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Design and Optimization of Coal Plants of the Future

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Stakeholder Advisory Board Meeting
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Outline

- Why do this?
  - Getting from existing fleet of power plants to next-generation
- What are the objectives?
  - Desired characteristics for the next-generation of power plants
  - Status quo of existing PSE tools to solve this problem
- How do we solve the problem?
  - The need for multiple tools with different capabilities
  - How the IDAES project fits here?

Why do this?

- Fossil Energy Objectives
  - Cost of Energy and CO_2 Capture from Advanced Power Systems – Develop cost-effective, efficient, and reliable CO_2 separation technologies and energy conversion technologies that inherently capture CO_2, for both new and existing coal-fired power plants.
  - Power Plant Efficiency Improvements – Develop cost-effective, reliable technologies to improve the efficiency of new and existing coal-fired power plants.

What should be the characteristics of the next-generation of power plants to provide secure, stable, and reliable power?

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What are the desired characteristics?

- Flexible operation
  - High ramp rates and minimum load operation (renewable targets 2050)
- Innovative design
  - > 40% HHV efficiency, near zero emissions, low water consumption
- Resilient operation
  - Minimize forced outages with enhanced monitoring and diagnostics
- Small scale
  - <350 MW, minimize field construction costs
- Transformative technologies
  - Coupled with energy storage, integrate with coal upgrading

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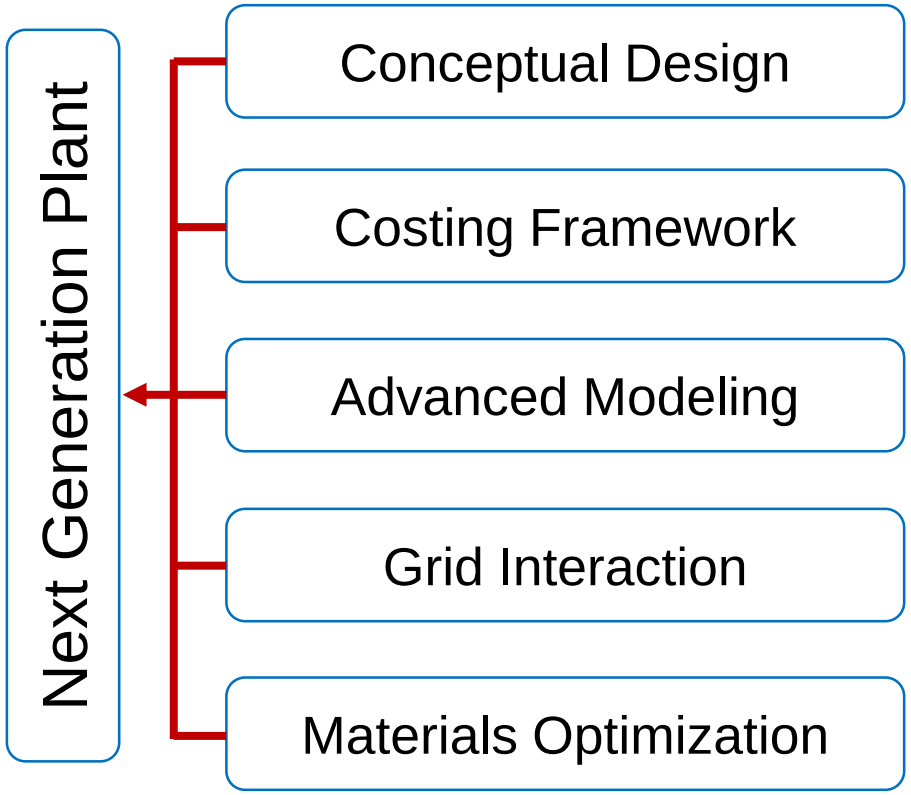
Project Inception: 2019

Required Capabilities to Design Power Plants



- Develop robust conceptual design tools to identify the best design
- Develop reliable cost-estimating methodologies for new and existing candidate technologies
- Create advanced models for transformational technologies that enable optimal design and analysis
- Develop design targets that best integrate with the evolving needs of the electric grid
- Identify innovative materials using optimization that might help meet high performance metrics

