DEPARTMENT SPOTLIGHT - ENERGY SYSTEMS RESEARCH AND TEACHING OVERVIEW

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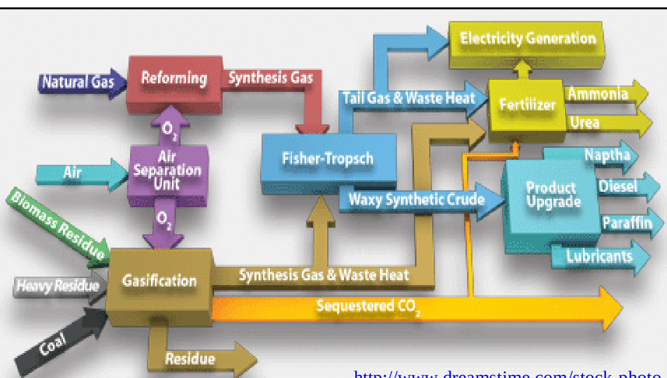
WVU Academy of Chemical Engineers



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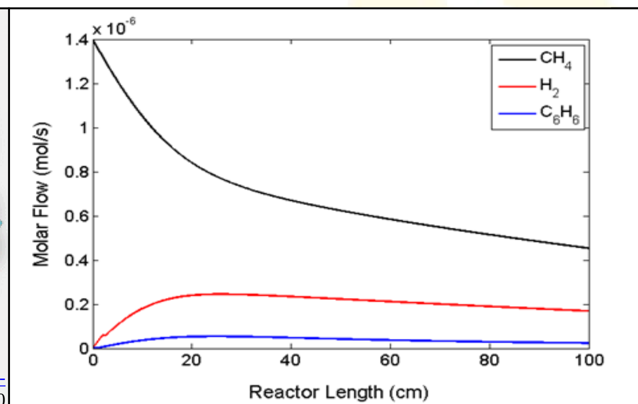

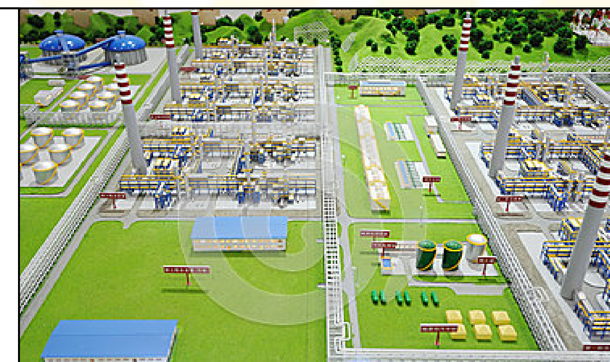

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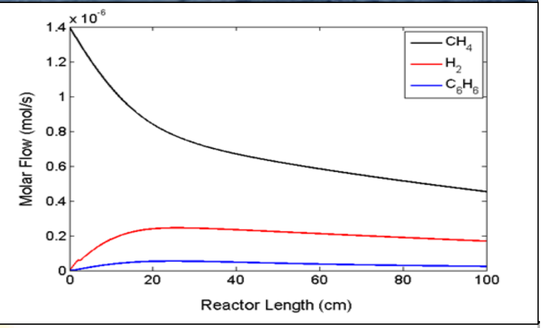
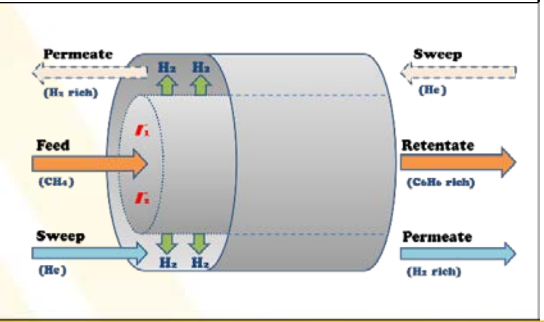
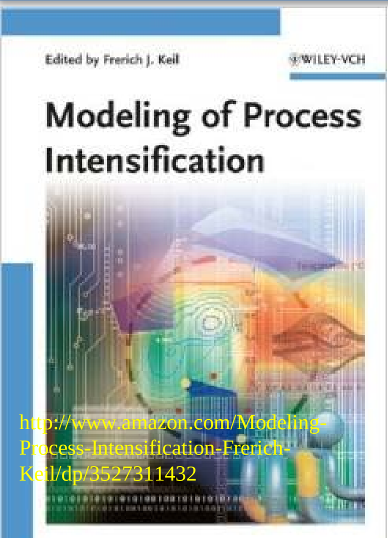
Presentation Outline



