

# Current and Future Development of **greenius**

Recent Updates and Outlook on Next Release

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**greenius** User Day 2015

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# Content

1. **Released Updates since October 2014**
2. Updates in the new release (October 2015)
3. Future Development



## Released Updates with Version 4.0.8.1

- Additional 21 new wind turbines are now shipped with **greenius**. Some old turbines were removed.
- Bug Fixing for all technologies for step lengths < 1h
- Degradation is included
- Release notes come now with **greenius**
- Manual now comes shipped with **greenius**
- Several minor bugs fixed



# Accounting for Degradation in greenius

**Test-DetailedSinglePhase**  
File Edit Costs Help

## Collector Field

Field Data | Field Operation

**Temperatures**  
 Nom. field outlet temp. 393 °C  
 Nom. mean field temp. 342.5 °C  
 Nom. field inlet temp. 292 °C

**Heat Transfer Fluid**  
 type: VP 1  Automatic calculation of fluidmass  
 Maximal fluid temp. 400 °C  
 Minimal fluid temp. 15 °C  
 Total mass 1098.87 t

density	heat cap.	temp.
kg/m <sup>3</sup>	Wh/(kgK)	°C
999	0.4928	100
866	0.6078	250
689	0.7189	400

**Parasitic Modifiers**  
 Constant need 1.000 W/m<sup>2</sup> SF  
 Power of field Pump 8.300 W/m<sup>2</sup> SF

**Miscellaneous**  
 Mean mirror cleanliness 97.0 %  
 Shut down wind speed 12.0 m/s  
 Field availability 99.0 %  
**Degradation 0.00 %**

**Pipes**  
 Piping loss coefficient<sup>2,3</sup> 0.0615 W/(m<sup>2</sup> K)  
 Expansion vessel losses<sup>3</sup> 0.0050 W/(m<sup>2</sup> K)  
<sup>2</sup> headers and pipes in loops  
<sup>3</sup> referred to field size

**Mass flow**  
 Nom. fluid mass flowrate 1110.088 kg/s  
 Max. fluid mass flowrate 120 %  
 Min. fluid mass flowrate 20 %  
 Nominal field outlet pressure 15 bar  
 Nominal field pressure drop 3.0 bar

OK Apply Cancel

**HFLCAL Tower Field**  
File Edit Costs Help

## Tower Field

Field Layout

**Design point specification**  
 Intercept power 350.00 MW  
 DNI 800.00 W/m<sup>2</sup>  
 Latitude 34.85 °  
 Longitude -116.80 °  
 Tower height 200.00 m  
 Time 21 03 11:54  
 Mirror Reflectivity 0.8794

**Miscellaneous**  
**Degradation 0.00 %**

**Field optimization parameters**  
 Design Heat Intercept 350.00 MW  
 Solar flux 500.00 kW/m<sup>2</sup>  
 Absorber area 700.00 m<sup>2</sup>  
 Specific heat loss 50.00 kW/m<sup>2</sup>  
 Absorbance 0.9500  
 Absorber design power 297.50 MW  
 Receiver efficiency 0.7800

