Multistage Stochastic Optimal Operation of Energy-Efficiency Building with CHP System

Ping Liu

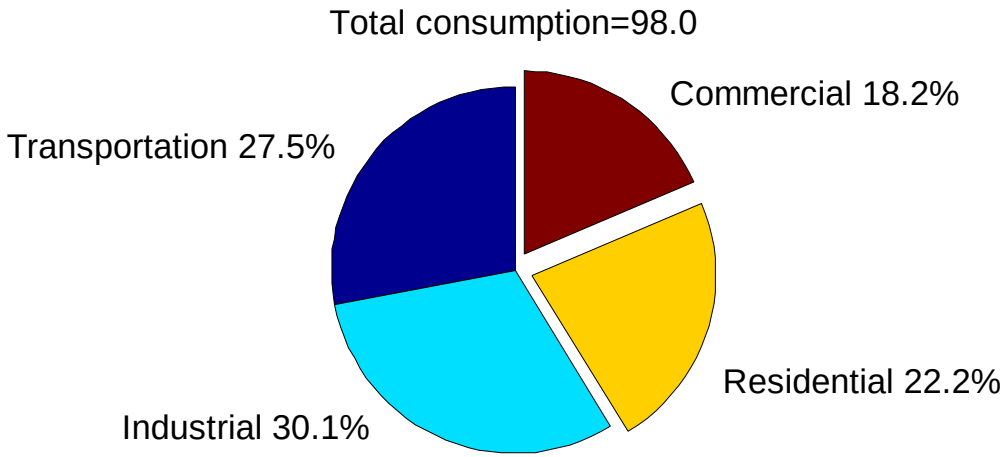
PhD Candidate

Department of Electrical and Computer Engineering

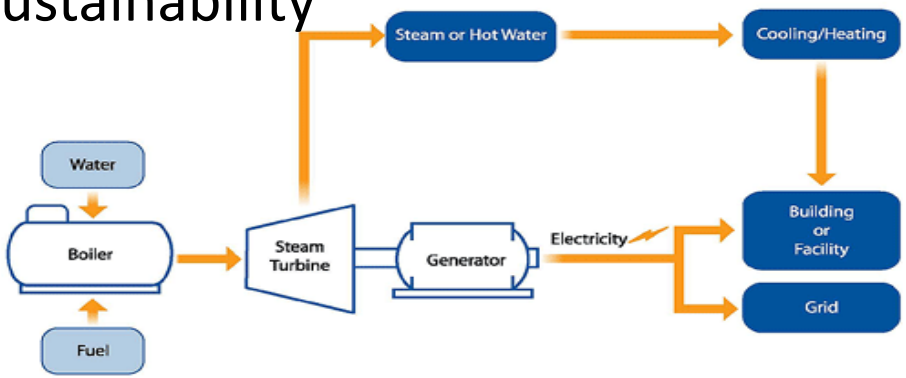
Mississippi State University

Introduction

- The operation of energy buildings have a surprisingly profound influence on the natural environment, health, economy, and productivity

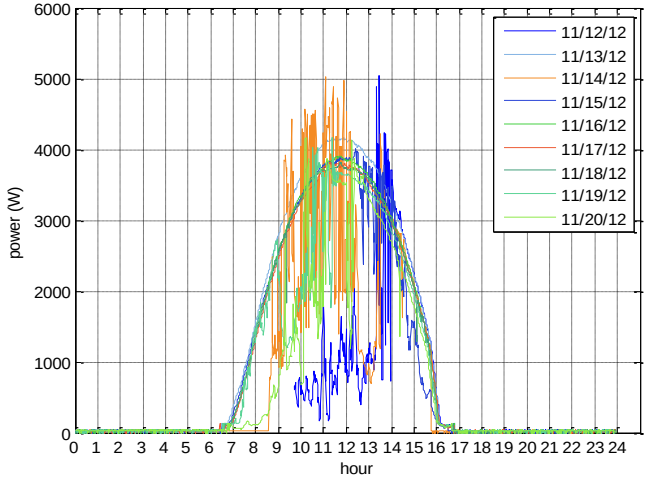


- Combined heat and power (CHP) systems are essential to efficiently reduce global energy use in buildings and improve the local environmental sustainability



Motivations

- Due to the global warming mitigation and depletion of energy resources, renewable energy like small wind farms and photovoltaic plants are getting interest in distribution systems.



