Coal & Biomass Co-firing: Advanced Modeling Tools and Their Application

For Energy and Environmental Solutions

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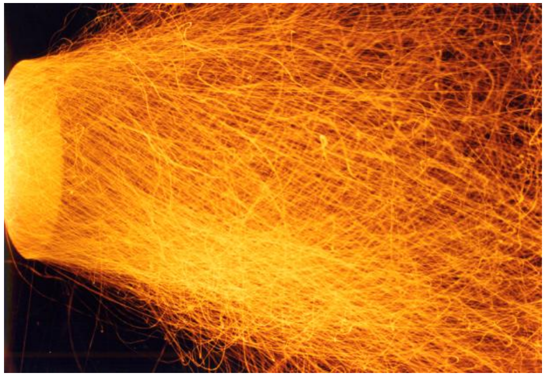
McIlvaine Hot Topic Hour

Co-Firing Sewage Sludge, Biomass and Municipal Waste

December 13, 2012

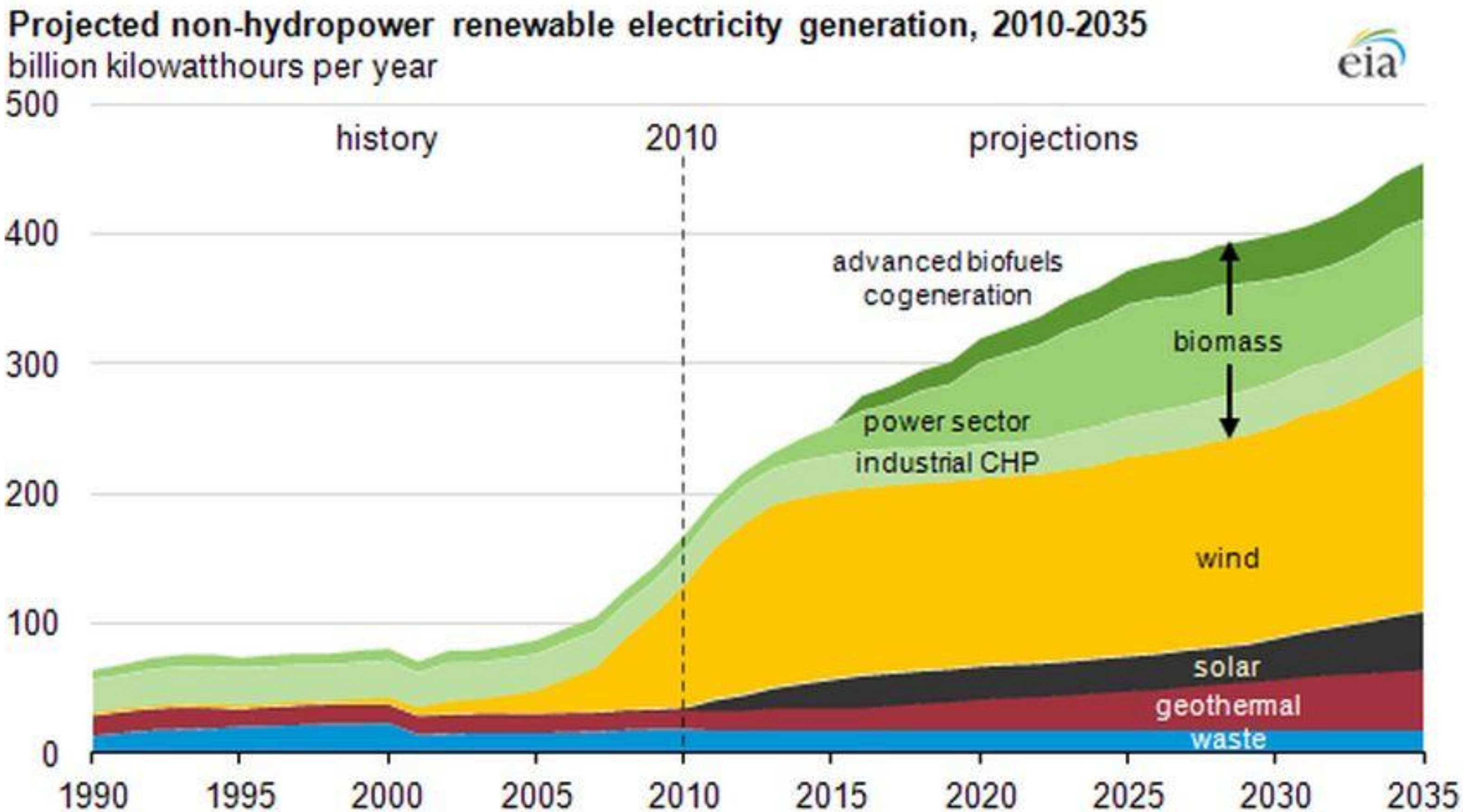
Reaction Engineering International

Objective: Solve Challenging Industrial Combustion Problems Using Specialist Talent & Technology



- Privately Held Consulting Firm
- Founded 1990
- Approximately 25 Employees
- Located in Salt Lake City, Utah
- Affiliates in Asia and Europe
- Focus on Multi-phase, Chemically Reacting Flows
- Capabilities Include Advanced Modeling and Testing

Biomass Power: The Past & Future of Renewable Power?



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Role of Biomass

- **Wind and Biomass dominate projected increases in renewable power**
- **Biomass co-firing drivers:**
  - **US State level RPS**
  - **Favorable economics in regions with forest residues**
  - **European Union Directive 2009/28/EC**
  - **UK incentives issued through Renewables Obligation Certificates (ROCs)**
