DNV KEMA KERMIT Overview

CEC CSP Project Workshop
Sacramento, CA
August 23, 2012

Agenda

- General Project Overview and Timeline
- List of Parameters and Rationale used for Technology Selection
- Detailed Technical Description of Work Done under Task 3
- Proposed Technical Path Forward

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Project Objectives

- Determine the most operationally effective CSP-TES configurations with the performance characteristics of conventional generation and/or pumped hydro;
- Define the reduction of area control error that results from adding optimal storage configurations;
- Determine the market benefits of adding substantial coupled CSP-TES capacity to the California Grid; and
- Broadcast the methods and outcomes of our dynamic modeling to the market through dedicated technology transfer activities.

CSP-TES Components

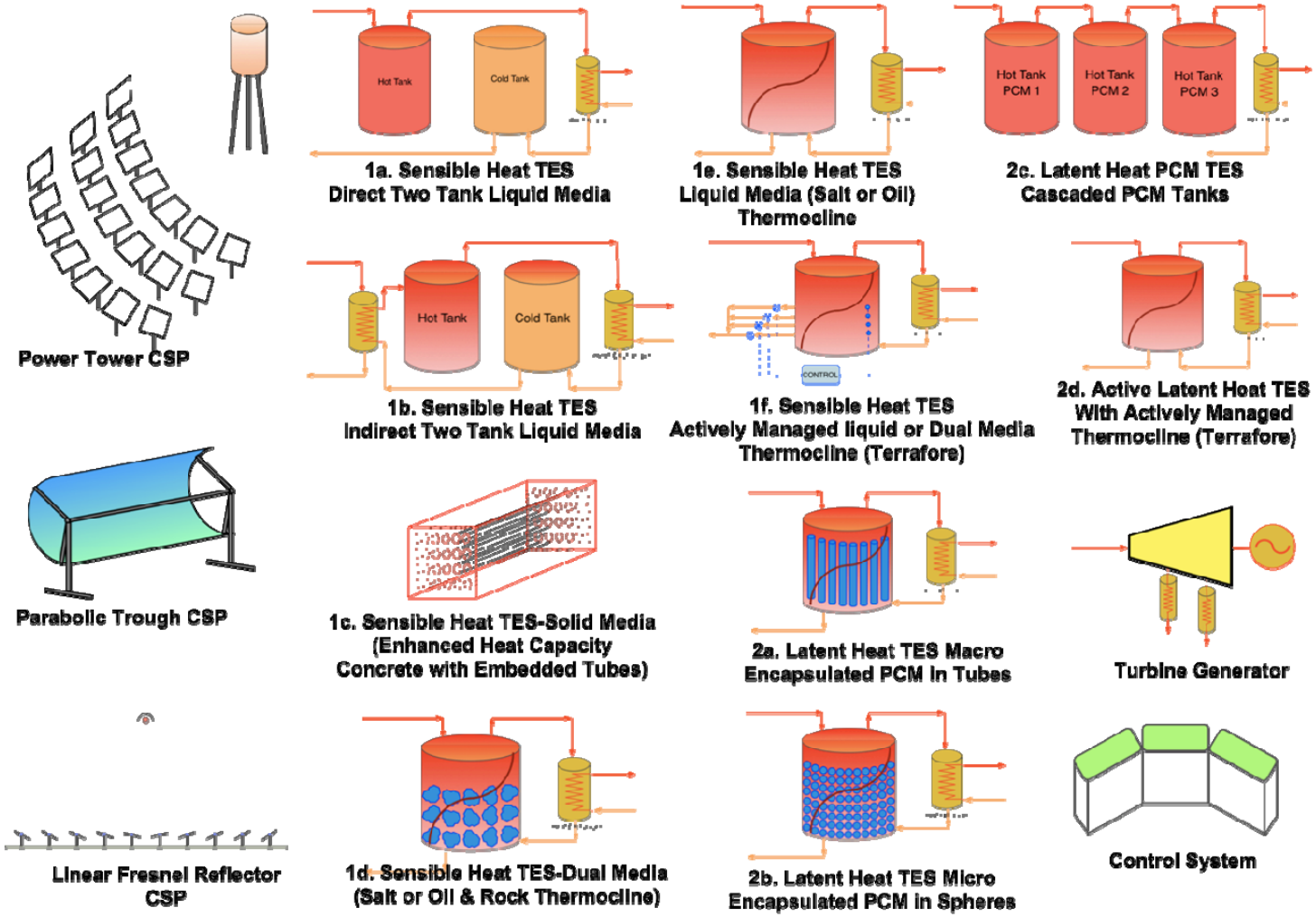


Figure 1. Components of Solar Power Generation & Thermal Energy Storage System

Technical Task Flow and Timeline

Task 2: Grid Economics (2011)

