

71 Combustion Performance and NO_x Control

Program Overview

Program Description

This program provides the knowledge and resources needed to develop, demonstrate, and apply cost-effective combustion-based NO_x reduction solutions that minimize risk and impact on boiler performance. Projects in five distinct groups help mitigate fireside corrosion and waterwall wastage in low-NO_x systems, develop and demonstrate cost-effective NO_x control through combustion modifications and assessments of emerging technologies, find solutions for fuel quality issues, measure and control coal and air flow, and optimize heat rate and cost.

Industry Needs and Issues Addressed

- Interstate Air Quality Rules, which may reduce current NO_x levels by more than 40%, will require cost-effective NO_x control solutions.
- Forced outages due to fireside corrosion resulting from low NO_x operation require cost-effective solutions.
- Rising fuel costs and potential CO₂ regulations increase the need to improve combustion performance.
- Emission and performance mandates demand more accurate measurement and control of coal and air flow to individual burners.
- Changing operating conditions and fuel diversification require improvements in traditional boiler performance measures.

Impact

- Combustion modifications are the most cost-effective method of reducing emissions, even when regulations require combining them with post-combustion controls.
- Avoiding a single forced outage due to fireside corrosion or slagging and fouling can save more than \$1 million per unit.
- Heat rate improvements yield significant savings in fuel costs and are the lowest-cost method of reducing CO₂.
- Enhancing NO_x reductions with existing hardware may yield increased revenues through the NO_x credit market.

Key Accomplishments

- Development of advanced models to predict and assess methods of combating fireside corrosion consequential to implementation of low NO_x systems
- Deployment of Coal Flow Loop (CFL), a full-scale facility to develop and evaluate methods of measuring and controlling coal flow from pulverizers to individual burners
- FLAME DOCTOR™ Flame Diagnostics System, an advanced burner diagnostics tool to improve performance and reduce emissions on wall-fired and cyclone boilers
- Innovative cost-effective technologies for combustion NO_x controls, such as advanced staging methods
- Slagging and Fouling Guidelines that offer quantifiable methods of identification and mitigation methods for ash deposition issues

Current Year Objectives

- Cost-effective solutions for fireside corrosion and weld overlay cracking
- Advanced sensors and feedback loops to quantify gaseous species distributions online and initiate corrective actions

- Methods to quantify and map fireside corrosion and tube cracking online
- Advanced combustion modifications, yielding lower levels of NO_x, mercury, and SO₃ formation
- Predictive software (based on mineralogy) for ash deposition
- Guidelines for improved performance and heat rate for lower fuel costs and as a first step in minimizing CO₂. By way of example, a 1% improvement in heat rate on a single 600-MW coal-fired boiler will reduce CO₂ emissions by approximately 50,000 tons per year.
- Site-specific applications of the Coal Flow Loop for eliminating coal roping and optimizing coal/air ratios

Industry Involvement

- Estimated 2009 funding: \$3.8M

Program Technical Lead

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Summary of Projects

Project Number	Project Title	Value
P71.001	Mitigation of Fireside Corrosion and Waterwall Wastage in Low-NO _x Systems	Assessment and mitigation strategies for fireside corrosion-related boiler tube failures due to low NO _x operation, based on coal quality, boiler design, and operational considerations.
P71.002	Cost-Effective NO _x Control via Combustion Modifications and Assessments of Emerging Technologies	Development of guidelines and best practices that enable implementation of cost-effective combustion modifications to minimize NO _x levels and other pollutants such as mercury and unburned carbon, as well as optimize combustion performance.
P71.003	Solutions for Fuel Quality Issues	Integrated solutions for fuel quality-related issues such as slagging and fouling experienced with units firing Powder River Basin (PRB), lignite, bituminous, and biomass fuels and fuel blends.
P71.004	Coal and Air Flow Measurement and Control	Improved boiler operation (including emissions and combustion performance) through validated coal and combustion air flow metering and control methods. EPRI's Coal Flow Loop will be deployed to assess advanced coal flow control and measurement methods.
P71.005	Heat Rate and Cost Optimization	Development and demonstration of a variety of deliverables and services to promote optimal heat rate and minimal cost of operations. Specific efforts include demonstrations of intelligent sootblowing and flame diagnostics, and focused conferences and workshops on key topics prioritized by participants.

