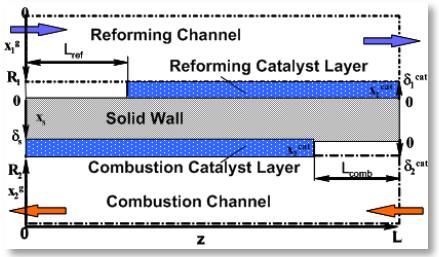
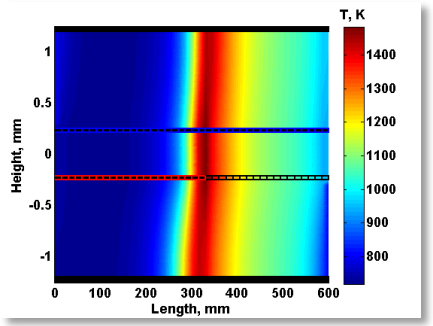
Process and Energy Systems Engineering

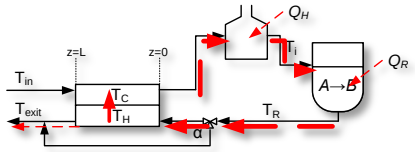
Research Overview

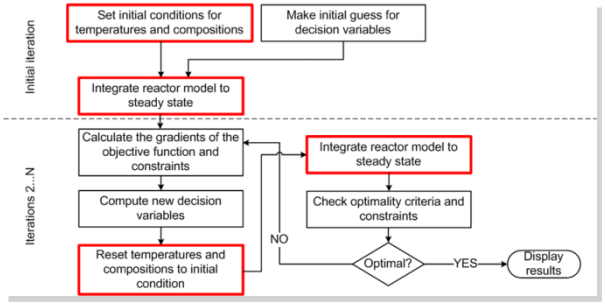
Michael Baldea

August 30, 2011









Systems Engineering Group

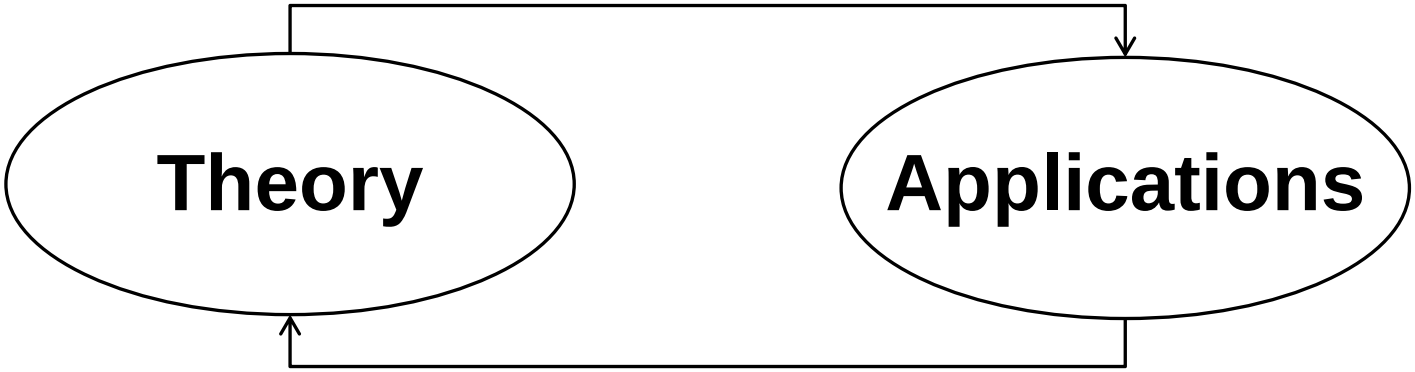
Michael Baldea

- "Babeş-Bolyai" University, Cluj-Napoca, Romania
  - Diploma (2000), M.Sc.(2001), Chemical Engineering
  - Model-based control of materials processing
- University of Minnesota, Twin Cities
  - Ph.D., Chemical Engineering (2006)
  - Emerging dynamics in integrated chemical plants
- Praxair Technology Center, Buffalo, NY
  - R&D Associate (2006-2011)
  - Energy recovery in cryogenic processes
- UT ChemE faculty since August 2011

