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Numerical Energy Analysis of PV Modules as Adaptive Building Shading Systems

Master Thesis

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Supervisor:
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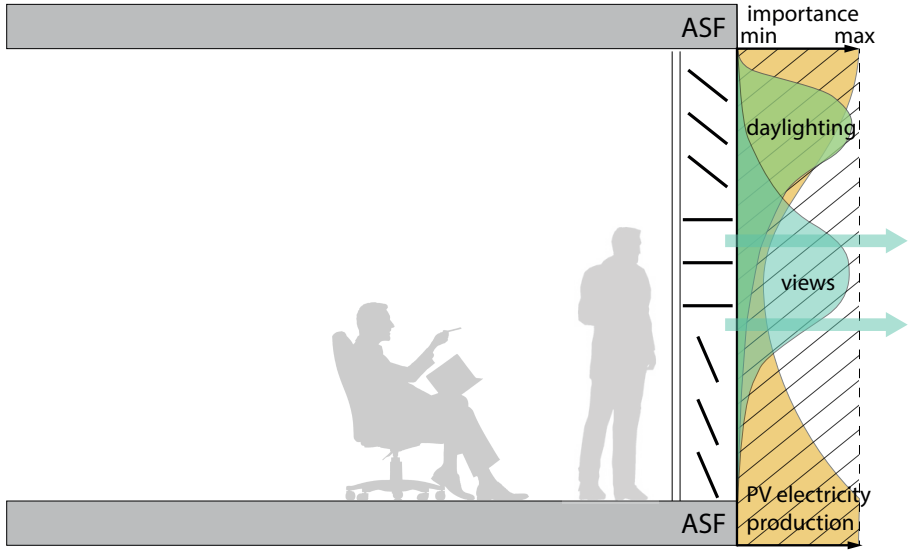
The Adaptive Solar Façade (ASF)

- 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

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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

Prageeth Jayathissa, Zoltan Nagy, Nicola Offeddu, Arno Schlueter
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Energy Science & Engineering
Open Access
RESEARCH ARTICLE

Parametric analysis and systems design of dynamic photovoltaic shading modules

Johannes Hofer[1], Abel Groenewolt[2], Prageeth Jayathissa[1], Zoltan Nagy[1] & Arno Schlueter[1]
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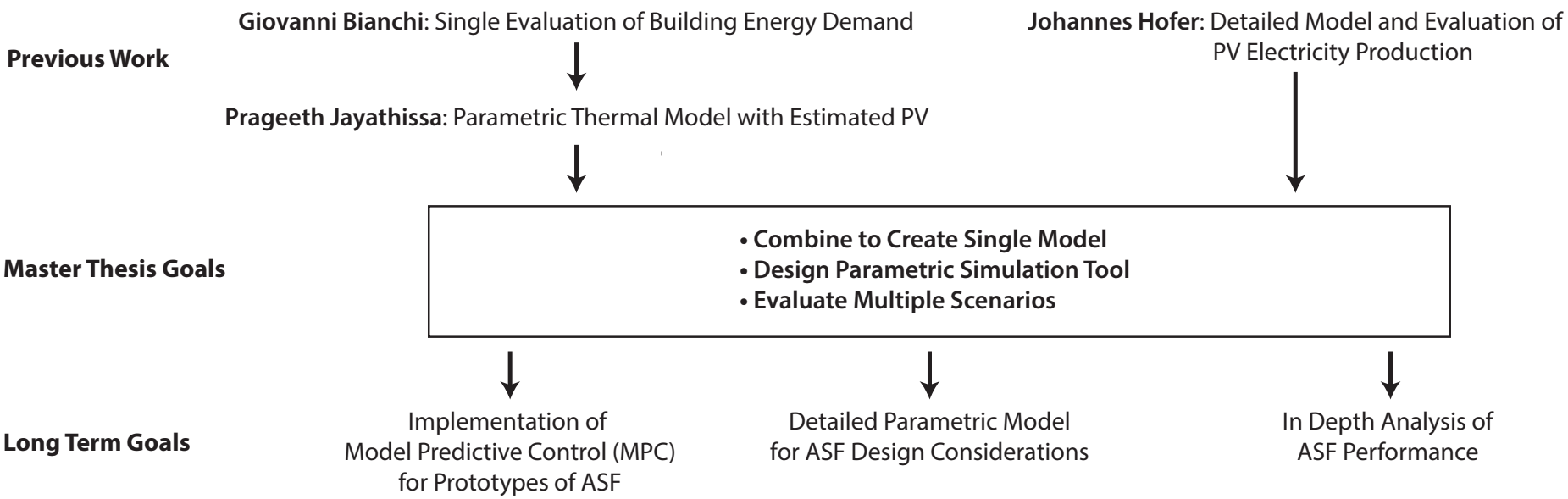
[2]Institute for Computational Design, University of Stuttgart, Keplerstrasse 11, 70174 Stuttgart, Germany