Project Descriptions

P71.001 Mitigation of Fireside Corrosion and Waterwall Wastage in Low-NOx Systems (100465)

Issue

Low NO_x operation can result in fireside corrosion and waterwall wastage-related boiler tube failures. Although weld overlays may alleviate this situation in many instances, associated problems with circumferential cracking may be exacerbated. Boiler system owners and operators need cost-effective solutions to reduce the number of such costly forced outages stemming from fireside corrosion and circumferential cracking.

Description

A multi-faceted approach to understanding and resolving the costly consequences of accelerated fireside corrosion, exacerbated by low-NO_x operation, will include

- impacts of coal quality, such as the roles of chlorine, sulfur, and fuel blends;
- effects of boiler design and various modes of low NO_x operation; and
- material-based solutions and issues.

The advanced Corrosion Predictor model and other state-of-the-art modeling tools will be used to develop guidelines to assess waterwall wastage based on coal quality, furnace design, and operability. Cost-effective solutions will be developed and demonstrated. The issue of circumferential cracking, exacerbated by both low NO_x operation as well as utilization of weld overlays, will be addressed, and alternative material solutions such as thermal spray and ceramic coatings will be assessed.

Value

- Reduce the number of costly forced outages due to fireside corrosion-related boiler tube failures that result from low-NO_x operation.
- Reduce O&M costs by selecting appropriate protective coatings and weld overlays as well as by taking into account coal quality considerations.
- Participate in EPRI's Waterwall Wastage Interest Group (WWIG), which will help members identify specific projects, disseminate results, and share best practices.
- Receive assistance in all aspects of fireside corrosion-related issues, including analysis of wastage problems, weld overlay cracking, fuel quality and blend ratio impacts, and appropriate selection of protective coating alternatives.

How to Apply Results

Plant personnel responsible for boiler systems reliability and performance can employ project findings and deliverables to mitigate accelerated fireside corrosion. Mitigation methods may be applied to boiler operation (especially combustion considerations), material-based coatings such as weld overlays and thermal sprays, and fuel quality.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Weld Overlay Database: This database will continue to be developed, compiling experiences with weld overlays and spray coatings, including data analysis. Information from database may be used to assess when cracking, hardening, and fatigue of weld overlays and spray coatings is probable.	12/31/2009	Assembled Package

Product Title & Description	Planned Completion Date	Product Type
Annual WWIG Workshop: This annual two-day interest group meeting will include technical presentations on all EPRI WWIG-related activities, as well as member presentations and group discussions of case studies and issues.	12/31/2009	Workshop, Training, or Conference
Weld Overlay Corrosion Fatigue/ cracking lab testing: Lab tests will continue to assess the impacts of corrosion fatigue and cracking on a variety of weld overlays, spray coatings, and deposits (e.g., reducing sulfur and chlorine species). Tests will investigate the impacts of temperature, surface roughness and defects, and new alloys, and assess crack initiation mechanisms.	12/31/2009	Technical Report
Corrosion Prediction Assessments for Members: Wastage estimates will be provided as a function of fuel quality and changes in fuel blend ratios using the Thermo-Chemical Equilibrium Simple Predictor, provided to funders on an as-needed basis.	12/31/2009	Technical Resource
WWIG Webcasts: Webcasts will be held on specific technical topics of key interest to WWIG members. Topics may include ceramic and thermal spray coatings, impacts of fuel quality, combustion modifications, and weld overlay longevity.	12/31/2009	Workshop, Training, or Conference
Thermal Spray and Ceramic Coating Assessments: An assessment will be made of available options for thermal spray coatings, including costs, performance data, and issues. The latest findings from field demonstrations will be incorporated.	12/31/2009	Technical Update
Crack Growth Model: Finite element modeling assessments will be conducted of the effects of weld overlay materials and temperatures on cracking potential.	12/31/2009	Technical Update
Tube materials for new units: Tube materials will be assessed for new units and new panels for existing units, based on performance, longevity, and economic considerations.	12/31/2009	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Annual WWIG Workshop: This annual interest group meeting will include technical presentations on all EPRI WWIG-related activities, as well as member presentations and group discussions of case studies and issues.	2010	Workshop, Training, or Conference
Weld Overlay Database: This database will continue to be developed, compiling experiences with weld overlays and spray coatings, including data analysis. Information from database may be used to assess when cracking, hardening, and fatigue of weld overlays and spray coatings is probable.	2010	Assembled Package