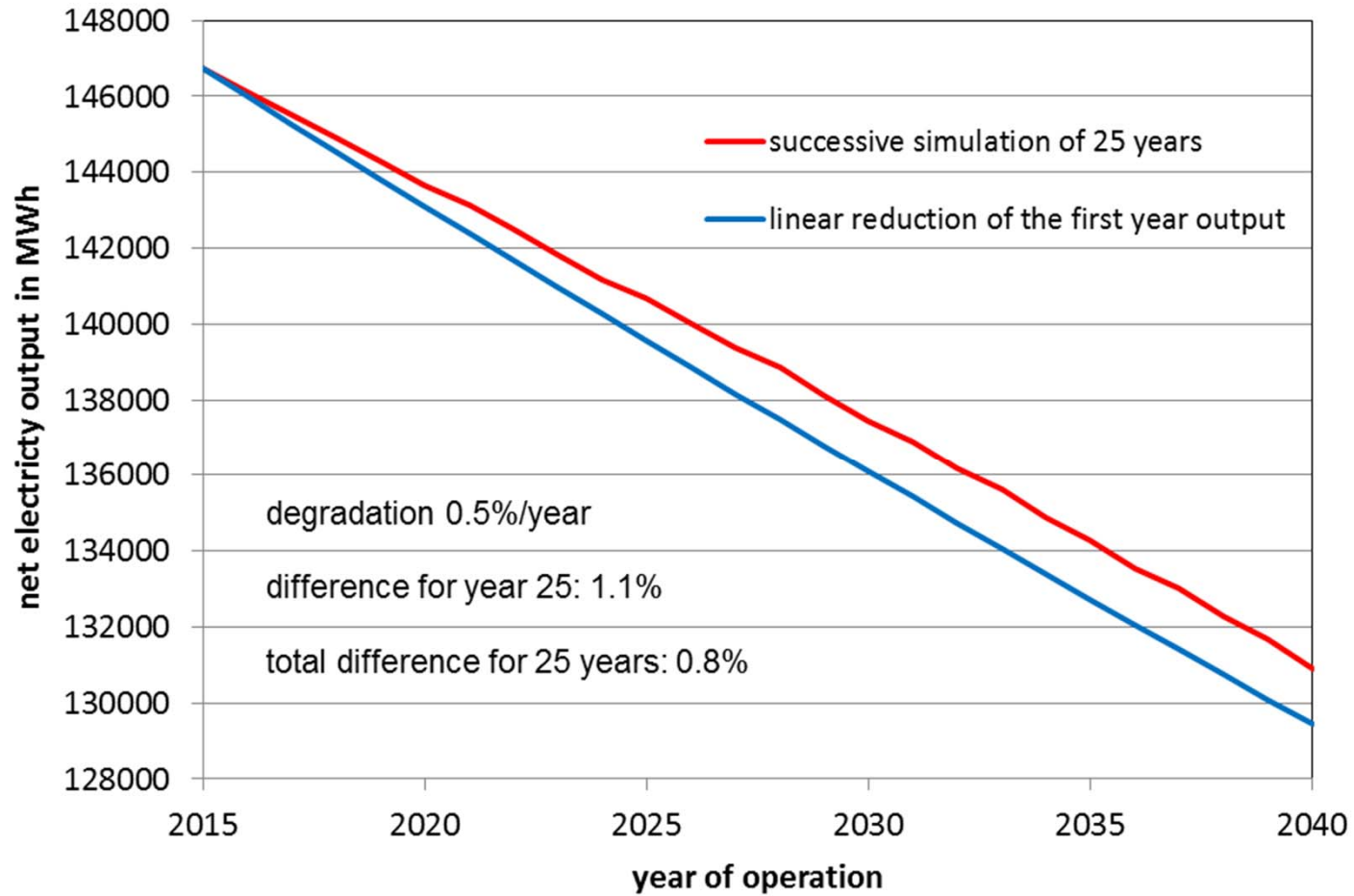
**Design calculation results**  
 Field Layout Heat Intercept 350.00 MW  
 Azimuth 180.00 °  
 Elevation 55.61 °  
 Field Efficiency 0.7442  
 Total reflective area 578486 m<sup>2</sup>  
 Tower height factor 1.00  
 Heliostat reflective area 147.90 m<sup>2</sup>  
 Number of heliostats 3911

**Graph: Intercept efficiency (%) vs Azimuth (°)**  
 Legend: 10° (red), 30° (green), 50° (yellow), 70° (blue), sun (purple)

OK Apply Cancel



# Comparison of Flat-Rate and Detailed Approach



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## Overview of Changes for the next release

- Freeze Protection → see *Molten Salt presentation by Jürgen Dersch*
- Implementation of CoolProp steam table
- Modification and documentation of output variables for line focusing systems
- Enhanced model for DSG
  - Optimisation of calculation algorithm
    - Reduce computational time
  - Modification of physics
  - Intensive validation