Goal of the Thesis



Overview

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

Problem Description

Optimization Problem

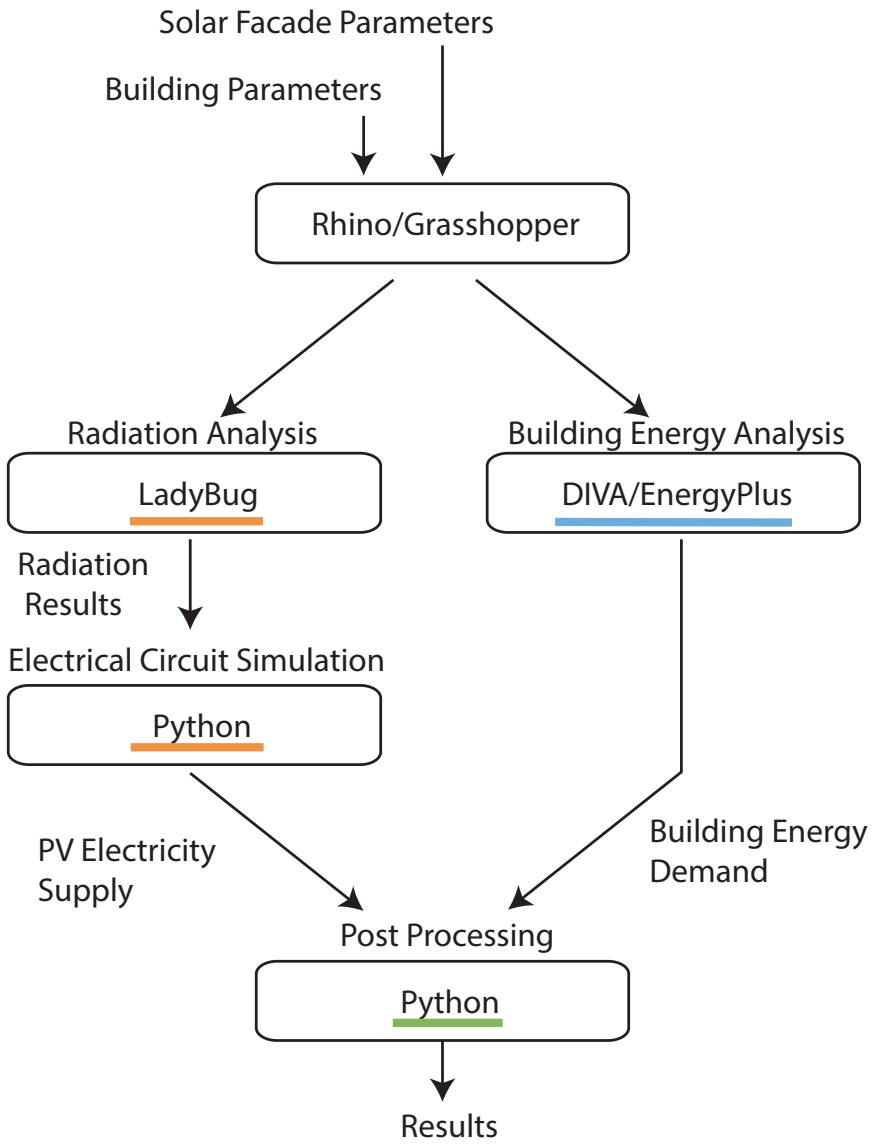
Minimize: C + H + L – PV

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

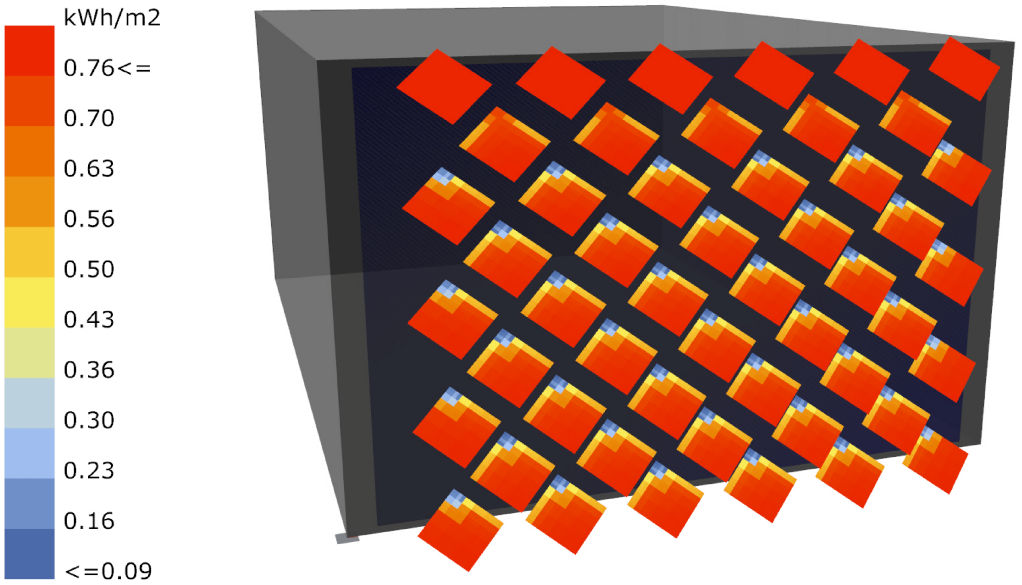
Minimize: C + H + L – PV



Radiation and PV analysis

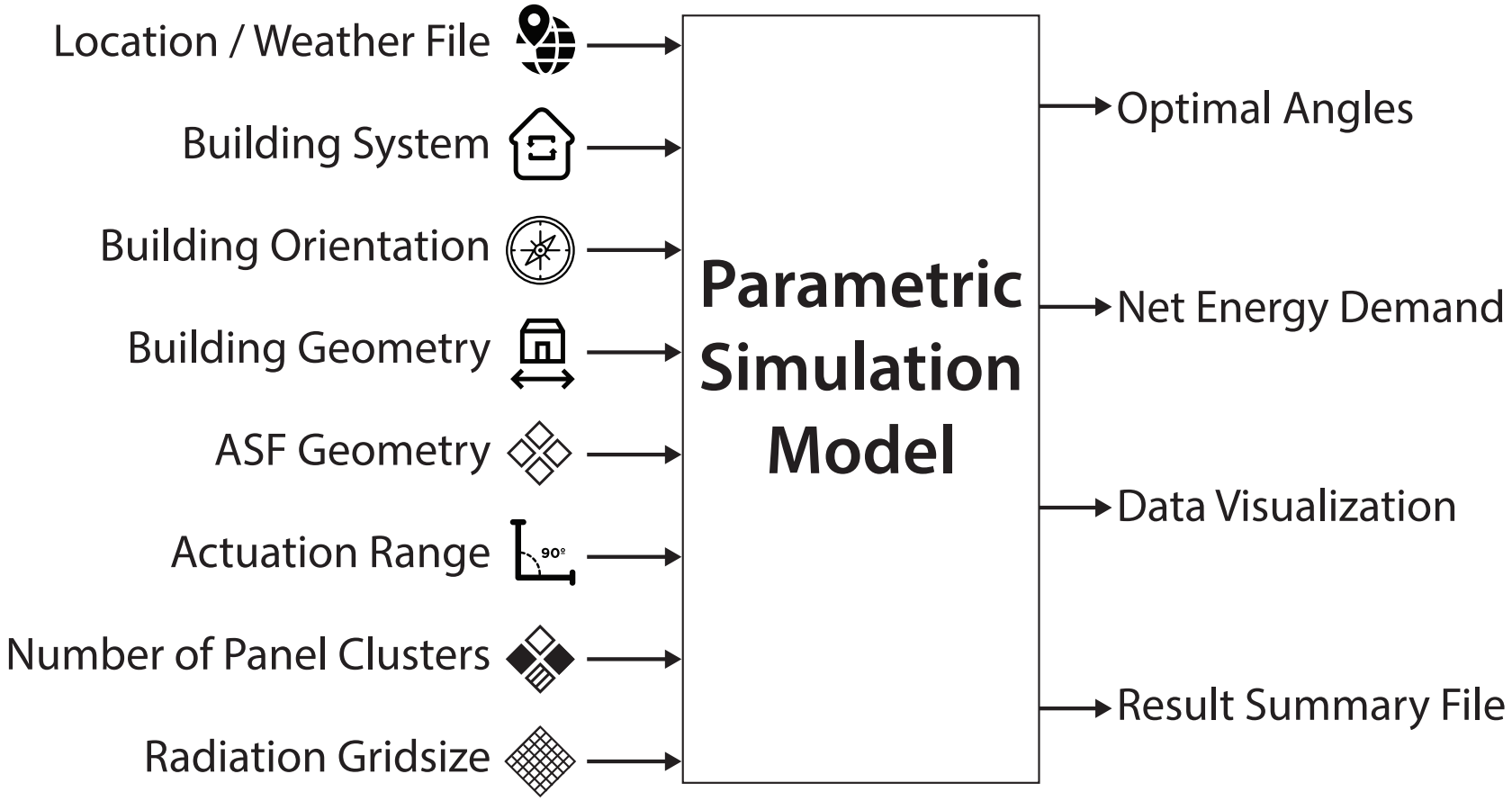
(Collaboration with Johannes)