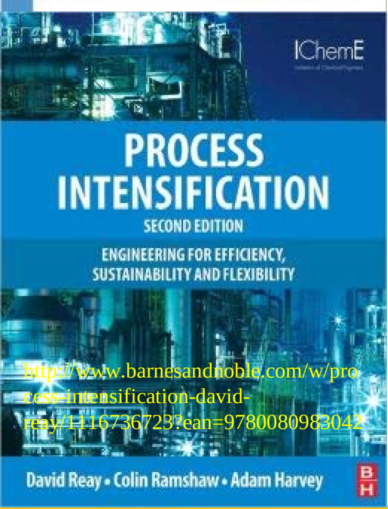


- ➢ **Research Overview**
  - ✓ **Process Design and Intensification**
  - ✓ **Biomimetic Control**
  - ✓ **Sustainability**
  - ✓ **Power Plant Cycling**
- ➢ **Teaching Overview**
- ➢ **Conclusions**

Process Intensification (PI)



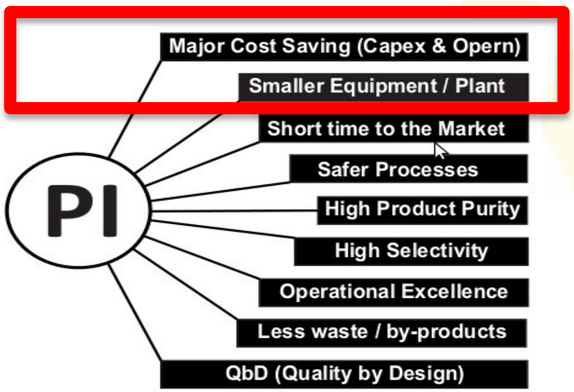
http://www.amazon.com/Modeling-Process-Intensification-Frerich-Keil/dp/3527311432



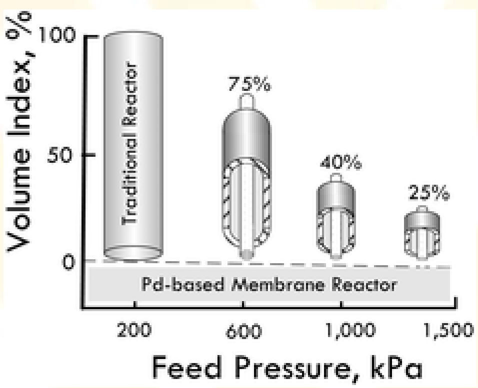
http://www.barnesandnoble.com/w/process-intensification-david-reay/1116736723?ean=9780080983042

Emerging equipment, … promise spectacular improvements in process plants, markedly shrinking their size and dramatically boosting their efficiency*

PI is a strategy for making dramatic reductions in the size of a chemical plant so as to reach a given production objective**



http://pi-inc.co/services.html



http://pubs.rsc.org/en/Content/ArticleLanding/2012/GC/C2GC16668B#!divAbstract

*Stankiewicz and Moulijn. Chemical Engineering Progress, 2000
**Ranshaw. Proceedings -1st Intl. Conf. Proc. Intensif. for Chem. Ind., 1995

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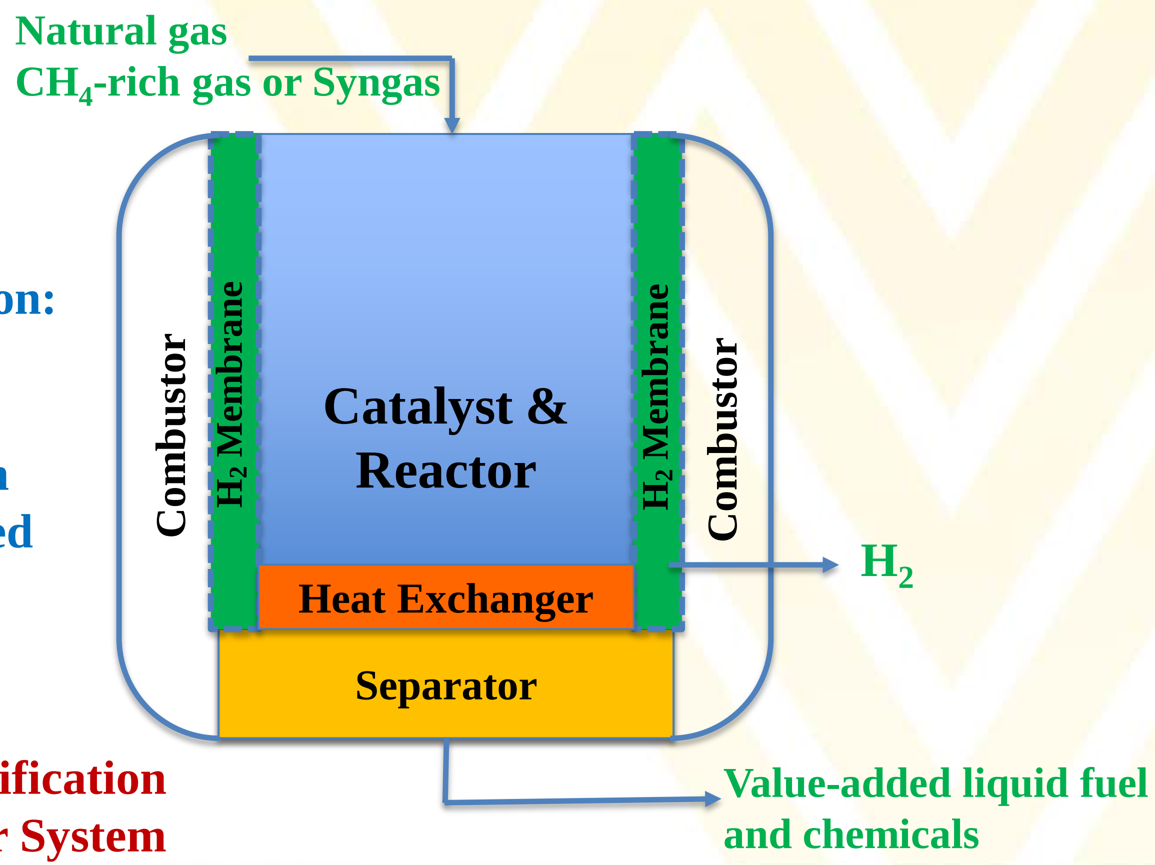
Modular Natural/Shale Gas System