- Analyze potential for CSP-TES revenues in CA
- Include system model scenarios for revenue analysis
- Define impact CSP-TES will have on market economics
- Describe forecasted tech and economic potential

Task 3: Plant-Level Thermodynamic Modeling (2012)

- Define baseline components and system configurations
- Develop mathematical models and equations
- Develop Matlab & Simulink code for the TES systems
- Integrate the models with KEMA code

Task 4: Parameter Based Optimization (2012)

- ID CSP-storage configurations best suited to controllable grid integration
- Perform sensitivity tests to establish a performance "envelope" for each selected CSP-TES configuration

Task 5: Grid Linkage Modeling (2012)

- Integrate CSP-TES Models into KERMIT
- Demonstrate CSP dynamic performance

Task 6: Develop Simulation Models (2013)

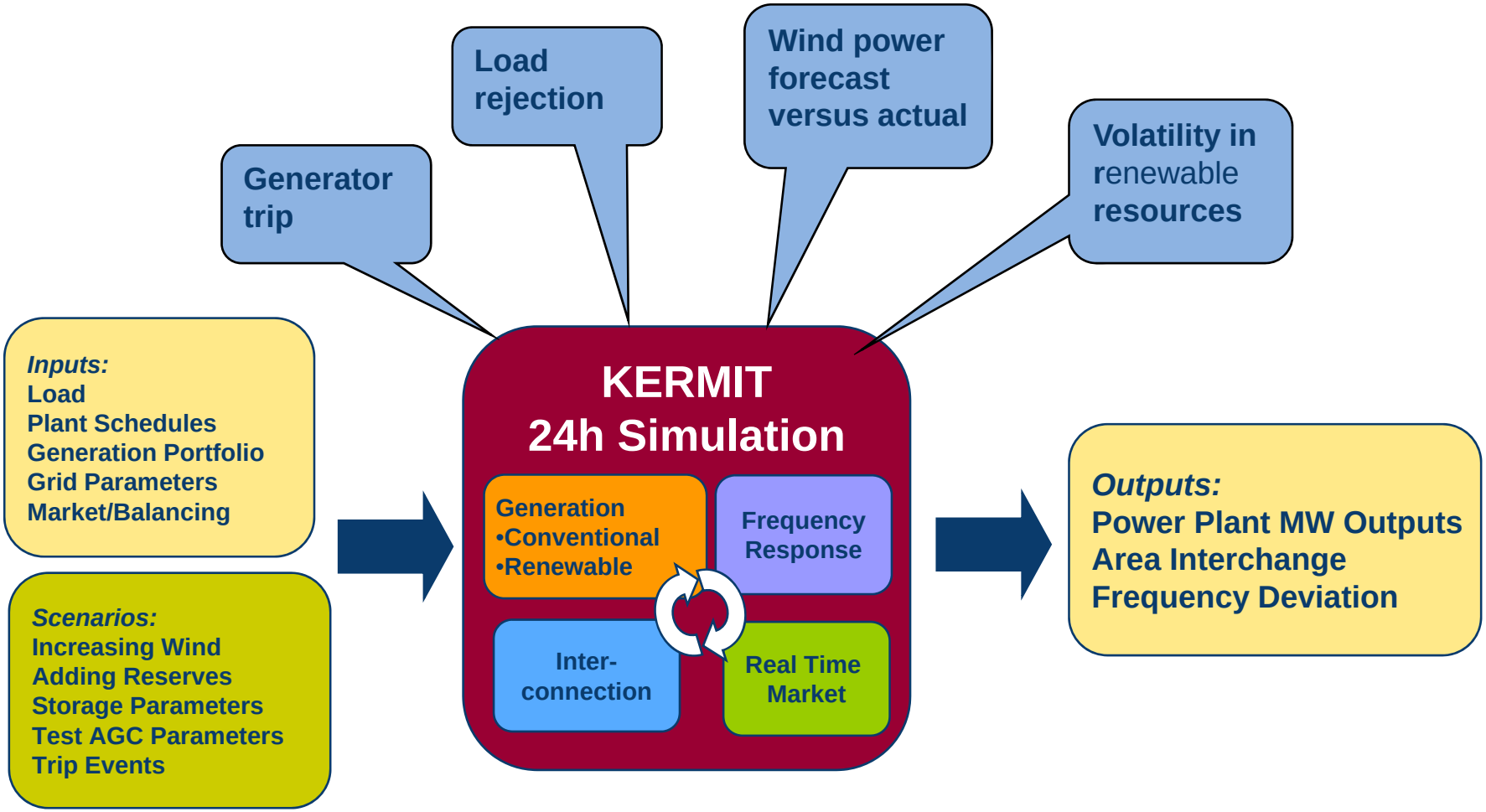
- Develop Unit Commitment models
- Develop shadow price model for TES dispatch