- 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

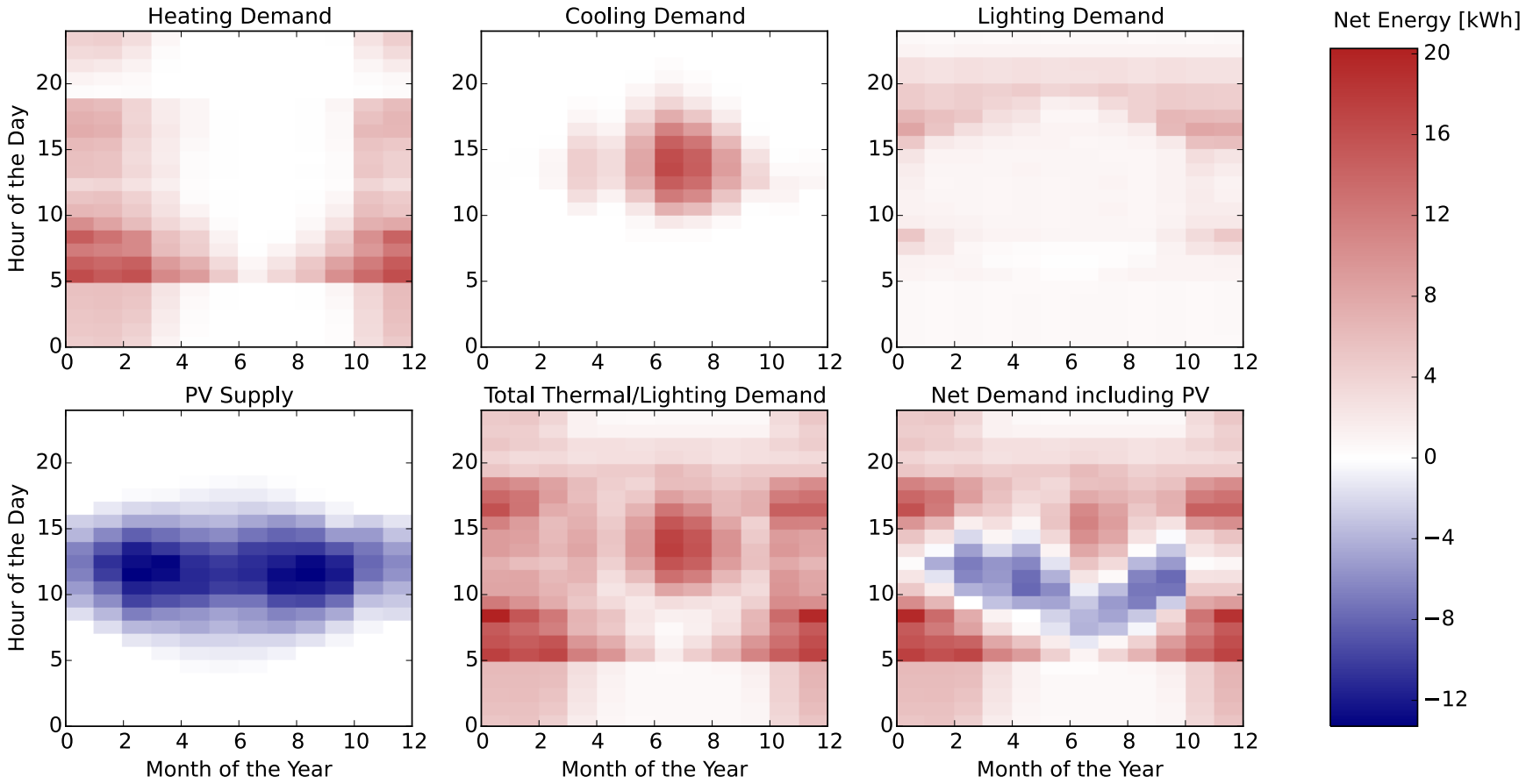
Parametric Model



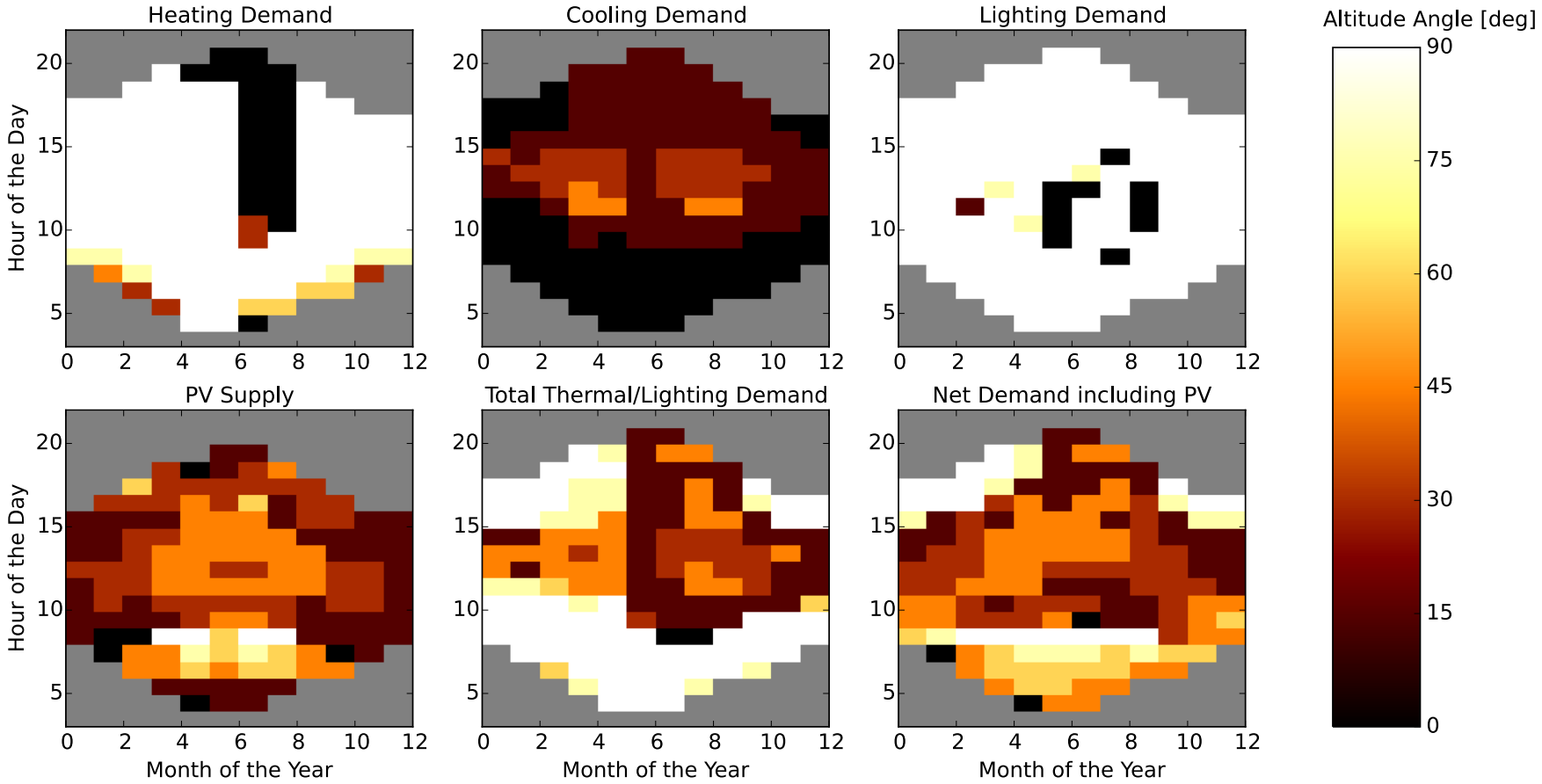
Base Case

- 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



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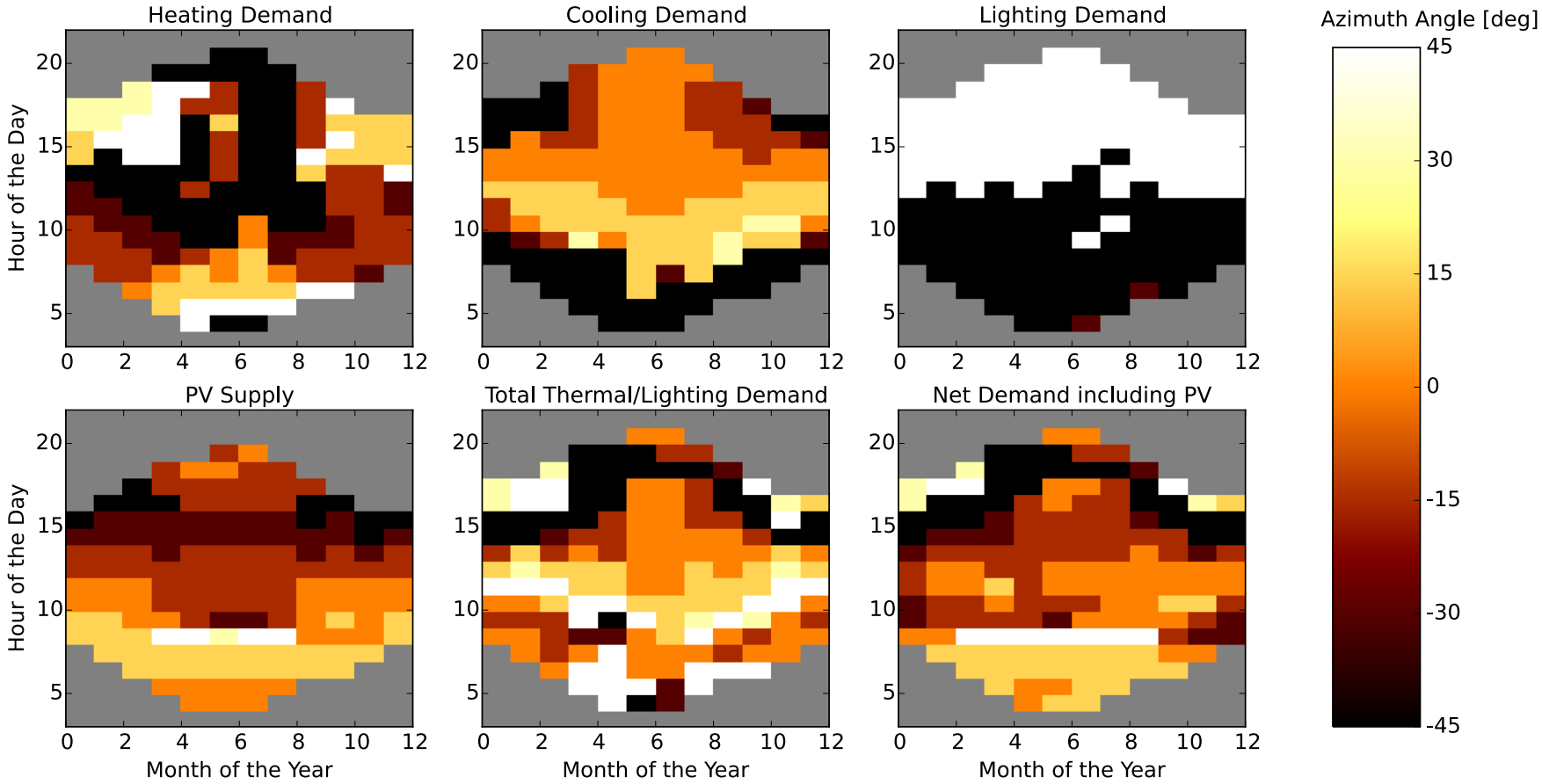
Optimum Azimuth Angles of Panels



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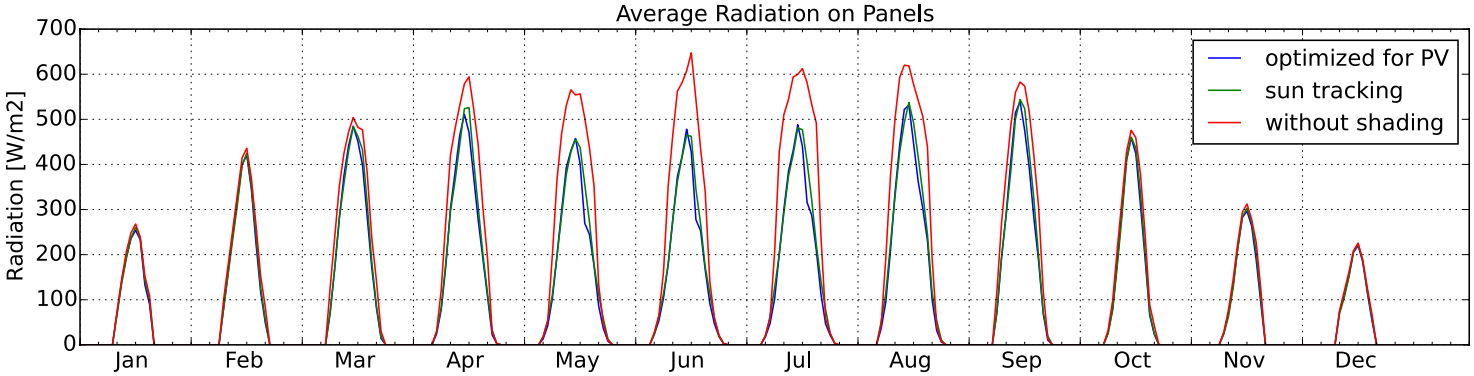
PV: Sun-Tracking vs. Optimization



- Similar Radiation
- Large Loss due to Shading

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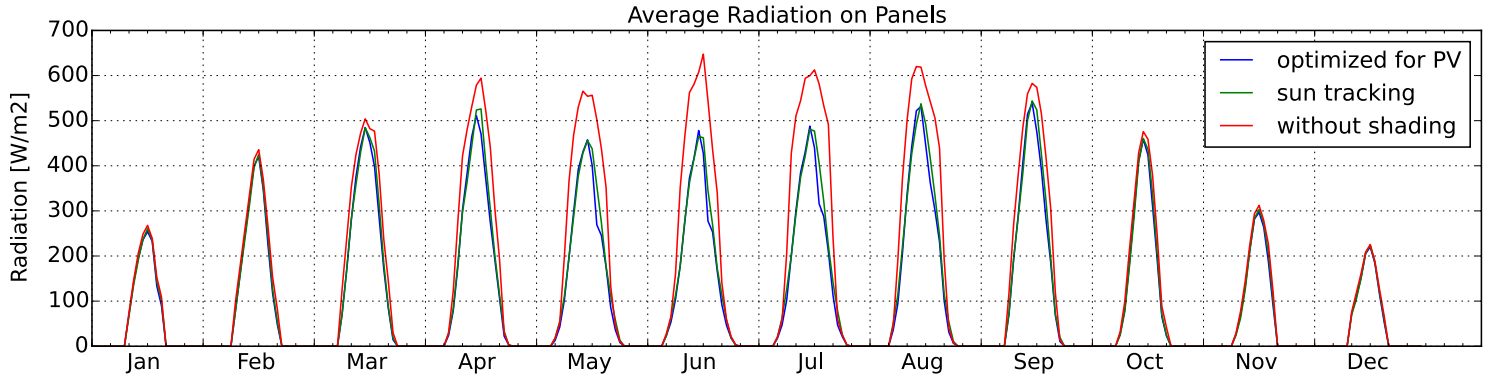
PV: Sun-Tracking vs. Optimization