Research Concept

Direct Methane Aromatization Conversion in a Modular System



Representative reaction:

$6CH_4 \rightarrow C_6H_6 + 9H_2$

Endothermic reaction

Equilibrium controlled

Catalytic Process Intensification for a Modular System

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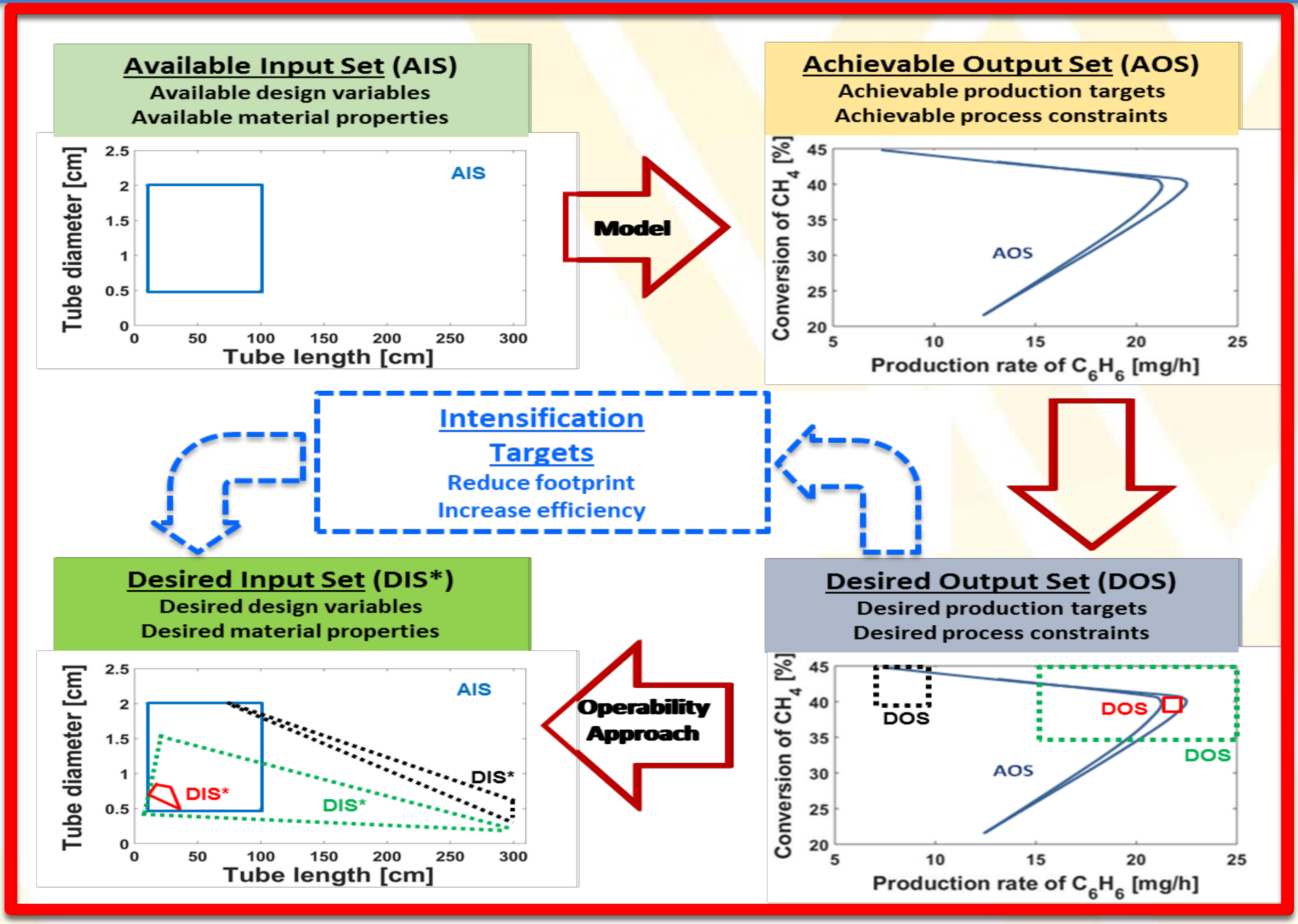
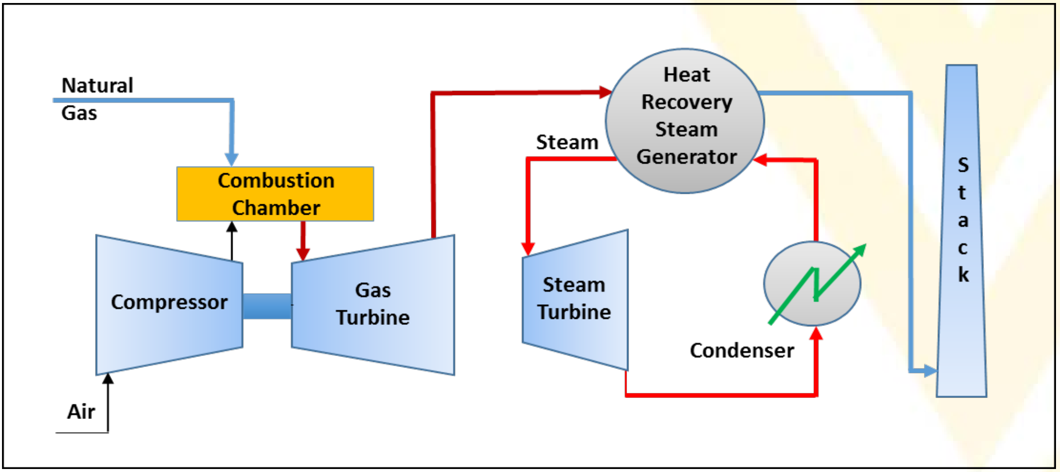
Optimization-based Operability Approach for Process Design and Intensification*



