Generation Plant Cost of Operations and Cycling Optimization (Coco)

Team Members

NETL Spring Meeting
05/13/2021

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Outline

- Overview
- Timeline and Progress
- Accomplishments
- Plans for Phase 2
- Benefits, Challenges, and Future Directions
- Education, Training, and Publications
- Summary

Overview

Motivation

Flexible, reliable, and cost competitive power generation at both new and existing plants, allowing **safe cycling** to address **increased penetration of renewables.**

Objective

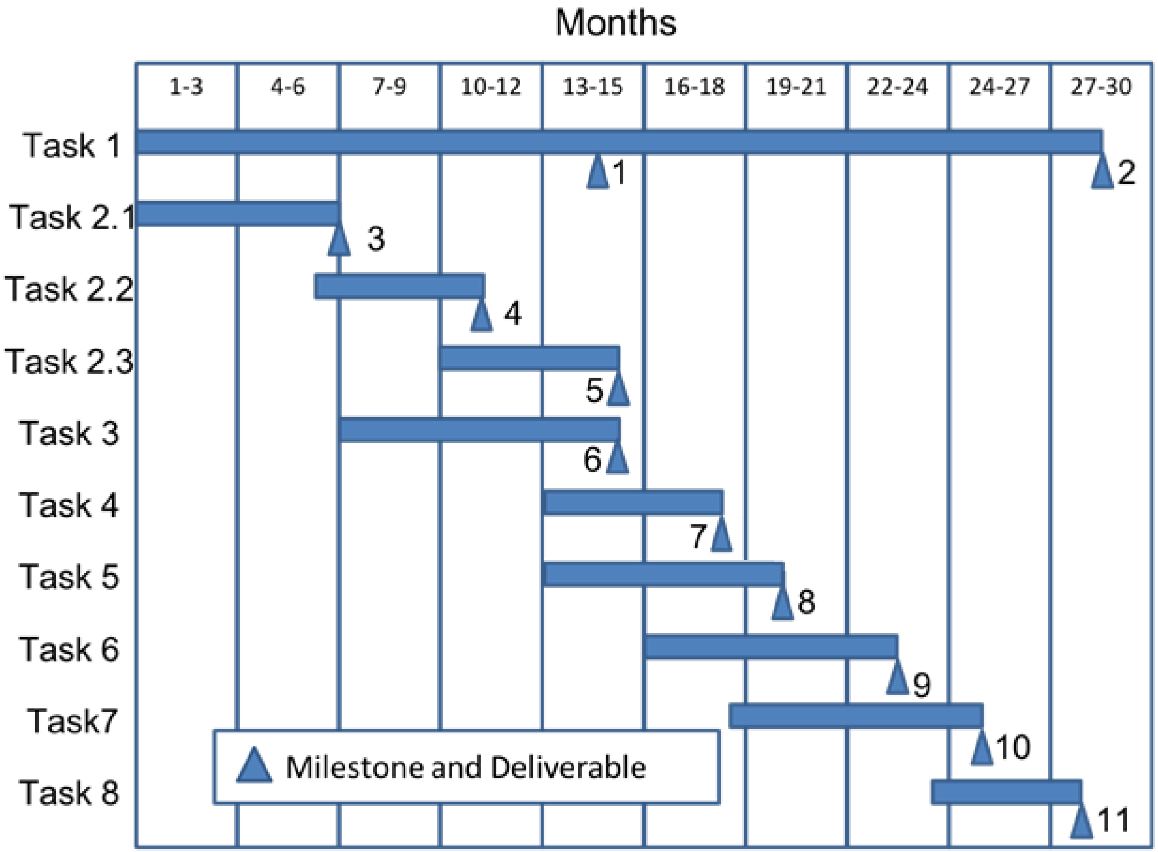
Develop a physics + data-driven model to estimate the **costs of cycling boilers to efficiently generate and dispatch.**

Approach

Physics + Data-Driven Models → Calibration / Training / Validation → Deploy and Refine