- Similar Radiation
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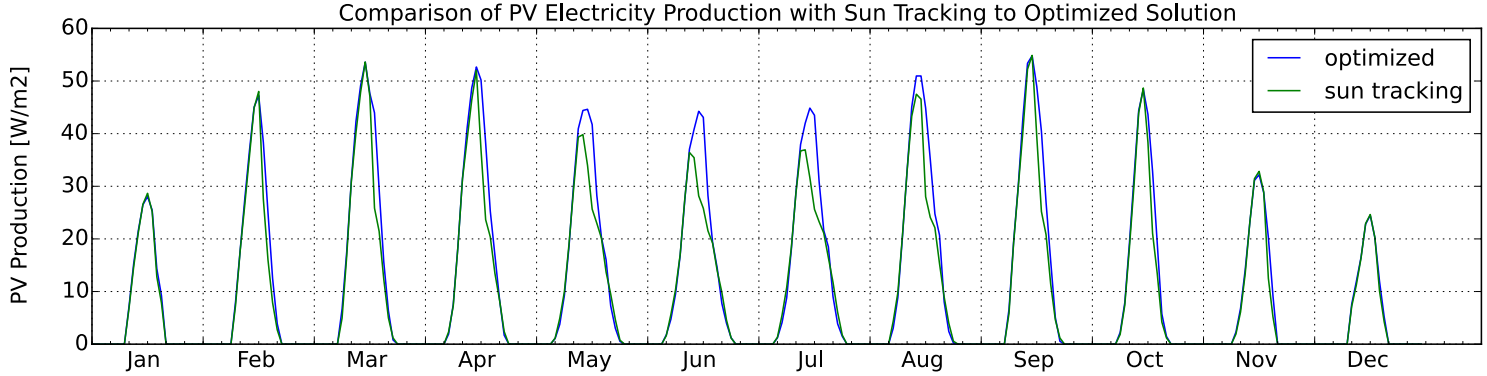
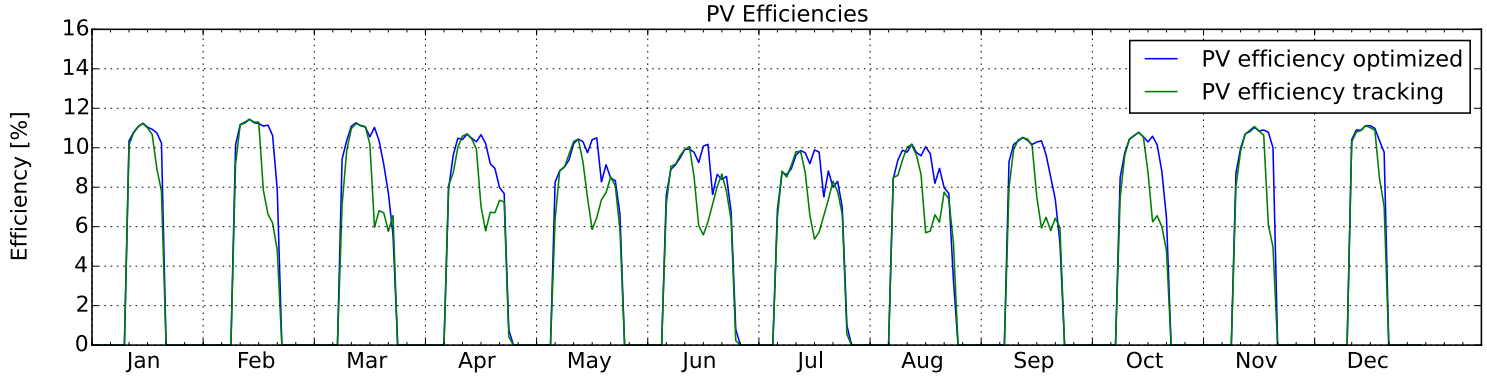


- Higher Electricity Production for Optimized Solution



- Higher Efficiency with Optimized Solution

Parameter Variations

Performance Evaluation in Dependence of:

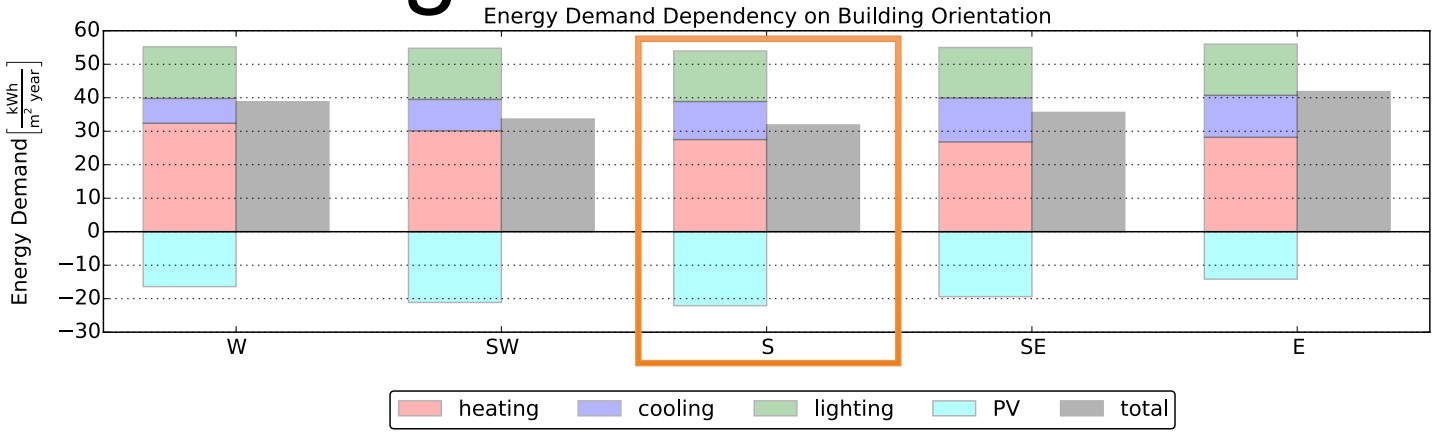

Building Orientation


Location / Weather File


Building System


Number of Panel Clusters

Building Orientation Performance



South facing office performs best

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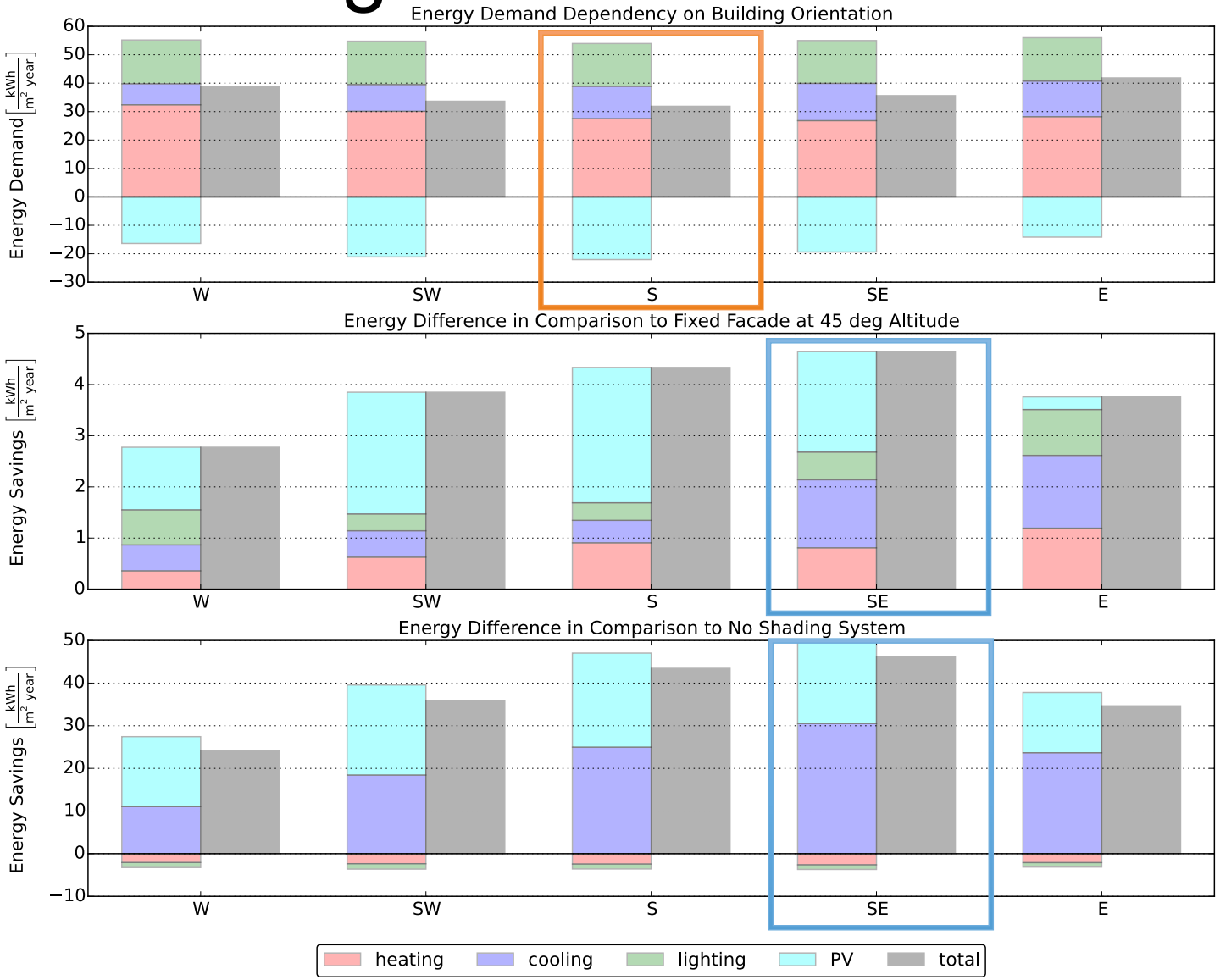
Building Orientation Performance



South facing office performs best

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

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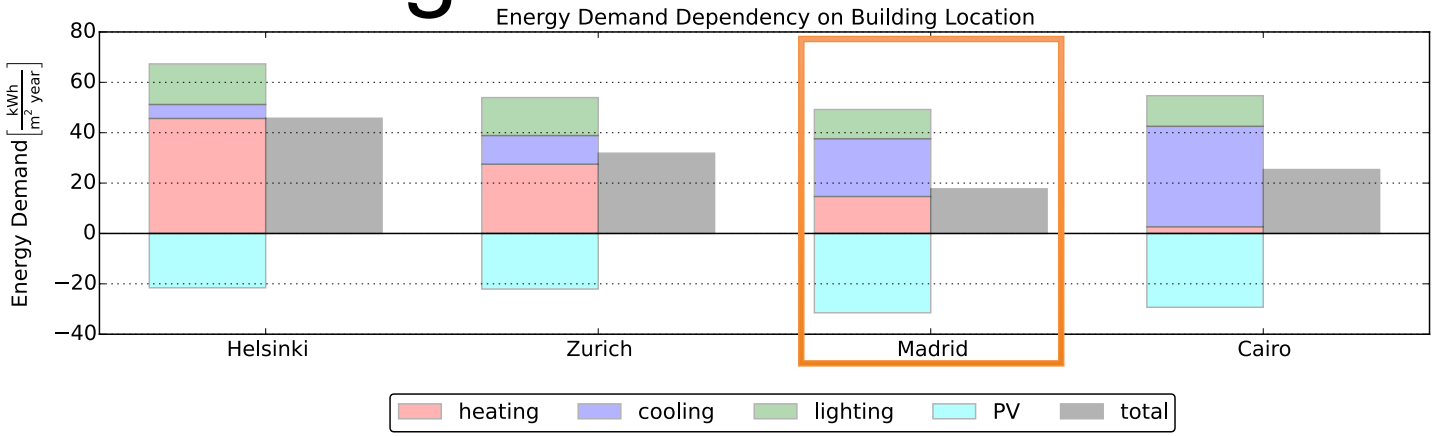
Building Location Performance