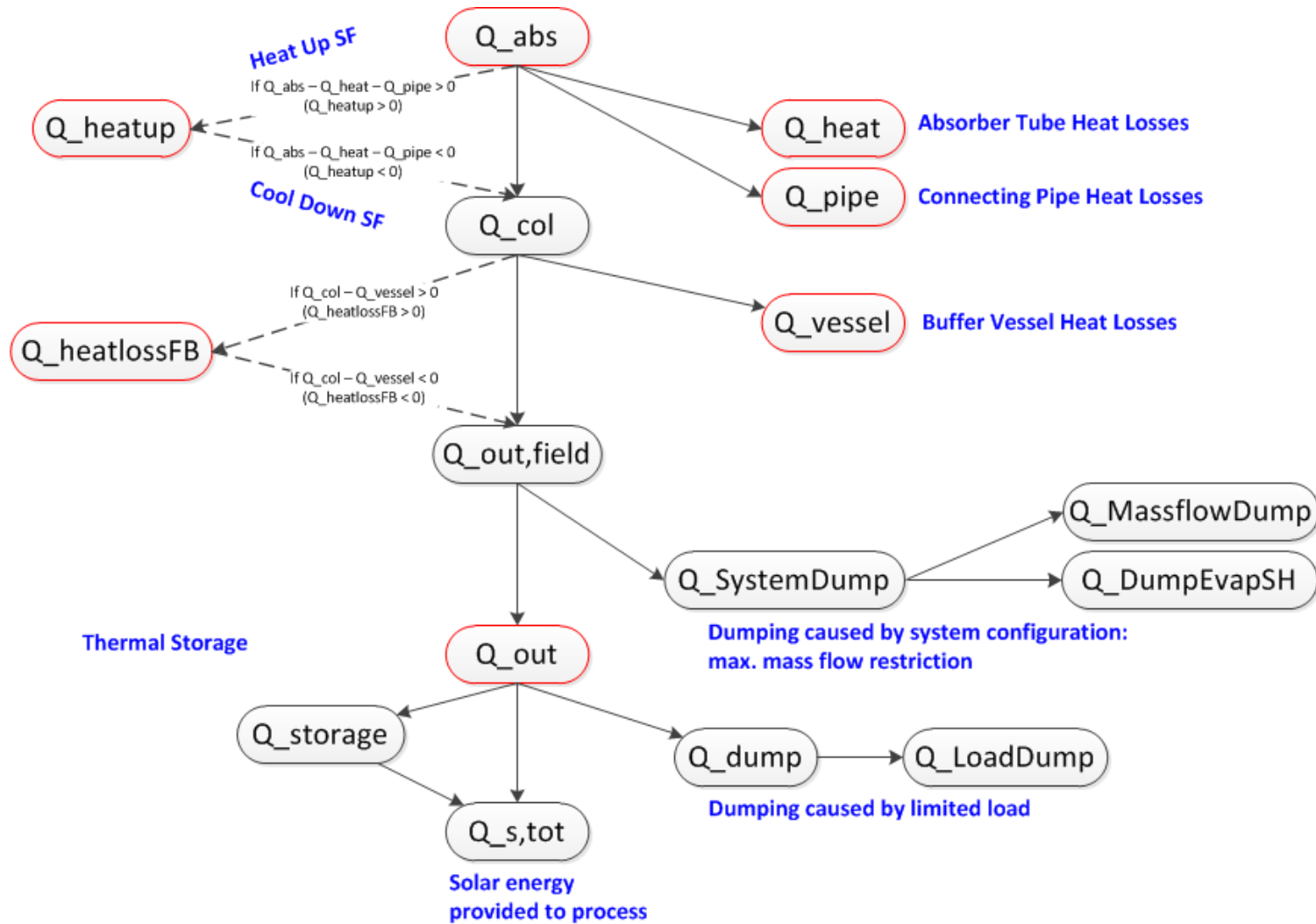
## Overview of Steam Tables for **greenius**

- Greenius includes interfaces for the following steam table libraries
  - Extended IAPWS-IF97 Steam Tables (Book with CD / eBook)  
<http://www.springer.com/3-540-21419-4>
  - WinSteam (Trial Version available)  
<http://www.techwareeng.com/prodws.html>
  - CoolProp (extremely slow, not recommended)  
<http://www.coolprop.org/>
  - FreeSteam (To be implemented)  
<http://freesteam.sourceforge.net/>
- More detailed information on usage of the libraries will be added to Help & Manual in the next release





# Proposed Scheme of Output Variables



## Enhanced Model – Optimisation / Speed Up

- Several measures in order to improve solver convergence
  - Simplified Newton's method
  - Manual Calculation of the Jacobi matrix
  - Scaling
- Total reduction of simulation time: 87%

Maßnahme	Zeitersparnis		Iterationen	Updates JM
	Einzel	Kumulativ		
Ausgangszustand	0.0 %	0.0 %	37 835	29 887
Vereinfachtes Newton-Verfahren	48.1 %	48.1 %	93 642	11 891
Manuelle, redundanzfreie Berechnung der JM	58.1 %	78.2 %	93 483	13 276
Vorgabe bekannter Nullen	2.0 %	78.7 %	93 483	13 276
Optimierung JM-Aktualisierung	22.2 %	83.4 %	47 020	21 824
Skalierung	23.4 %	87.3 %	32 447	15 621