Project Status

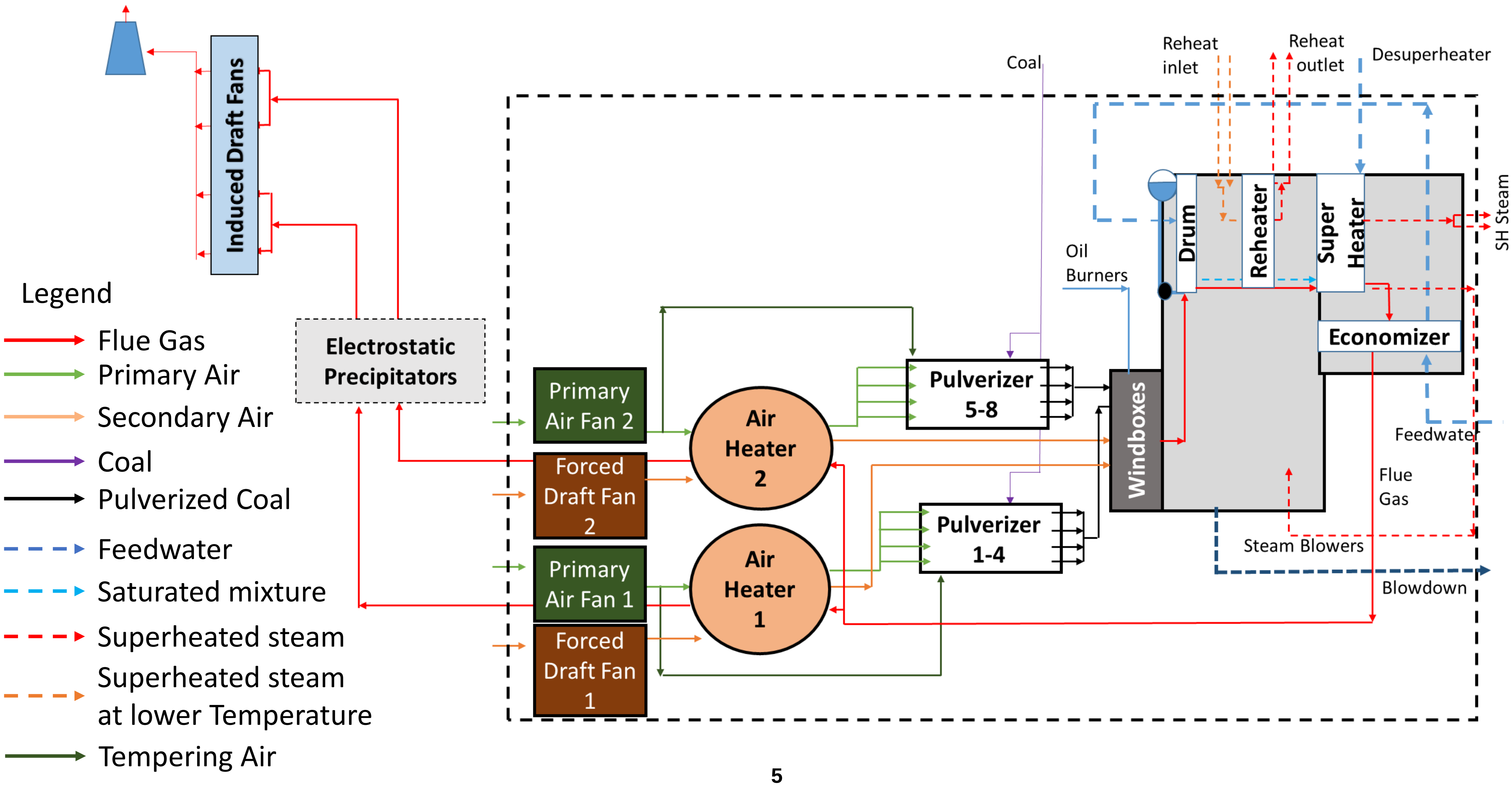
Milestone	Task	Event	Schedule	Verification	Status
1	1	End of Phase 1	Month 14	Status report	Completed
2	1	End of Project	Month 28	Final report	In Progress
Phase 1					
3	2.1	Boiler performance model	Month 6	Model running at Purdue	Completed
4	2.2	Exergy cost analysis	Month 10	Model running at Purdue	Completed
5	2.3	Reliability analysis complete	Month 14	Model running at Purdue	Completed
6	3	Artificial Neural Net	Month 14	Model running at Purdue	Completed
Phase 2					
7	4	Model components integrated	Month 17	Model running at all partners	Completed
8	5	Coco operational for Coal Creek Station	Month 19	Model accurately represents Coal Creek Station and successfully runs at Coal Creek	Completed
9	6	Model refinements complete*	Month 22	Running at all partners	In Progress
10	7	Coco integrated into utility applications	Month 24	Utility application pulling data from the API	
11	8	Model released and publicized	Month 28	Demonstration and presentation at event(s)	