- **May 2012 projections based on the Clean Energy Standard Act of 2012 see biomass growth increasing from 4x (Nov 2011) to 7x (May 2012)**

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Utilization Issues

- Fuel collection, storage, processing and handling
- Combustion
  - Combustion stability
  - Burnout
  - Temperature / Heat transfer
  - Efficiency
- Emissions
  - Carbon Dioxide
  - Sulfur Oxides
  - Mercury
  - Fine Particles
  - Nitrogen Oxides
  - Carbon Monoxide

- Operational Impacts
  - Ash Deposition, Slagging, Fouling
  - Catalyst deactivation
  - Fly-ash properties
  - Corrosion
- Economics
- Regulatory

Operational Impacts

Fenger, L.D., The use of Straw as Energy Source-example Denmark, Proceedings of European Biomass Conference, Graz, 2008

- **Deposition, Slagging, Sintering and Fouling**
  - **Depends on deposition rates and ash chemistry**
  - **100% biomass systems more susceptible**
  - **Co-firing less susceptible (minimal impacts with <10 wt%)**
- **Potential for corrosion**
  - **Chlorine**
  - **Alkali**

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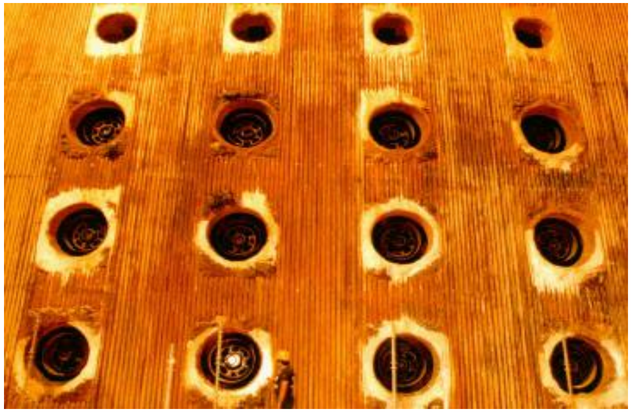
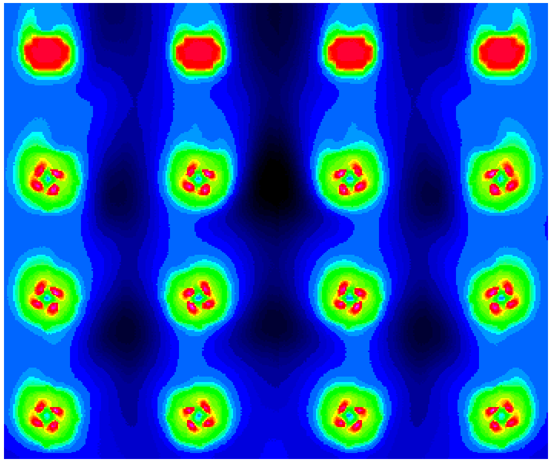
CFD Tools for Boiler Evaluations

