

# New Combustion Turbine/Combined-Cycle Plant Design and Technology Selection - Program 80

## Program Overview

### Program Description

Gas turbines and combined-cycle plants increasingly are being selected for new generation additions and replacements for retired plants. Electrical capacity and generation from natural gas fuel are forecasted to increase in the coming years due to favorable gas supply availability. Recently, gas supply reserves have been revised upward, based on significant additions from shale formations and new liquefied natural gas (LNG) sources. Competitive fuel prices have resulted in increased dispatch of combined-cycle plants. Favorable gas pricing also has renewed interest in distributed generation and cogeneration opportunities with gas turbines. Combustion turbine-based plants often are selected due to their lower capital costs compared to coal and nuclear energy, and their capacity typically is used to complement intermittent wind and solar generation. Gas turbine and combined-cycle technologies continue to evolve, providing significant efficiency gains and relative improvements in installed cost. These factors, combined with a general trend towards less-carbon-intensive generation, portend an expanding role for gas turbines and combined-cycle plants in the coming decades.

Informed decisions about gas turbine technologies and plant designs are especially important because design choices can have a profound impact on operability and performance. Technology selection affects efficiency, emissions, availability, maintainability, and durability. Air and water environmental control technologies are needed to meet regulatory requirements. The ability to fire fuels of variable composition while meeting emission constraints is important in locations that may receive natural gas or LNG from multiple sources. Flexible operational capabilities are needed for optimal plant dispatch, and planners need to understand coming trends and potential improvements for future growth. Plant engineering designers are confronted by a growing number of combustion turbine/combined-cycle (CTCC) plant offerings with unique heat recovery steam generator (HRSG) and steam turbine configurations, aimed at particular market missions (peaking, intermediate/cycling, and baseload). Information about and analyses of factors affecting these performance parameters are key to achieving a design optimized on specific generation needs.

The Electric Power Research Institute's (EPRI's) New Combustion Turbine/Combined-Cycle (CTCC) Plant Design and Technology Selection program (Program 80) provides the information and analysis needed to select combustion turbine technologies and specify combined-cycle plant designs for today's new generation requirements while planning for future technological advances.

### Research Value

The research in this program helps engineers and project developers select and specify appropriate equipment for new plants that have the flexibility to start quickly, operate efficiently at varying loads, and fire fuels of varying composition while meeting regulatory emission limits. Improved gas turbine plant operation is achieved through an overall life-cycle approach, which includes a balanced understanding of capital and O&M costs, performance improvements, and technical risks associated with new high-efficiency turbine designs and the market contexts in which they operate. The program focuses on identifying risk issues and addressing the most significant plant design improvements that differ from the previous combined-cycle build-out. Benefits include:

- Optimal plant technology selections for generation market niche: distributed generation, peaking, cycling, intermediate, or baseload;
- Managing technology risk helps control operation and maintenance expenditures; and
- Objective, expert assessment of technology trends and worldwide experience can improve procurement decisions.

## Approach

Up-to-date information and evaluations enable better procurement decisions and help minimize costs while optimizing plant performance, reliability, and operational flexibility for simple-cycle and combined-cycle combustion turbine plants.

- Document current information from EPRI durability/failure analyses, industry contacts, conferences, periodicals and news releases on industry trends, new equipment offerings and capabilities, and technical risk issues relevant to technical selection and decisions related to new project development and procurement
- Obtain reliability statistics on specific gas turbine models and provide analysis
- Prepare guidelines and specifications directly applicable to new project development, incorporating industry experience and related EPRI R&D
- Develop software designed to provide life-cycle cost perspective on O&M costs and risks
- Identify environmental and regulatory issues affecting new project planning

## Accomplishments

EPRI's New Combustion Turbine/Combined-Cycle Plant Design and Technology Selection program provides an objective, timely, life-cycle perspective on technology choice and improved plant design.