*Carrasco and Lima. *AIChE Journal*, 2017

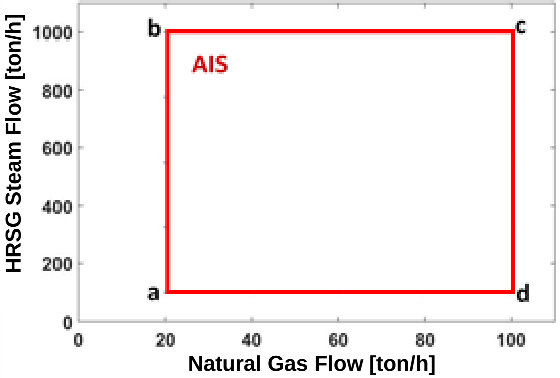
Natural Gas Combined Cycle (High-D Application)

Simplified Schematic of NGCC Power Plant*

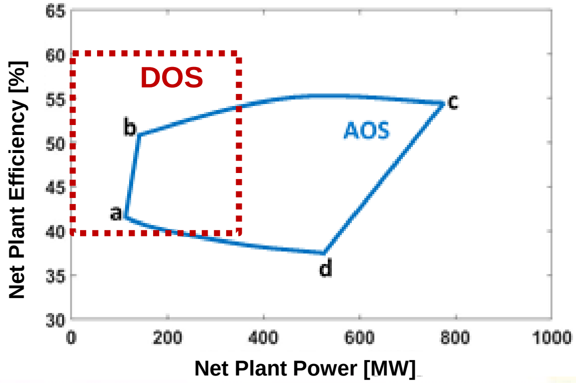


- Input variables: natural gas and steam flows
- Outputs: net plant power and efficiency
- Minimize size (power generation) of NGCC plant for intensification and modularity
- Maintain combined cycle efficiency

Available Input Set (AIS)



Achievable Output Set (AOS)



*Carrasco and Lima. *AIChE Journal*, 2018
*Carrasco and Lima. *Comput. Chem. Eng.*, 2017

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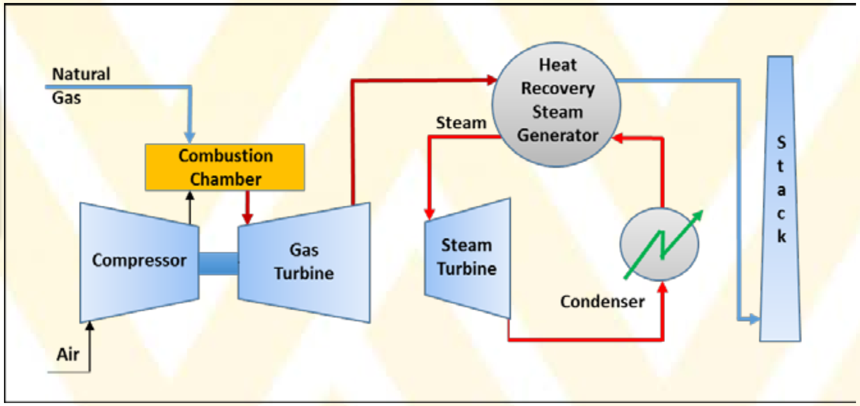
NGCC High-D System (8x8)