- **Two-phase, turbulent, reacting flow in boilers is inherently complex**
- **Additional Complexities of biomass as a co-firing fuel**
  - **Devolatilization rates and product speciation**
  - **Limited availability/predictability of char oxidation rates**
  - **Particle size and associated difficulties in describing intra-particle heat and mass transfer**
  - **Particle shape and associated difficulties describing particle dynamics**
  - **Unique NOx Chemistry**





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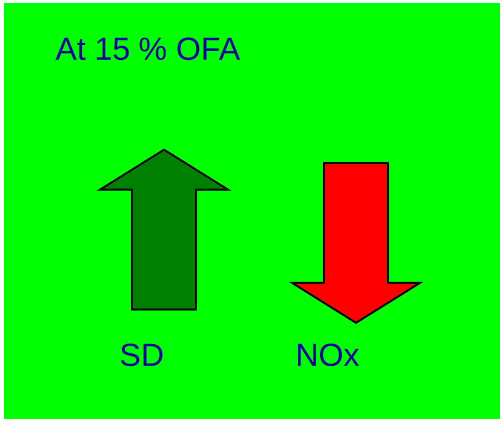
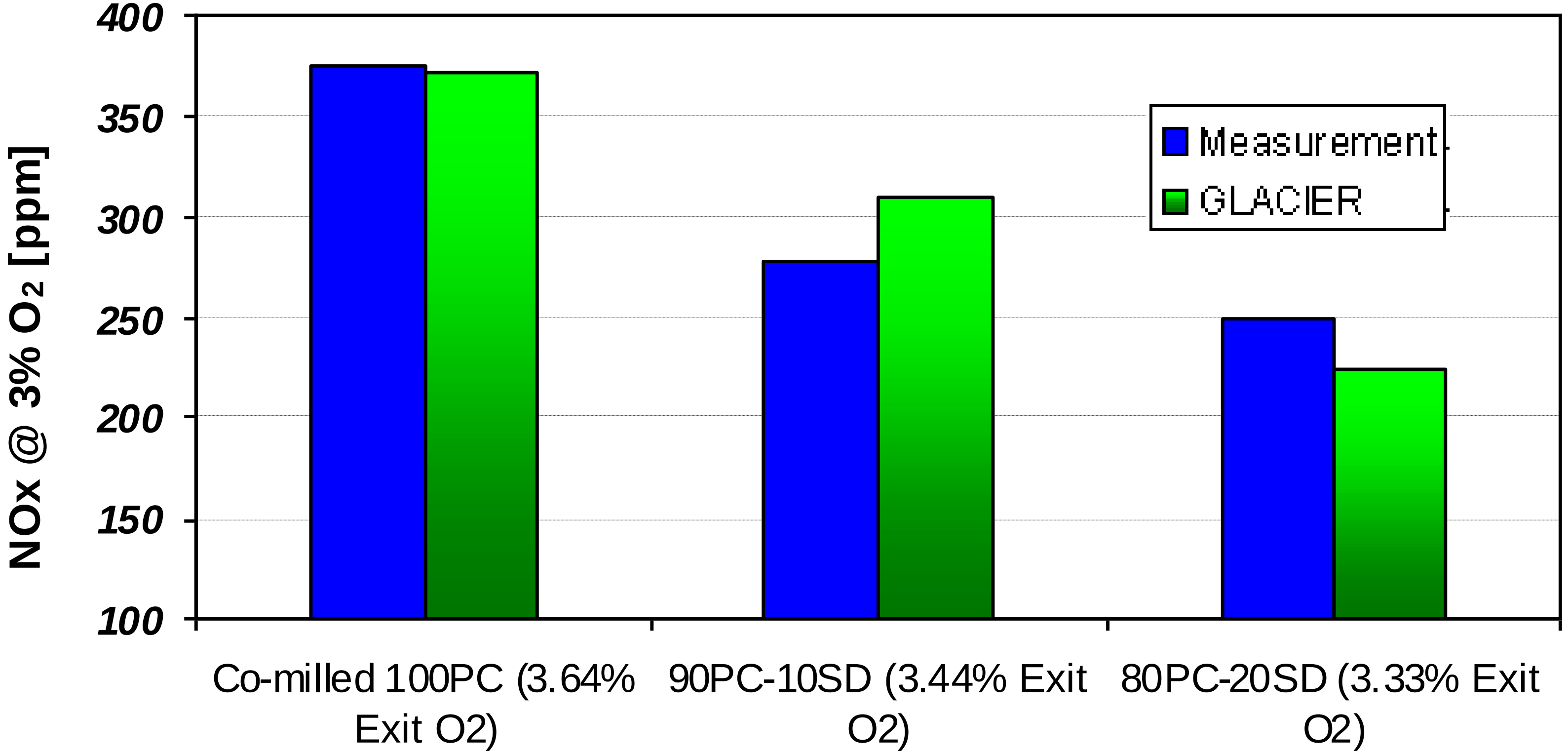
Pilot-scale Validation for NOx Emissions