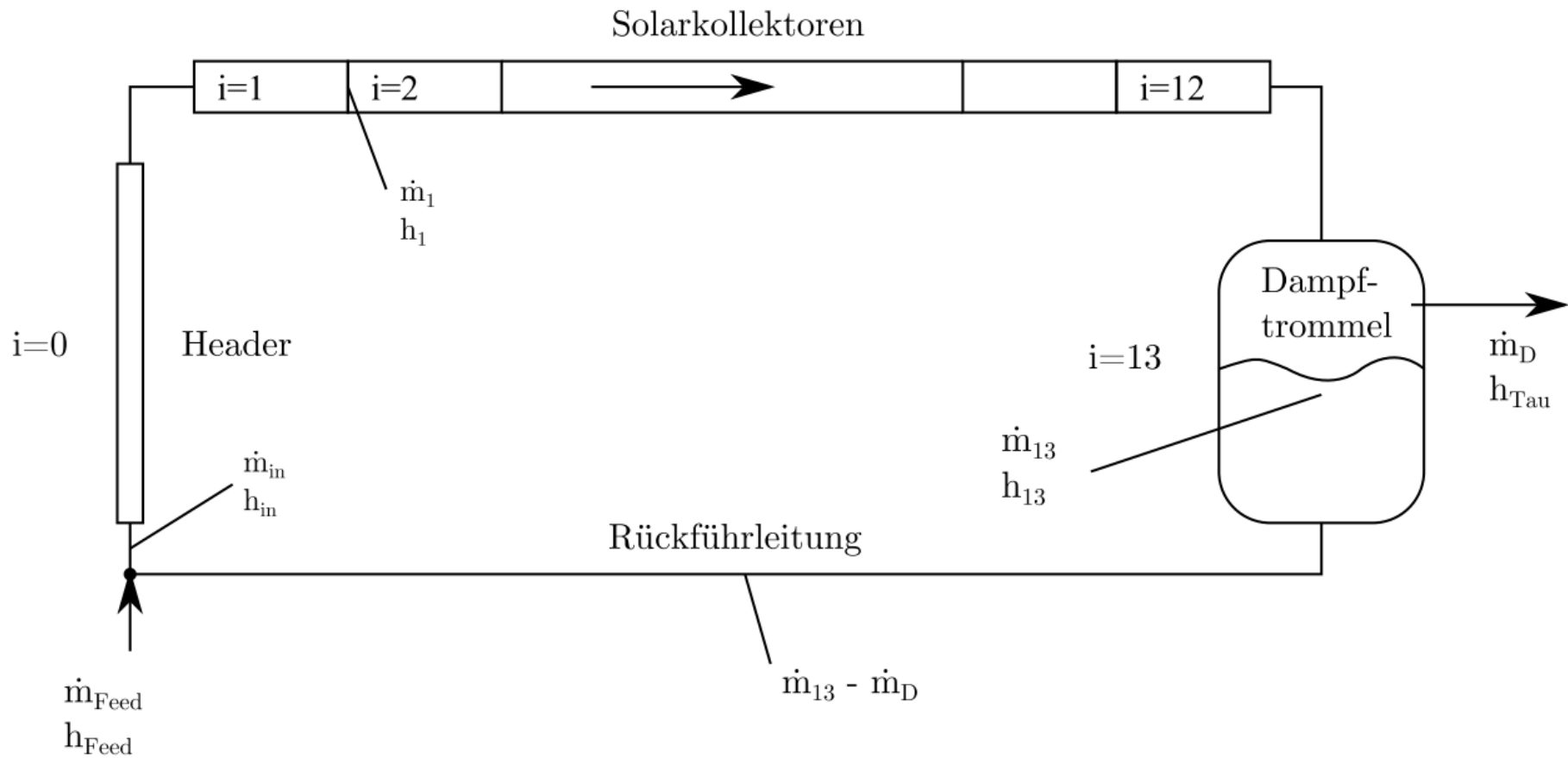


## Enhanced Model – Previous Issues

- Assumption of a constant mass flow is unrealistic, especially close to boiling point
- Unrealistic enthalpy profiles over loop length
  - ➔ especially for fine temporal resolutions
- Significant deviations from dynamic models
- Initial guess based on realistic conditions is not appropriate for a model which leads to unrealistic enthalpy profiles
  - ➔ Worse convergence
- Sometimes extreme fluctuation of the solution
  - ➔ Worse convergence



# Enhanced Model – Modification of Physics I



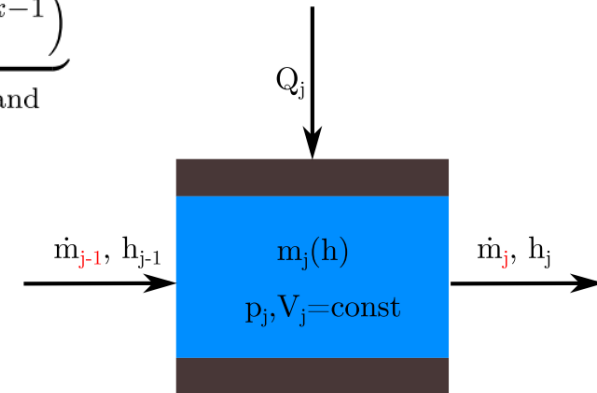
# Enhanced Model – Modification of Physics II