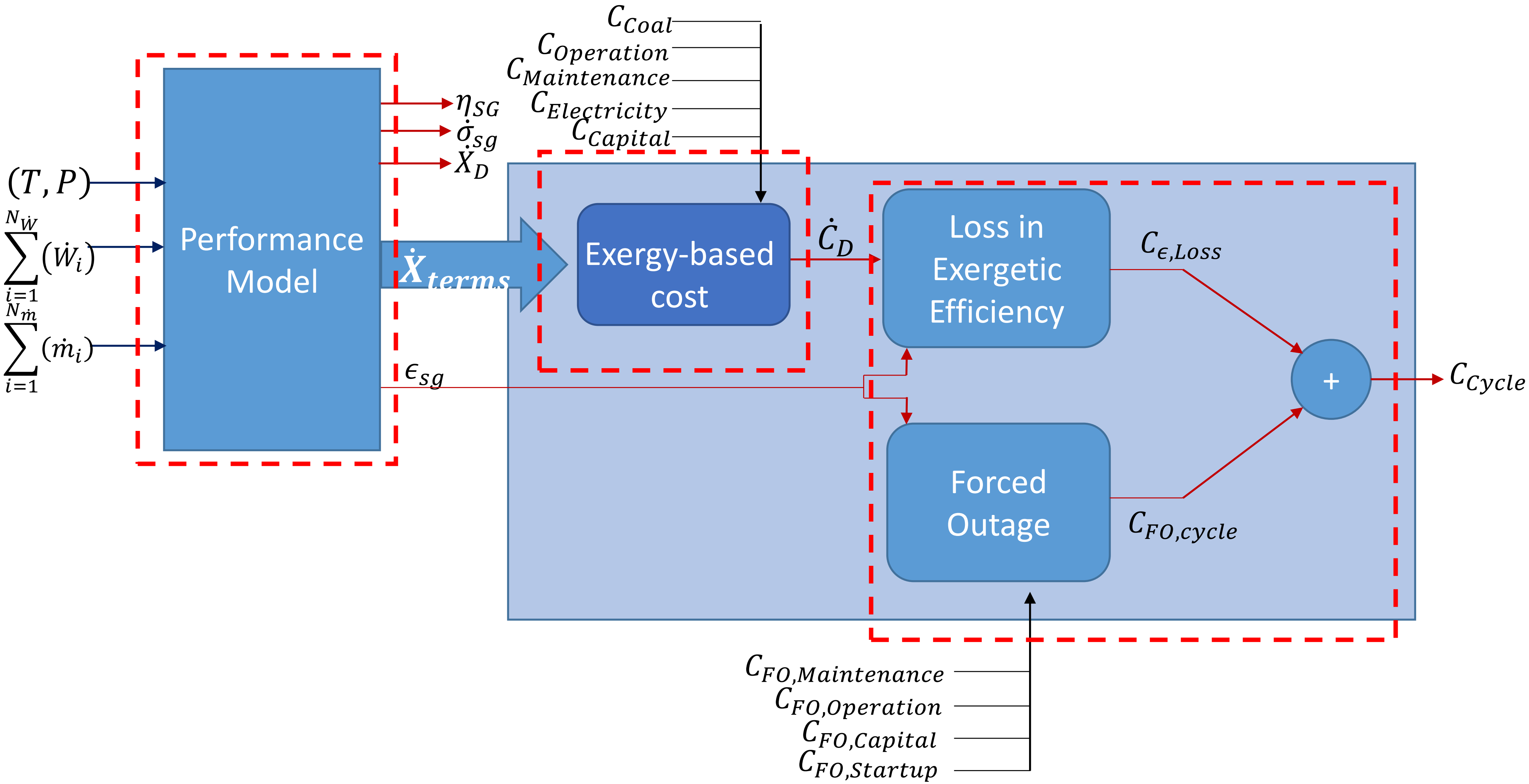
* Testing and improvements are in progress based on user feedback