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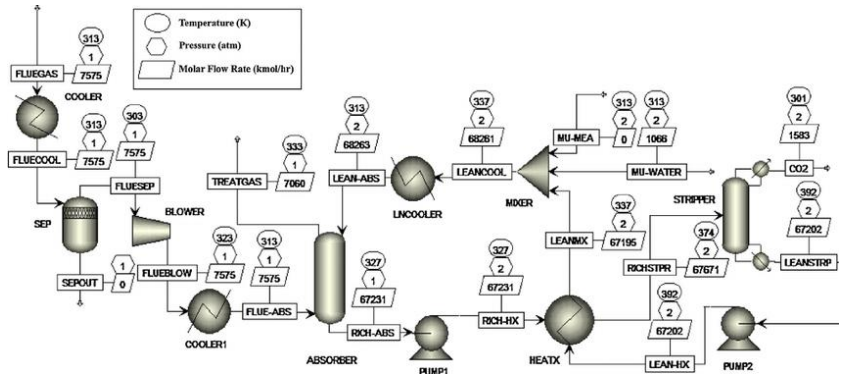
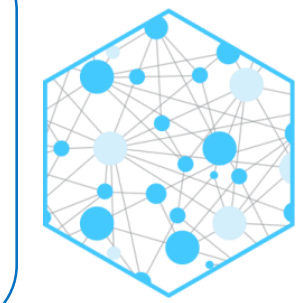
Process Design Studies – Status Quo

Techno-economic Studies



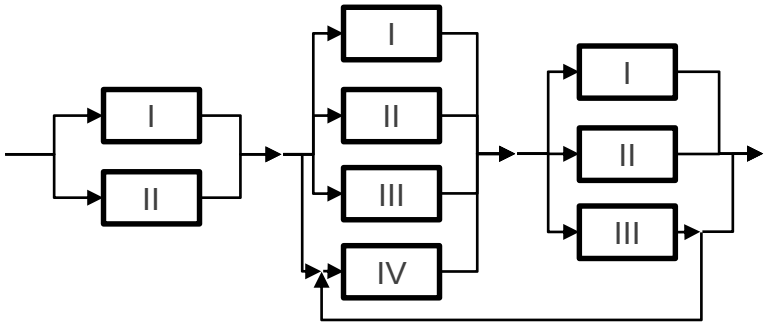
- Detailed steady-state models ✓
- Reasonable cost estimates ✓
- Not extensive, case by case analysis ✘
- Difficult to realize synergistic advantages ✘
- More a sensitivity study ✘

Update model



Validate design

Conceptual Design Studies



- Extensive search space ✓
- Realize synergies between processes ✓
- Simple input/output models ✘
- Performance prediction maybe erroneous ✘
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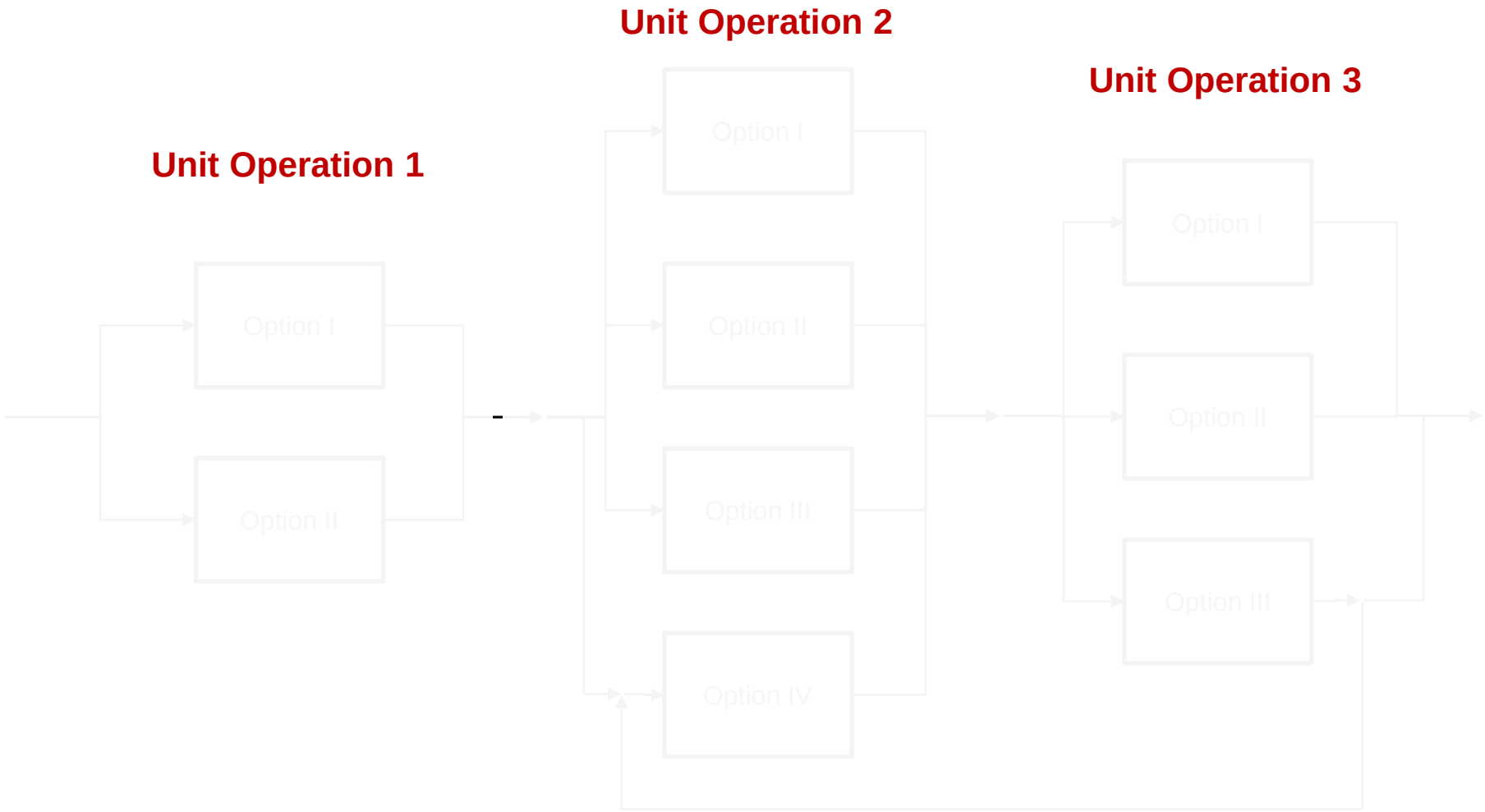
Conceptual Design