Selected intensified 5 inputs	Inputs points
Natural gas feed [ton/h]	0.013
HRSG steam feed [ton/h]	0.157
Compressor outlet pressure [atm]	5.8
Air feed temperature [K]	329
Steam cycle pressure [atm]	140

Selected intensified 5 outputs	Output points
Net plant power [MW]	0.11
Net plant efficiency [%]	56.5
Capital cost* [$ millions]	0.5
Gas turbine power [MW]	0.09
Air compressor power [MW]	0.06

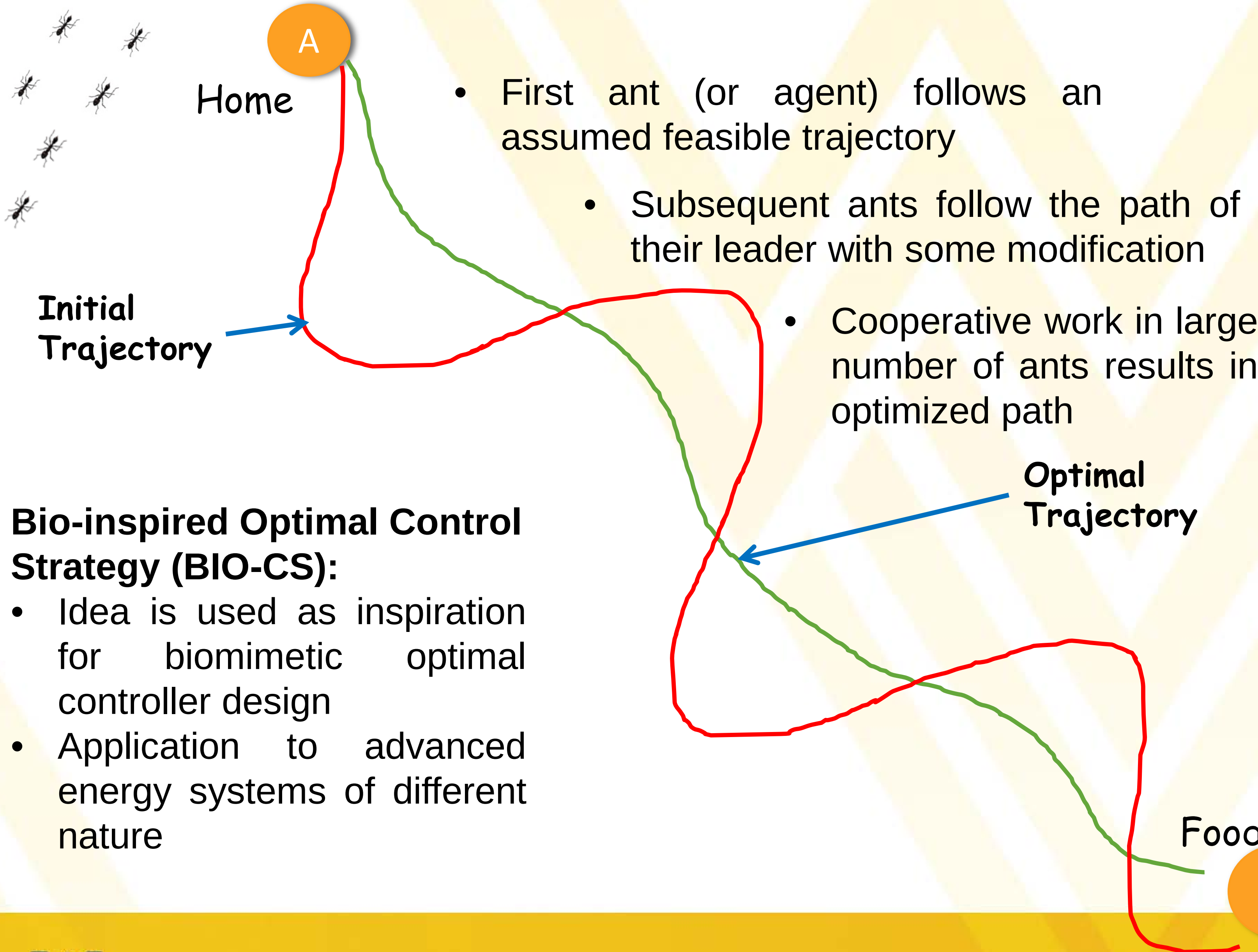


NGCC Subsystems	P4 (63 cores) Time [hr:min:sec]	Reduction after parallelization [times]
4x4	00:00:07	5.4
8x8	00:14:24	70.6

Capital Cost* [MM$] = 2.821 $(NPP)^{0.7991}$
NPP: Net plant power [MW]

U.S. EIA, 2013. Updated capital cost estimates for utility scale electricity generating plants
ESMAP Technical paper 122/09. Study of equipment prices in the power sector