Project is on track with good progress…

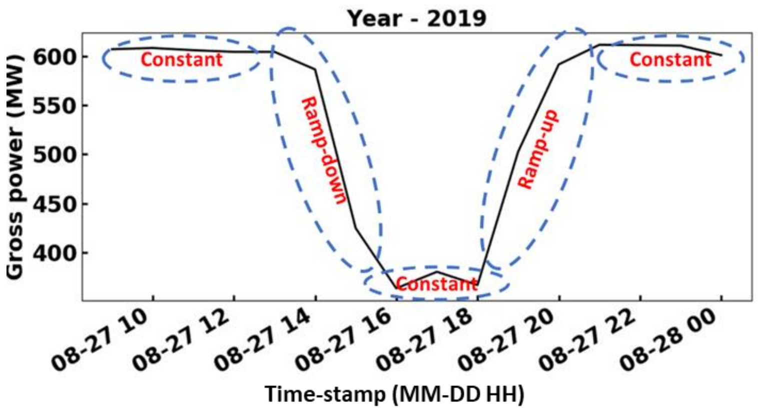
Steam Generator System



Physics + Data-Driven Model



Break Down of Cycling Cost

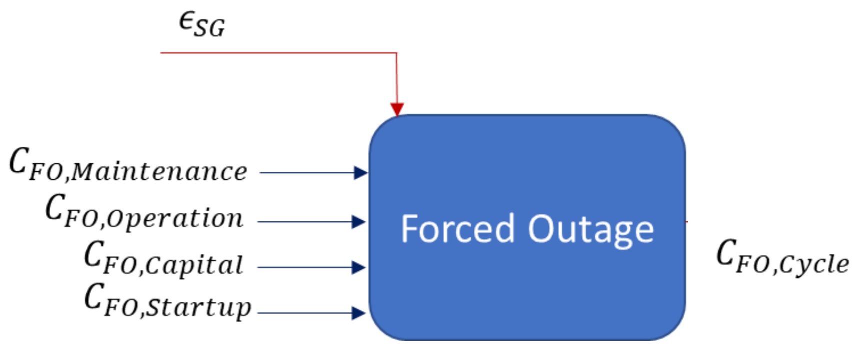


Load cycling (Generator output) → Operating off-peak Exergetic Efficiency → Increases Exergy Destruction → Forced Outages Costs; Increased Resources Costs due to Losses