- *Combustion Turbine Experience and Intelligence* reports and project risk reports provide concise analyses of subjects of topical interest, including current and emerging CTCC designs and cycles, reliability issues, maintenance strategies, industry trends, and related market conditions.
- CTCC technology durability, design, and performance reports cover original equipment manufacturer (OEM) combustion turbine product lines, including design features, related risk concerns, and reliability, availability, maintainability-durability (RAM-D) experience. Component failure risk and durability information is based on in-depth studies of fleet-leading issues. All 50-Hz and 60-Hz models over 10 megawatts (MW) are covered, including advanced and upgraded mature engines. Procurement guidelines and specifications incorporate lessons learned from recent plant experience to support technical bid packages.
- Plant design, repowering, and environmental siting reports cover design features, risks, and operating experience of heat recovery steam generators, steam turbines, and electrical generators, as well as integration in an operationally flexible plant design. Emissions control equipment is described, and regulatory trends are monitored. Software provides model-specific O&M cost estimates. Design provisions are identified for plant operational flexibility and fuel variability appropriate for generation mission.

## Current Year Activities

The program R&D for 2012 will focus on creating additional procurement guidelines and specifications and on gas turbine-based plant designs offering higher overall efficiency and lower emissions from startup to shutdown with improved cycling capability and low-load operation. Specific efforts will include:

- Following current subjects of interest in *Combustion Turbine Experience and Intelligence* reports
- Identifying new models, capabilities, and features in *Gas Turbine Product Line Design Evolution and RAM-D Issues* reports, and documenting emerging risk issues affecting durability
- Developing Engineering, Procurement, Construction (EPC)-style procurement specifications and guidelines that describe equipment and system design features for improved plant operability and fuel flexibility
- Enhancing maintenance life-cycle costing capability in Combustion Turbine/Combined-Cycle O&M Cost Analyzer software

## Estimated 2012 Program Funding

\$0.9M

## Program Manager

John Scheibel, 650-855-2446, jscheibe@epri.com

## Summary of Projects

Project Number	Project Title	Description
P80.001	Experience-Intelligence Reports and Project Risks	Project reports provide concise analyses of subjects of topical interest, including current and emerging CTCC designs and cycles, reliability/durability issues, maintenance strategies, industry trends, and related market conditions. Additional reports address specific project risk issues of interest to members.
P80.002	CT Technology: Durability, Design and Performance	Project reports cover CT product lines from major OEMs, including design features, related risk issues, and RAM-durability experience. All 50-Hz and 60Hz models over 10 MW are covered, including advanced and upgraded conventional engines.
P80.003	Plant Design, Repowering and Environmental Siting	Project reports cover design features and procurement specifications for commercially available combined-cycle plant equipment such as heat recovery steam generators (HRSG), gas and steam turbines, electrical generators, condensers, and cooling towers, and include best practices for integration in an operationally flexible plant design. The focus is on significant design improvements that differ from the previous plant build-out. Air emissions control and water usage equipment is described, and regulatory trends are monitored. Software tools provide rapid plant conceptual design and model-specific performance and cost estimate comparison. As equipment innovations occur, such as when new materials are introduced in the HRSG or new features are introduced in steam turbines to improve efficiency, existing reports and software are updated.

### P80.001 Experience-Intelligence Reports and Project Risks (067359)

#### Key Research Question

Technical advances and issues surrounding combustion turbine (CT) and combined-cycle (CC) plants are major factors in new generation decisions, and the impact of those decisions will be felt for years to come. To optimize use of new technologies, plant managers and technical staff need objective, concise knowledge of innovation drivers and industry experience.

CT/CC plant owners and developers are challenged with multiple considerations and objectives in the plant design and selection of technology. A balanced approach to risk identification and cost allocation is essential in the technical development and financial strategy of any new plant project. For example, CT maintenance can cost two to three times the price of the original equipment over the project life. CT owners need to consider major maintenance costs during project development and recognize the technical maturity of particular turbine models. CT/CC project engineers must consider the many elements affecting plant operability and life-cycle costs. In addition, owners and developers need to understand price trends in fuel and electricity markets, and their impact on plant dispatch and profitability. Longer term, owners and operators need to consider the consequences of climate change legislation leading to carbon capture with CT/CC modifications in new plants and possibly retrofit applications.

### Approach

EPRI collects and analyzes information about current and emerging CTCC designs and cycle configurations, and publishes the results in a series of concise reports supplemented by technical presentations. Topics covered include emerging technologies and processes that could affect future gas turbine and combined-cycle plant designs, commercially available technology comparisons, and projected trends in electricity and natural gas markets. Topics also include subjects such as best practices for fuel gas line cleaning, guidance on steam blows during commissioning, overviews of CT hot-section design features and durability issues, advanced clearance control techniques, emerging alternative parts suppliers, compressor dependability analyses, studies on low-NOx combustion instability studies, alternative fuel firing impacts, zero liquid discharge, carbon capture processes, air-cooled generator issues, and other topics as suggested by members.

