ASSESMENT OF SOLAR STEAM INJECTION IN GAS TURBINES

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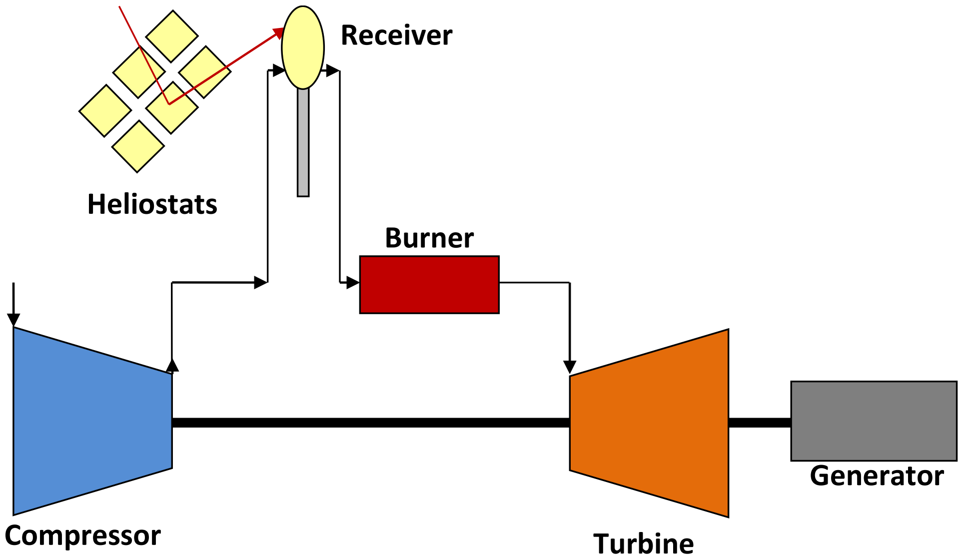
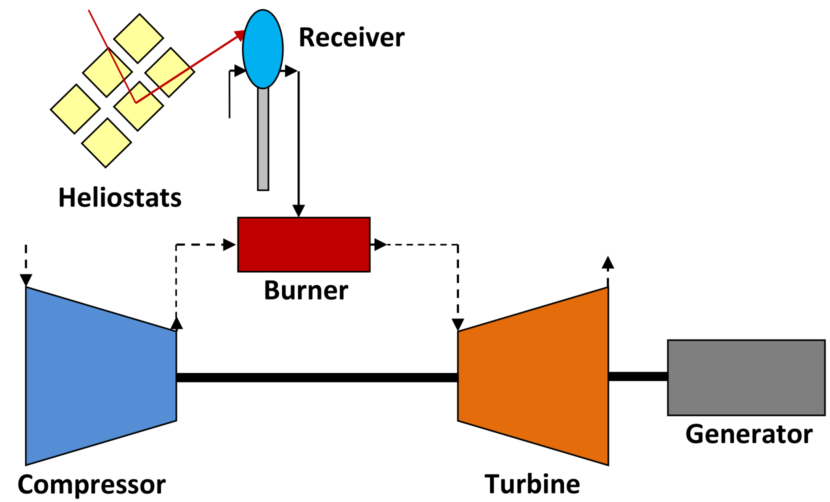
Motivation & Objectives





- **Conventional hybridization**
  - **Energy production penalty**
  - **Air extraction difficulties**
  - **Burner cooling difficulties**
- **Solar STIG**
  - **Increased produced energy**
  - **Fewer construction difficulties**
  - **STIG: Used technology**
  - **Solar steam: Used technology**