Superstructure for Conceptual Design



+

PYOMO GDP

9 disjunctions, 18 binary variables → 315 choices

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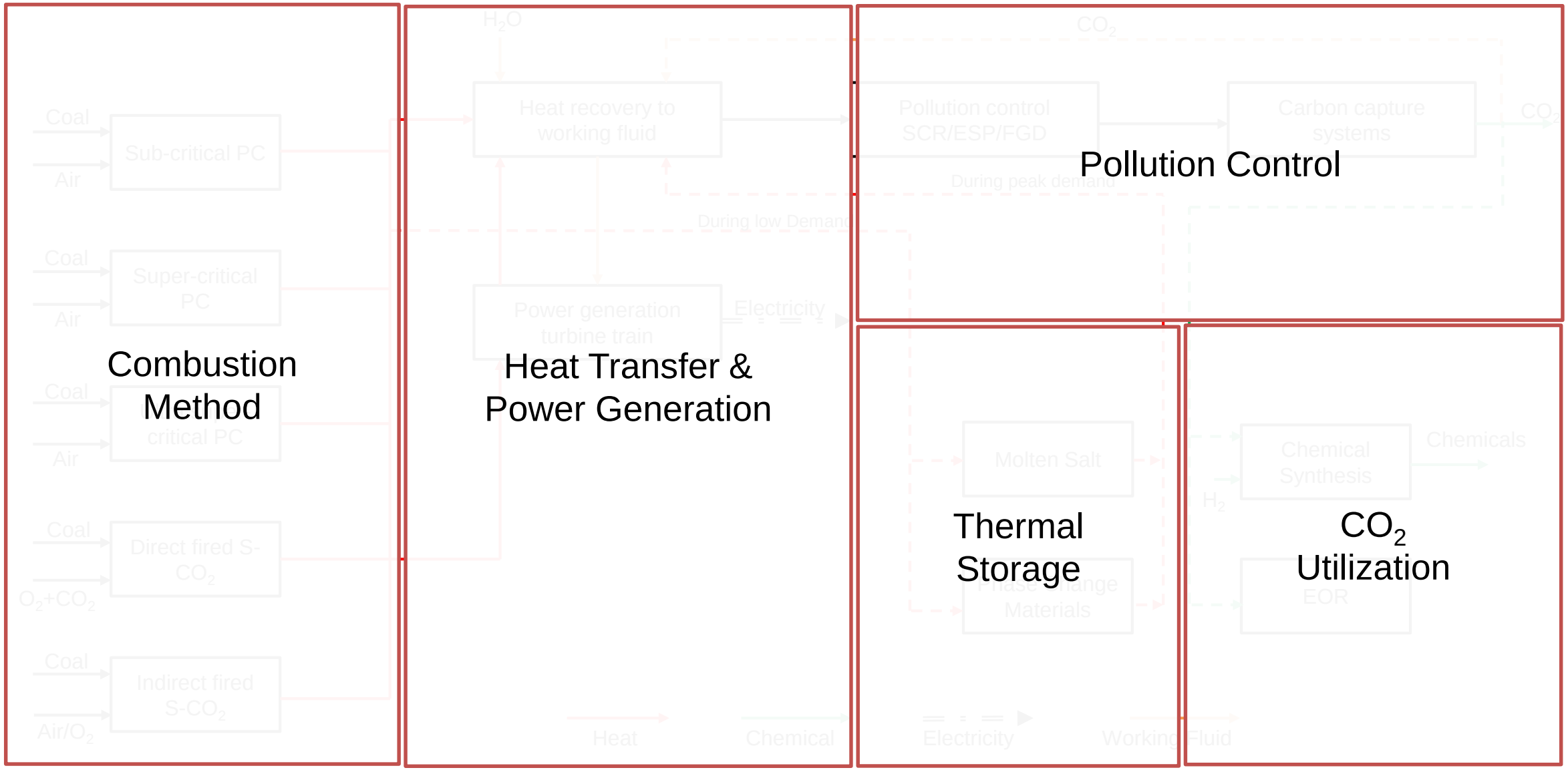
Superstructure for Power Generation Application