Office in Madrid performs best

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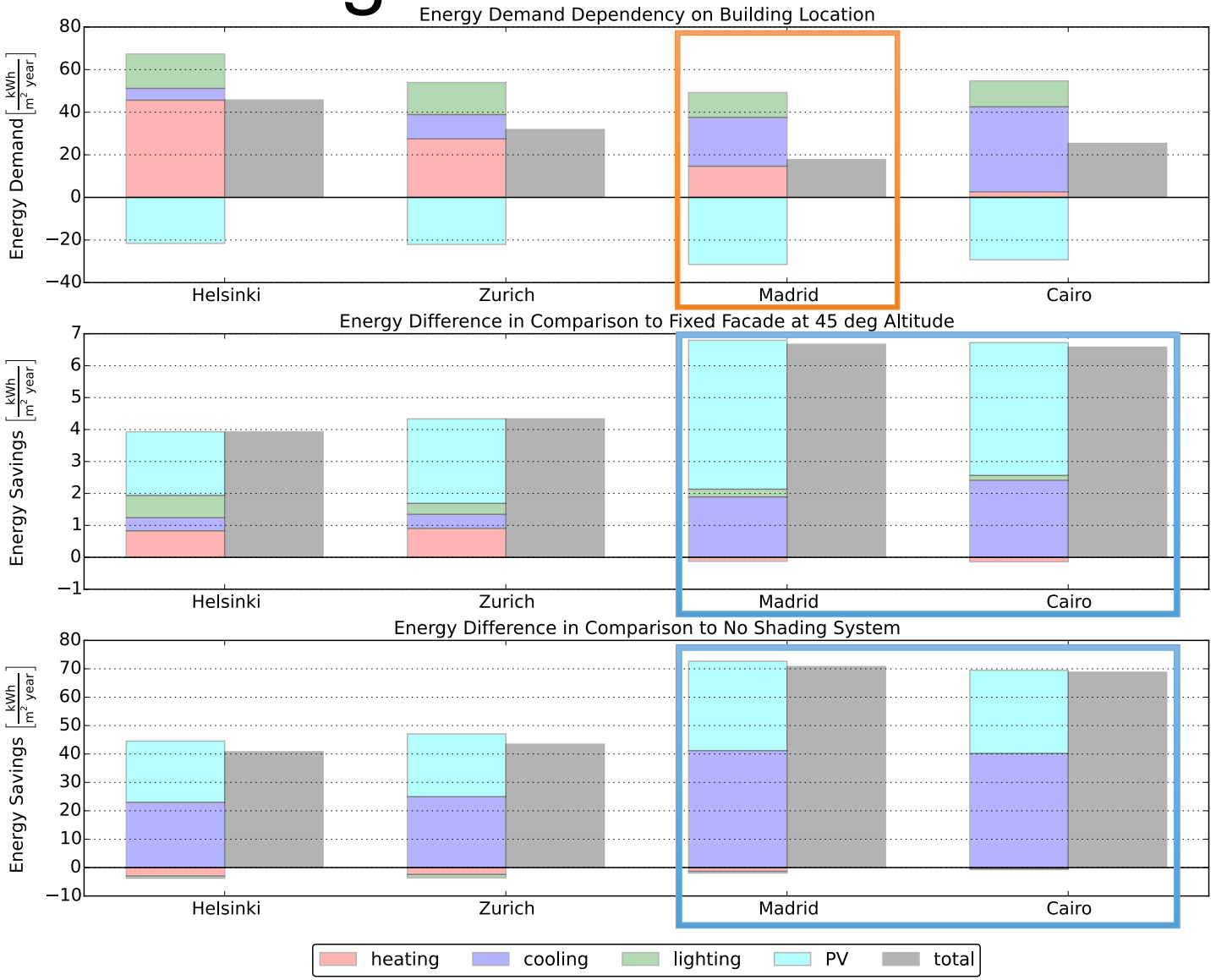
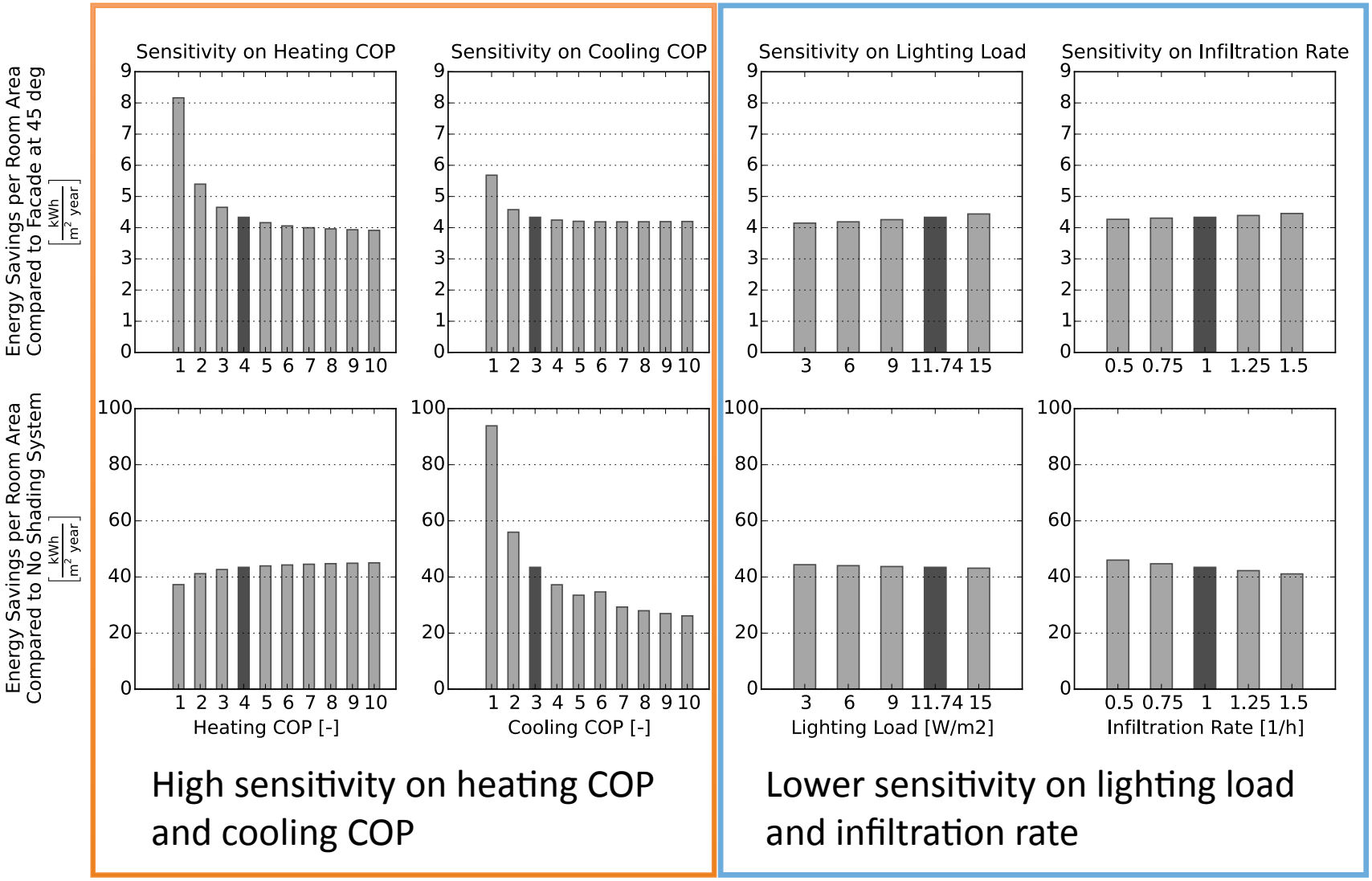
Building Location Performance



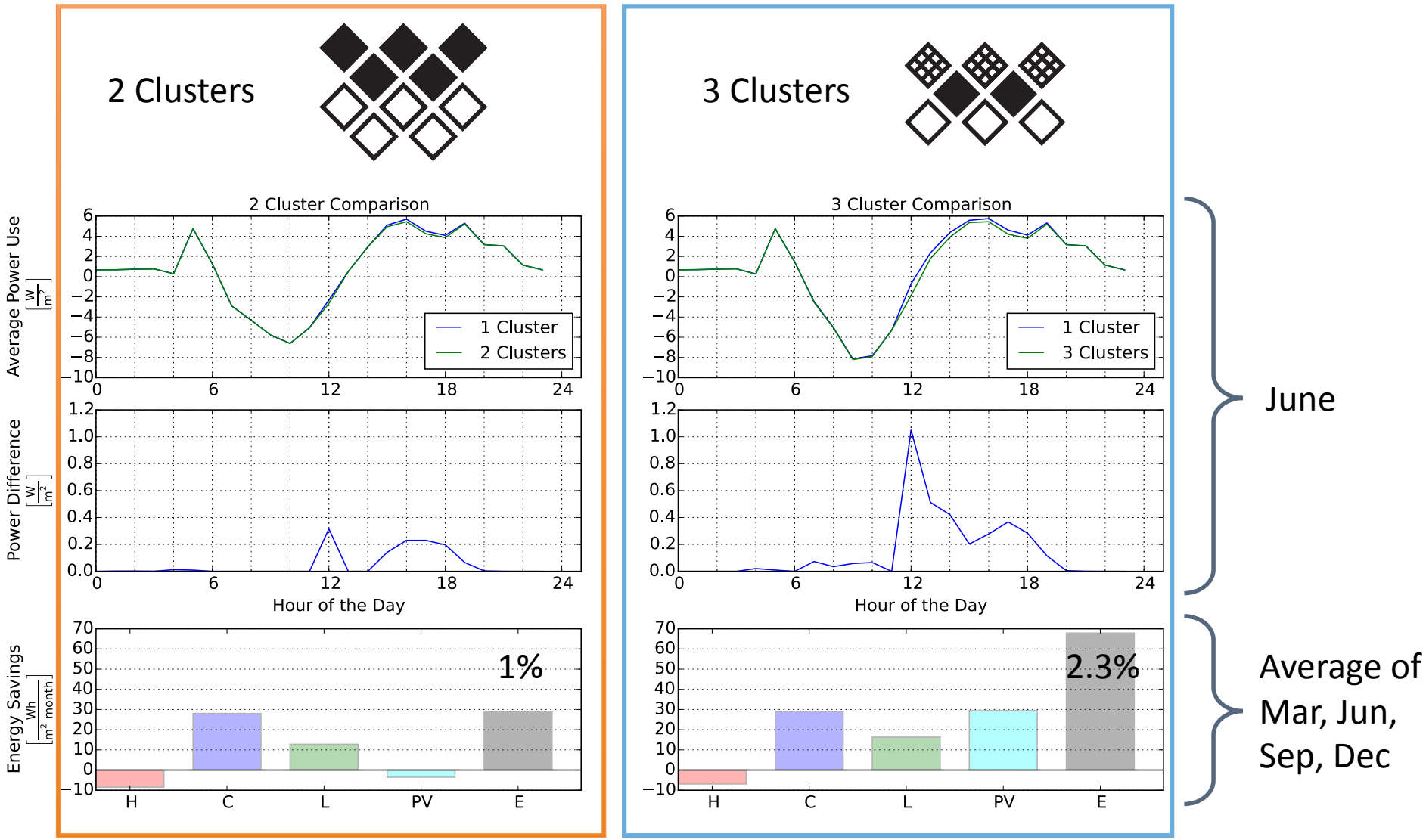
Office in Madrid performs best

Highest benefit from ASF for warm regions

Building System Sensitivity



Cluster Analysis



Conclusions

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

Master Thesis Goals

- **Combine to Create Single Model**
- **Design Parametric Simulation Tool**
- **Evaluate Multiple Scenarios**