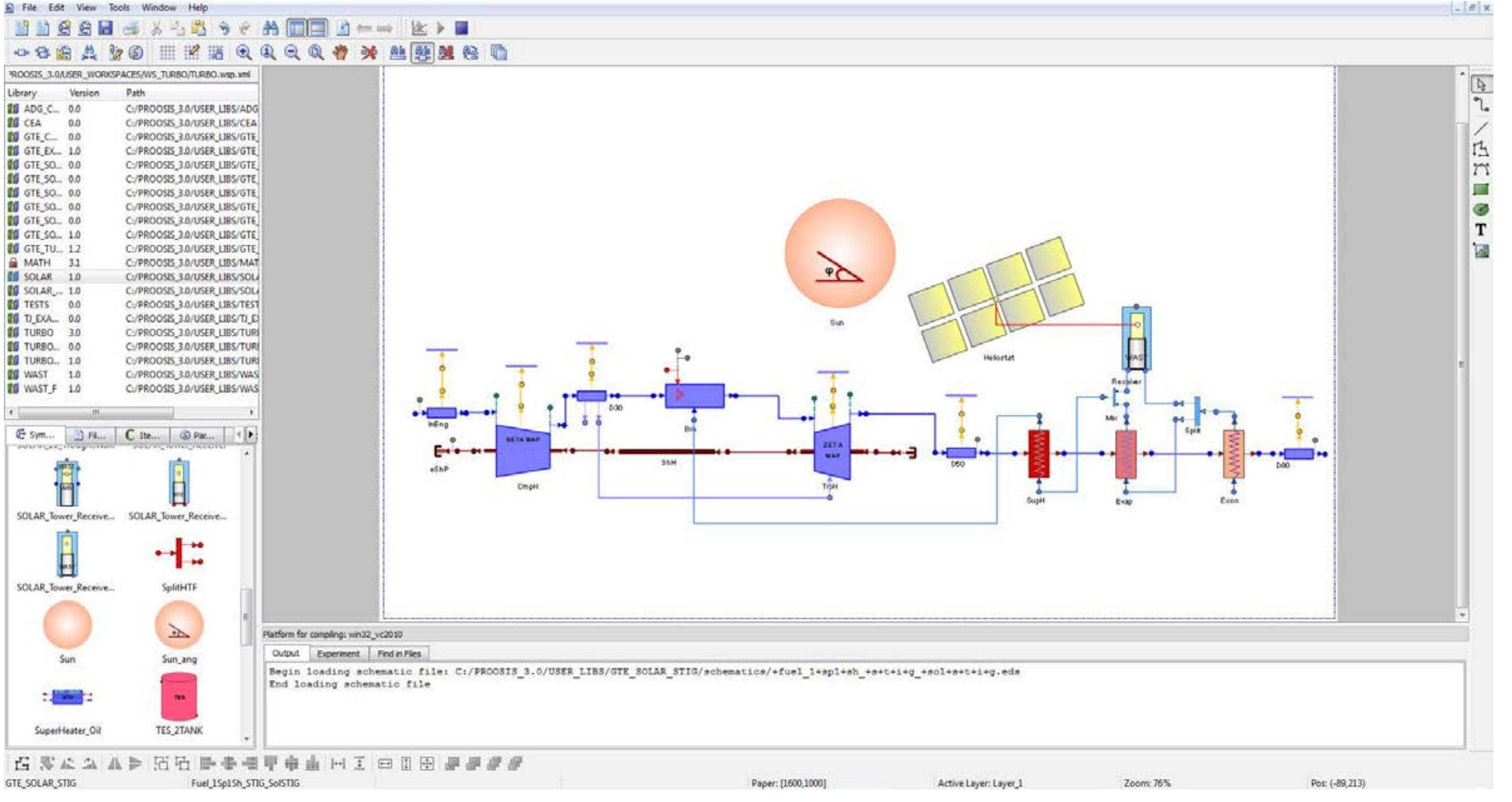
Contents

- MODELLING
- SOLAR STEAM PRODUCTION METHOD
  - Design Specifications & Operating Scenario
  - Performance Simulation
- SOLAR STEAM IN A STIG ENGINE
  - Design Specifications & Operating Scenario
  - Performance Simulation
  - Change Of Operating Point
- SUMMARY & CONCLUSIONS