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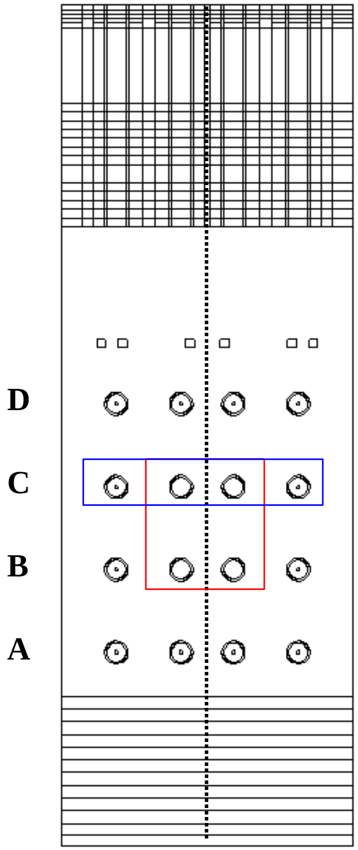
Co-firing Injection Evaluations

- **150 MW front wall-fired boiler**
- **16 Low NOx burners in 4 elevations and OFA**
- **Co-firing scenarios**
  - **7% Green Wood Chips based on total heat input.**
  - **Multifuel burners in "C" row.**
  - **Mulitifuel burners at center 2 locations in B, and C rows**
- **Determine operational impacts**
  - **NO_x Reduction**
  - **LOI**
  - **CO**



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Deposition&Slagging of Complex Fuel Blends

- **Predict deposition impacts w/ *GLACIER* CFD software**
  - **Deposition patterns and rates**
  - **Size, shape, composition of fly ash**
  - **Fly ash viscosity = *f* (composition, temperature, local stoichiometry)**
  - **Deposit sintering = *f* (deposit thickness, composition, temperature, time)**
- **Fuels characterization**
  - **CCSEM (bulk ash elemental used for normalization)**
  - **Partial Chemical Fractionation**
- **Model application experience**
  - **Bituminous – SubBituminous blends**
  - **Bituminous – Pelletized biomass blends**
  - **100% biomass**
  - **Independent ongoing efforts to evaluate the impacts of torrefied biomass and oxy-firing**