Currently looking for 2 graduate students

About Our Research

SYSTEMS ENGINEERING



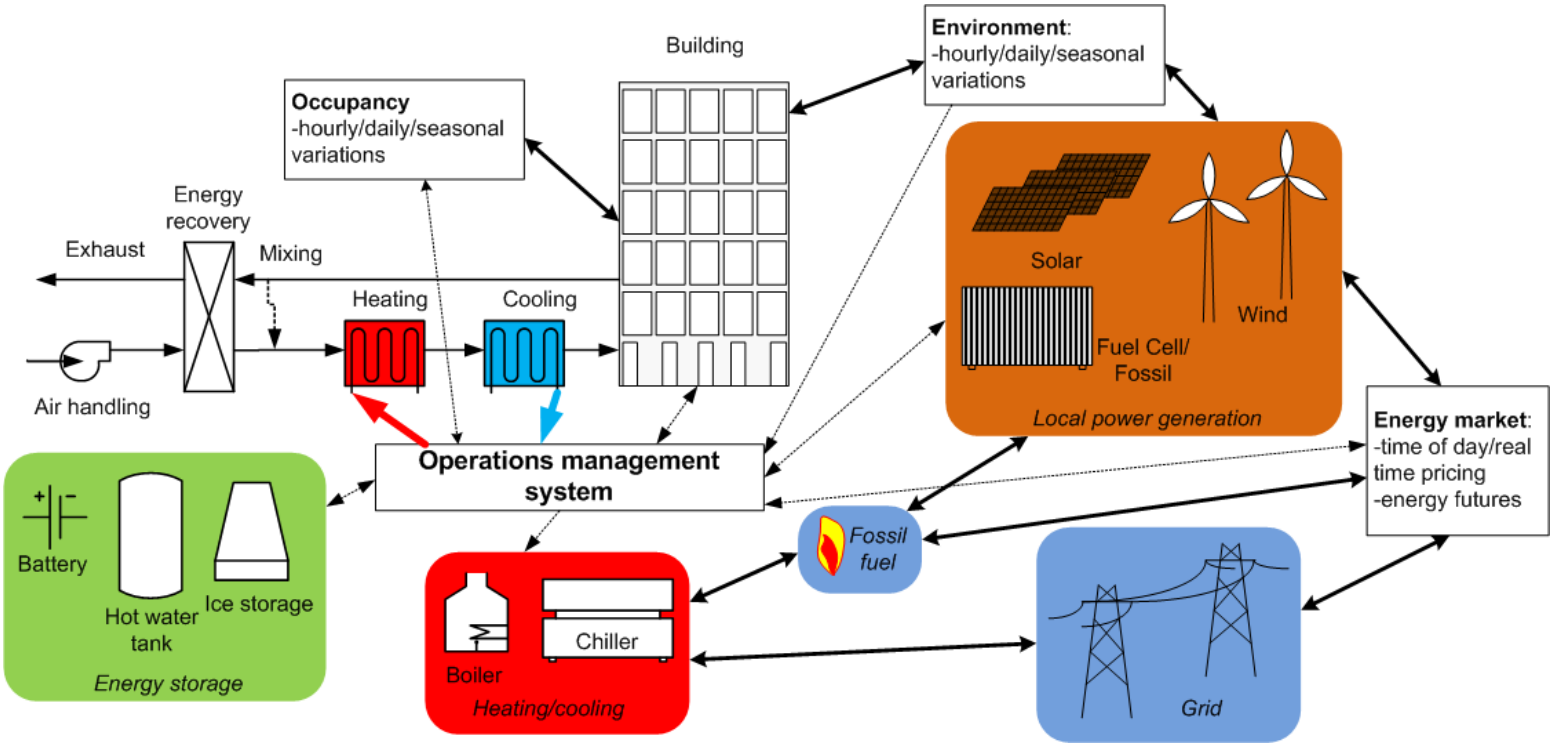
Depth

- Modeling/model reduction
- Control
- Optimization
- Numerical methods, data analysis