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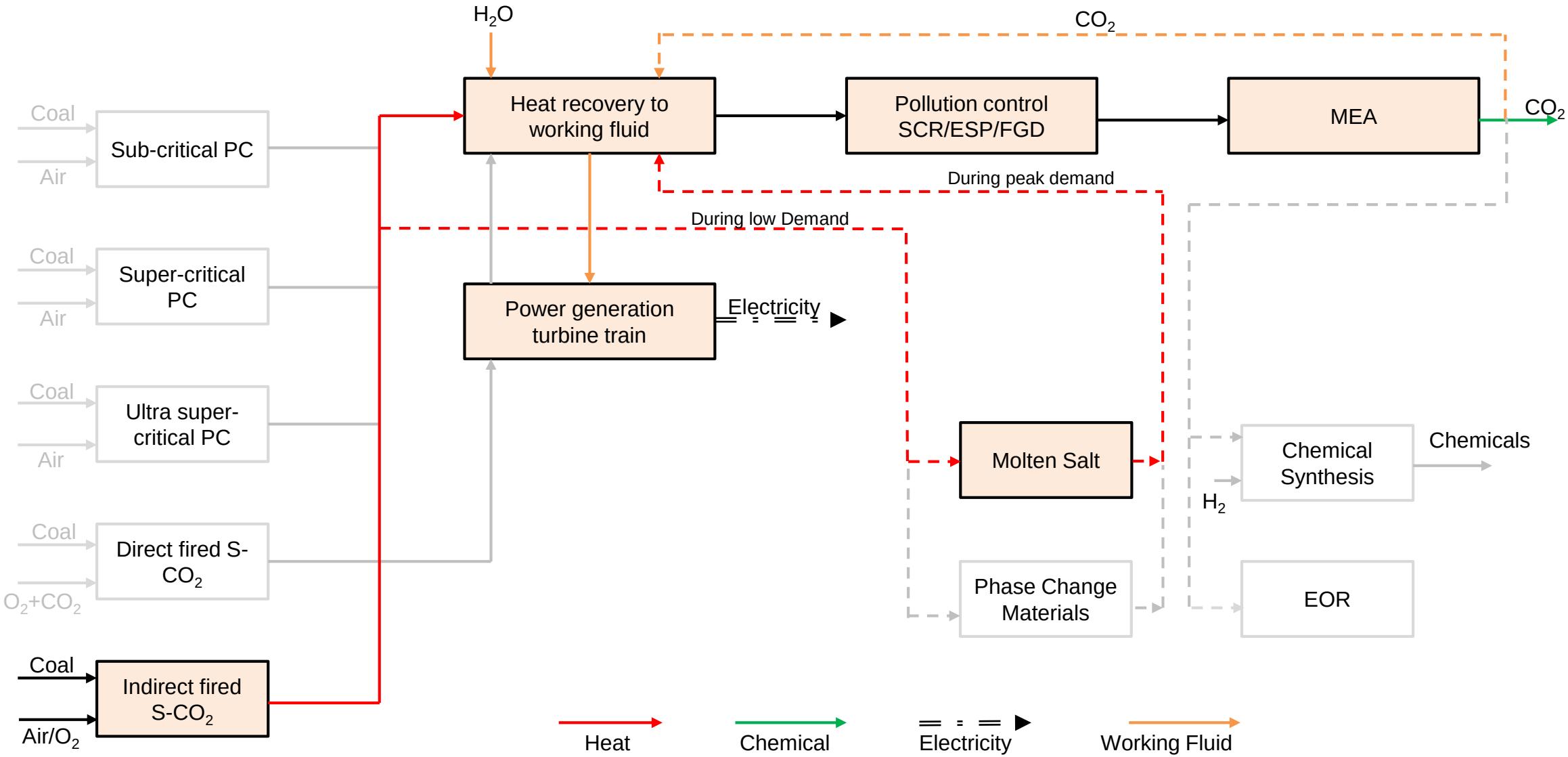
A Possible Solution