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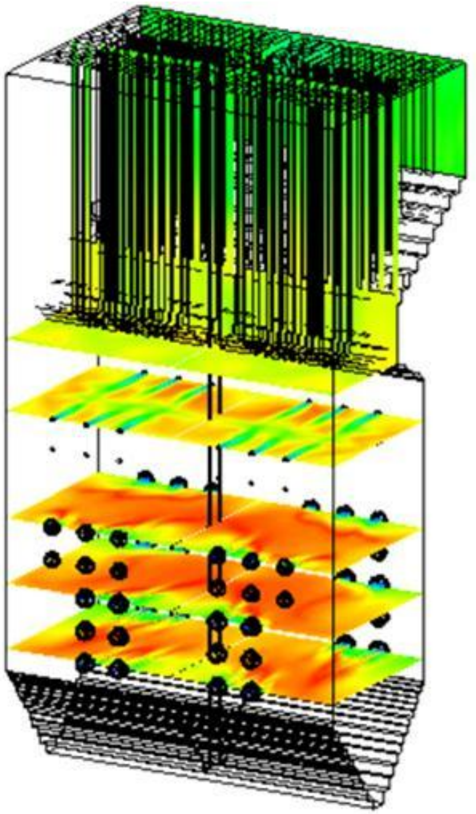
Case Study: PC to Biomass Pellet Co-firing

- 660 MW opposed-wall, pulverized coal fired unit
- Comparison of Coal-only and 60% biomass pellet co-firing:
  - 3 woods (WP1, WP2, WP3)
  - 1 wood & straw mixture (WP1&SP1)
- Overall simulation results indicate:
  - Modest increase in FEGT for biomass firing
  - Some reduction in wall heat transfer
  - 35-40% decrease in NOx emissions
  - Similar CO emissions
  - Slight decrease in carbon in flyash