- Load forecasting technique is essential to achieve efficient load management. Actual demand of individual households varies over time depending on the outside temperature seasons and end-user behavior.

Distribution system

CHP with Boiler

Battery

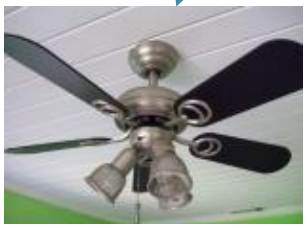
Refrigerator

Building system

Microwave Oven

Air Conditioner

Washing Machine

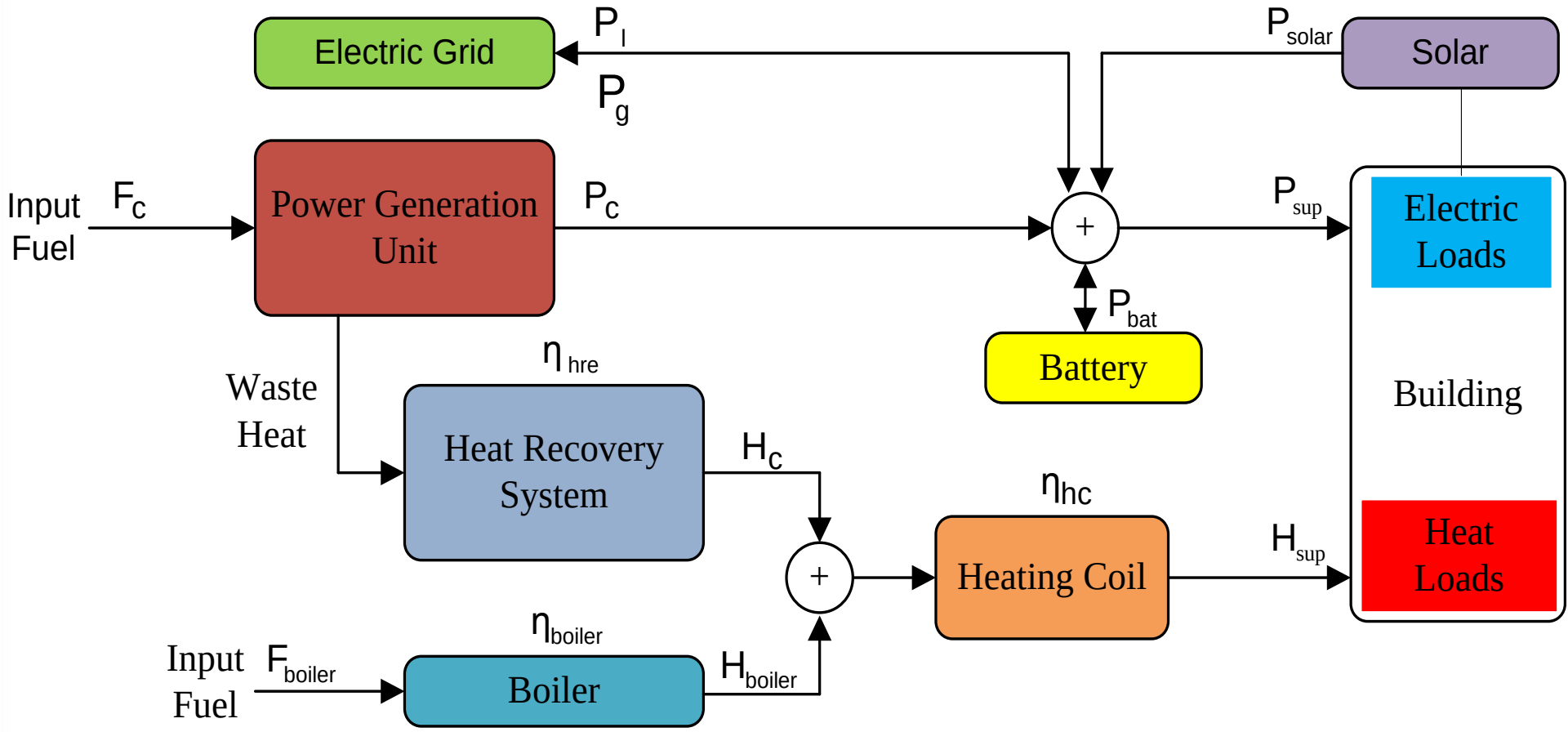


Ceiling Fan

PC