- **Energy** (green buildings, next-generation H2 technology)
- **Complex engineered systems** (fault detection and isolation, self-healing process units)

Breadth

Green Building Energy Management

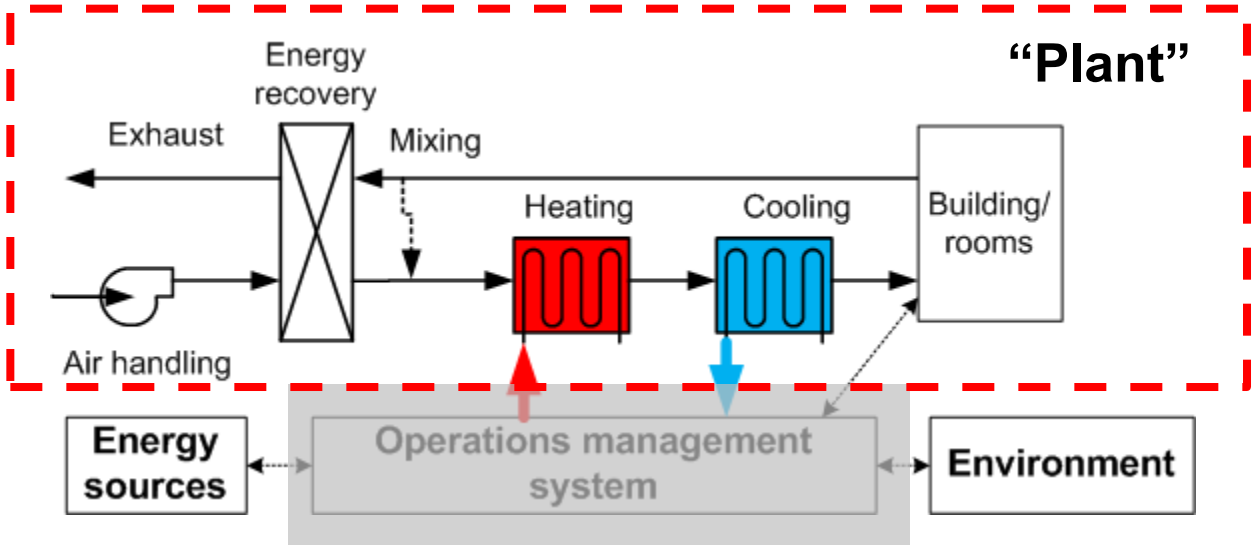


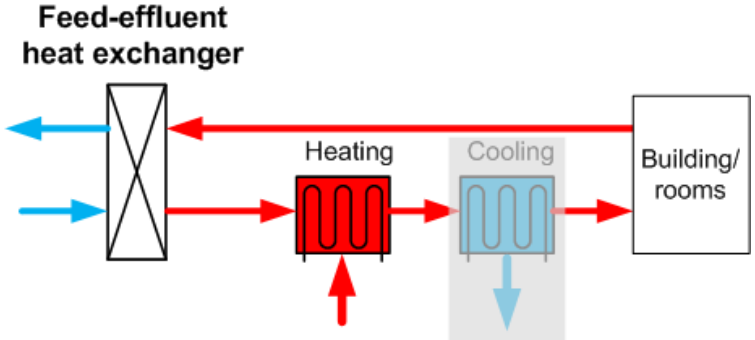
Buildings consume over 70% of the electricity generated in US