Task 7: Simulate Market Outcomes (2013)

- Perform market simulations
- Analyze impact of CSP-TES on market economics

Task 8: Technology Transfer

Grid Modeling - Overview of KERMIT Architecture



Summary

APPROACH:

- Economic analyses
- Dynamic models for CSP-TES system
- Parameter optimization
- KERMIT model for grid effects
- Outreach and distribution of results

Results…

Identify the most likely CSP-TES combinations

Model effects of CSP-TES penetration on grid reliability

Develop realistic predictions of costs and effects of CSP-TES penetration on California grid

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CSP TES Selection Criteria

Screening Parameters for economic viability:

- State of Development
- Capital Cost
- Size (area)
- O&M costs
- Water Use
- Flexibility
- Time to Commercial Deployment

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CSP-TES Components Selected

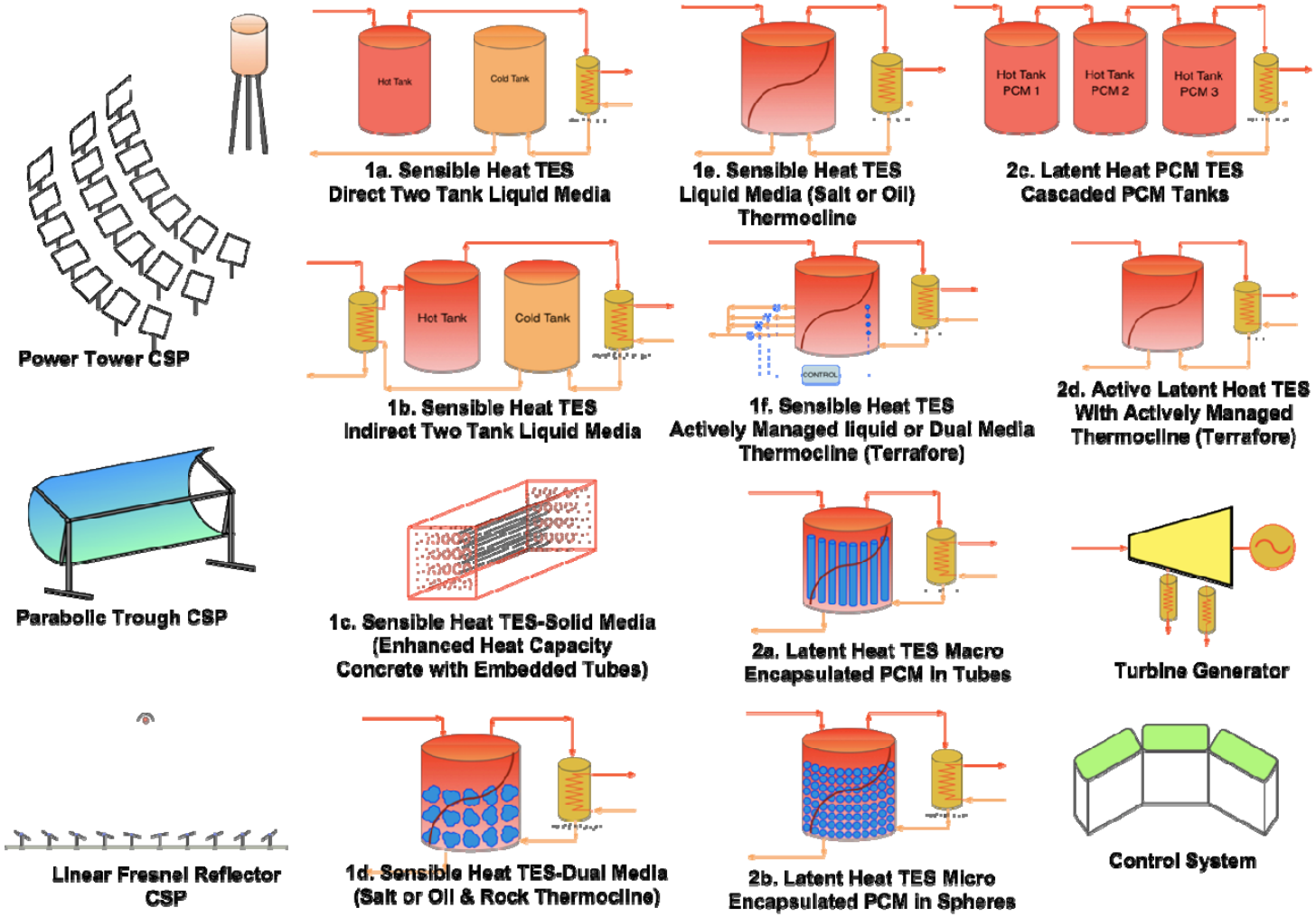


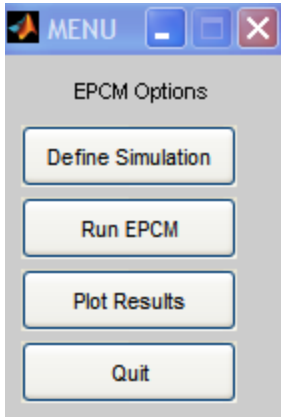
Figure 1. Components of Solar Power Generation & Thermal Energy Storage System

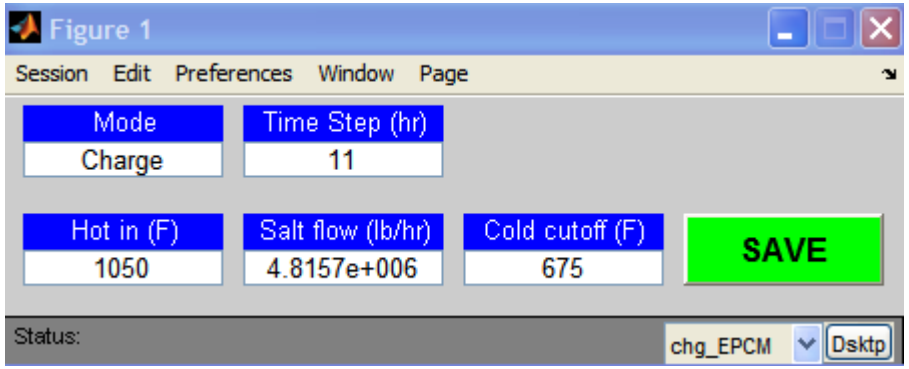
CSP Modeling

- Want to develop detailed thermodynamic model of CSP with TES
- Need to develop detailed thermodynamic models of the components of CSP and TES systems
- Terrafore developed the detailed thermodynamic models for the following CSP solar collectors
  - Power tower
  - Trough
- In addition, Terrafore developed detailed thermodynamic models for the following TES systems
  - Two tank salt storage
  - One tank thermocline storage
- KERMIT already has detailed models for steam turbines and heat exchangers