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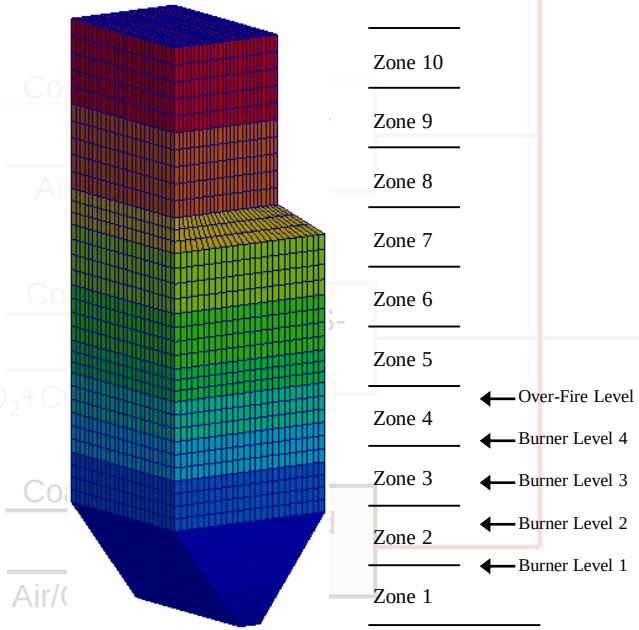
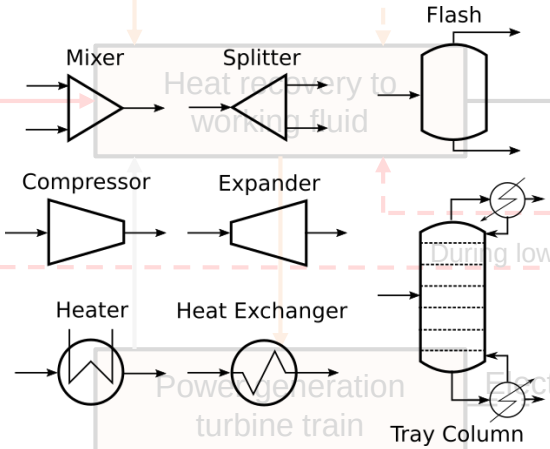
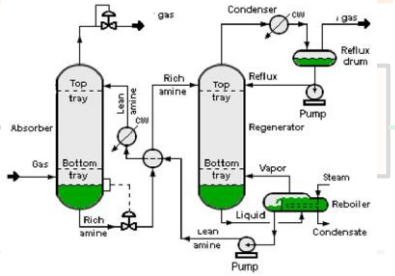
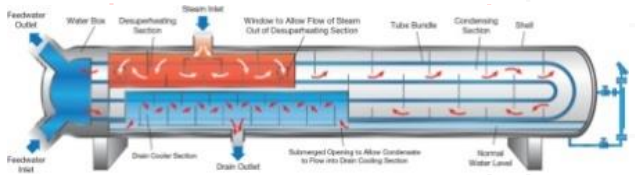
Detailed Modeling