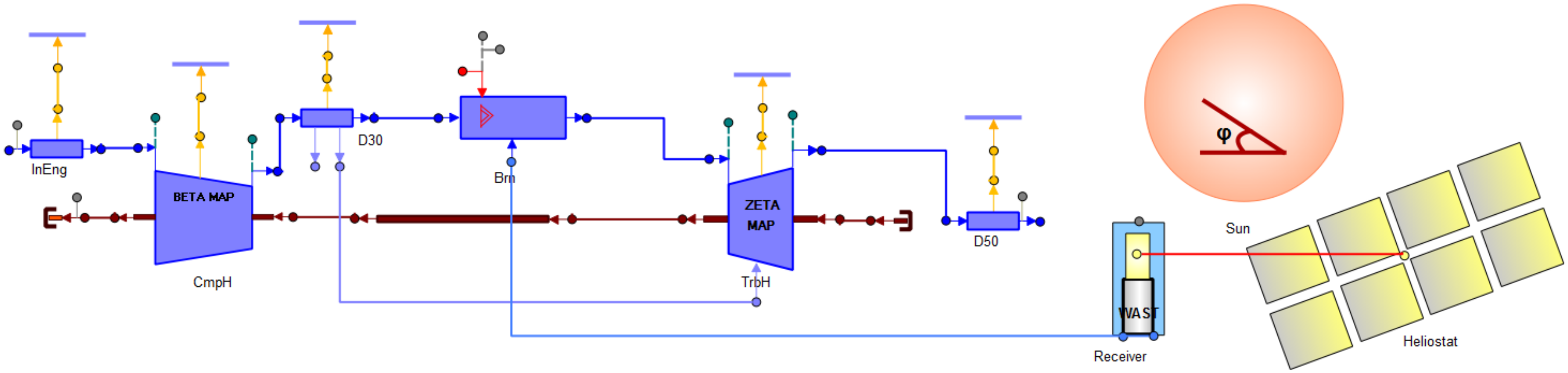
Contents

Modeling

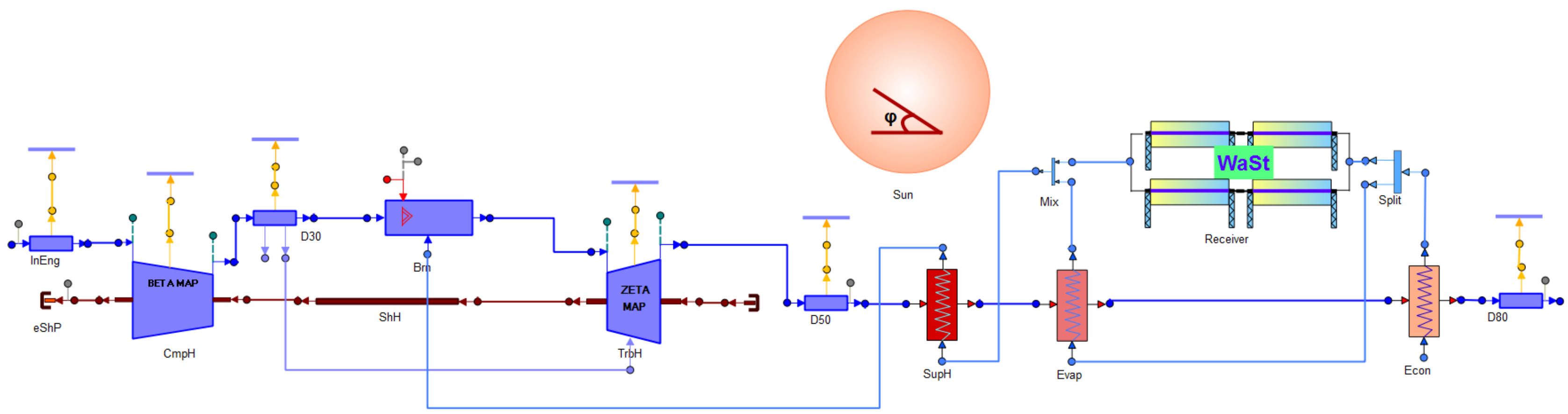
- Modeling with PROOSIS: an object oriented environment
- TURBO: Brayton cycle components
- WAST: Rankine cycle components
- SOLAR: Solar part components



Modeling



Solar-only STIG



Solar STIG with troughs

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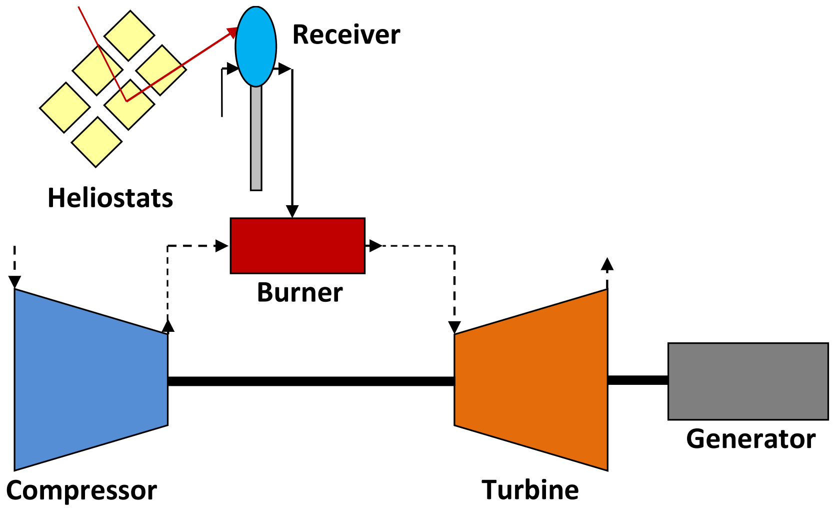
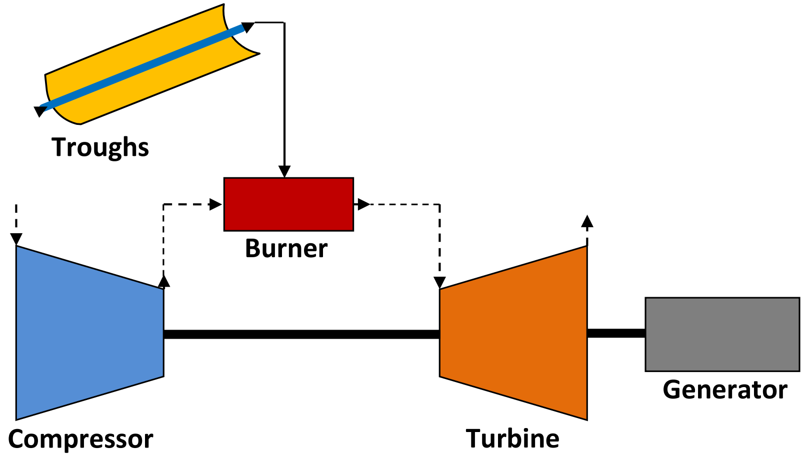
Solar Steam Production Method