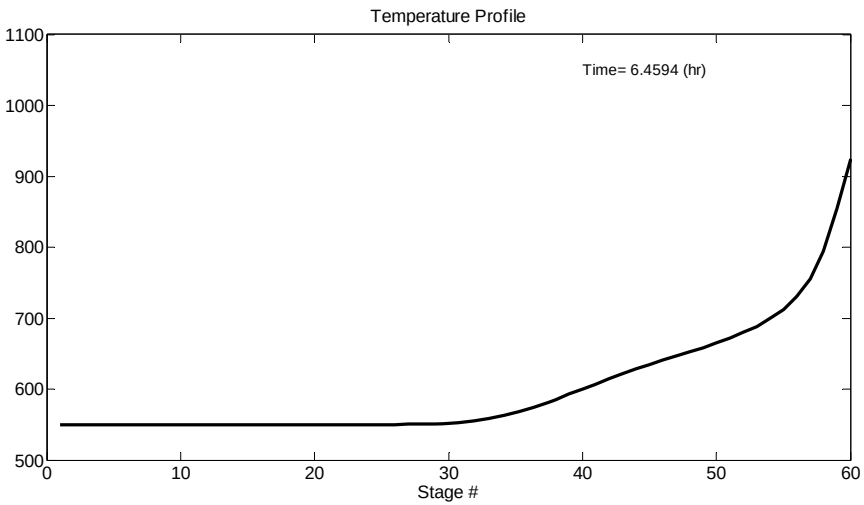
Matlab Modeling

- Terrafore implemented the thermodynamic models in m-files in Matlab
- Enables transient analysis of CSP and TES systems
- Example screenshots of thermocline charge and discharge code