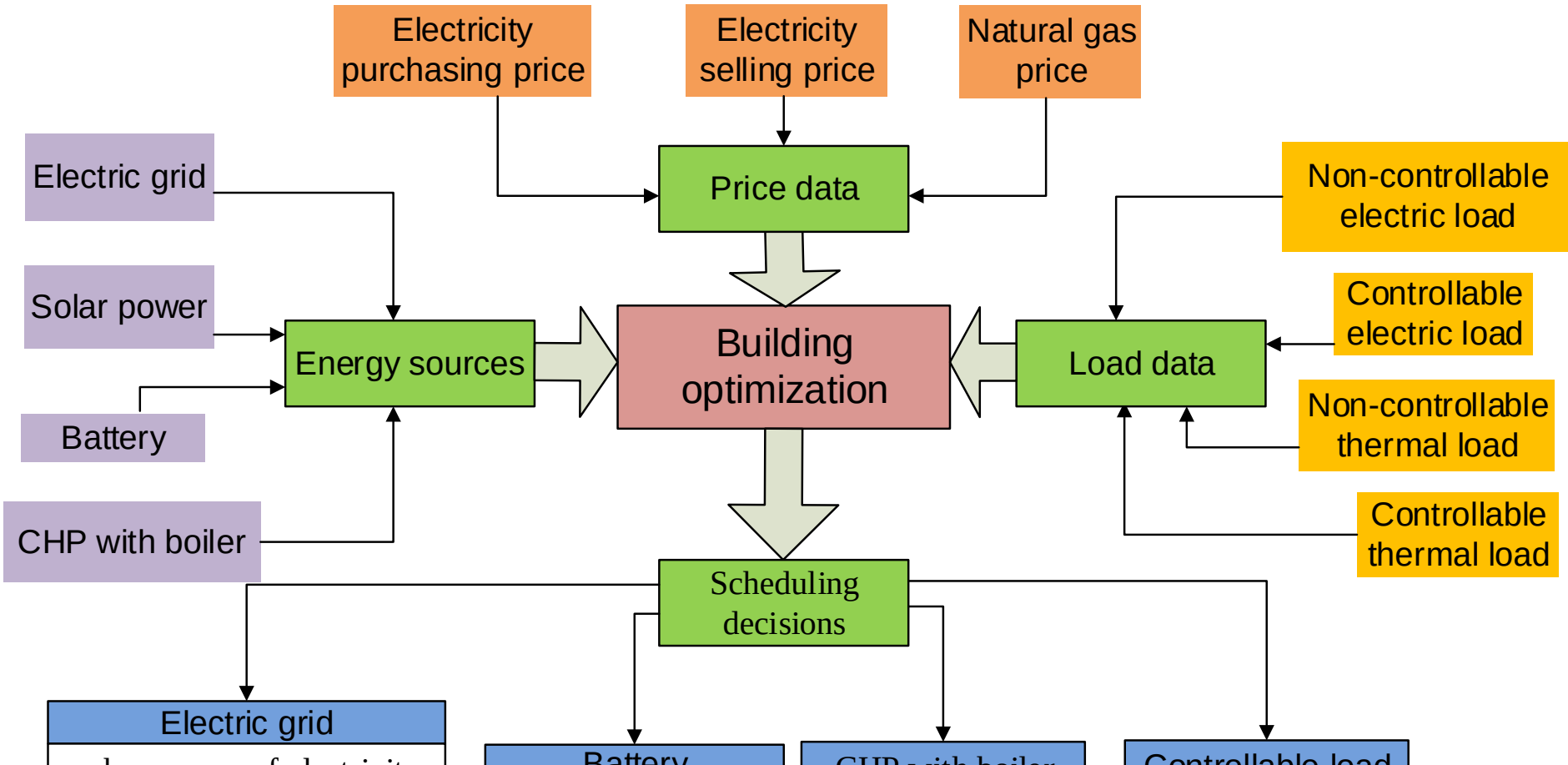
TV

System Modeling



Energy flow diagram of energy-efficiency building

Problem Description



Stochastic Programming Model

$$Min \quad C_{gf,1} \cdot P_{gf,1} - C_{gt,1} \cdot P_{gt,1} + C_{gas,1} \cdot (F_{chp,1} + F_{boi,1})$$

$$+ \sum_{t=2}^{T} \sum_{j=1}^{J_t} \rho_t^j \cdot [C_{gf,t} \cdot P_{gf,t}^j - C_{gt,t} \cdot P_{gt,t}^j + C_{gas,t} \cdot (F_{chp,t}^j + F_{boi,t}^j)]$$