In addition, project risk assessment reports help define and quantify risks associated with investment in new CT technologies. Guidance covers decisions about up-front maintenance strategies, such as self-managed maintenance or long-term contracts offered by the OEM or third parties. The INformation database of combustion TURBine engines (INTURB) for CT owners and operators provides a worldwide directory to facilitate contact with peers to discuss model- and configuration-specific concerns affecting procurement decisions. More in-depth special studies may examine detailed aspects of project risk such as the electricity market, natural gas supply, and the timing and impact of carbon capture and credits in the marketplace.

### Impact

EPRI reports provide the background and analysis to evaluate various technology and configuration options, allowing program members to:

- Take full advantage of lessons learned in new and existing CTCC plants through concise, current information on new technology developments and issues affecting efficiency, emissions, durability, reliability, and plant operating flexibility to meet dispatch demands;
- Help mitigate technology and market risk for new CTCC project development through evaluation of alternative maintenance approaches and insights on natural gas and electricity markets; and

Understand technology trends likely to be incorporated in the next generation of equipment/plant design

### How to Apply Results

Reports serve as a resource for understanding major components of risk in project development and the use of insurance and maintenance contracts to mitigate a portion of the technical risk. Insights on model maturity and alternative parts suppliers support maintenance strategy planning. Other EPRI studies are employed to address project stakeholder concerns about equipment reliability risks and impacts from changing fuel and electricity market conditions. The INTURB CT owners' directory can help identify other companies and contacts potentially able to provide valuable information and lessons learned from experience with equipment.

### 2012 Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>CT Experience and Intelligence Reports:</b> Concise reports in article format provide analysis of subjects of topical interest, including current and emerging CTCC designs and cycles, reliability/durability issues, maintenance strategies, industry trends, and related market conditions. Reports, supplemented by technical presentations and webcasts, are compiled annually into a single report.</p>	12/31/12	Technical Update

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Project/Technical Risks Assessment:</b> Reports address subjects of topical interest to members and update reports addressing project risk.	12/31/13	Technical Update
<b>CT Experience and Intelligence Reports:</b> Reports address approaches to managing risks and improving financial performance in gas turbine projects.	12/31/13	Technical Update

## P80.002 CT Technology: Durability, Design and Performance (104059)

### Key Research Question

Understanding the design features of each gas turbine model and their relationship to overall capabilities and possible risks is a challenge. Project developers and electricity generation owners and operators need an in-depth perspective on technology design evolution, potential risks and benefits, as well as operation and maintenance (O&M) implications of new and upgraded model offerings for all major original equipment manufacturer (OEM) suppliers. When generating technologies are being selected, the mission requirements (baseload, daily start-stop, peaking, or electrical T&D support) influence the relative importance of the major competing goals of fuel efficiency, operational flexibility, and technical risk. Gas turbine manufacturers continue to add new and upgraded models to their combustion turbine (CT) product lines. New technology is improving performance, cycling capability, and durability of engines. Major innovations introduced by the OEMs to improve performance and correct deficiencies need to be evaluated and their risk attributes assessed.

### Approach

This project periodically updates a multivolume series of reports, covering heavy-duty and aero-derivative engines over 10-MW capacity that are most frequently used in power generation applications. These reports summarize design characteristics of the turbine product lines manufactured by General Electric, Siemens (including Siemens-Westinghouse), Mitsubishi, Alstom, Pratt & Whitney, and Rolls-Royce. Smaller CTs produced by Solar, Hitachi, Kawasaki, and others used in distributed generation and cogeneration applications also are addressed. Each report includes a pedigree matrix, detailing design attributes in a standard format. Technical risk design features are identified, and relevant technical issues and experience are discussed. Reliability, availability, and maintainability (RAM) statistics are provided for selected models to further identify the overall model maturity and quantify RAM performance. Models of particular interest include advanced air- and steam-cooled F-, G-, and H/J-class machines, and engines suited for highly cyclic duty. The project seeks additional information about advanced models in design and field verification as opportunities arise.