Product Title & Description	Planned Completion Date	Product Type
WIGG Webcasts: Webcasts will be held on specific technical topics of key interest to WWIG members. Topics may include ceramic and thermal spray coatings, impacts of fuel quality, combustion modifications, and weld overlay longevity.	2010	Workshop, Training, or Conference
Corrosion Prediction Assessments for Members: Wastage estimates will be provided as a function of fuel quality and changes in fuel blend ratios using the Thermo-Chemical Equilibrium Simple Predictor, provided to funders on an as-needed basis.	2010	Technical Resource
Weld Overlay Corrosion Fatigue/ cracking lab testing: Lab tests will continue to assess the impacts of corrosion fatigue and cracking on a variety of weld overlays, spray coatings, and deposits (e.g., reducing sulfur and chlorine species). Tests will investigate the impacts of temperature, surface roughness and defects, and new alloys, and assess crack initiation mechanisms. Advanced coating materials will be assessed.	2011	Technical Report
Crack Growth Model: A final report will be published on the finite element predictive model of the effects of weld overlay materials and temperatures on cracking potential.	2011	Technical Report

P71.002 Cost-Effective NOX Control via Combustion Modifications and Assessments of Emerging Technologies (050311)

Issue

Combustion modifications are the most cost-effective first-line approach to reducing emissions—primarily NO_x but also mercury, sulfur oxide (SO_x), and unburned carbon in ash. This project will assess emissions reductions achievable with combustion modifications by considering fuel quality, boiler design, boiler operating modes, and other site-specific factors. The consequences of candidate combustion modifications on boiler performance, reliability, and other pollutants will also be addressed.

Description

This project group will develop guidelines and best practices that enable funders to exploit cost-effective combustion modifications to the fullest extent for the purpose of reducing emissions and improving performance. Activities will include the following:

- Objective assessments of emerging in-furnace NO_x control technologies (including field data)
- Impacts of combustion modifications on mercury capture
- Case studies documenting combustion factors influencing achievable NO_x emissions
- Methods of improving mill performance such as throughput, particle size, and distribution, which will in turn improve combustion performance and emissions
- Demonstration of continuous in-furnace and economizer gaseous species monitoring devices

Value

- Capitalize on the NO_x credit market, and avoid higher-cost NO_x controls required to comply with present and future regulations.
- Access performance data and third-party assessments of emerging combustion-based NO_x control options to help select the most appropriate technologies for a given application.

- Apply results of the development and demonstration of the impacts of combustion modifications on control of mercury, sulfur trioxide (SO₃), and other pollutants.

How to Apply Results

Utility personnel who are involved in economic assessments, applicability issues, and considerations of combustion modification-related technologies can apply project deliverables. Information on emerging technologies, which will be maintained in real time on the EPRI website, may be applied by project participants assessing which emerging technologies merit further consideration. In addition, participants in full-scale demonstrations of advanced technologies, which are available to all project participants, will gain first-hand experience with technology performance and the advantages and shortcomings of emerging options relative to more established approaches.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Field Test Results of Mercury Capture Methods: Site-specific studies will be conducted, including studies of advanced methods of maximizing mercury capture through the combustion process.	12/31/2009	Technical Update
Emerging Combustion NOx Control Technologies Web Site: This project provides for the continuation of the Emerging Combustion NOx Control Technologies website, a “living document” providing up-to-date findings, performance data, and performance impacts of all combustion-based NOx controls.	12/31/2009	Technical Resource
Demonstrations of FTIR / TDL applications: Site demonstrations will be conducted of Fourier Transform Infrared Spectroscopy (FTIR) and tunable diode laser (TDL) technologies for combustion optimization and alternate NOx measurements.	12/31/2009	Technical Report
Pulverizer Modifications for Improved System Performance: This project will conduct assessments and provide data of performance improvement (including fineness, throughput, distribution) with add-on hardware. It will also assess new and emerging technologies for fineness measurement and impacts of fuel quality.	12/31/2009	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Emerging Combustion NOx Control Technologies Web Site: This project provides for the continuation of the Emerging Combustion NOx Control Technologies website, a “living document” providing up-to-date findings, performance data, and performance impacts of all combustion-based NOx controls.	2010	Technical Resource
Demonstrations of FTIR / TDL applications: Site demonstrations will be conducted of advanced Fourier Transform Infrared Spectroscopy (FTIR) and tunable diode laser (TDL) technologies for combustion optimization and alternate NOx measurements.	2010	Technical Report