- **Tower**
  - **Direct steam generation**
  - **Engine on tower**
  - **Used technology for Rankine cycles**
  - **Higher investment cost**

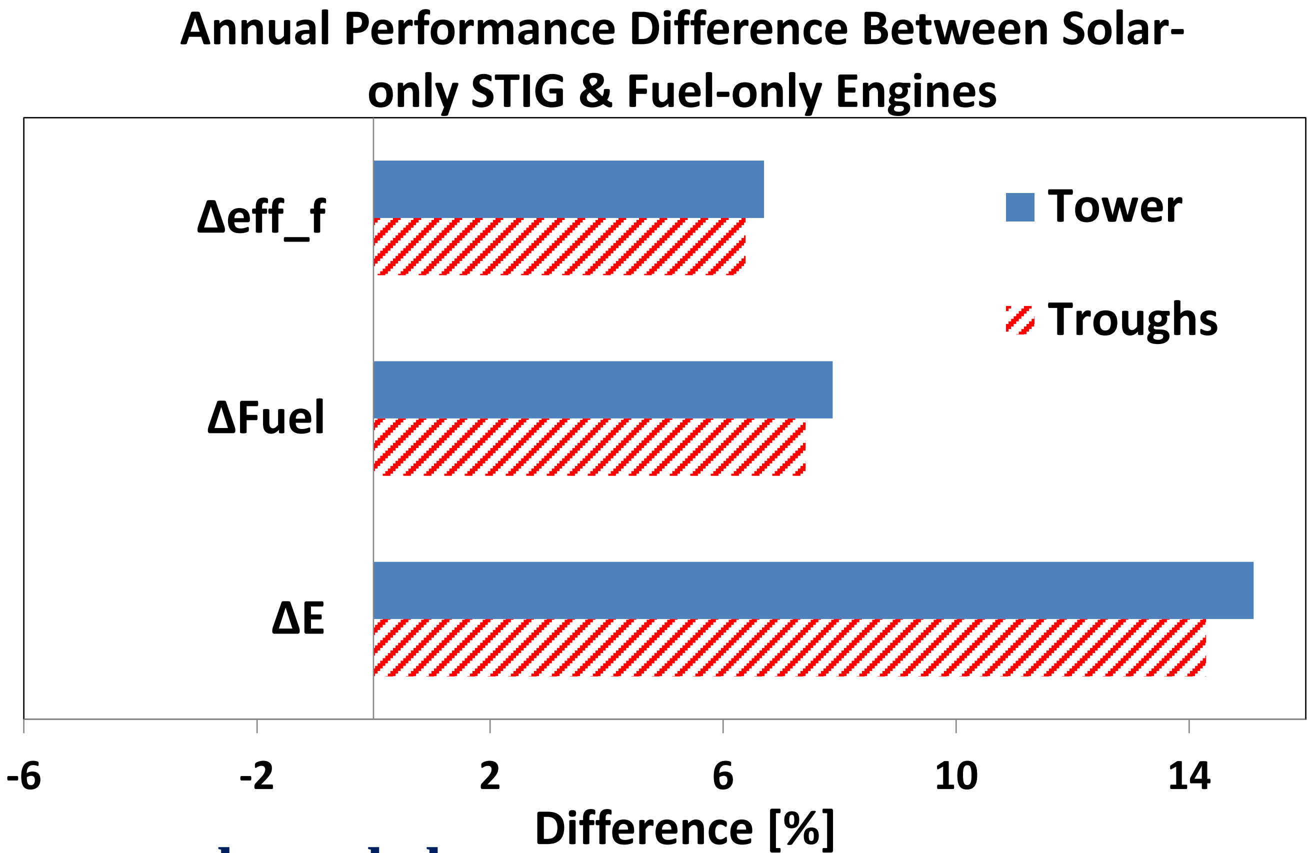
- **Troughs**
  - **Direct steam generation experimental stage**
  - **Engine on ground**
  - **Lower investment cost**