Long Term Goals

Implementation of Model Predictive Control (MPC) for Prototypes of ASF

Detailed Parametric Model for ASF Design Considerations

In Depth Analysis of ASF Performance

- **Optimal Angles Found for Single Cluster of Panels**
- **Evaluated Sensitivity on Building Orientation, Location, System and Control Strategy**

Outlook

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

Master Thesis Goals

- Combine to Create Single Model
- Design Parametric Simulation Tool
- Evaluate Multiple Scenarios

Long Term Goals

Implementation of Model Predictive Control (MPC) for Prototypes of ASF

Detailed Parametric Model for ASF Design Considerations

- Add Bypass Diodes and String Connection to PV Model
- Implement RC Model
- Include Energy for Actuation

In Depth Analysis of ASF Performance

- Extended Evaluation of Individual Actuation
- Iterative Algorithm to Increase Accuracy
- Life Cycle Analysis

Questions?

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

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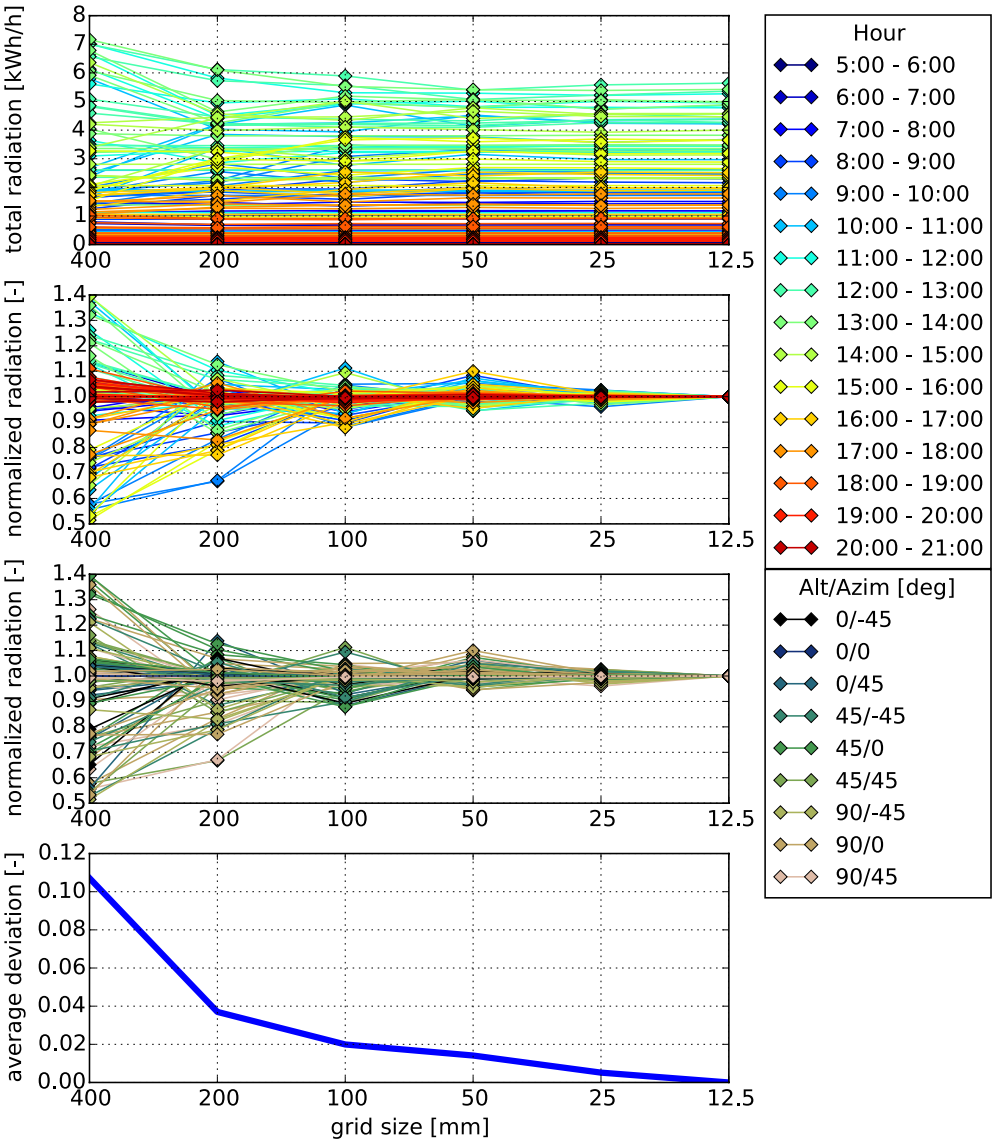
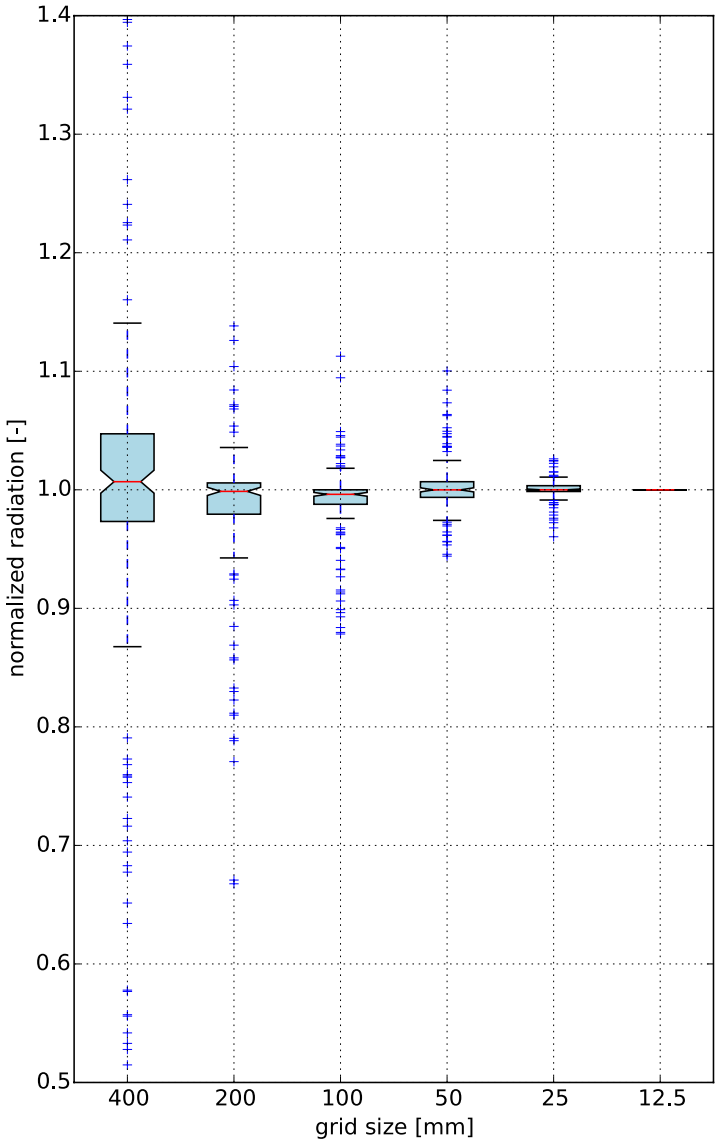
Grid Convergence Study





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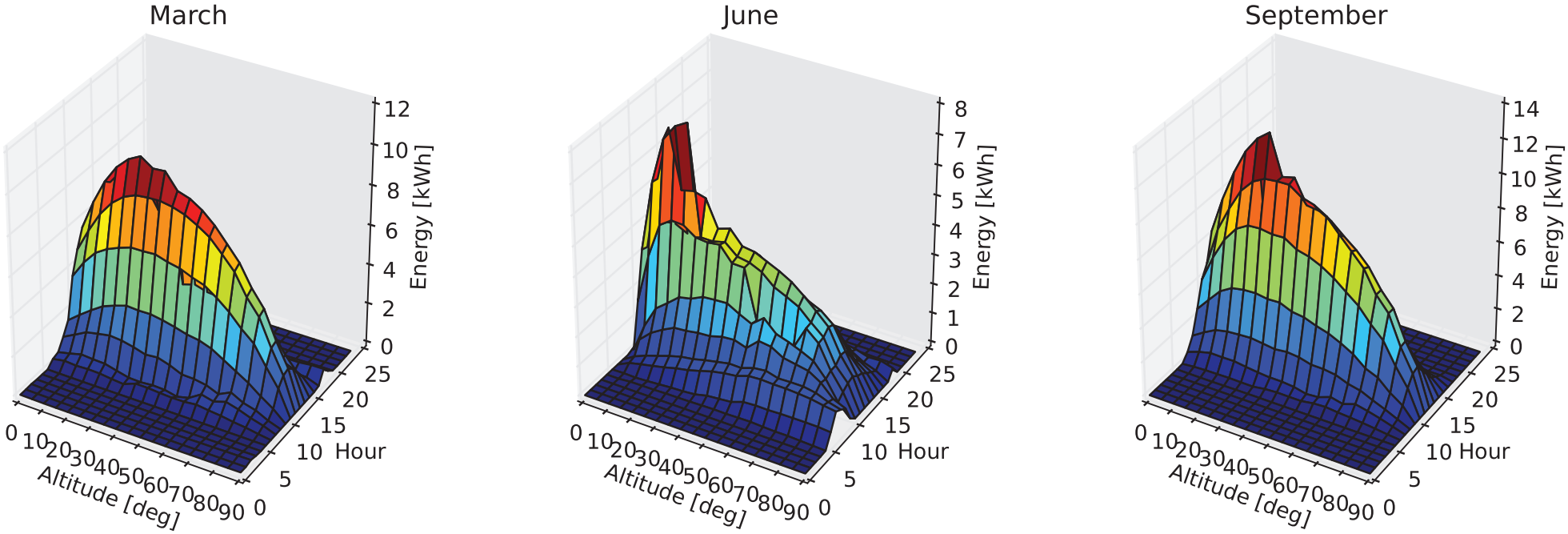
Influence of Actuation