Product Title & Description	Planned Completion Date	Product Type
<p>Continuous combustion optimization through multipoint O₂/CO measurement: A demonstration will be conducted of continuous multipoint oxygen/carbon monoxide (O₂/CO) measurement technologies with sufficient resolution across the duct to provide operators with real-time information regarding fuel/air distribution. Host site applications will document potential boiler efficiency improvements and associated NOx reductions.</p>	2010	Technical Update
<p>Demonstration of a Continous Unburned Carbon Monitor - Technical Update: One necessary component associated with identification of mill or boiler combustion performance is the real-time monitoring of fly ash unburned carbon levels. The current project focuses on a new approach that was initially explored within the Cyclone Interest Group that relates changes in fly ash size distribution to fly ash carbon content, which can be potentially monitored in real time on an in situ basis.</p>	2010	Technical Update
<p>Results of site assessments on methods of improving pulverizer performance: This technical report will summarize data and findings on advanced methods of improving pulverizer performance through add-on hardware and other methods.</p>	2010	Technical Report
<p>Field Test Results of Mercury Capture Methods: A final report will be published on demonstration of methods of minimizing mercury levels through changes in the combustion process.</p>	2011	Technical Report
<p>Integration of Multipoint O₂/CO Measurements with an Optimizer: Full benefit of multipoint O₂/CO measurements are best realized in real time, with potential coordinated use with an optimizer. The current project will assess how best to utilize concentration gradient information in coordination with an optimizer to maintain efficient boiler operation.</p>	2011	Technical Update

P71.003 Solutions for Fuel Quality Issues (103508)

Issue

Fuel quality issues, such as slagging and fouling of furnace and convection tubes, significantly affect unit reliability and operations, leading to increased downtime and negatively affecting heat rate. Solutions developed through this project can enhance fuel flexibility, unit reliability, and combustion performance.

Description

Specific tasks and goals include

- Site demonstrations to assess innovative methods of mitigating ash deposition, including ceramic coatings, pulse-based sootblowers, additives, and other advanced methods
- Development and application of ash deposition predictive models based on Computer Controlled Scanning Electron Microscope (CCSEM)/Fractionation
- Participation in the Coal Quality Interest Group (CQIG) to share best practices and experiences
- Enhancement of guidelines for identifying and solving ash deposition-related problems

Value

- Achieve substantial cost savings through improved boiler performance
- Increase revenue through regained lost capacity
- Benefit from increased flexibility in fuel sourcing

How to Apply Results

Participants involved in boiler performance can use project findings and deliverables in their efforts to mitigate ash deposition and other coal quality issues at their coal-fired facilities. In addition, predictive tools and guidelines developed through this program will allow more accurate assessments of the costs and performance impacts of alternative coal selections.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Demonstration of Novel Slag Management Technologies: Site demonstrations will be conducted to assess and evaluate a variety of innovative methods to mitigate ash deposition. Examples may include using impulse generators (such as the Impulse Deposit Removal System), additives, and intelligent sootblowing routines integrated with commercial optimizers.	12/31/2009	Technical Update
Slagging and Fouling Guidelines: The EPRI Slagging and Fouling Guidelines will be enhanced based on the latest case studies conducted at members' sites and the best practices that have been documented.	12/31/2009	Technical Report
Coal Quality Interest Group: This interest group will provide a forum where participants can share information, exchange ideas, and define and prioritize coal quality-related efforts. A minimum of one webcast and one onsite meeting will be held.	12/31/2009	Workshop, Training, or Conference
Slagging Prediction Assessments for Members: Slagging and fouling estimates will be made as a function of ash mineralogy, using the advanced slagging predictor, provided to funders on an as-needed basis.	12/31/2009	Technical Resource