Design Specifications & Operating Scenario

- **Fuel-only engine: 5MW, TIT = 1000°C, PR = 10**
- **Solar field / Water-Steam**
  - **Steam pressure: 35 bar**
  - **Steam temperature: Saturated steam**
  - **Receiver/troughs outlet: SAR=12% @ 800W/m^2 Summer solstice**

- **Operating scenario**
  - **Maximum power → TIT constant**
  - **Yearly continuous baseload operation**
- **Performance simulation**
  - **Hourly simulation → Integration → Annual performance**

Performance Simulation



- **Tower less season-depended**
- **Solar STIG results to**
  - **Augmented produced energy (higher mass flow, composition change)**
  - **Augmented fuel consumption (added mass with higher Cp)**

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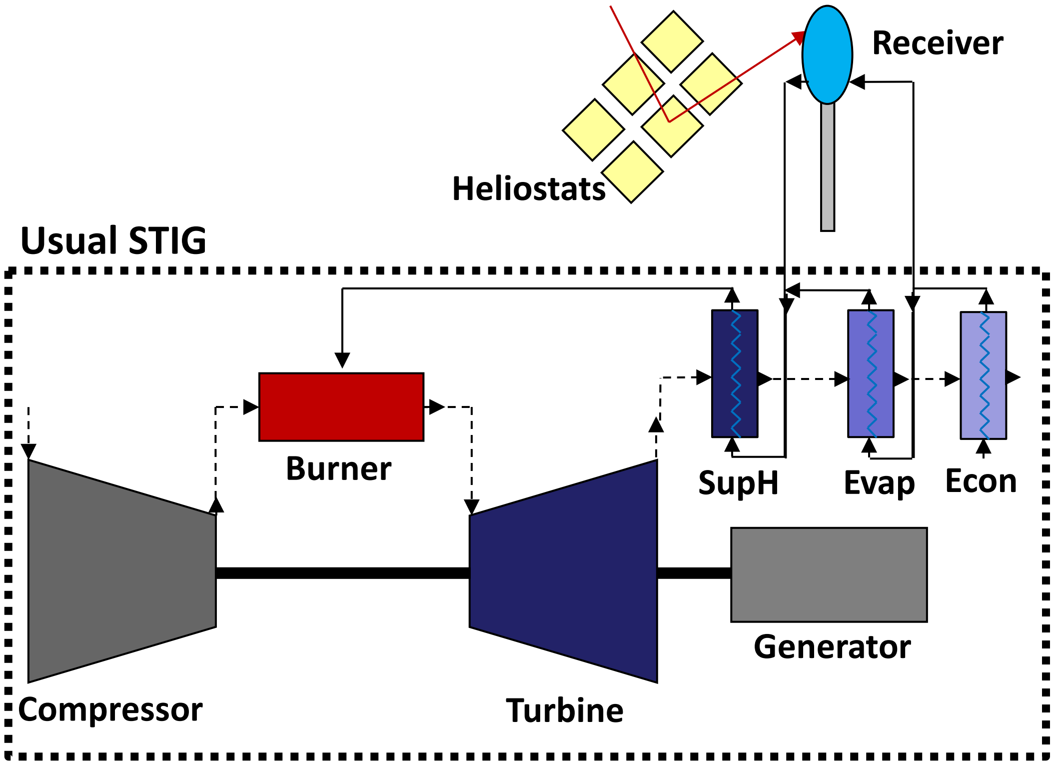
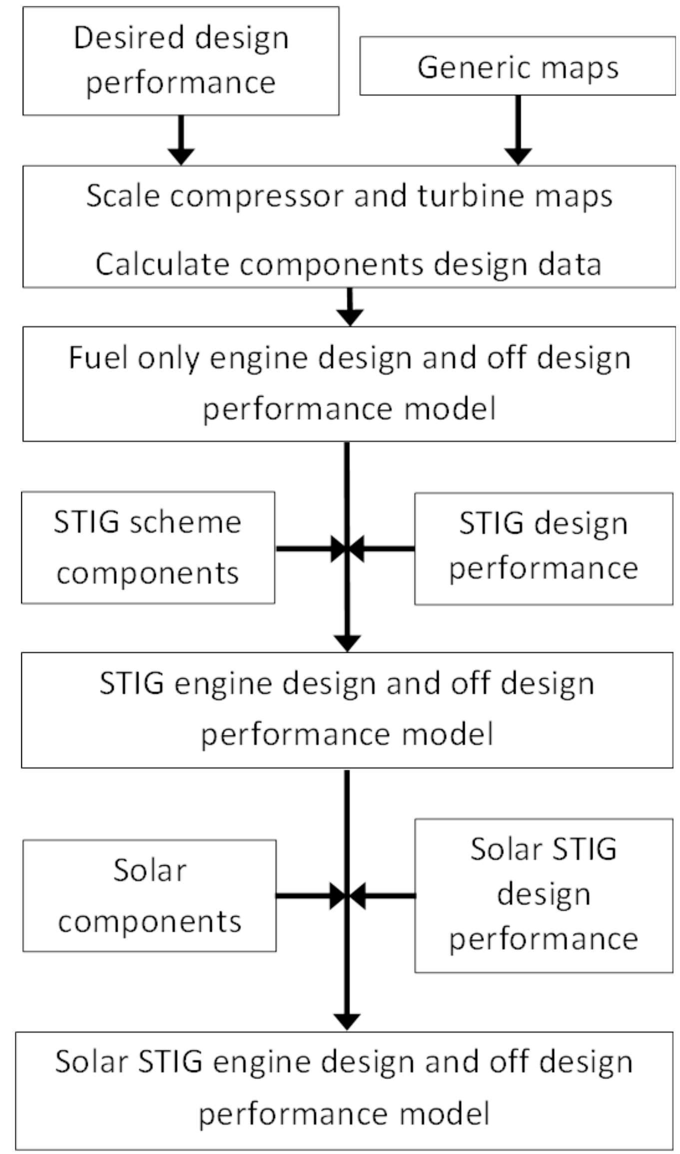
Addition Of Solar Steam