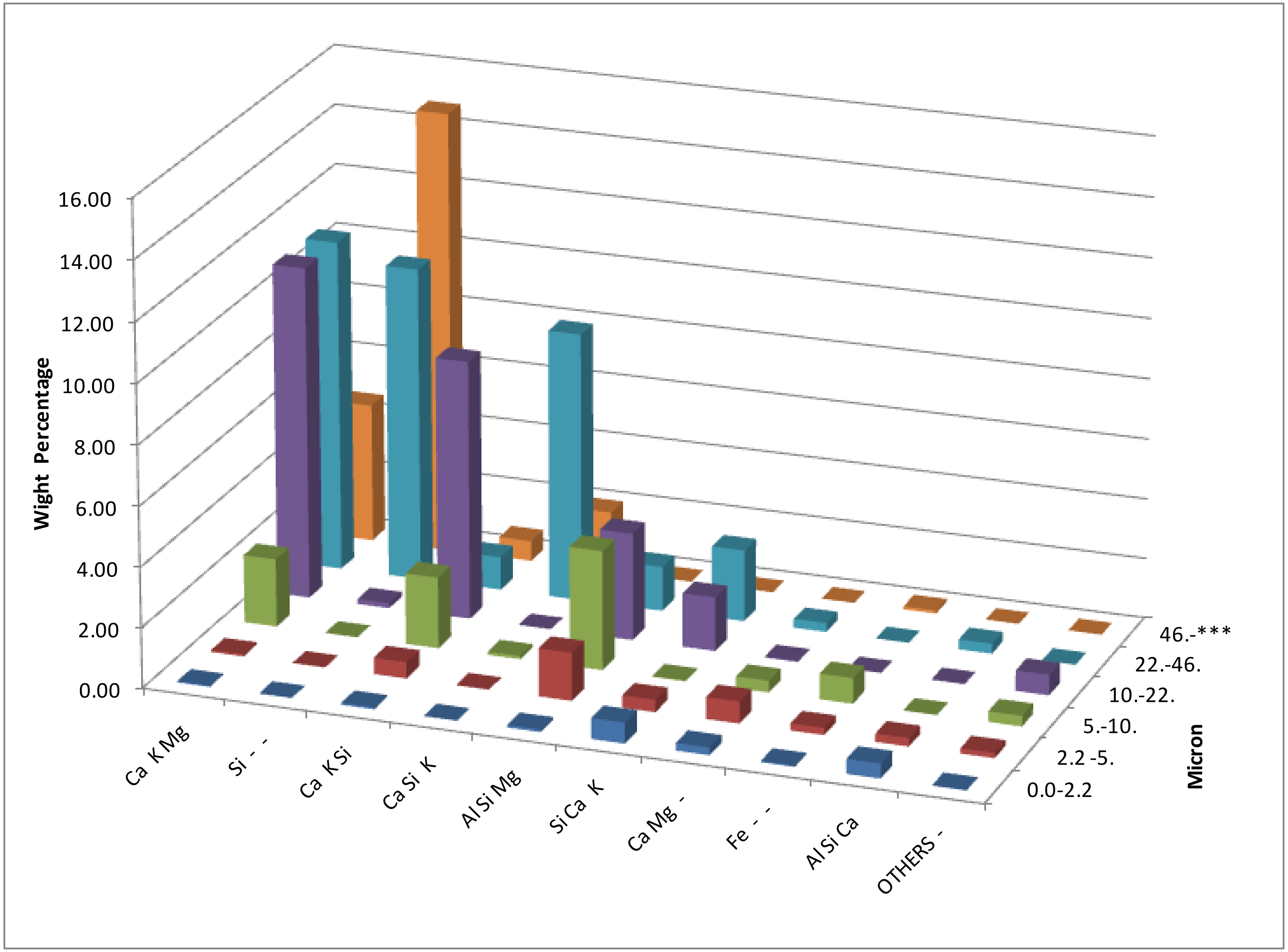


Fuel Properties

Proximate Analysis		Coal only	WP1	WP2	WP3	SP3
Volatiles Matter	[wt % ar]	27.33	80.80	80.40	77.40	71.80
Fixed Carbon	[wt % ar]	43.16	14.10	15.20	16.90	15.30
Moisture	[wt % ar]	14.47	4.60	4.10	4.20	7.40
Ash	[wt % ar]	15.04	0.50	0.30	1.50	5.50
HHV	[kJ/kg]	23523.5	18769.7	19080.4	18775.6	16083.4
LHV	[kJ/kg]	22337.8	17458.2	17741.5	17435.6	14816
Ultimate Analysis						
C	[wt % ar]	59.70	49.42	48.91	48.86	41.67
H	[wt % ar]	3.73	5.64	5.75	5.75	5.00
S	[wt % ar]	1.24	0.01	0.01	0.02	0.07
O	[wt % ar]	4.67	39.62	40.62	39.30	39.86
N	[wt % ar]	1.15	0.22	0.31	0.37	0.50
Cl	[wt % ar]	0.260	0.003	0.003	0.021	0.114
H2O	[wt % ar]	14.47	4.60	4.10	4.20	7.4
Ash	[wt % ar]	15.04	0.50	0.30	1.50	5.5