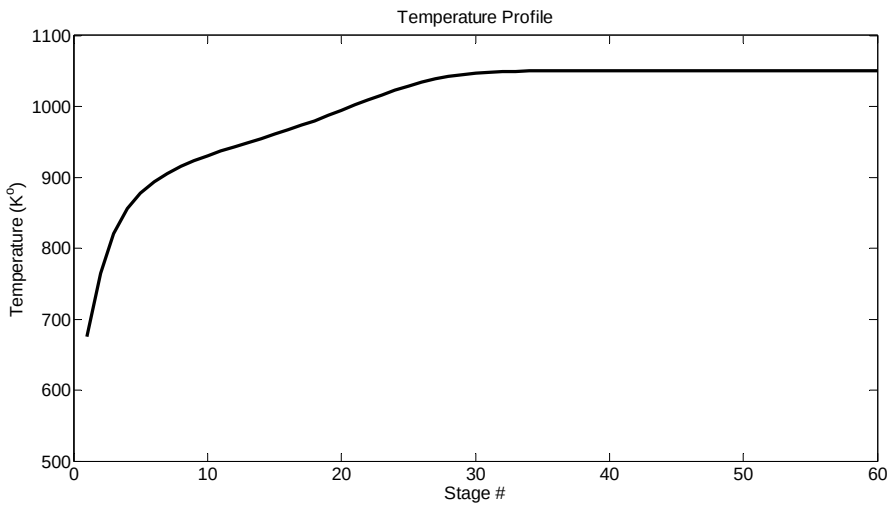


Thermocline Model Results

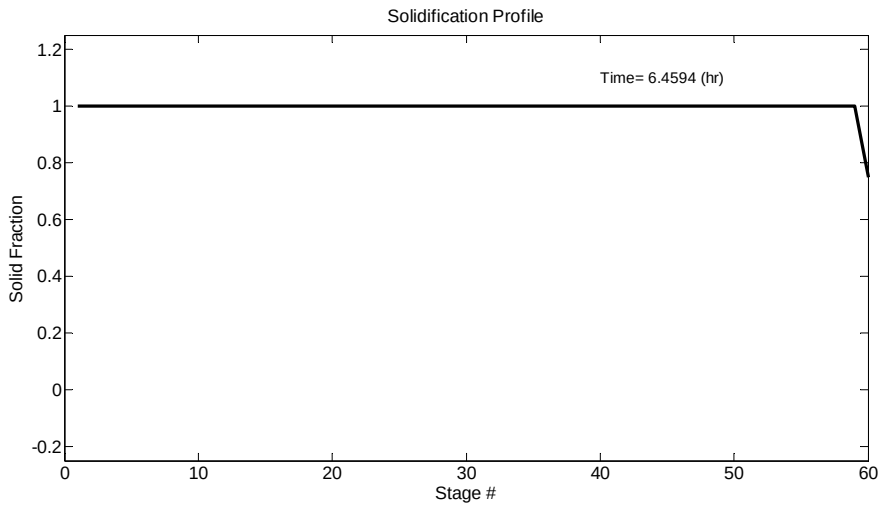


Discharged storage temperature profile

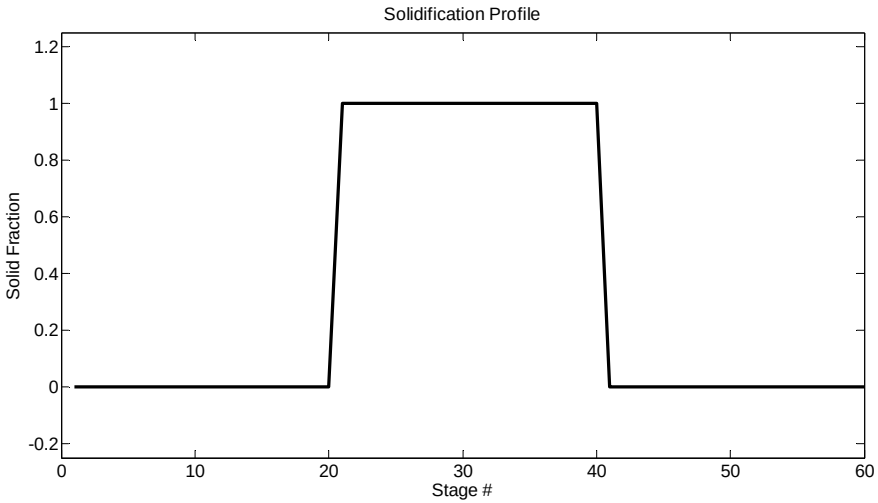
Charged storage temperature profile



Thermocline Model Results (2)



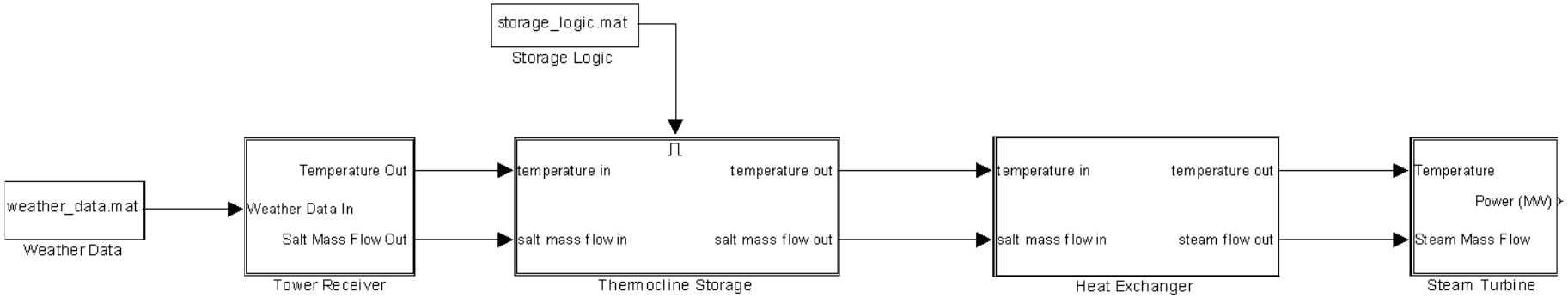
Discharged storage solidification profile



Charged storage solidification profile

Simulink Models

- DNV KEMA translated Terrafore's Matlab m-code into simplified Simulink models
- Next steps of project are to add constraints and control logic to produce a more realistic CSP with TES plant



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Proposed Technical Path Forward

- Finish modeling TES technologies and the fresnel collector
- Develop the control algorithms capable of deciding when to charge or discharge TES based on insolation forecasts, regulation, and load following requests
- Develop and apply primary constraints for each subsystem and for the larger CSP plant
- With complete CSP with TES Matlab and Simulink models, optimization stage begins
  - Develop optimization routine to vary CSP and TES parameters to determine optimal configurations of CSP plants
- Take results from optimization step and develop reduced list of parameters that can define a CSP with TES plant
  - Enables system operators, policy makers, and other stakeholders without detailed knowledge of CSP / TES systems to define a plant based on reduced list of parameters
  - For example, nameplate capacity, hours of storage, type of TES, ramp rates.