1. **Fuel-only engine**
2. **Conventional STIG (+HRSG)**
3. **Solar STIG (+Solar evaporator)**

Design Specifications & Operating Scenario

- **Fuel-only engine: 5MW, TIT = 1000^{o}C, PR = 10**
- **Heat Recovery Steam Generator**
  - **Inlet water: 35 bar, 15^{o}C, Outlet steam: 700K**
  - **Tpinch = 20^{o}C, Tapproach = 15^{o}C**
  - **Water mass flow → Saturated steam @ evaporator outlet & SAR=6%**
- **Heliostat field**
  - **SAR=12% @ 800W/m^2 Summer solstice**

- **Operating scenario**
  - **Maximum power → TIT constant**
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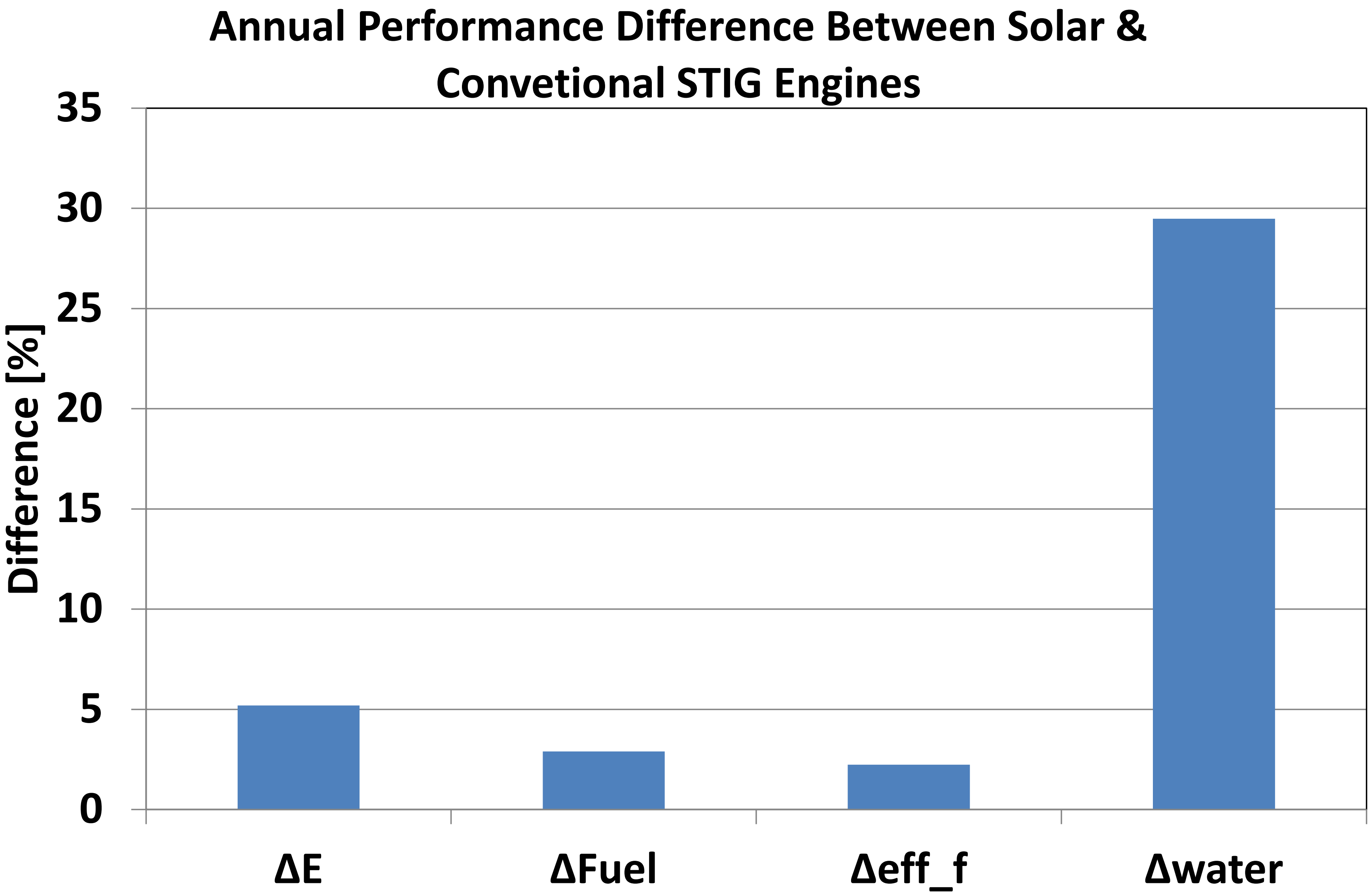
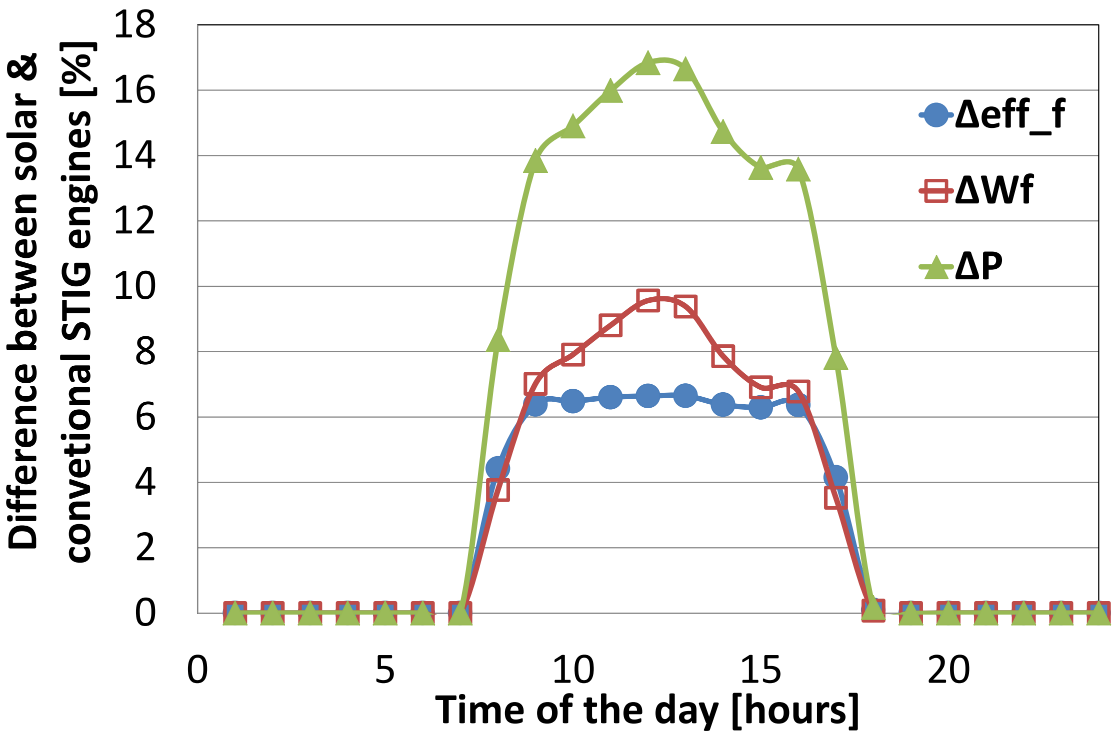
Performance Simulation