Biomimetic Control



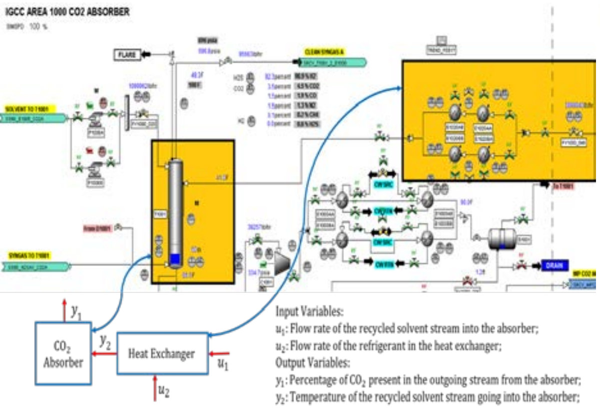
- First ant (or agent) follows an assumed feasible trajectory
  - Subsequent ants follow the path of their leader with some modification
    - Cooperative work in large number of ants results in optimized path

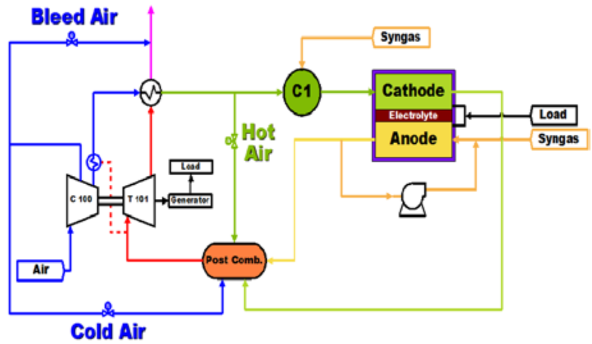
Bio-inspired Optimal Control Strategy (BIO-CS):

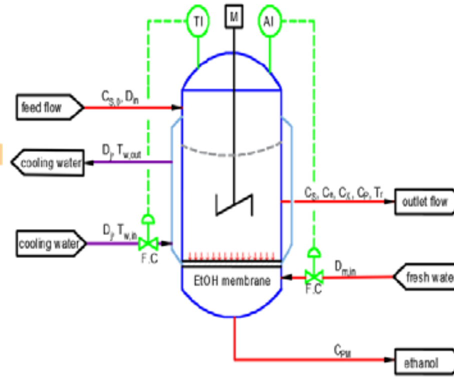
- Idea is used as inspiration for biomimetic optimal controller design
- Application to advanced energy systems of different nature

Biomimetic Control Applications

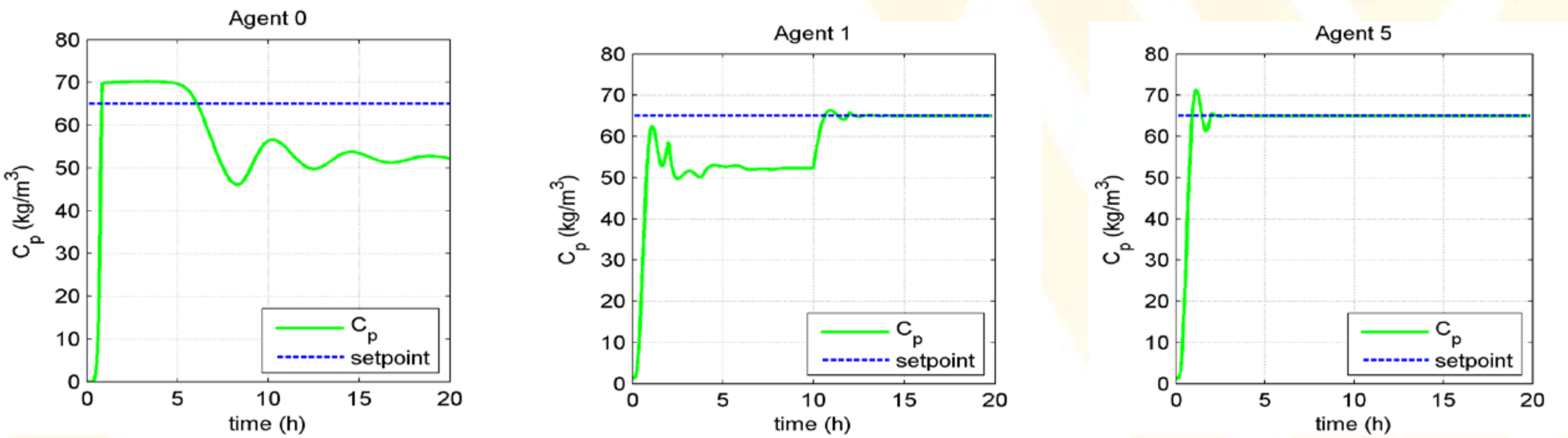
IGCC-AGR | **HYPER system (NETL)** | **Fermentation process***