### Impact

- High-quality design assessments and in-service data support high-confidence technology selection and procurement decisions.
- Independently derived RAM statistics can be used in model evaluations.

### How to Apply Results

Members can use these detailed reports to identify technical attributes and associated risks when planning generation additions with gas turbines. In the procurement process, the information is used to evaluate equipment and select appropriate technology.

## 2012 Products

Product Title & Description	Planned Completion Date	Product Type
<b>General Electric Aero-Derivative CT Product Line - Design Evolution and RAM-D Issues:</b> This report describes the design evolution, features, and performance of the LMS100, LM6000, and LM2500 gas turbine models, including recent upgrades. Current reliability and availability data is included. Technical issues affecting maintenance, durability, reliability, and life-cycle costs are reported. Maintenance intervals and activities are described. Existing sites are listed.	12/31/12	Technical Update
<b>Small Combustion Turbines for Distributed Power Generation and Cogeneration (Solar, Kawasaki, Hitachi):</b> This report describes the design evolution, features, and performance of the gas turbine models, generally in the range of 5-30 MW, manufactured by Solar, Kawasaki, Hitachi, MAN and others, including recent upgrades. Approaches to maintenance are described.	12/31/12	Technical Update
<b>General Electric Heavy-Duty CT Product Line - Design Evolution and RAM-D Issues:</b> This report describes the design evolution, features, and performance of the GE 7FA/9FA/6FA, 7FB/9FB, 7H/9H, 7EA/9E, and 6B/6C heavy-duty gas turbine models, including recent upgrades. Current reliability and availability data are included. Technical issues impacting life-cycle costs affecting maintenance, durability, and reliability are reported. Existing sites are listed.	12/31/12	Technical Update
<b>Mitsubishi CT Product Line - Design Evolution and RAM-D Issues:</b> This report describes the design evolution, features, and performance of the MHI M501F/M701F, M501G/M701G, and M501D/M701D heavy-duty gas turbine models, including recent upgrades. The status of the M501J/M701J also will be covered. Current reliability and availability data are included. Technical issues impacting life-cycle costs affecting maintenance, durability, and reliability are reported. Existing sites are listed.	12/31/12	Technical Update

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Update to Heavy Duty CT Product Line Reports - Design Evolution and RAM-D Issues:</b> Reports on large CTs by Siemens, Alstom, Mitsubishi, and General Electric are updated on a periodic basis to include the latest product offerings and capabilities, descriptions of durability and reliability issues, and site installations.	12/31/13	Technical Update
<b>Update to Aero-Derivative CT Product Line Reports - Design Evolution and RAM-D Issues:</b> Reports on aero-derivative CTs by Rolls-Royce, Pratt & Whitney, and General Electric are updated on a periodic basis to include the latest product offerings and capabilities, description of durability and reliability issues, and site installations.	12/31/13	Technical Update
<b>Update to Small CT Product Line Reports:</b> Reports on small CTs by Solar, Kawasaki, Hitachi, and others will be updated on a periodic basis.	12/31/13	Technical Update

**P80.003 Plant Design, Repowering and Environmental Siting (067360)**

**Key Research Question**

A plant design must satisfy multiple requirements, including increasingly stringent environmental regulations, high efficiency and reliability, and good operational flexibility. Features such as rapid startup and load change and low-load operation are highly valued in many markets, and some regions may require that plants have "carbon capture-ready" provisions. New regulations potentially could limit annual CO<sub>2</sub> production and further limit transient air emissions during startups. Water use and management is another growing environmental constraint. The drive for higher efficiency has led to innovations in the steam bottoming cycle, including operation at higher pressures and temperatures, requiring advanced materials in the heat recovery steam generator (HRSG) and steam turbine. OEMs are introducing plant configurations designed for certain missions. For instance, the FlexPlant 30 focuses on high efficiency with good startup times, whereas FlexPlant 10 focuses on rapid startup and reduced capital expenditures. Repowering an existing fossil steam site using natural gas-fired combustion turbines requires additional considerations. Plant developers need high-quality information and insight on best design practices and features. An integrated approach that includes evaluation of plant performance, capital costs, O&M costs, and market conditions on an overall life-cycle cost basis provides an opportunity for optimized plant design.

