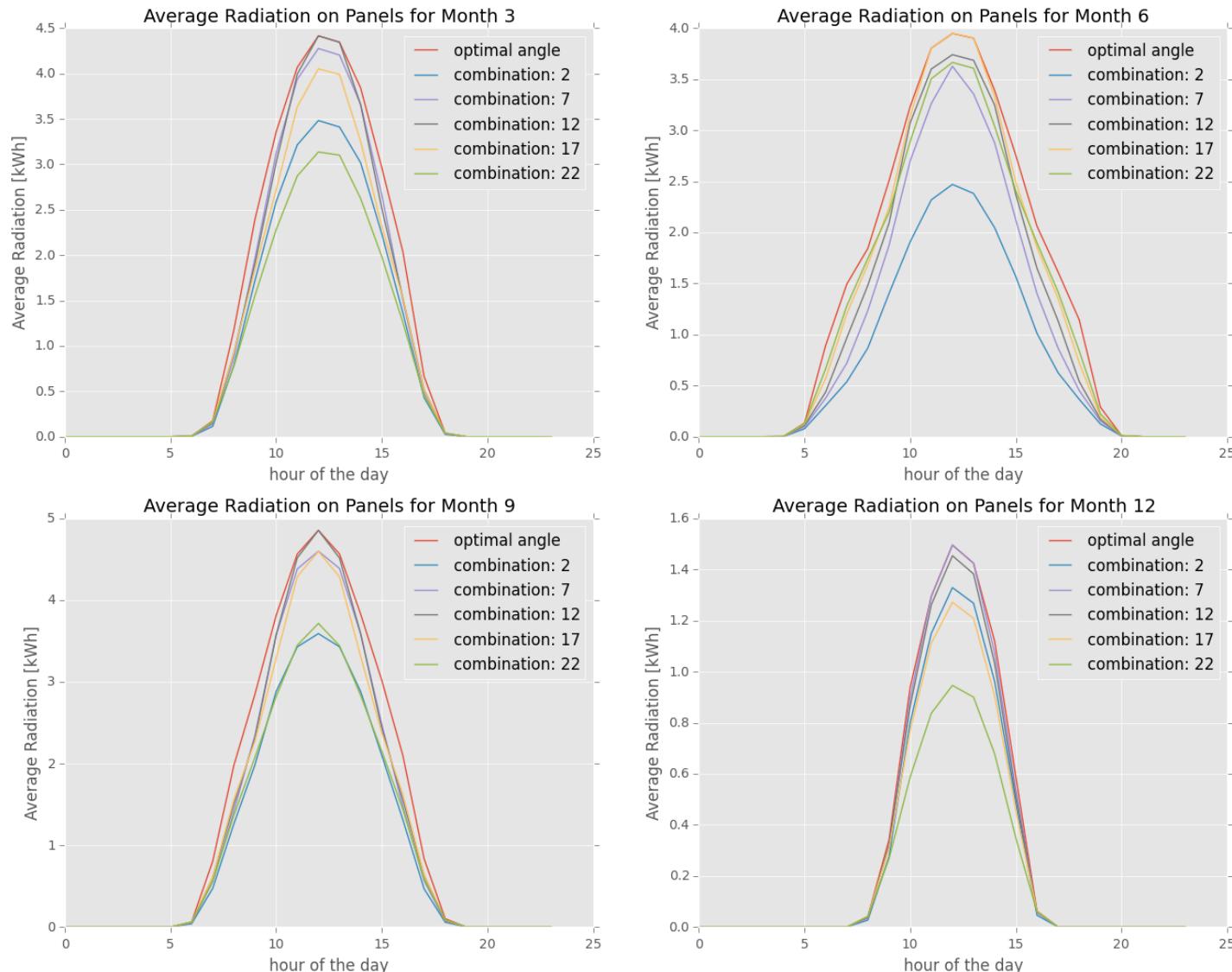
Average of
Mar, Jun,
Sep, Dec