Open and Closed-loop Responses



*Mirlekar, Li and Lima. *Ind. Eng. Chem. Res.*, 2017

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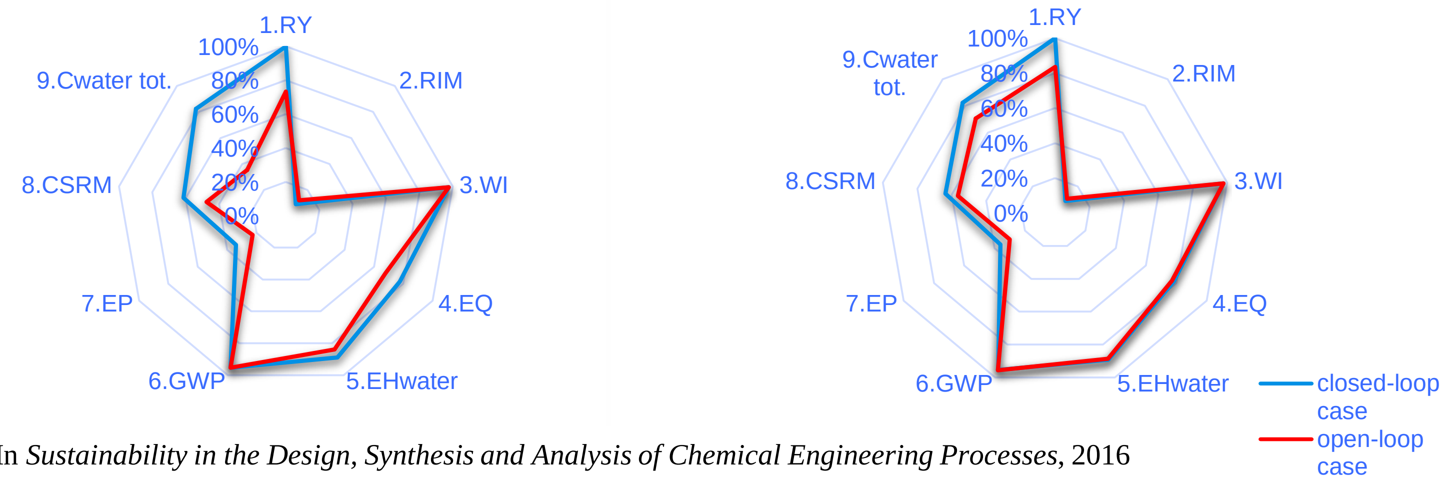
Sustainability Assessment

- **Method**: integrate *process control* with *sustainability assessment tools* for the simultaneous *evaluation* and *optimization* of process operation
- **GREENSCOPE** (U.S. EPA software) indicators show *improvement* of *sustainability performance* after controller implementation for fermentation process*
- **Life Cycle Inventory** (LCI) analysis can be incorporated into *sustainable process control framework* using reduced models of chemical processes



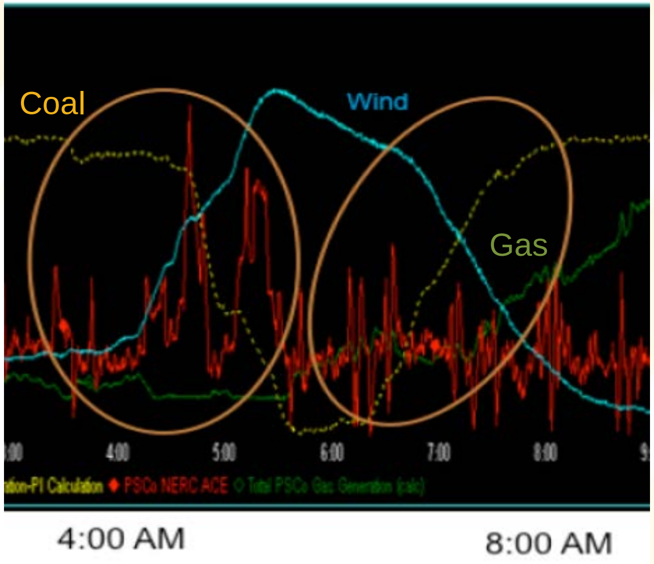
*Lima et al. In *Sustainability in the Design, Synthesis and Analysis of Chemical Engineering Processes*, 2016
*Li, Mirlekar and Lima. *Processes*, 2016

Power Plant Cycling

Approach: model the impact of power plant cycling and develop model-based optimization and control methods for improving load-following behavior

Consequences of power plant cycling

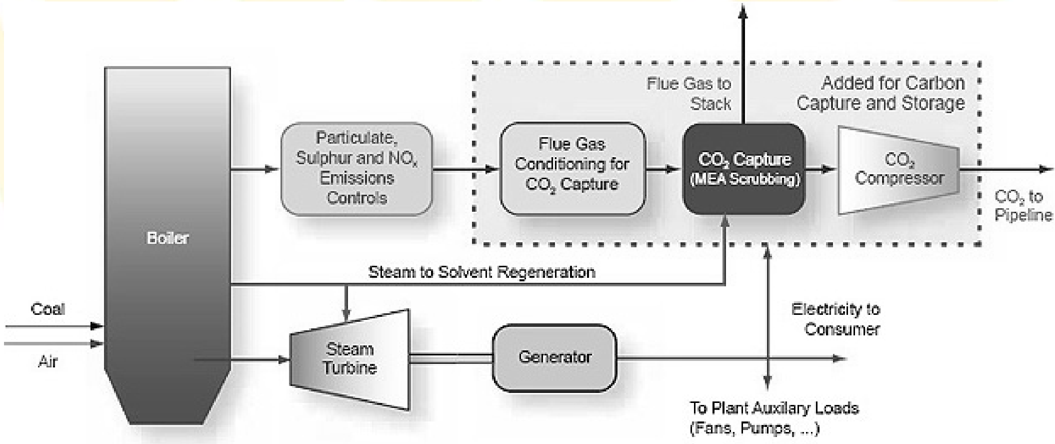
- Cost and maintenance of cycling plants – thermal stresses from cycling and cold/warm start-ups
- Decreased efficiency from base-loaded design operation
- Increased emissions