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

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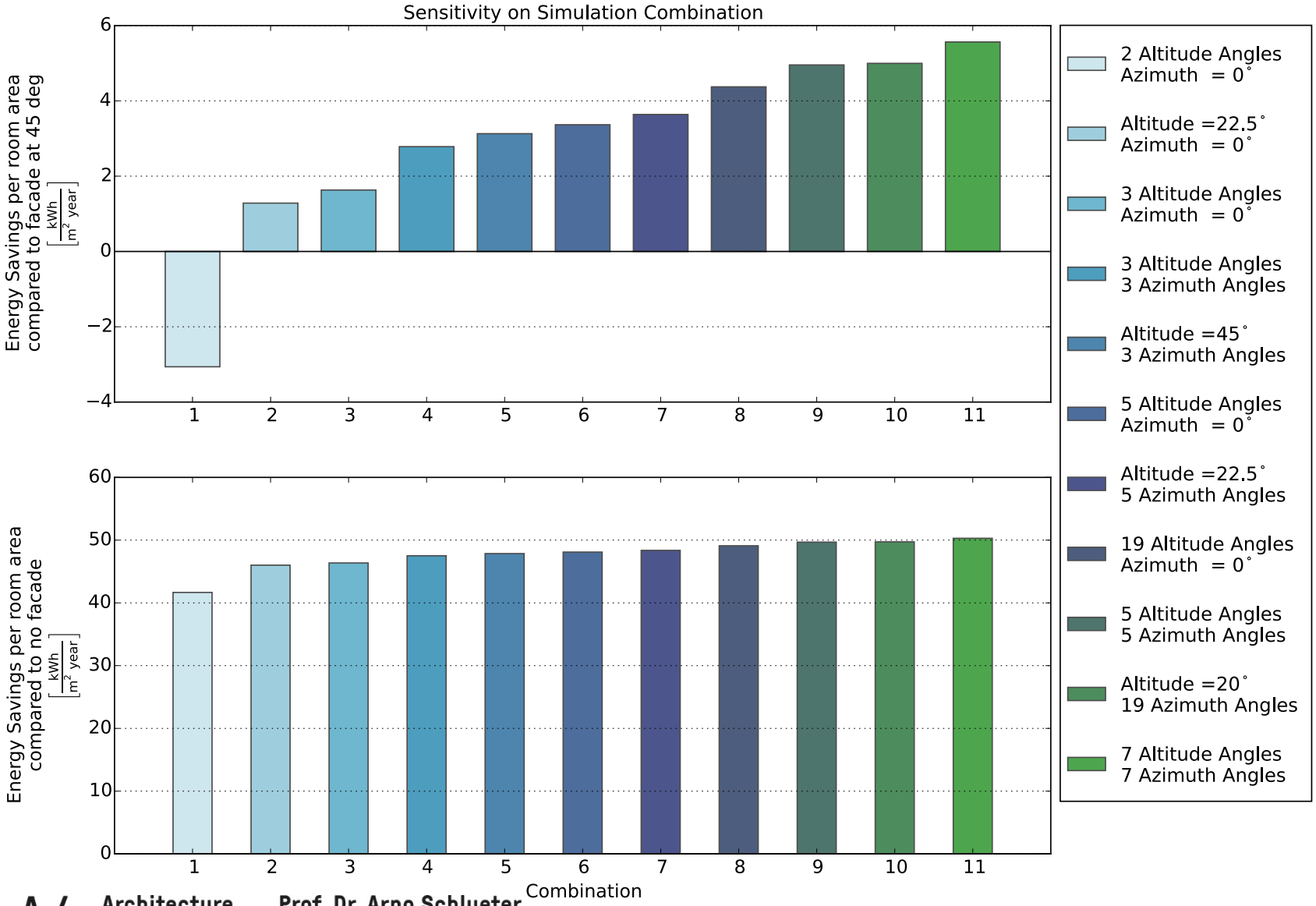
Sensitivity on Simulation Combination



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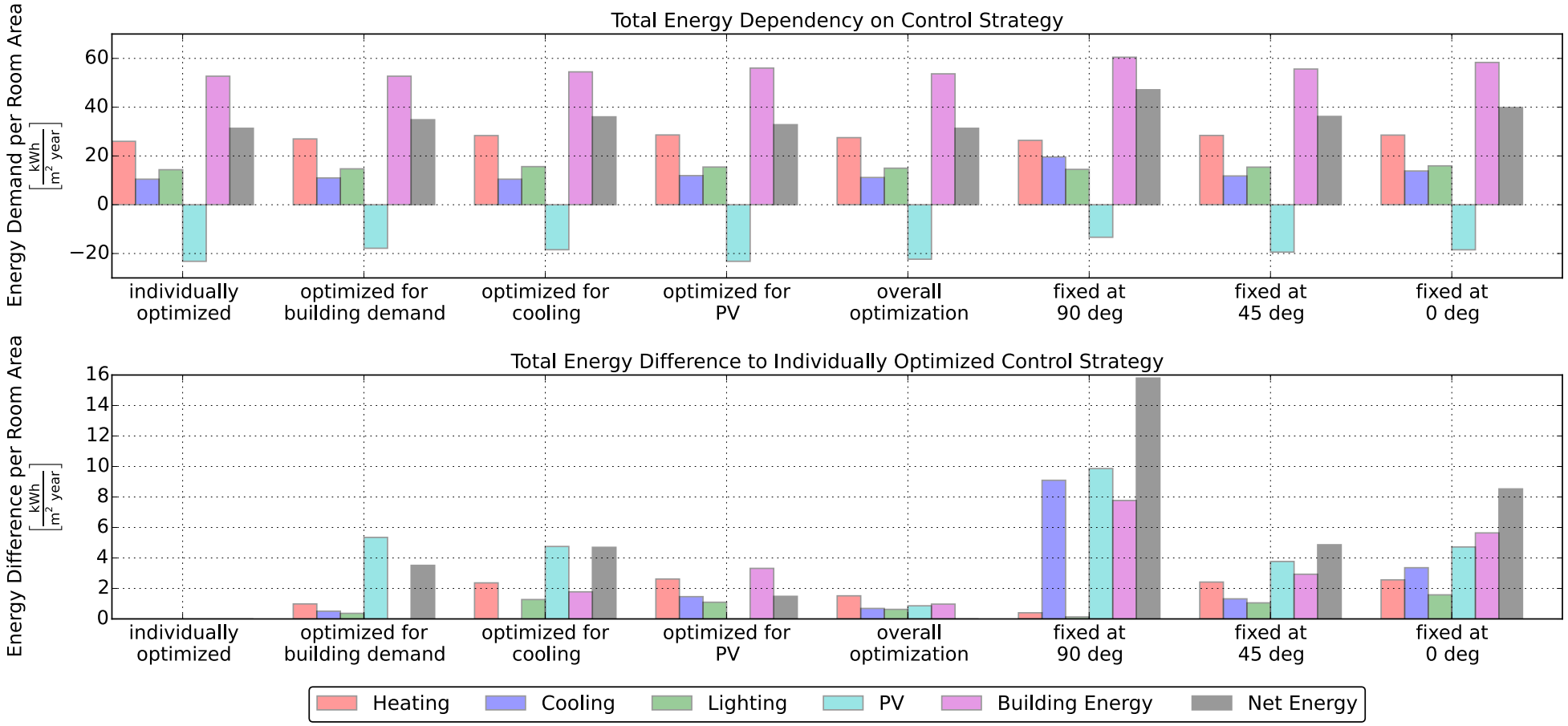
Energy Dependency on Control Strategy