Electric balance

$$P_{gf,t}^j - P_{gt,t}^j + P_{chp,t}^j + P_{bd,t}^j - P_{bc,t}^j + P_{sol,t}^j = P_{nc,t}^j + P_{cntr,t} \cdot x_{ele,t}^j$$

$$0 \le P_{gf,t}^j \le M_{gf} \cdot x_{gf,t}^j$$

$$0 \le P_{gt,t}^j \le M_{gt} \cdot x_{gt,t}^j$$

$$x_{gf,t}^j + x_{gt,t}^j \le 1$$

$$S_{bat,t+1}^j = S_{bat,t}^j + (\eta_{bc} \cdot P_{bc,t+1}^j - P_{bd,t+1}^j / \eta_{bd}) \cdot T_d / C_{bat}^{\max}$$

$$P_{bc}^{\min} \cdot x_{bc,t}^j \le P_{bc,t}^j \le P_{bc}^{\max} \cdot x_{bc,t}^j$$

$$P_{bd}^{\min} \cdot x_{bd,t}^j \le P_{bd,t}^j \le P_{bd}^{\max} \cdot x_{bd,t}^j$$

$$x_{bc,t}^j + x_{bd,t}^j \le 1$$

Thermal balance

$$\eta_{hc} (H_{chp,t}^j + H_{boi,t}^j) = H_{nc,t}^j + H_{cntr,t} \cdot x_{heat,t}^j$$

$$F_{chp,t}^j = \alpha \cdot P_{chp,t}^j + \beta \cdot x_{chp,t}^j$$

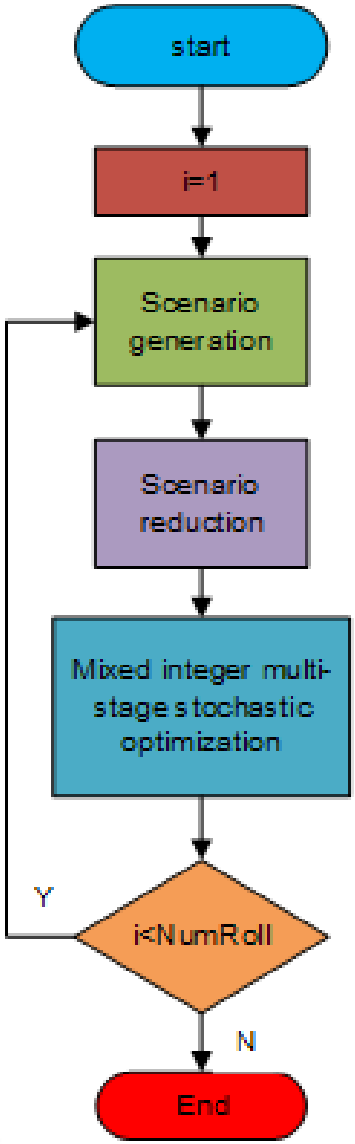
$$H_{chp,t}^j = \eta_{hre} (F_{chp,t}^j - P_{chp,t}^j)$$

$$P_{chp}^{\min} \cdot x_{chp,t}^j \le P_{chp,t}^j \le P_{chp}^{\max} \cdot x_{chp,t}^j$$

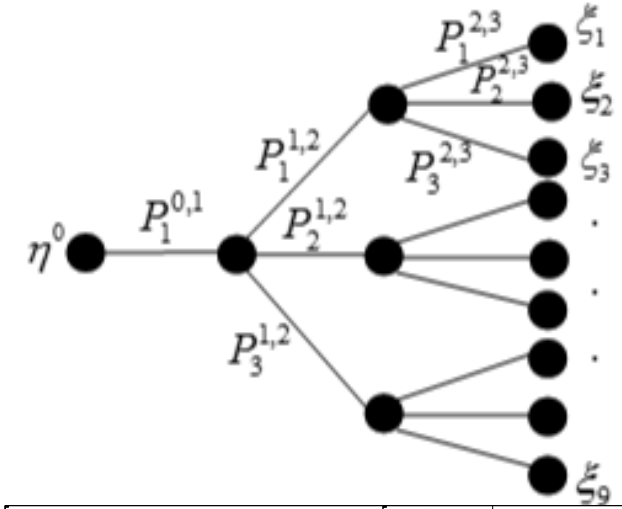
$$H_{boi,t}^j = \eta_{boi} . F_{boi,t}^j$$