Control for Power Plant Cycling

- Advanced control strategies (model predictive control) have been implemented on the carbon capture subsystem of the SCPC power plant*

- Plant-wide control for the SCPC plant is currently being addressed based on the optimal profiles from the cycling impact optimization



*He, Wang, Bhattacharyya, Lima and Turton. *Chem. Eng. Res. Des.*, 2018

Teaching Overview

- Objective: Contribute to Applied Mathematics (Modeling, Simulation, Design, Control) and Software Components in Department Curriculum

- Numerical Methods for Chemical Engineering (ChE 230)
  - ✓ further incorporate practical aspects into traditional methods
  - ✓ interactive lectures with board and computer exercises
  - ✓ apply theoretical training to chemical engineering examples

Teaching Overview

- Chemical Process Design (ChE 455/456)
  - ✓ employ ChE learned concepts in design of chemical and energy processes
  - ✓ yearlong design project (industrial partners, e.g., MATRIC, input)
  - ✓ emphasize presentation and communication skills

- Advanced Process Control (ChE 693A)
  - ✓ interactive lectures with board and programming exercises
  - ✓ apply theoretical training to projects of students' interest
  - ✓ emphasize project proposal writing, presentation and communication skills

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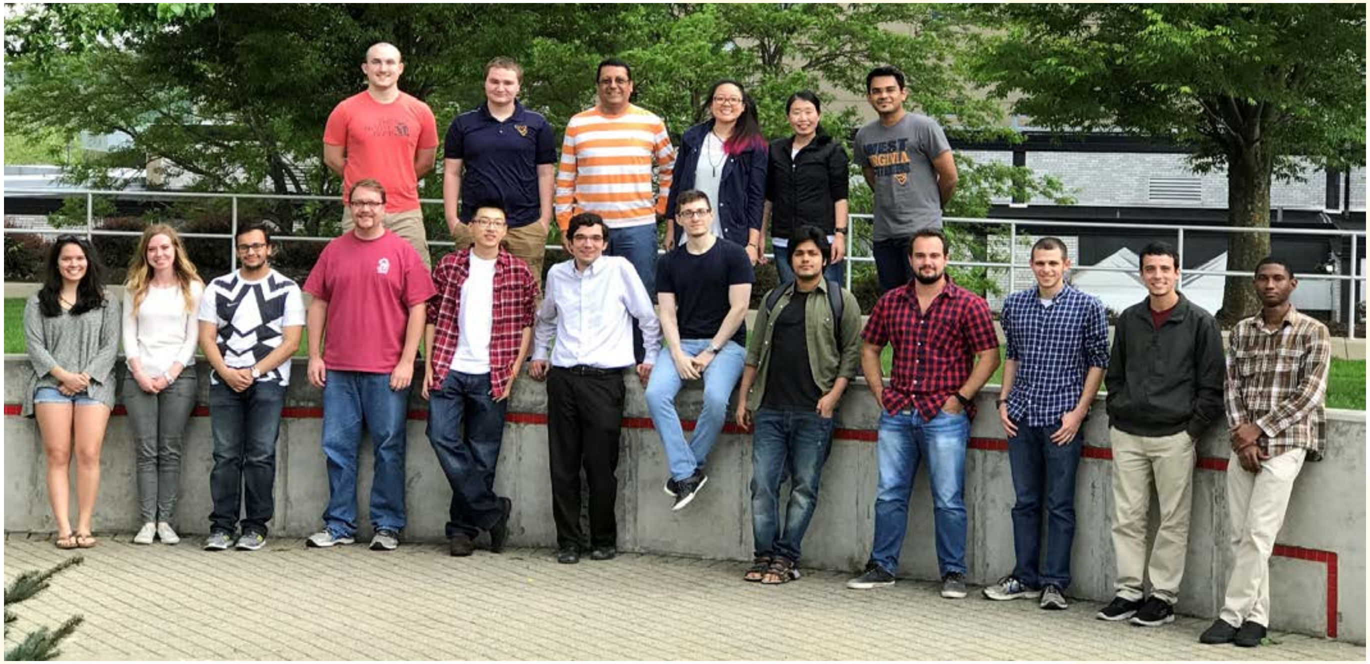

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