$$C_{cycle} = C_{\epsilon,Loss} + C_{FO,Cycle}$$

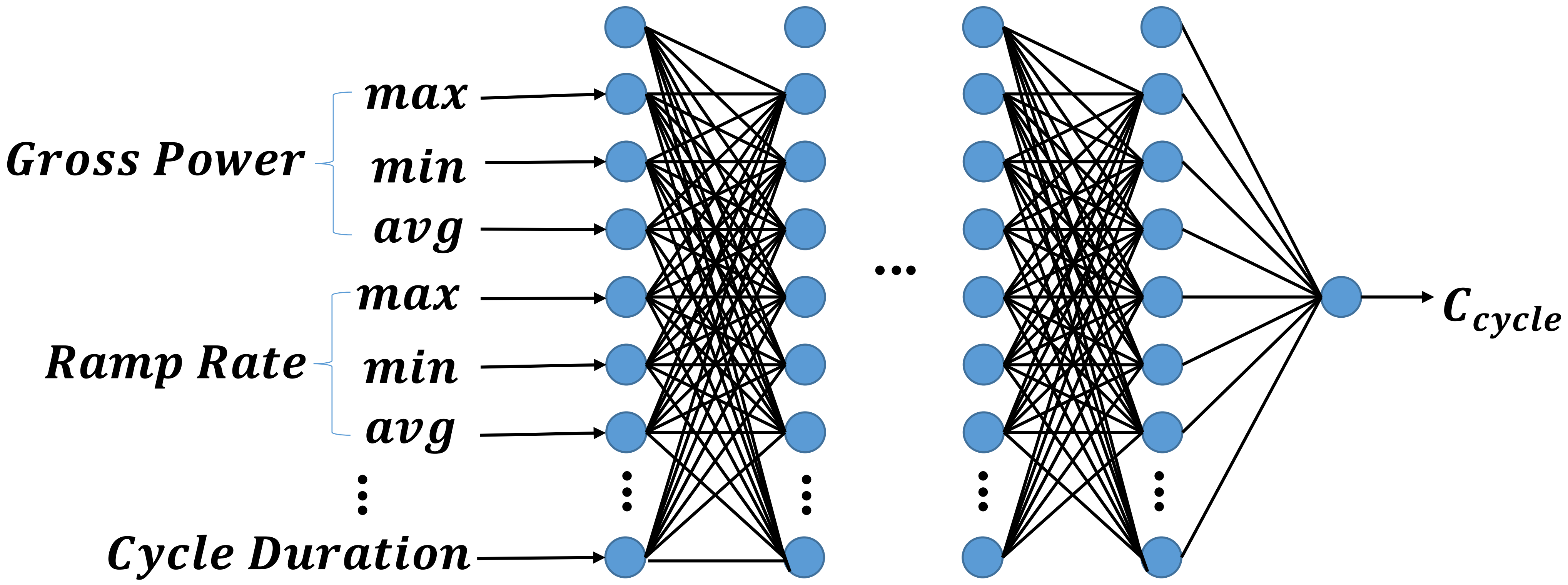
$$C_{FO} = C_{FO,Maintenace} + C_{FO,Operations} + C_{FO,Capital} + C_{FO,startup}$$

(Labor Costs) (Replacement Power) (Assets, Machinery, Parts) (Auxiliary power, startup fuel, chemicals etc.,)