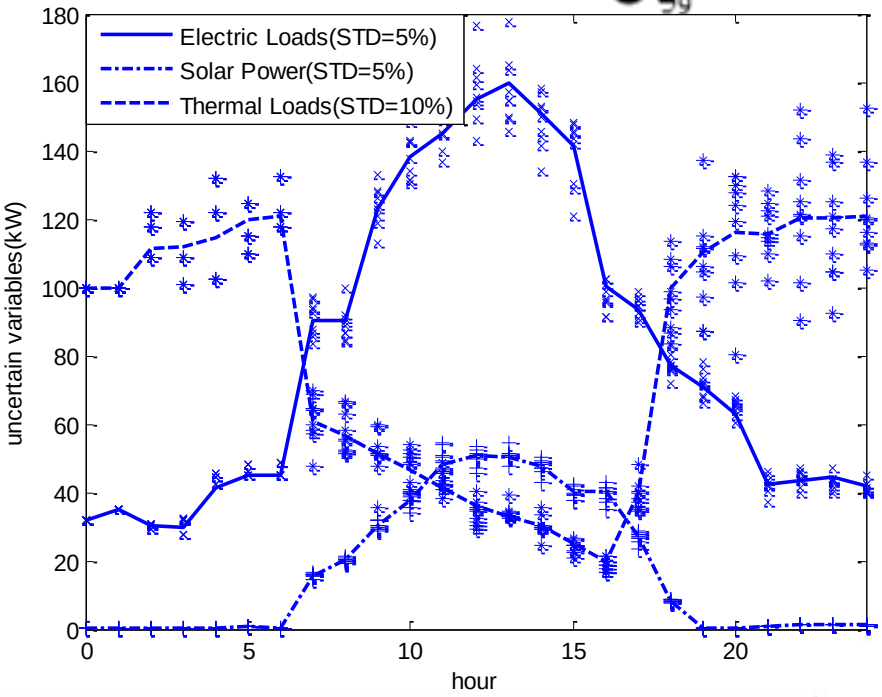
$$H_{boi}^{\min} \cdot x_{boi,t}^j \le H_{boi,t}^j \le H_{boi}^{\max} \cdot x_{boi,t}^j$$