**Approach**

Reports focus on aspects of plant equipment and sub-systems that improve flexibility, durability, and efficiency. Procurement guidelines and specifications incorporate "lessons learned" from the previous build-out of combined-cycle plants. Software provides a framework for estimating operation and maintenance (O&M) costs based on specific CT model and operating duty on a life-cycle cost basis. Other software and studies provide detailed conceptual design and life-cycle cost analysis.

**Impact**

- Develop more competitive designs and improve equipment procurement decisions by using detailed information on combined-cycle design features, performance, and reliability trade-offs.
- Enhance operational flexibility by identifying and evaluating new plant design features.
- Assess air and water environmental control options.
- Quantify and compare plant conceptual designs and life-cycle costs based on user-defined scenarios.

**How to Apply Results**

Reports provide information for understanding equipment designs, making procurement decisions, and determining the most effective configurations to meet duty cycles and flexibility requirements. Equipment procurement guidelines can be used directly to support competitive bidding activities. Software quantifies the impact of operating scenarios on O&M costs and provides an overall life-cycle perspective.

**2012 Products**

Product Title & Description	Planned Completion Date	Product Type
<p><b>CO Oxidation Catalyst and Selective Catalytic Reduction of NOx: Design Best Practices and Procurement Guidelines:</b> This report describes the best practices for design and procurement of CO oxidation and NOx reduction (SCR) catalysts.</p>	12/31/12	Technical Update
<p><b>Gas Turbine/Combined-Cycle Environmental Control Technology and Regulatory Issues Handbook:</b> This report update includes information on the technical assessment of equipment for emissions controls and information on regulatory guidance for plant siting in the United States and select international regions. Typical regional permit levels for priority pollutants are included. Trends in new regulatory requirements are discussed.</p>	12/31/12	Technical Update

Product Title & Description	Planned Completion Date	Product Type
<b>Gas Turbine Equipment Selection Best Practices and Procurement Guidelines/Specifications:</b> This report provides EPC-style procurement specifications and best practices guidelines for heavy-duty gas turbines commonly used in combined-cycle, simple-cycle, and cogeneration applications.	12/31/12	Technical Update
<b>Repowering Studies and Assessments:</b> This report will provide costs and performance data for repowering a fossil steam plant and summarize lessons learned in the reuse of existing steam turbines and other balance-of-plant equipment.	12/31/12	Technical Update
<b>CTCC O&amp;M Cost Analyzer:</b> This software update is an Excel® spreadsheet-based software that estimates the O&M costs for combined-cycle and simple-cycle plants for user-specified operating scenarios. CT model-specific maintenance costs are based on component replacement and repair costs, life estimates, and maintenance intervals. This product is shared with Program 79 (Combustion Turbine & Combined Cycle O&M).	12/31/12	Software
<b>SOAPP-CT Workstation, Initial Access:</b> State-of-the-Art Power Plant (SOAPP) software provides capital costs and performance estimates for a life-cycle cost perspective on new combustion turbine/combined-cycle plant designs. New Program 80 funders obtain an initial one-year, two-user license to SOAPP-CT Workstation as part of a three-year Program 80 commitment. Future versions are accessed and supported through continuing supplemental project funding.	12/31/12	Technical Resource

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Cyclic Operation of Combined-Cycle Plants: Designs, Maintenance, Reliability and Cost Impacts:</b> Updates to existing reports on "lessons learned," repowering applications, and impact of cycling will be made periodically. A new version of the CTCC O&M Cost Analyzer software will be released annually with updated costs and enhancements. New and updated procurement guidelines, including updates to the HRSG procurement specifications, will be issued based on new information and experience from members.	12/31/13	Technical Update
<b>Lessons Learned in Startup and Commissioning of Simple-Cycle and Combined-Cycle Plants:</b> Update to an existing report on "lessons learned" with additional content from recent plant startups.	12/31/13	Technical Update
<b>Equipment Selection Best Practices and Procurement Guidelines/Specifications:</b> New and updated procurement guidelines, including updates to the HRSG procurement specifications, will be issued based on new information and experience from members.	12/31/13	Technical Update
<b>CTCC O&amp;M Cost Analyzer:</b> An updated version of the CTCC O&M Cost Analyzer software will be released annually with updated costs and enhancements.	12/31/13	Software