## Enthalpy Balance

### Classic Model:

$$Q_j^k = \underbrace{\dot{m}^k (h_j^k - h_{j-1}^k)}_{\text{Konvektiver Transport}} \Delta t + \underbrace{m_j^k h_j^k - m_j^{k-1} h_j^{k-1}}_{\text{Aufheizung Massendifferenz}} + \underbrace{m_w c_{p,w} (T_j^k - T_j^{k-1})}_{\text{Aufheizung Rohrwand}}$$

→ Allow variation of mass flow



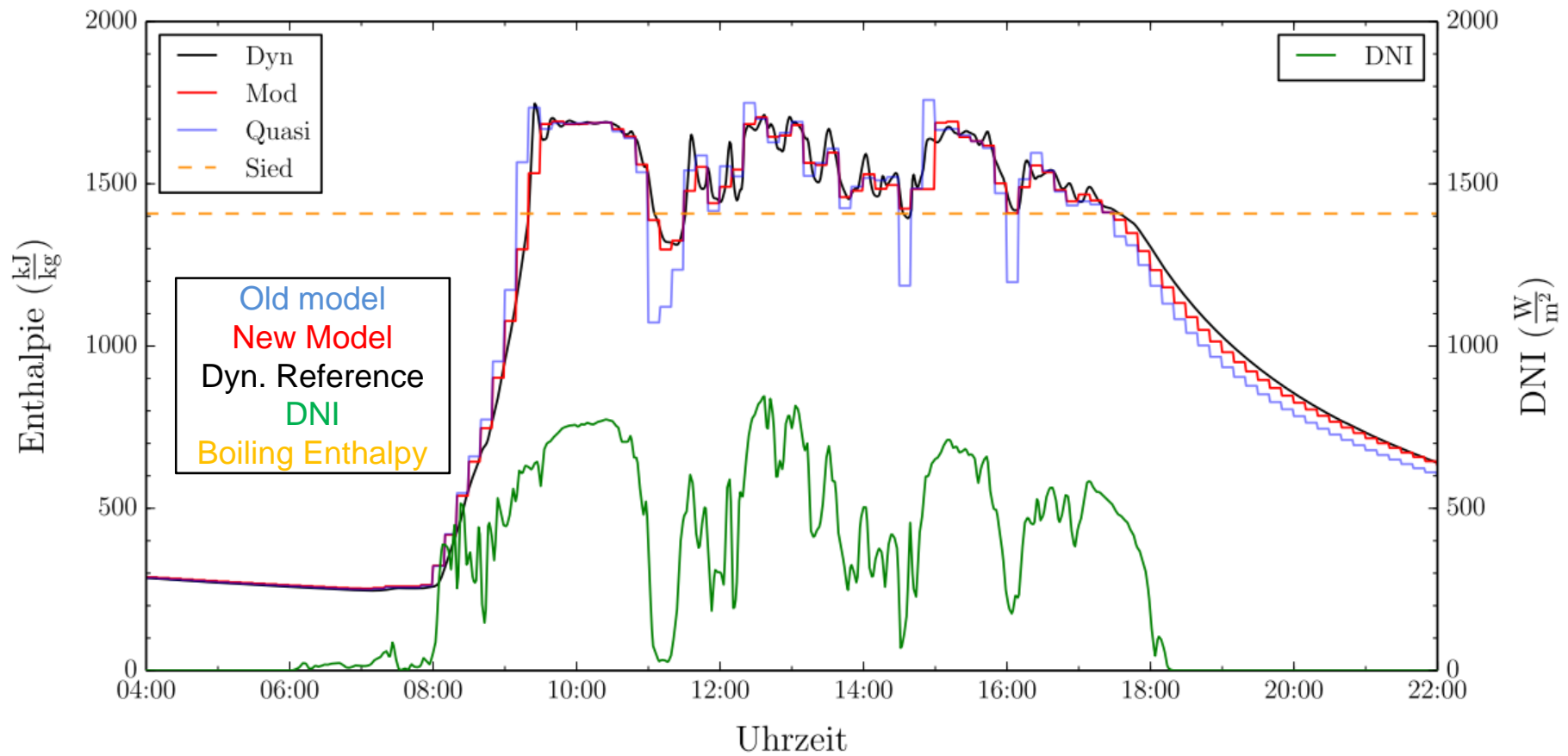
### New Model:

$$Q_j^k = \underbrace{(\dot{m}_j^k h_j^k - \dot{m}_{j-1}^k h_{j-1}^k)}_{\text{Konvektiver Transport}} \Delta t + \underbrace{m_j^k h_j^k - m_j^{k-1} h_j^{k-1}}_{\text{Aufheizung Massendifferenz}} + \underbrace{m_w c_{p,w} (T_j^k - T_j^{k-1})}_{\text{Aufheizung Rohrwand}}$$