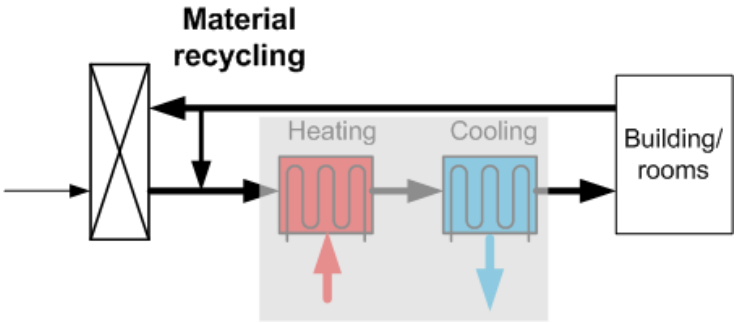
Optimal operation: ensure occupant comfort at minimum cost

- maximize energy recovery, minimize utility load
- large-scale problem with discrete (on/off) and continuous decisions
- difficult to solve in a practical amount of time

Green Buildings Research Topics







- Exploit fundamental similarities with integrated chemical processes to design novel energy management strategies

Green Buildings Research Topics (contd.)

Modeling

- model reduction (novel hybrid systems approach)
- fast identification of new models from field data

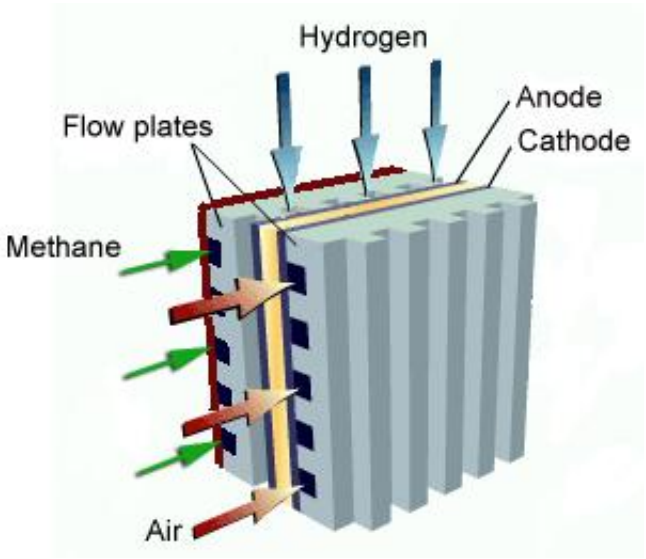
Proactive energy management strategies

- *Building-level:*
  - optimization-based control
  - ***predictive*** vs. reactive: incorporate weather, cost forecasts
- *Cooperative energy management (campus-level)*

Strategic decision support

- *Long-term economic planning models*
  - optimal capital investment in renewable energy
  - evaluate energy market opportunities
  - zero net energy use