## Supplemental Projects

### Repowering Fossil Steam Plants with Combustion Turbines (072059)

#### Background, Objectives, and New Learnings

Many conventional fossil steam plants face uncertainty in future operation due to environmental regulations that would require significant upgrades to meet new emission standards. The capital expenditures required may be relatively high, particularly for moderately-sized to smaller-sized units firing coal or heavy oil. Older units may need significant boiler refurbishment to continue operation into the future. A reduction in carbon emissions also may be desired. One option commonly considered is conversion to a natural gas-fired combined-cycle configuration while maximizing reuse of existing equipment. This option is being more frequently implemented in the industry now that a period of secure availability of natural gas and relatively low fuel prices is projected. The objective of this project is to support the decisions involving the future of existing fossil steam plant assets in the generating fleet, particularly for those assets that require capital improvements and can no longer continue to operate at the status quo. In particular, owner/operators need to assess alternatives based on natural gas firing, such as repowering with combustion turbines in a combined-cycle configuration and either reusing the steam turbine(s) or installing a new combined-cycle unit at the existing plant site. This project adds the experience and lessons learned in repowering over the last decade to the background of EPRI experience in repowering to provide general guidance on repowering configurations, cost and performance attributes, and considerations unique to repowering existing fossil steam plants. These lessons then are applied to specific site repowering, leading to additional new learnings.

#### Project Approach and Summary

EPRI will conduct targeted evaluations of existing fossil plants to identify the technical and economic issues associated with converting conventional fossil steam units to combined-cycle operation. EPRI will use an extensive background from previous repowering studies and modeling tools such as the SOAPP Combustion Turbine/Combined-Cycle and SOAPP Repowering Workstations to provide an initial screening evaluation. After initial screening and focus, a detailed engineering evaluation of repowering the designated site will be performed. Information on completed repowering projects will be gathered and lessons learned from completed projects and studies will be compiled.

#### Benefits

Results from this project provide plant owners with a thorough assessment of costs to repower their sites with combustion turbines in a combined-cycle configuration, including reuse of existing equipment such as the steam turbine. Comparisons of performance and life-cycle costs with an all-new combined-cycle plant lead to better-informed decisions regarding repowering options. In addition, updated repowering guidelines summarize lessons learned from previous repowering projects that can be applied to other plants in the owner's fleet.

## Carbon Capture for Combined-Cycle Plants (068863)

### Background, Objectives, and New Learnings

If legislation mandating a reduction in CO<sub>2</sub> production from fossil power plants is enacted, natural gas-fired combustion turbine/combined-cycle (CTCC) plants might also be required to capture and store carbon dioxide (CO<sub>2</sub>). CTCC plants produce less than half the CO<sub>2</sub> per MWh of their pulverized coal (PC) counterparts, but they still are CO<sub>2</sub> emitters. As companies plan their future generation portfolios, there is growing interest in the feasibility and costs associated with applying large-scale CCS to CTCC plants and the impact on performance. That leads to questions about future emissions from CTCCs, including:

- Will highly dispatched CTCCs be challenged to reduce their CO<sub>2</sub> emissions level
- Will CTCC plants require retrofit in the future
- What preparations and pre-investments could be made to make the plant CO<sub>2</sub> capture-ready
- What are the corresponding cost, performance, and operational implications of retrofitting CCS

The objective of this project is to provide CTCC owners/operators with the information they need to understand the impact that a CCS retrofit would have on their plant performance and economics. This project provides new learning in the cost and performance of retrofitting post-combustion advanced amine solvent-based CCS to an existing or new CTCC plant. For a new planned plant, the project includes recommended provisions to enable a less-costly retrofit with CCS at a later date (i.e. "capture-ready").

### Project Approach and Summary

EPRI will examine CO<sub>2</sub> post-combustion capture (PCC) on a combustion turbine combined-cycle (CTCC) power plant for retrofit or planned application. Based on a planned or existing CTCC power plant designated by a host participant, the study will highlight the technical and economic issues associated with applying advanced amine post-combustion capture technology, one of the most developed processes available today.

EPRI has extensive background in evaluation of new and retrofit coal-fired applications of CCS and currently is conducting a technical and economic assessment study of post-combustion capture on natural gas-fired combined-cycle plants as a means to reduce CO<sub>2</sub> emissions from a typical F-class 2x1 CTCC plant. The current study will compare costs and performance for the generic new-build and retrofit cases and provide background for examining site-specific CCS applications.