Solution Methodology



Flow chart

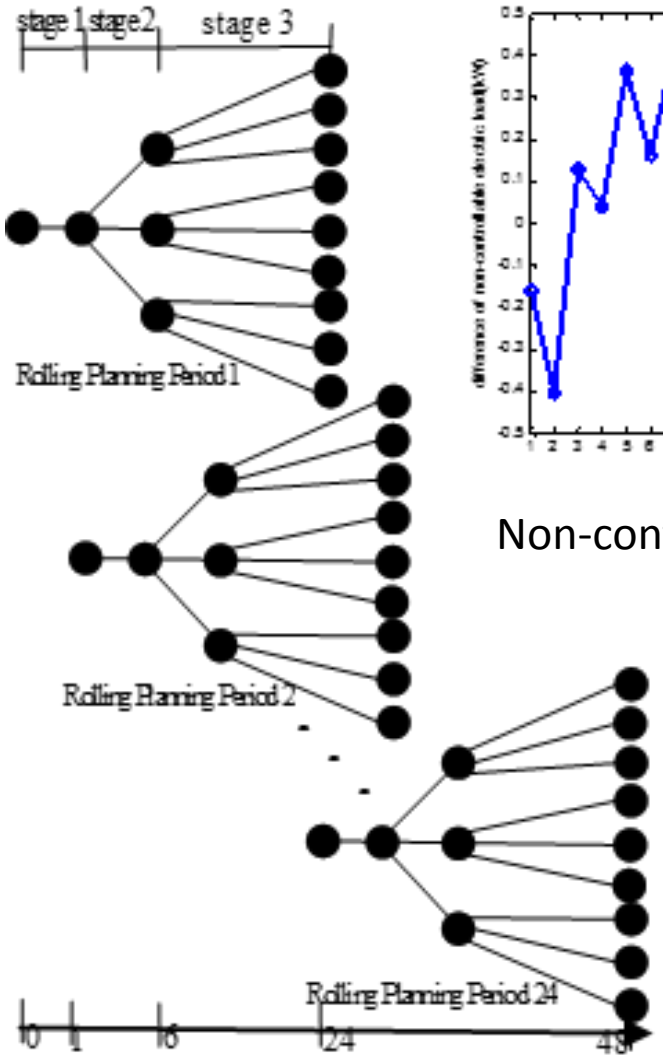




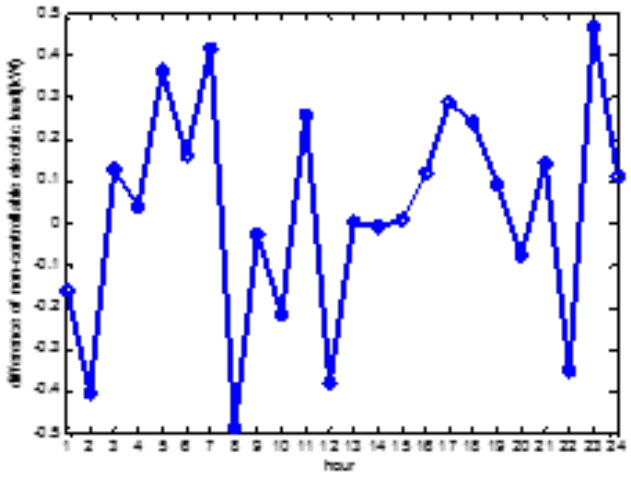
galvin at ILLINOIS INSTITUTE OF TECHNOLOGY