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Coal Quality Interest Group: This interest group will provide a forum where participants can share information, exchange ideas, and define and prioritize coal quality-related efforts. A minimum of one webcast and one onsite meeting will be held.	2010	Workshop, Training, or Conference
Slagging Prediction Assessments for Members: Slagging and fouling estimates will be made as a function of ash mineralogy, using the advanced slagging predictor, provided to funders on an as-needed basis.	2010	Technical Resource

Product Title & Description	Planned Completion Date	Product Type
Coal Quality Interest Group: This interest group will provide a forum where participants can share information, exchange ideas, and define and prioritize coal-quality-related efforts. A minimum of one webcast and one onsite meeting will be held.	2011	Workshop, Training, or Conference
Slagging Prediction Assessments for Members: Slagging and fouling estimates will be made as a function of ash mineralogy, using the advanced slagging predictor, provided to funders on an as-needed basis.	2011	Technical Resource

P71.004 Coal and Air Flow Measurement and Control (062029)

Issue

Monitoring and control of burner-specific air/fuel ratios must be improved to reduce emission levels (such as NO_x, loss on ignition [LOI] and mercury), optimize boiler efficiency (and consequently fuel costs and CO₂ levels), and minimize performance issues such as fireside corrosion, slagging and fouling. Fuel/air maldistributions will become less forgiving as emission levels become increasingly stringent.

Description

EPRI will continue to investigate and identify solutions for controlling the distribution of air and pulverized coal flow to individual burners. Towards this goal, EPRI will continue with studies of coal flow control devices at its Particulate Flow Laboratory (PFL). The efforts, when appropriate, could be supplemented by advanced numerical modeling analysis methods, along with field validation testing. In addition, this program will also assess methods of improving secondary combustion air flow measurement and control, which is equally crucial for optimum NO_x and efficiency.

Value

- Lower emissions
- Reduce fuel costs
- Improve boiler operation
- Minimize operability issues such as fireside corrosion and unburned carbon in ash

How to Apply Results

Participants can employ project findings and deliverables in their efforts to resolve coal and combustion air flow distribution issues at their coal-fired facilities for the purpose of improving emissions and performance. Benefits and applications may include insights into optimizing existing splitter arrangements, utilizing coal and air flow measurement technologies, and integrating these technologies into an optimization routine.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Assessment of Coal Flow Splitters and Control Devices: The PFL rig will be deployed to investigate three-way and four-way coal flow splitter devices to support the development control methods or other splitter designs based on participants' interest. Other designs, such as classifiers typically found in ball-tube mills, can be tested and will be selected by project participants.	12/31/2009	Technical Report
Combustion Air Flow Measurement and Control: Areas of study may include assessments of issues that affect air measurement devices such as temperature stratification, development of cost-effective methods to measure individual flows on T-fired windboxes, and support for field demonstrations of advanced measurement methods.	12/31/2009	Technical Update
Development of Portable Dynamical Acoustic Coal Flow Sensor: A portable coal flow measurement device will be developed and field tested at a number of member plants. This device is based on results of tests at the EPRI Coal Flow Loop and uses the dynamical signal concept developed by Foster Miller, Inc.	12/31/2009	Technical Report
Power Plant version of Rotating Sampling Port: Test results will be published of a prototype rotating test port designed for power plant environments. The device will allow test crews to sample coal pipe traverse sections in multiple directions, thereby allowing more representative coal pipe sampling than when fixed ports are used.	12/31/2009	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Portable Coal Flow Measurement/Diagnostic Tool: Full-scale demonstrations will be conducted of portable coal flow measurement technology.	2010	Technical Report
Field evaluation of dynamic coal flow control methods: Performance evaluations will be made of emerging technologies to control coal flow to individual burners.	2010	Technical Report
Field demonstrations of combustion air flow measurement methods: Performance evaluations will be made of emerging technologies to control air flow to individual burners.	2010	Technical Report

P71.005 Heat Rate and Cost Optimization (051807)

Issue

Improving heat rate can reduce the cost of operation through fuel savings and increased availability. In addition, improving heat rate is the by far the most cost-effective method and the only “ready now” method of reducing CO₂ levels.