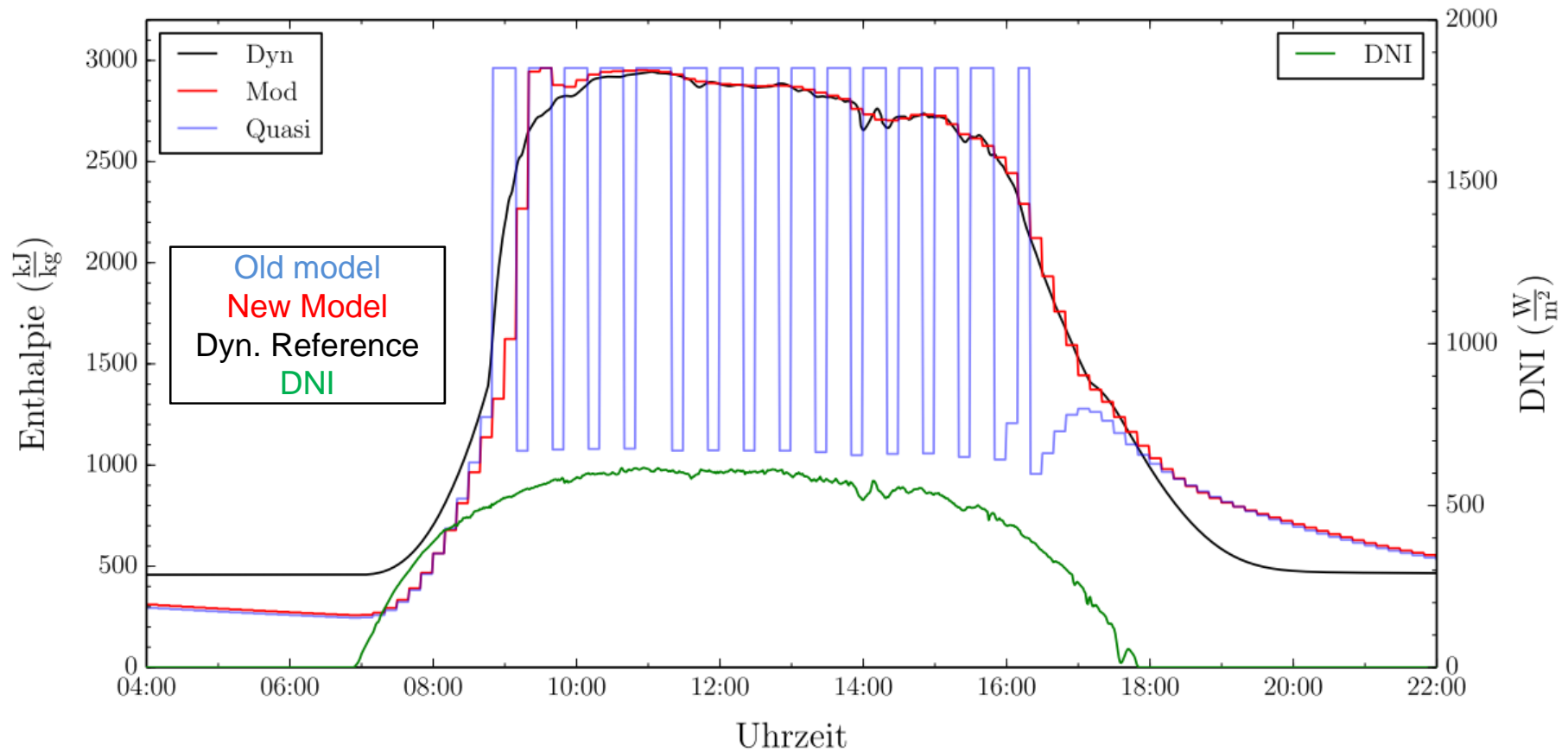
# Enhanced Model – Modification of Physics III