IEEE PES Power & Energy Society®

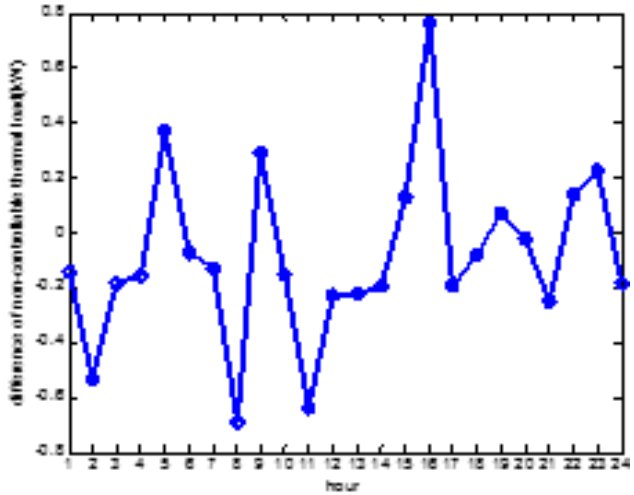
Solution Methodology



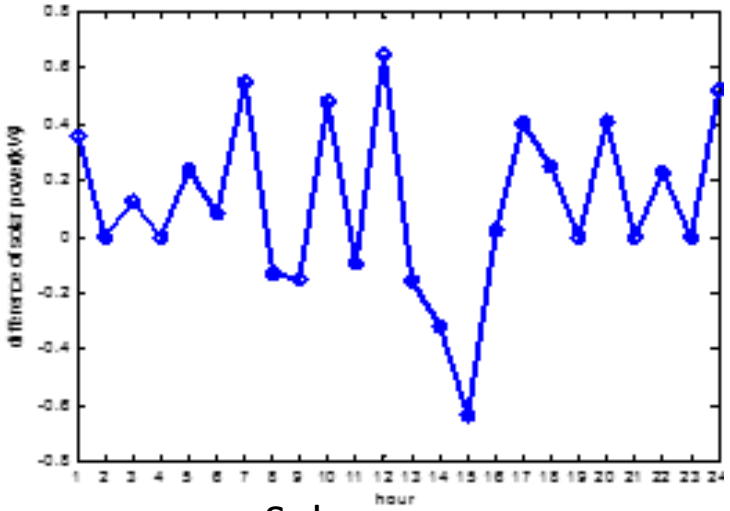
Rolling scheduling



Non-controllable electric load



Non-controllable thermal load



Solar power

Rolling difference for uncertainties

Case Studies

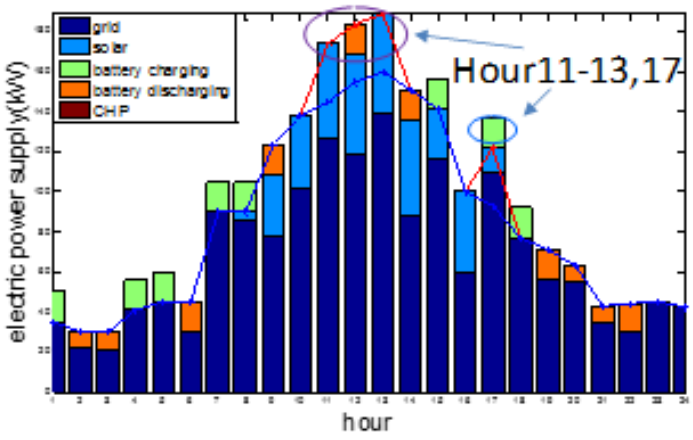
Cases		1	2	3	4	5	6(Stochastic)
Power Generation	Electric Grid	✓	✓	✓	✓	✓	✓
	Solar	×	✓	✓	✓	✓	✓
	Battery	×	×	✓	✓	✓	✓
	CHP	×	×	×	×	✓	✓
	Boiler	×	×	×	✓	✓	✓
Household Loads	NC electric loads	✓	✓	✓	✓	✓	✓
	Controllable Electric Loads	-	-	-	…	…	…
	NC Heat Loads	×	×	×	✓	✓	✓
	Controllable Heat Loads	×	×	×	…	…	…

'NC' means non-controllable; '✓' means candidate;'×'mean non-candidate;'-'means fixed status;'…' means unfixed status

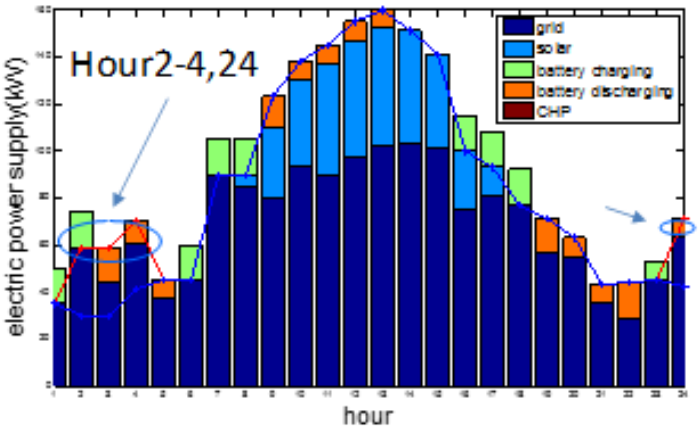
Daily production cost ($)