WP1 - Fly Ash

Predicted Fly Ash Composition and Size Distributions



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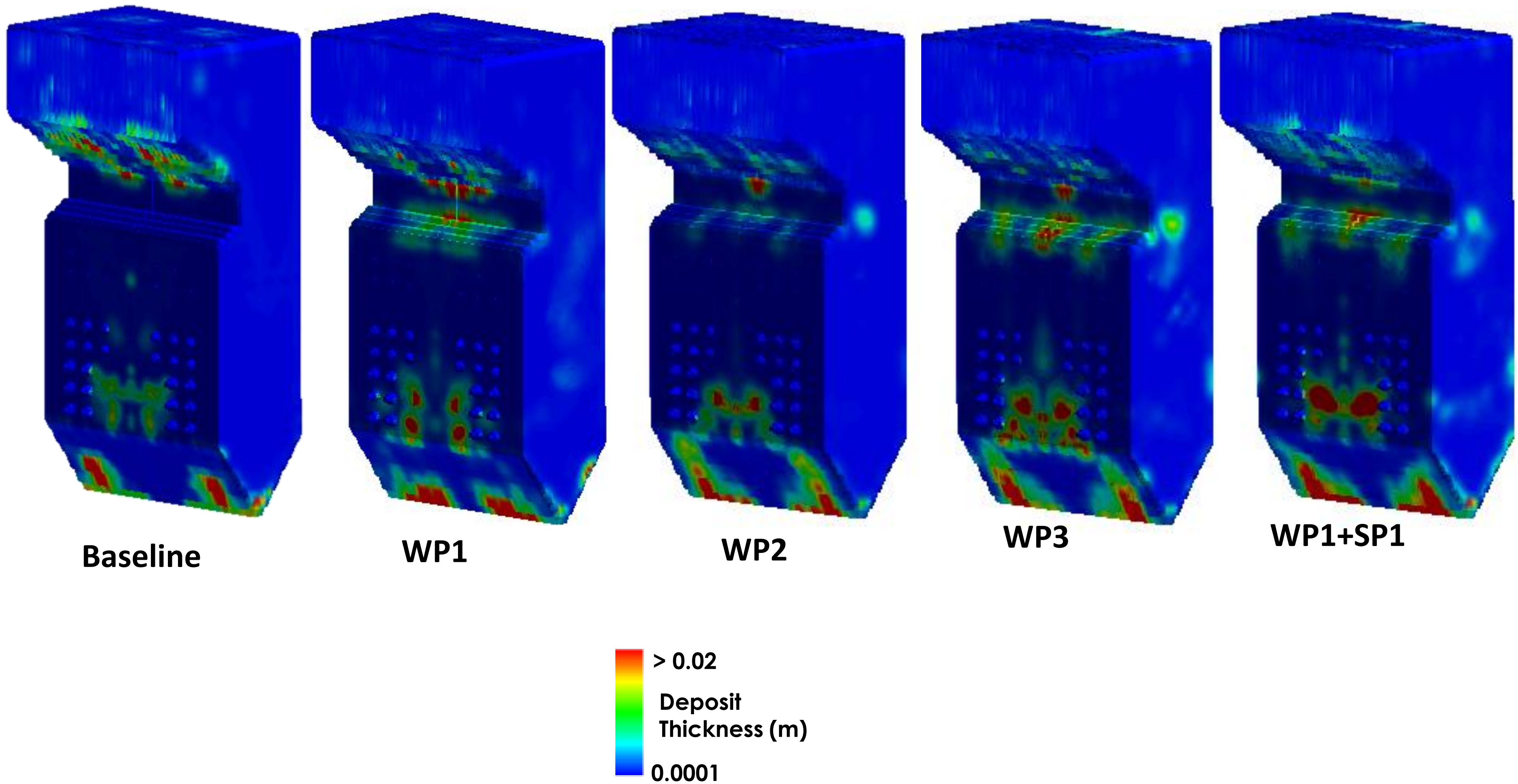
Deposit Thickness After Four Hours