Description

This project group will develop and demonstrate a variety of deliverables and services that promote optimal heat rate and minimal cost of operations. Specific efforts will include intelligent sootblowing (ISB); technology transfer vehicles such as conferences, workshops, and webcasts; optimization guidelines; tuning guidelines; and combustion diagnostics (e.g., the Flame Doctor), applications, and enhancements. In addition, participation will include membership in the Heat Rate Interest Group (HRIG), where best practices, information sharing, and prioritizing available resources are discussed. Finally, this project will house the Productivity Cost Optimization Interest Group, dedicated to seeking heat rate improvements of 1% or greater through cost-effective operational modifications, and significantly higher through more capital-intensive improvements.

Value

- Reduce fuel costs
- Improve availability and emissions goals with existing hardware
- Realize future benefits, including reducing CO₂ emissions at costs orders-of-magnitude less than those of post-combustion options

How to Apply Results

Participants can use project deliverables in assessing and implementing tools and technologies consistent with improved plant performance and lowered heat rate and CO₂ emissions. In addition, participants of full-scale demonstrations, which are available to all program members, will gain first-hand experience with issues and solutions. Deliverables should enable participants to apply findings and best practices at their units, enabling savings in fuel costs, reduced CO₂ emissions, and increased productivity and availability.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Heat Rate Improvement Conference: This project includes this conference and resulting proceedings on all aspects of heat rate. The conference is expected to be a three-day event that includes technical presentations, panel discussions, and information sharing.	12/31/2009	Technical Report
Cooling Tower Technology Seminar and Symposium: A collection of industry experts will conduct a training seminar and two-day conference with proceedings.	12/31/2009	Technical Report
Guidelines for Implementation of Heat Rate Programs: This report will provide a summary of the first three years of efforts in Production Cost Optimization.	12/31/2009	Technical Report
Beta Program for T-Fired Flame Doctor Application: Demonstration tests will be conducted at multiple sites.	12/31/2009	Technical Update

Product Title & Description	Planned Completion Date	Product Type
Web conferences focusing on key Heat Rate related topics.: Web conferences will be conducted focusing on key heat-rate-related topics as determined by funders.	12/31/2009	Workshop, Training, or Conference

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Economic evaluation of fuel quality impacts on heat rate: This project will quantify the impacts on combustion performance of key fuel parameters such as moisture content, volatility, and ash.	2010	Technical Report
Web conferences focusing on key Heat Rate related topics: Web conferences will be conducted focusing on key heat-rate-related topics as determined by funders.	2010	Workshop, Training, or Conference
Production Cost Optimization Phase 2 Implementation: Production Cost Optimization (PCO) Phase 2 will add capital projects to the operating improvements in Phase 1 to achieve at least 2% overall efficiency improvement and CO ₂ reduction at each unit.	2010	Technical Update
Plant Experiences Meeting: This members-only meeting allows plant operators and engineers to discuss engineering solutions to operating and performance problems.	2010	Workshop, Training, or Conference
Intelligent Sootblowing Workshop: The biennial Intelligent Sootblowing (ISB) Workshop brings together utilities and technology developers to assess results from demonstrations and discuss technological improvements.	2010	Workshop, Training, or Conference
Feedwater Heater Technology Seminar and Conference: This seminar and conference bring together industry experts from utilities and vendors to discuss current issues and R&D needs.	2010	Workshop, Training, or Conference
Production Cost Optimization Phase 2 Completion: The PCO Phase 2 final report will document the sources of the 2% overall efficiency improvement and CO ₂ reduction at each unit.	2011	Technical Report
Heat Rate Improvement Conference: This biennial event brings together performance experts from utilities, vendors, and contractors to compare the latest results in heat rate improvement and identify additional R&D needs.	2011	Workshop, Training, or Conference
Condenser Technology Seminar and Conference: This seminar and conference bring together industry experts from utilities and vendors to discuss current issues and R&D needs.	2011	Workshop, Training, or Conference