Case	1	2	3	4	5	6
Cost	196.80	155.67	150.32	221.08	195.49	216.54

Electric Power Supply

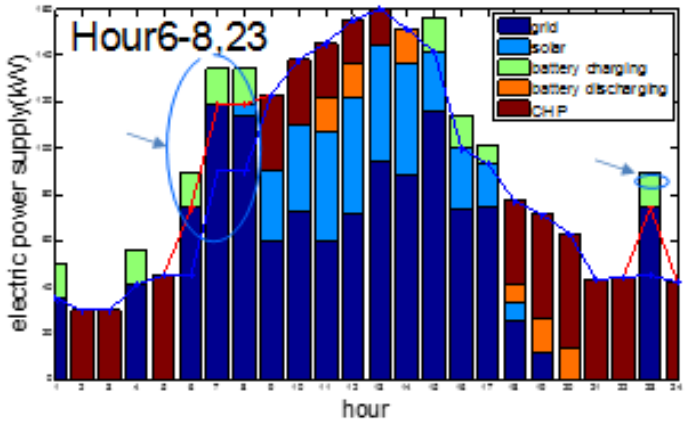


Case 3

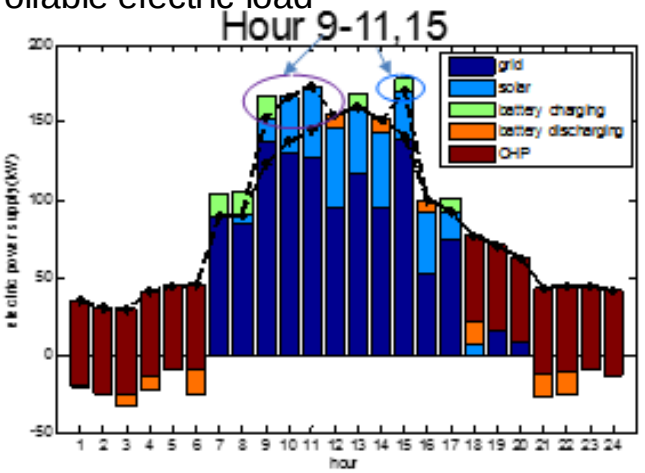


Case 4

Fixed V.S unfixed controllable electric load

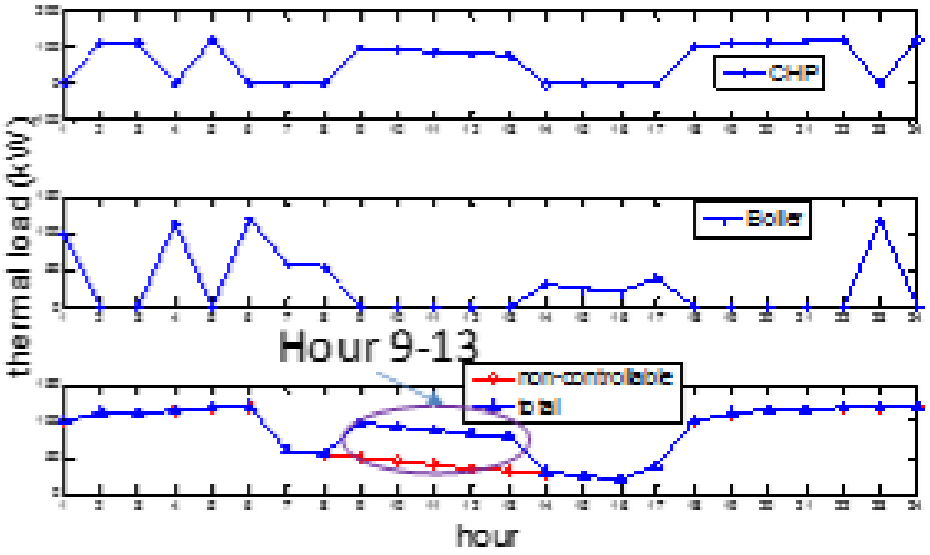


Case 5:deterministic

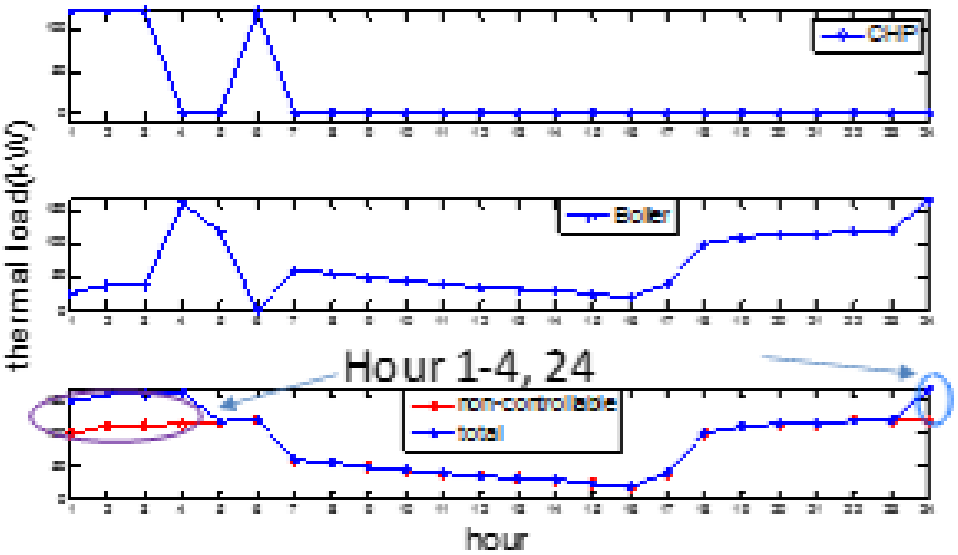


Case 6:stochastic

Thermal Power Supply



Case 5



Case 6

Conclusions

- The optimization of energy distribution of buildings for time horizons of one day is considered as a multistage stochastic optimization problem.
- The incorporation of uncertainties about solar power production, non-controllable electric and heat loads in the optimization model is considered through a multistage scenario tree.
- A manageable number of scenarios are considered by the backward scenario reduction method.
- Rolling scheduling will take into account the updated information on a continuous hourly basis for uncertainties, including solar power production, non-controllable electric and heat loads .
- The consideration of uncertainties will introduce more cost for the operation of energy-efficiency building with CHP system.

Q&A

Thanks