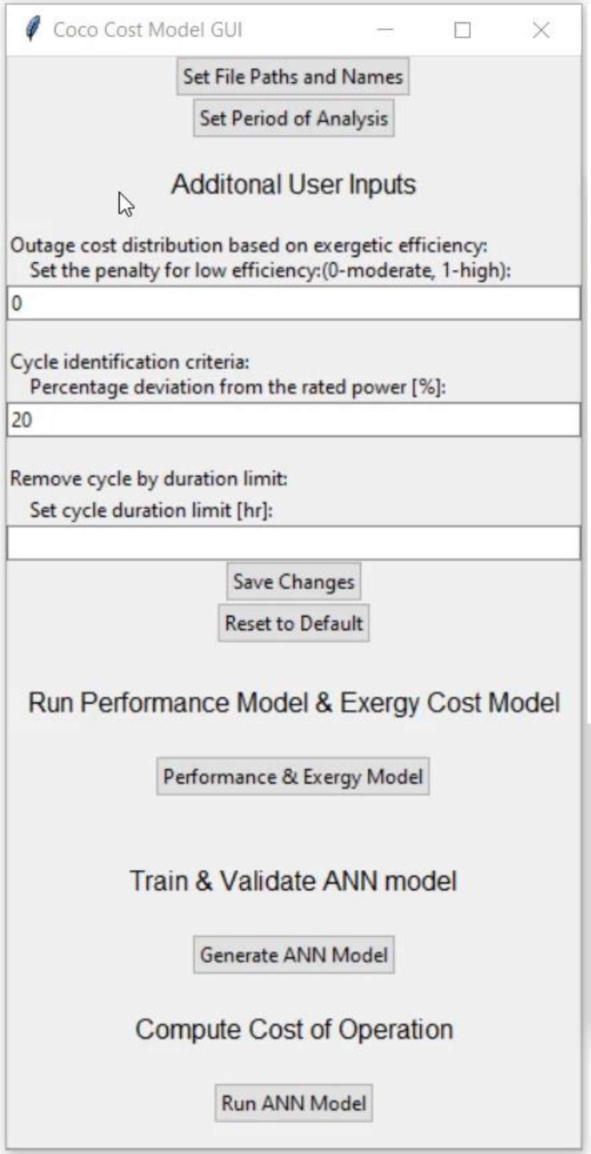


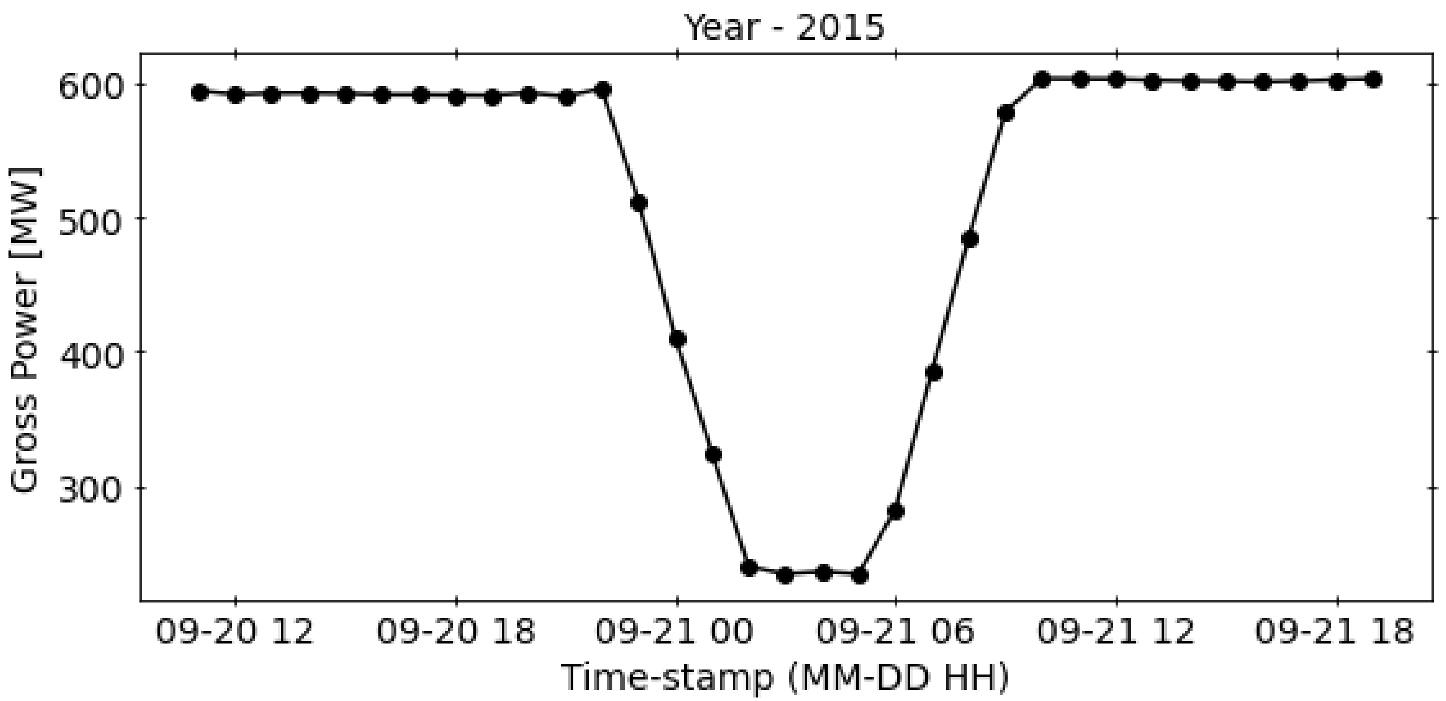
Artificial Neural Networks (ANN) Cost Model