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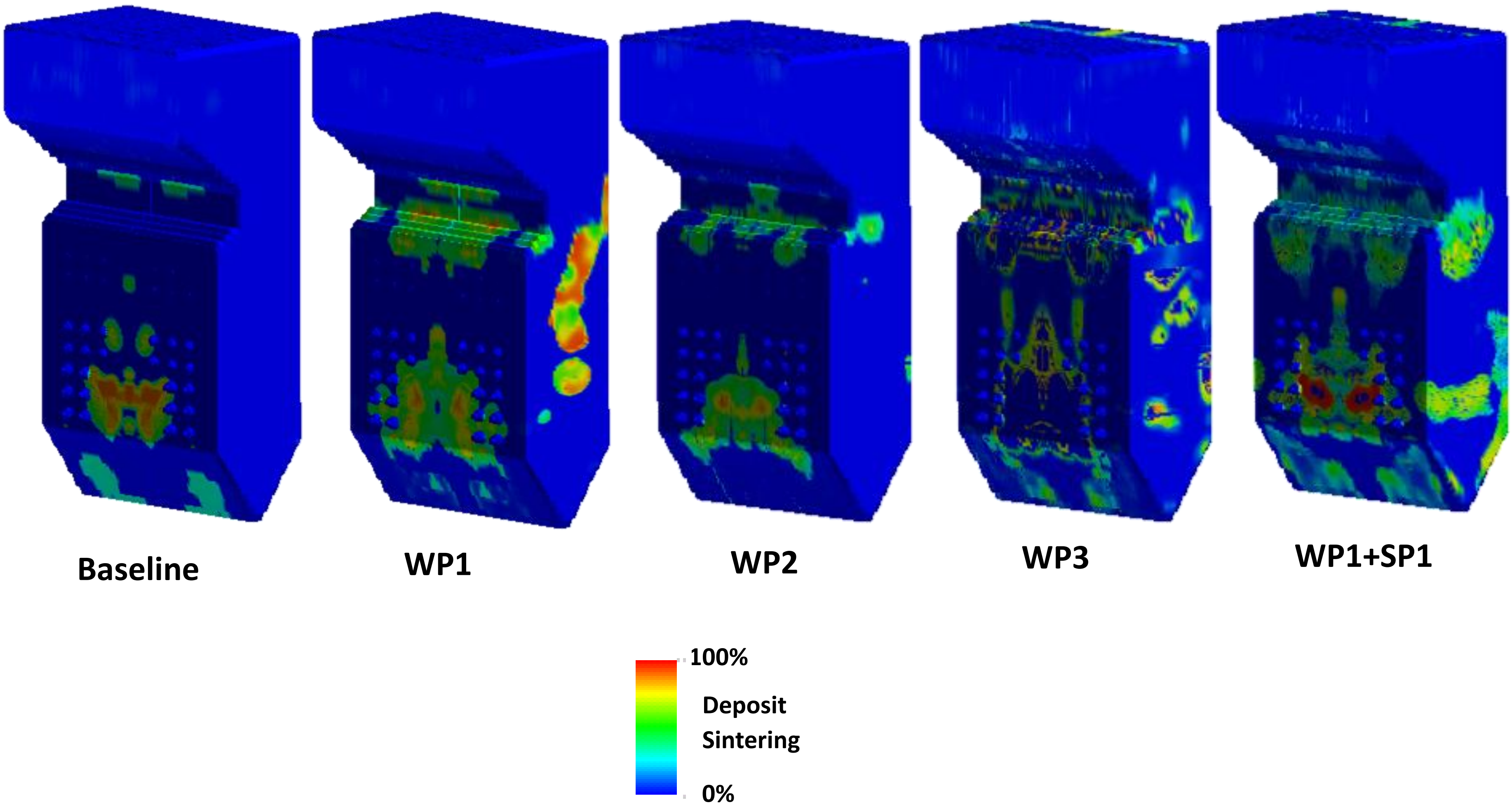
Deposit Sintering Extent After Four Hours



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Summary

- **Computational Tools**
  - **Detailed models for describing mineral matter transformation, ash deposit build-up and sintering are available**
  - **These models have been implemented in a CFD framework and applied to multiple full-scale coal-fired boilers resulting in predictions that are qualitatively accurate**
  - **Extension of this approach to biomass co-firing has also been and appears qualitatively reasonable**
  - **Estimation method for CCSEM results for bituminous coal using only bulk ash elemental analysis appears promising**
- **Ash Behavior: Coal-only vs Biomass/Coal**
  - **Deposition patterns/rates, sintering extent, and corrosion rates can vary extensively as a function of biomass source**
  - **Ash management can range from very similar to significantly more challenging**
  - **Waterwall corrosion rates can be significantly reduced**