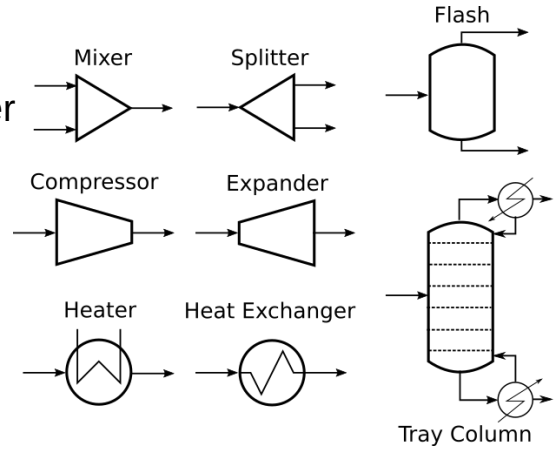


Advanced Modeling in IDAES

Detailed Modeling

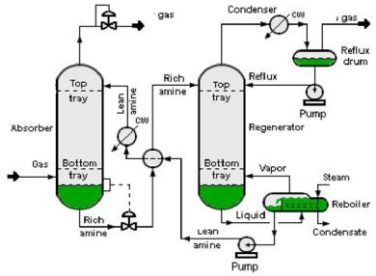
Unit Models

- Customized model library for power plant unit operations

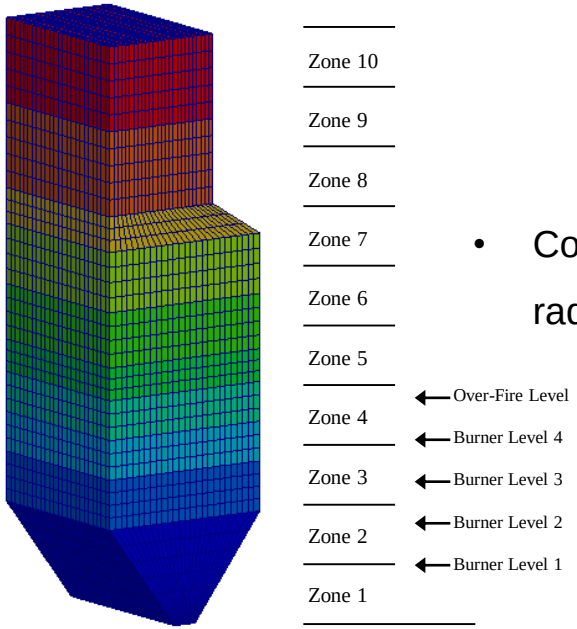


MEA Model

- Liquid-gas contactor model

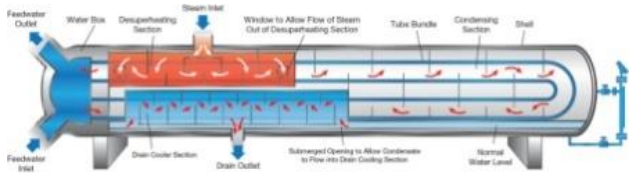