Input Data: Cycle Statistical Characterization					
Ramp Rate: Max, Min, Avg	Gross Power: Max, Min, Avg, Range	Cycle Duration	Month	Day	Time



Coco Software





Start Time	Stop Time	Cycle Cost [$]
9/20/2015 22:00	9/21/2015 10:00	121003.31

Plans for Phase 2

- Integration and implementation
- Testing and refinements
- Application Programming Interface (API)
- Integration into utility applications
- Release and promotion

Model integration

Data plane

User analysis configuration
- EES-model-run-config-csv.json
- EES-model-run-config-xlsx.json

- relational DB
- flat file
- tabular
- web API
- graph DB

Data source

extra parameters (coal, operation, maintenance, electricity costs)

data

Functional plane

Model integration and running tool for:
- Boiler performance model
- Exergy cost analysis

Physics-based model
- executable (sg_PM_python.EXE)
- EES macro
- USERLIB (Windows libraries)

- Data-driven reliability model

- Physics-based reliability model
- Hybrid (Physics-based and Data-driven)

ANN cost model

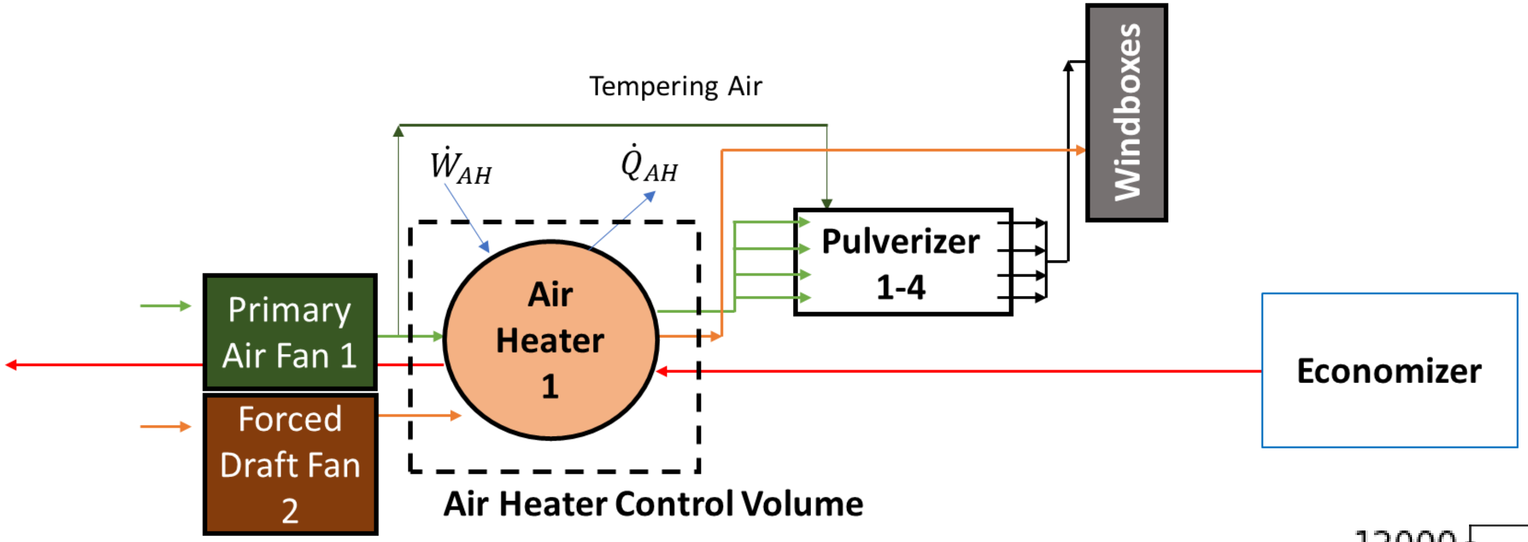
data

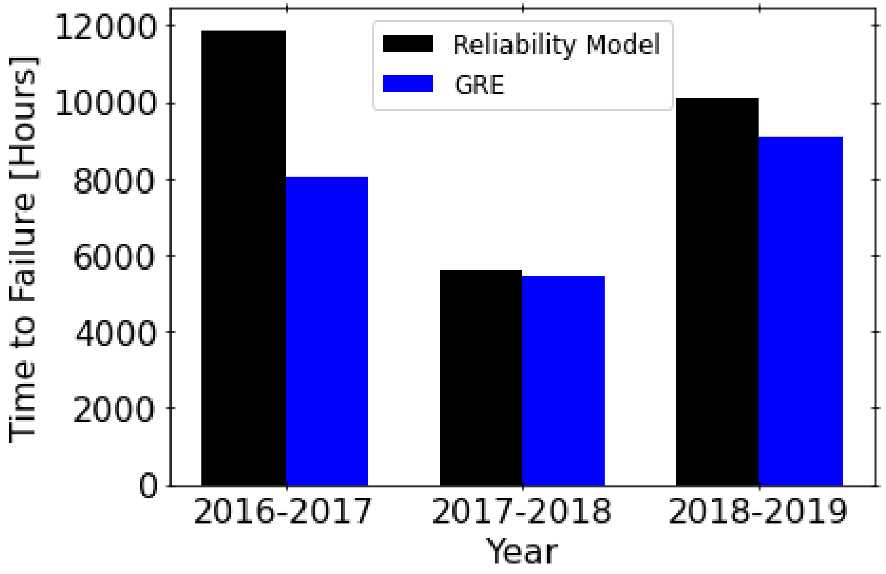
Presentation plane

- flat file
- visualization

Reliability Analysis

- **Thermodynamic Degradation & Data Driven Approach**





Benefits, Challenges and Extensions

Benefits:
- Predicts cycling damage and costs for maintenance and operations
- Correlation between plant cycling data and damage can predict and reduce cost
- Help shape ramping rates and ramping limits.

Challenges:
- Plant-plant variations in design, operations and maintenance philosophies make the accuracy of the cost prediction difficult