Results for 7 Azimuth and 7 Altitude Angles

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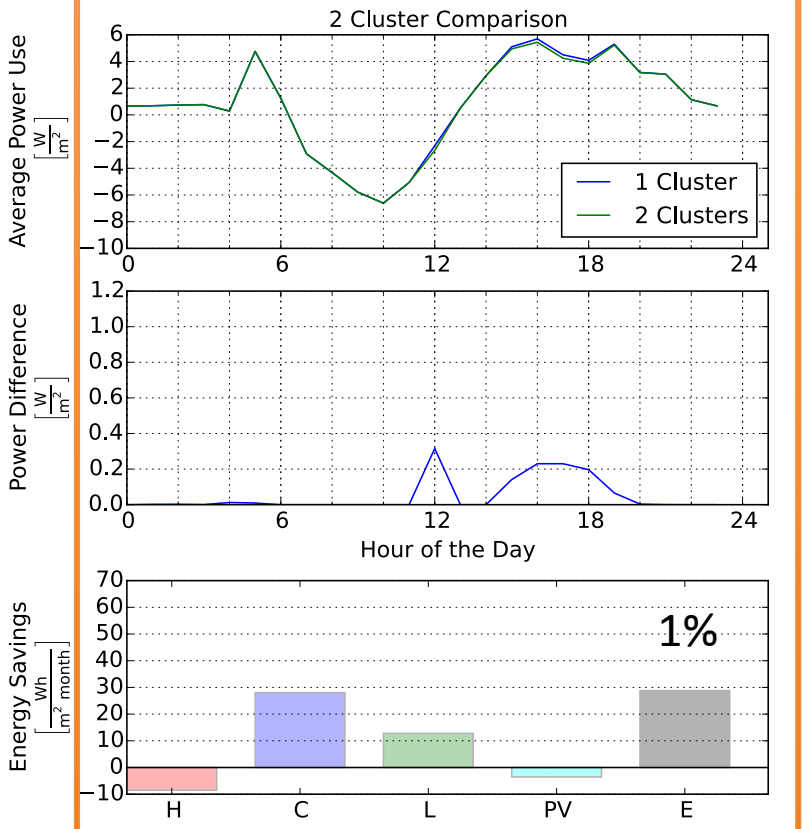
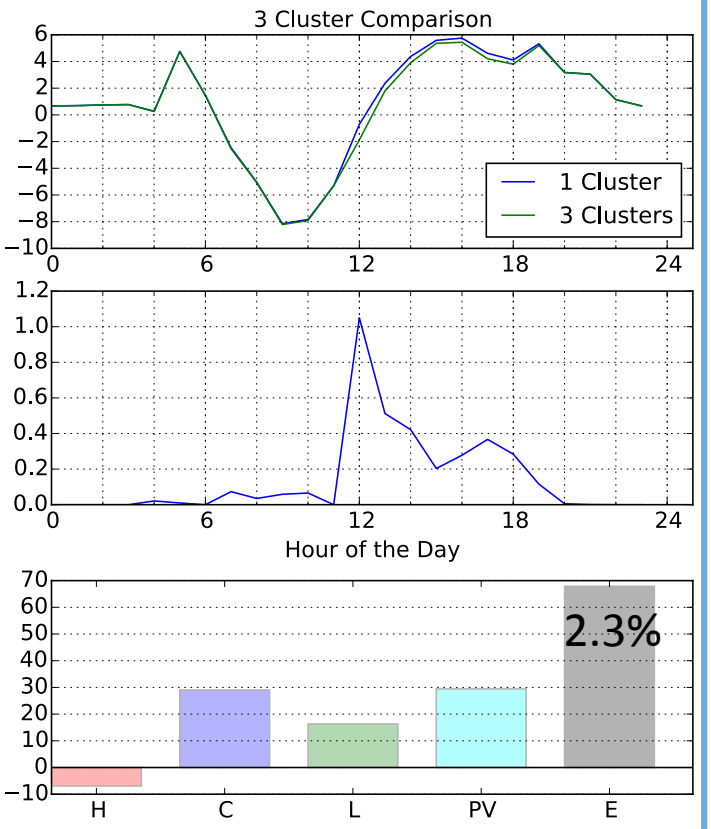
Cluster Analysis

2 Clusters
10 Panels for Radiation
5 Azimuth / 5 Altitude Angles



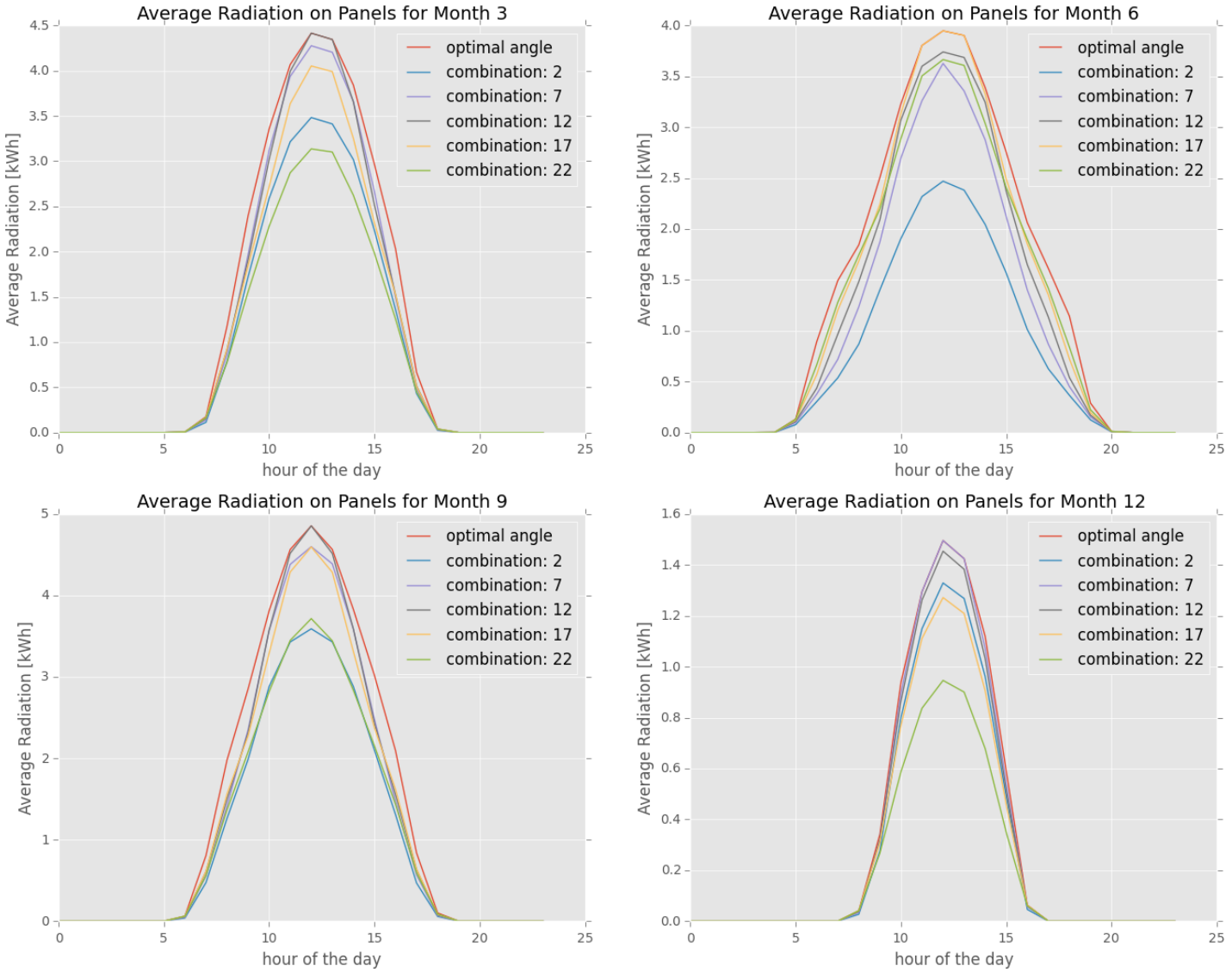
3 Clusters
8 Panels for Radiation
1 Azimuth / 5 Altitude Angles



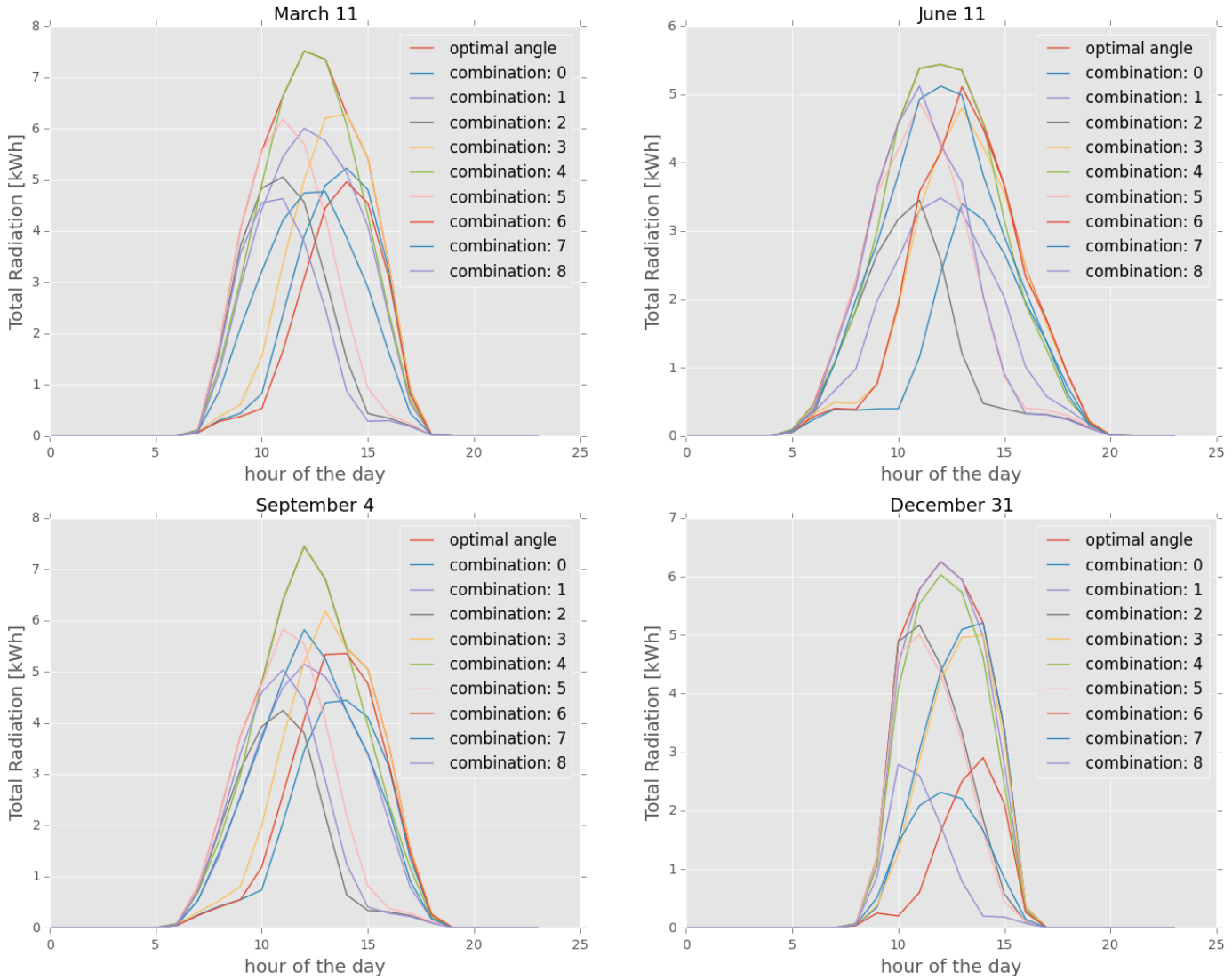
June

Average of Mar, Jun, Sep, Dec

Average Radiation on Panels



Total 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