## Enthalpy at Field Outlet (Recirculation)



# Enhanced Model – Modification of Physics IV

## Enthalpy at field outlet (1-Through)



# Enhanced Model – Modification of Physics V

## Summary

	DNI	Quasi	Mod
Annual solar field output:	Kanchanaburi	-1.39 %	-3.08 %
	Almeria	+0.60 %	-0.54 %
	Granada	+0.37 %	-0.61 %

### → Advantages of new model

- Enthalpy and mass flow profiles are modeled correctly
- No implausible enthalpy profiles over loop length
- More robust
- 10-15% faster

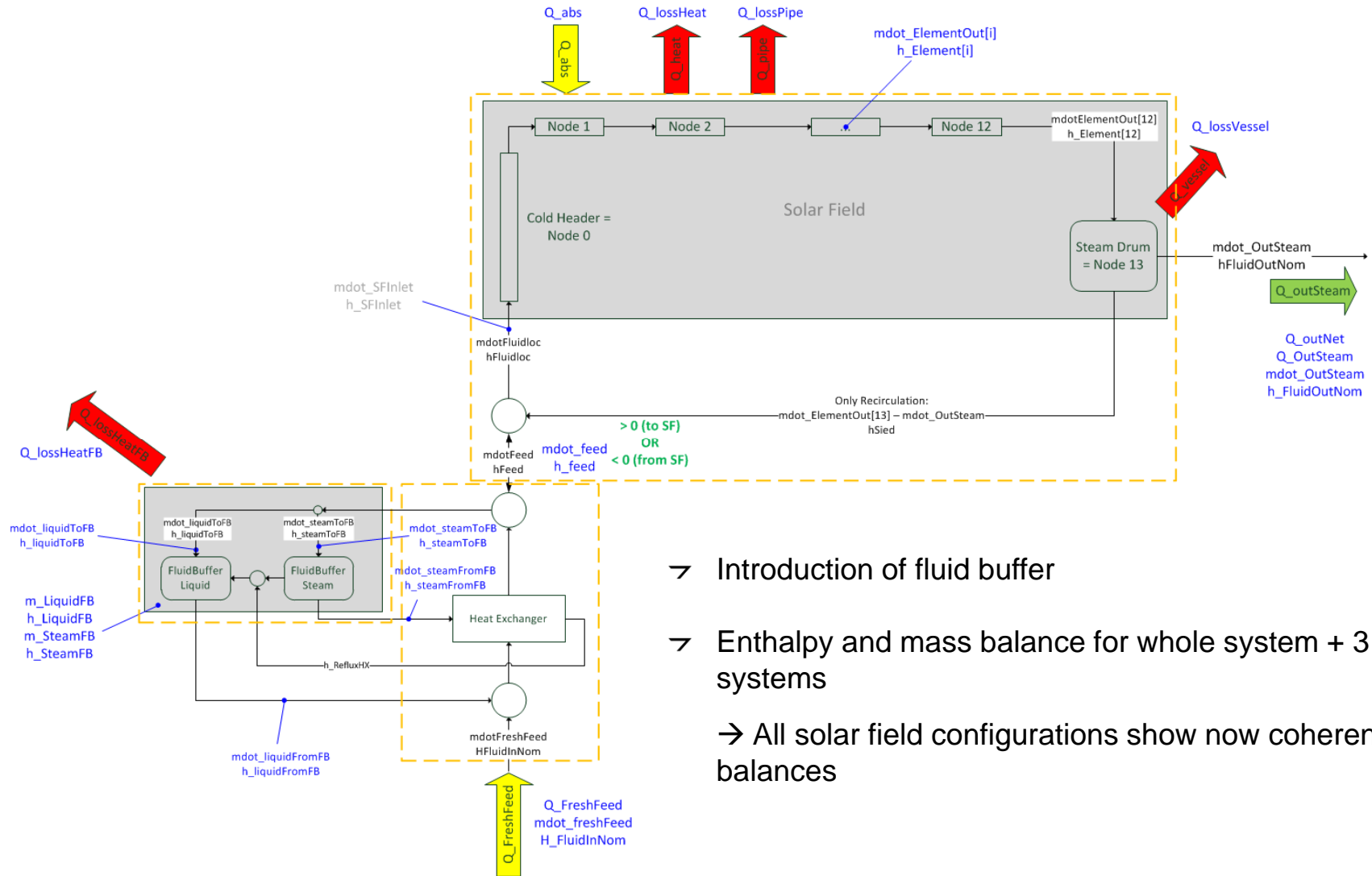
### → Disadvantages of new model

- Implementation is much more complex
  - Mass flow difference between SF inlet and outlet