- Difficulty in distinguishing cycling damage from regular operating damages
- Differences in cycling patterns based on market-driven energy demand
- Methods for efficient inputs of plants specific information are necessary.

Extensions:
- Boiler based Coco methods for turbine and high-pressure steam and water systems
- Optimizing ramping cost V.S. ramping benefits.

Education, Training and Publications

Students' education and training activities:

Abhishek Navarkar, Elihu Deneke, Radhika Bhopatkar, Siddhant Joshi, Kshitija Kulkarni

Publications:

Navarkar A., Hasti V.R., Deneke E., Gore J.P., A data-driven model for thermodynamic properties of a steam generator under cycling operation. Energy. 2020 Nov 15;211:118973.

Himanshu S., Veronica A., Laurentiu M., Herbert T. S., Data driven approach to analyzing the impact of power plant cycling on air preheater degradation and remaining useful life. ASME 2021 Turbomachinery Technical Conference & Exposition Conference

Deneke E., Hasti V.R., Gore J.P., Cyclic loading condition analysis of a steam generator in a coal-burning power plant. Applied Energy (Under Review)

Summary

- **Goal:** Develop a user-friendly app that is easy to deploy and use to estimate cost of cycling large coal boilers
- **Breakthrough:** Exergy efficiency based improved operations
- **Progress:** Completed Phase1 of the project with successful development of a hybrid ANN cost model
- **Challenges:** COVID-19 related
- **Future Work:** Implement → / Extend → → Refine → Release