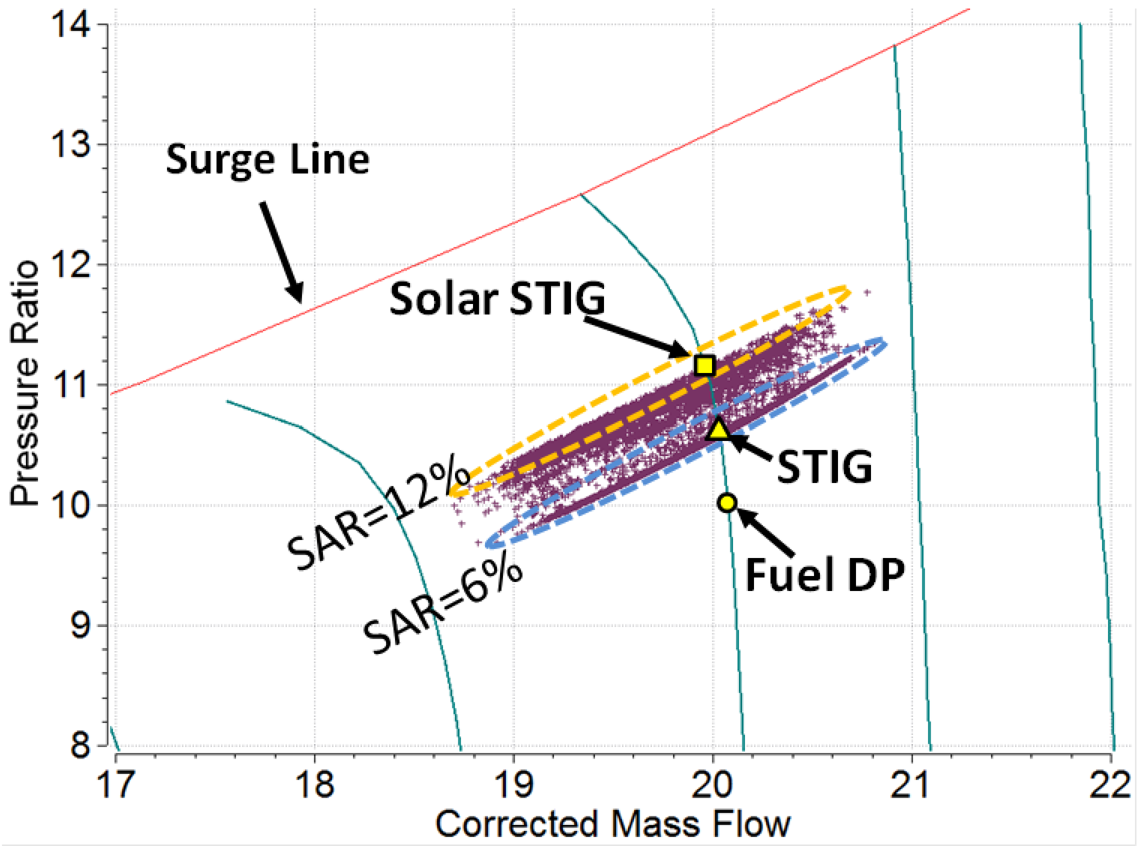
Performance Simulation



Performance difference between solar and conventional STIG engines for a winter day

- **Higher energy production, fuel and water consumption**
- **Similar results if troughs were used (Direct Steam Generation)**
- **Troughs with oil could be used:**
  - **Inferior performance (addition of oil-water heat exchanger)**
  - **Already used technology in commercial state**

Change Of Operating Point



Operating Points On Compressors Map

- Steam injection & chocked turbine with constant TIT
  → higher PR
- High SAR may result to surge
- In this study:
  - SAR=6%
    → SM ↓ ~25% from fuel-only operation
  - SAR=12%
    → SM ↓ ~50% from fuel-only operation

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Summary – Conclusions

- Solar STIG studied as an alternative to conventional solar hybridization
  - Based on proven technologies (STIG & solar steam)
  - Fewer GT modifications
  - Augmented energy production
- Steam generation method: Tower scheme performs better than troughs
- Assessment of performance and operability on addition of solar steam into an already STIG engine
  - Produced energy, fuel and water consumption increase
  - Surge margin decreases
  - Similar results if troughs were used

THANK YOU

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