For this proposed project, EPRI will examine post-combustion capture on a CTCC power plant for retrofit applications. It will include the knowledge gained from previous coal plant studies and current CTCC plant study, including process design improvements uniquely applicable to CTCC plants such as exhaust gas recirculation to improve CO<sub>2</sub> capture economics, and integration of the heat recovery steam generator (HRSG) with the post-combustion capture plant to minimize reduction in steam turbine output.

### Benefits

Results from this project provide plant owners with a site-specific assessment of the costs to include carbon capture and compression in their designated site. Cost and performance for site retrofits then can be compared to generic differences between retrofit and new-build, leading to informed decisions regarding CCS options and risks. In addition, participants can gain insights into other host site configurations that can be applied to their own fleets.

## Combined-Cycle Plant Design, Cost and Performance Software (057519)

### Background, Objectives, and New Learnings

Companies in the electric utility industry increasingly find it difficult to allocate sufficient resources to study the latest developments, evaluate alternatives, and optimize solutions for new plants. The impact of different scenarios on plant cost and performance, and consequently on the most cost-efficient plant design, often is neglected. Competitive pressures have driven engineering towards more standardized designs, which offer cost/performance for “average” applications but often are sub-optimal for any specific application. State-of-the-Art Power Plant (SOAPP<sup>®</sup>) software products address these issues.

Starting with user-defined inputs and guidance from initial default values, the SOAPP Workstation validates inputs, sizes and costs equipment, and performs detailed performance and economic analyses of the resulting conceptual design. Outputs include plant performance summaries, equipment lists and sizing, capital costs and O&M costs, diagrams and drawings. Financial outputs include capital outlay schedules, capacity and energy payments, *pro forma* income and cash flow statements, and internal rates of return.

Ongoing support and development are key to providing an up-to-date software tool for the user and incorporating state-of-the-art information. The objectives of this supplemental project are to:

- Provide scientific tools for analysis of performance, design and profitability of power projects in a site-specific context to enable a life-cycle cost perspective on power plant projects;
- Provide development of the SOAPP-CT Workstation software for use by project participants; and
- Provide technology transfer and strategic decision support for developing new electric power generating plants

The SOAPP software enables the evaluation of alternatives through the scientific modeling and simulation of power plants, and generates substantial new learning by using feasible scientific and technical solutions for the problems of identifying and communicating state-of-the-art complex technical relationships. Accurate planning and optimized projects for minimum electricity cost, lessened environmental impact and maximum reliability, are made possible through the funders' use of the software for improved productivity of their technology assessment efforts and ability to evaluate potentially beneficial alternatives. Major technology trends related to new gas turbines and steam turbines underlie SOAPP software development. The SOAPP-CT Workstation software captures the performance and costs of these new state-of-the-art innovations.

### Project Approach and Summary

The project develops new versions of the SOAPP-CT Workstation to incorporate new design characteristics of combined-cycle plants, up-to-date performance and cost information, and additional enhancements, as well as supports funders through updates to the SOAPP website and preparation of training materials and communications to current and prospective funders.

### Benefits

The fully-integrated SOAPP-CT Workstation enables users to quickly develop a detailed plant conceptual design and then evaluate the impact of different equipment choices and design criteria on plant design, performance, emissions, and costs. This allows business and technical decisions to be made in concert, encouraging development of project-specific power plant designs with the lowest life-cycle costs. The CT Technology Modules summarize and compare viable, commercially available state-of-the-art technologies and can be used for general technology transfer and training. The Windows-based SOAPP software has an extensive on-line help function. The software and user manual are distributed on CD-ROM for installation on individual PCs.

SOAPP helps to optimize the numerous decisions tied to a typical \$200 to \$500 million combined-cycle project. Use of the SOAPP products can lead to better-informed decisions regarding construction of new power plants and the upgrading of existing plants, reducing the cost of electricity and environmental impact. The SOAPP-CT

Workstation reduces a task that otherwise could take several man-months of effort to less than an hour, resulting in productivity savings. More importantly, it enables users to evaluate many more alternatives than they could afford without SOAPP and thus achieve an optimal design. Substantial benefits can be realized when the use of the SOAPP-CT Workstation results in the choice of technologies that produce a different, more economical plant design.