1D-3D Boiler Model



- Complex 1D-3D radiation models

Advanced HX Models



- Temporal/spatial variations in temperature

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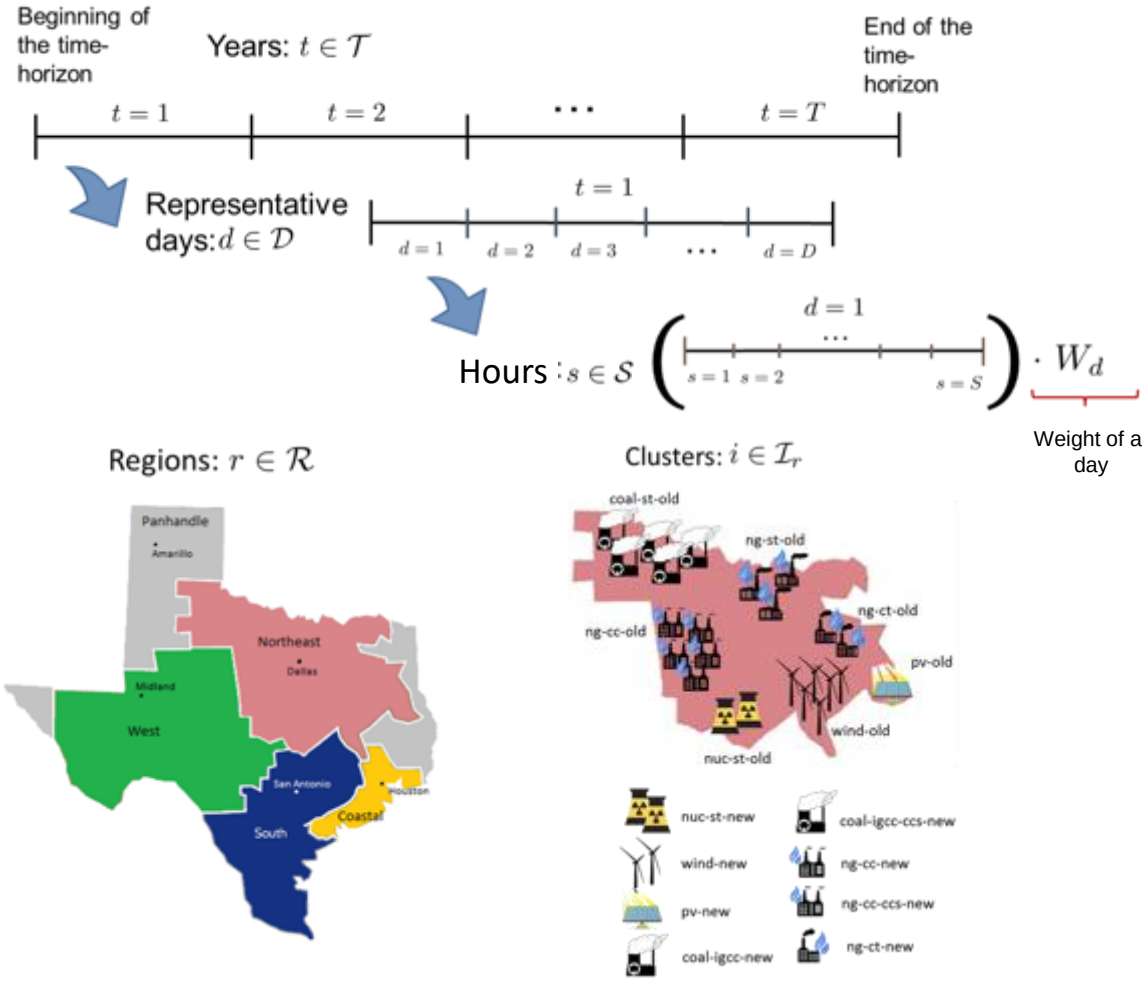
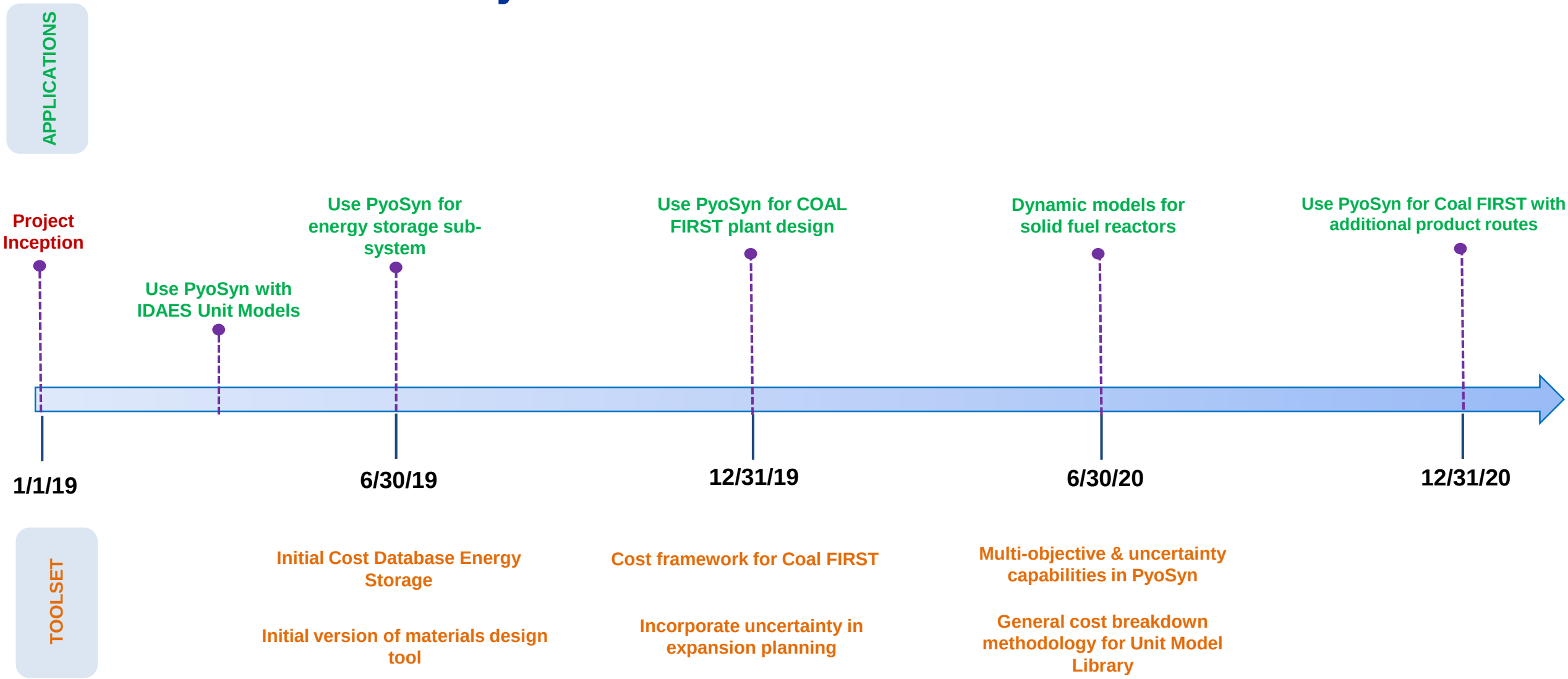
Grid and Infrastructure Planning