# Enhanced Model – Fluid Buffer and Validation



- Introduction of fluid buffer
- Enthalpy and mass balance for whole system + 3 sub systems
- ➔ All solar field configurations show now coherent balances



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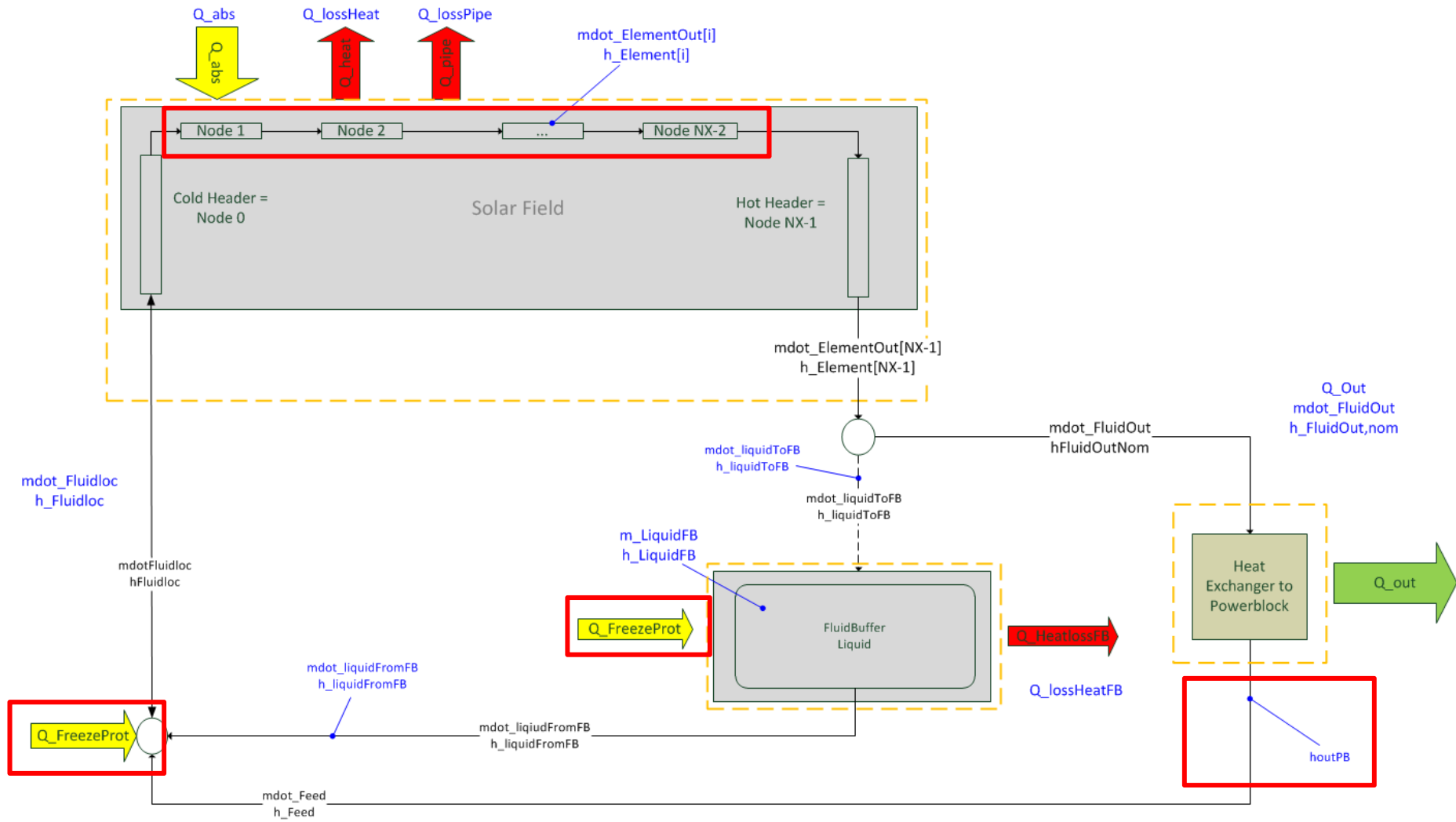


## Concrete Future Development Plans

- Interface for FreeSteam Library for DSG
- Enhanced model for single phase HTFs in line focusing solar systems
  - Spatial resolution single phase fluids
  - Freeze protection
  - Variable HTF return temperature at partial power block load
- Salt and water/steam as HTFs in solar towers



# Example: Scheme of New Model for Single Phase Fluids



**THANK YOU**  
for your attention.

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DLR



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