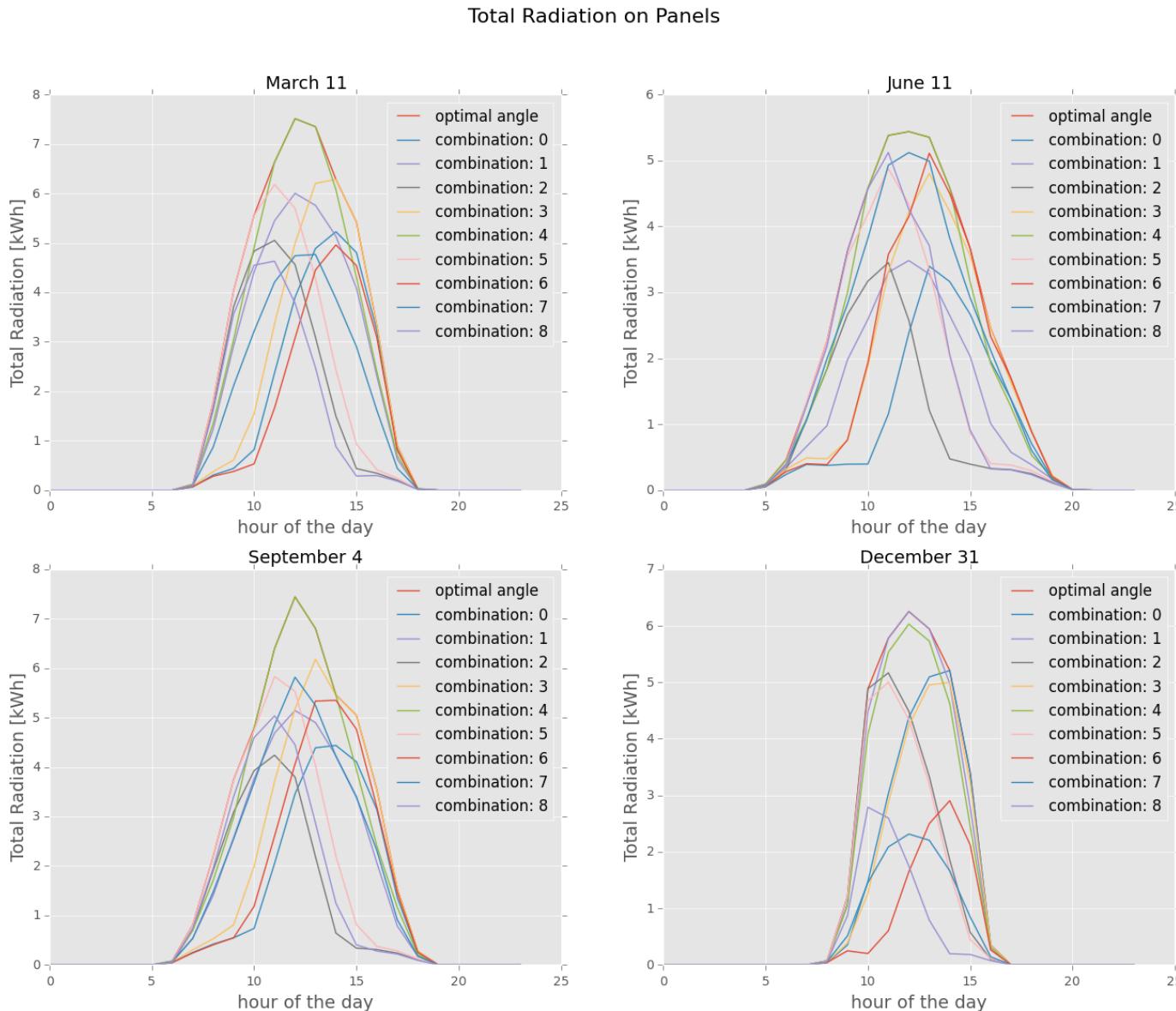
Icons Downloaded from:

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Average Radiation on Panels





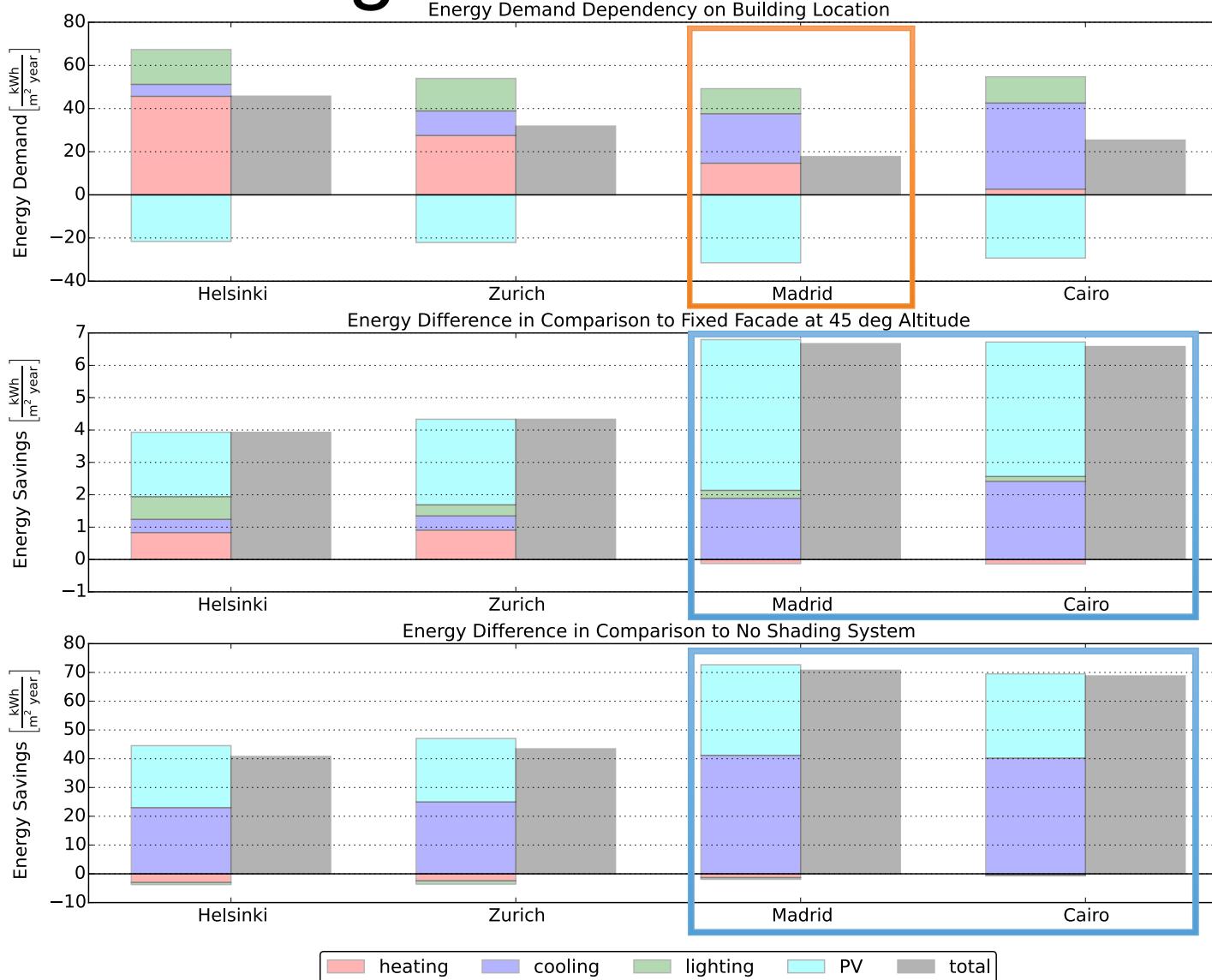
Conclusions

- Developed Parametric Simulation Model for PV Modules as Adaptive Building Shading Systems
- Successfully combined detailed PV-Electricity Production with Building Energy Demand
- Optimal Angles for single Cluster found
- Sensitivity on Building Orientation, Location, System and Control Strategy evaluated

Outlook

- Development and Implementation of RC-Building Energy Simulation Tool
- Include Bypass Diodes and String Connection in PV Electricity Simulation
- Include Energy-Use for Actuation in Simulation
- Implement Iterative Algorithm to increase Accuracy
- Extended Evaluation of individual Actuation
- Development of Control System for Prototypes of ASF
- Life Cycle Analysis

Building Location Performance



Office in Madrid performs best

Highest benefit from ASF for warm regions

Building System Sensitivity