Complex Engineered Systems

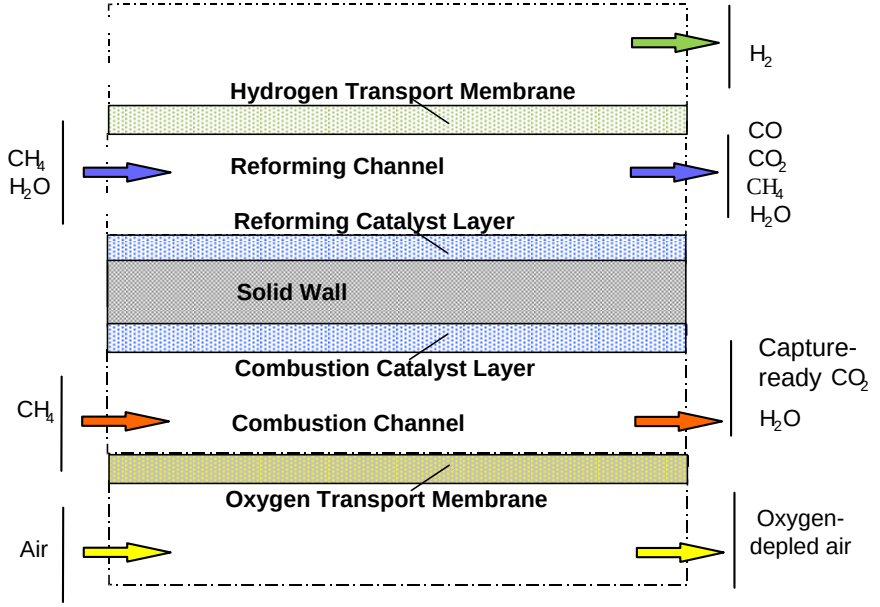


Integrated SOFC/FP: maximize power density, improve fuel flexibility

- optimal flow configuration (co-current/counter-current/cross-current)?

Membrane-assisted reforming: capture – ready CO_2

- optimal design (e.g., shell-and tube, plate) and flow configuration (e.g., co-/counter-/cross-current)?
- catalyst distribution and membrane location?



Complex Systems Research Topics

Fundamental concepts:

Modeling: use systems and control ideas to improve numerical properties without altering solution (static equivalence)

Optimization: time relaxation-based approach (recent algorithm released commercially)

Classes:

Systems with ***multiple (unstable) steady-states***

Switched systems (IF….THEN….ELSE)

Time-periodic/cyclical systems

Multi-scale modeling

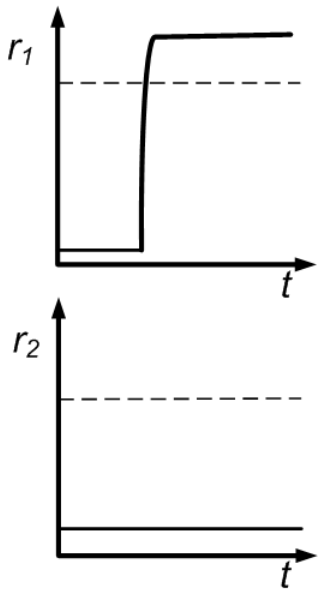
- Simultaneous optimal macroscopic system design and material selection

Fault Detection and Isolation

Model-based FDI

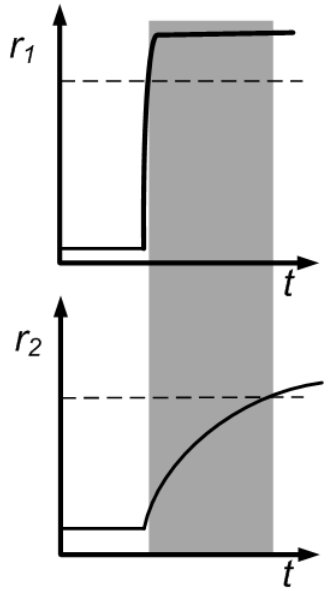
- track residual (system output $\bar{x}$ - reference model output $\hat{\bar{x}}$)
- detection: acknowledge occurrence of a fault
- isolation: identify specific fault

$e_1 \equiv [r_1^+ \quad 0]^T$ easily isolated



$$\dot{r}_1 = f_1(\bar{x}, \hat{\bar{x}})$$
$$\dot{r}_2 = 0.001\, f_2(\bar{x}, \hat{\bar{x}})$$

$e_2 \equiv [r_1^+ \quad r_2^+]^T$ **isolated as e_1**



Multi-scale dynamics: potential FDI failure

FDI Research Topics

FDI for multiple time scale systems

- *Model-based residual generation*
  - models of dynamics in each time scale
  - hierarchical structure: account for time scale multiplicity
- *Sensing*
  - sensor location to improve fault detection and isolation in integrated chemical processes
- *Actuation*
  - optimal placement of backup actuators and sensors
  - actuator switching algorithm

Contact Information

Michael Baldea

- email: mbaldea@che.utexas.edu
- call: 471-1281
- stop by: CPE 4.466
- visit: www.che.utexas.edu > Faculty > Baldea