Generation Expansion Planning

- Time scale approach:
  - Multi-year, days per year, hours per day
- Region and cluster representation
  - Area represented by a few zones
  - Potential locations are the midpoint in each zone
  - Clustering of generators
- Transmission representation
  - Flow in each line is determined by the energy balance between each region *r*



Project Milestones & Timeline



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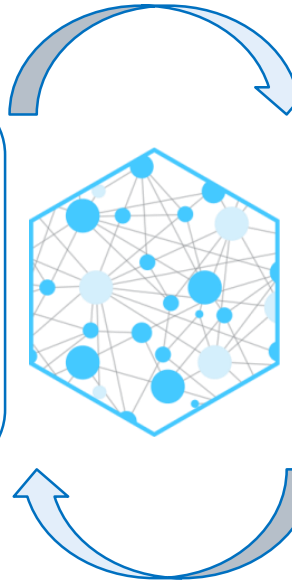
Conclusions

- Next generation designs
  - Large and complex problem
  - Multi-scale (particle level to grid interactions)
  - Explore value addition for power plants (power +)

- Detailed steady-state models ✓
- Reasonable cost estimates ✓
- Not extensive, case by case analysis ×
- Difficult to realize synergistic advantages ×
- More a sensitivity study ×

Developing next-generation PSE tools



Applying the tools to solve challenging problems

- Extensive search space ✓
- Realize synergies between processes ✓
- Simple input/output models ×
- Performance prediction maybe erroneous ×
- No commercial tool; mostly academic ×

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Related Posters

Morning Session

- Optimizing Opportunities for Power Grid Participation (Xian Gao/Alex Dowling)
- Power Grid Participation and Planning Studies (Ben Knueven)
- State-of-the-Art Modeling and Optimization of Electrolyte Systems (Paul Akula/Debangsu Bhattacharya)
- Design and Optimization of Chemical Looping Combustion Processes (Chinedu Okoli/Anca Ostace)

Afternoon Session

- A Generalized Cutting-Set Approach for Robust Process Design (Natalie Isenberg)
- Advanced Tools for Conceptual Design (Qi Chen/Michael Bynum)
- Advanced Capabilities for Grid and Infrastructure Planning (John Siirola)
- Towards a Mathematical Optimization Toolkit for Nanoscale Materials Design (Chris Hanselman)
- Advanced Dynamic Modeling for Fluidized Beds (Rob Parker/David Thierry)

Acknowledgments

www.idaes.org

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- LBL: Deb Agarwal, Dan Gunter, Keith Beattie, John Shinn, Hamdy Elgammal, Joshua Boverhof, Karen Whitenack
- CMU: Larry Biegler, Nick Sahinidis, Chrysanthos Gounaris, Ignacio Grossmann, Owais Sarwar, Natalie Isenberg, Chris Hanselman, Marissa Engle, Qi Chen, Cristiana Lara, Robert Parker, Ben Sauk, Vibhav Dabadghao, Can Li, David Molina Thierry
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- ND: Alexander Dowling, Xian Gao

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