Technology Transition Case Study

Carbon Capture Simulation Initiative (CCSI)

The Carbon Capture Simulation Initiative (CCSI) grew out of a series of meetings conducted in early 2010 in response to a Presidential memorandum, which charged a Carbon Capture and Storage (CCS) Task Force to overcome the barriers to widespread, cost-effective deployment of CCS technology. These meetings included representatives from DOE HQ, industry (including energy companies and technology providers), and technical leaders from the national laboratories and universities. The purpose of the planning meetings was to determine how computational modeling could be effectively used to reduce the time required to move new energy technologies from discovery to broad commercial deployment, which historically takes two to three decades. By meeting together, industry was able to explain barriers to technology development encountered by industry and provide information on the capabilities and limitations of modeling and simulation within an industry context, while laboratory and university leaders were able to explain how new advances in modeling, optimization and uncertainty quantification could address the barriers from an academic or scientific perspective. The resulting CCSI project plan focused on developing computational tools and models *to be used by industry* to accelerate the development and scale up of carbon capture technologies.

CCSI is led by the National Energy Technology Laboratory (NETL) and leverages the Department of Energy's national laboratories' core strengths in modeling and simulation, bringing together a complimentary set of capabilities from NETL, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Pacific Northwest National Laboratory. CCSI's academic participants (Carnegie Mellon University, West Virginia University, Princeton University, Boston University, and University of Texas) bring expertise in process synthesis and optimization, process control techniques for energy processes, multiphase flow reactors, and amine scrubbing. University participants serve as subcontractors to the national laboratories, providing specialized expertise. Overall, the project's technical team provides an excellent example of the significant accomplishments possible when bringing together the talent that exists across DOE to work collaboratively on an issue of national importance. A Board of Directors (BoD), consisting of the chief research officer of each laboratory, meets annually to review the program and offer guidance. An executive committee consisting of senior leadership from each lab (i.e., Focus Area Leader, Division Director, Department Head, Program Manager, etc.), who report to their lab's representative on the BoD, as well as two distinguished university researchers, provides high-level management of the program.

With a focus on impacting *industry's* ability to accelerate technology development, representatives from key industry partners participated in the initial planning. This was essential to ensure that the initial plan both met industry needs (i.e., addressed current industrial barriers to accelerated development) and was readily usable by industry within the constraints of their computational resources and expertise. In addition, because industry

involvement is vital to the success of CCSI, an Industry Advisory Board (IAB) was immediately formed and met with the CCSI Technical Team in February 2011, following the formal kickoff of the project earlier that month.*

The most significant contributors to the success of CCSI include the early and ongoing involvement of industry partners and the development of an innovative approach to managing intellectual property that fosters creativity, maximizes the contributions of all individuals, and promotes unity of the overall technical team. As testament to this unity, an industry representative remarked at an early IAB meeting that until he was told that the team represented five national laboratories and five universities, he had thought that everyone was from single institution based on how well everyone worked together.

CCSI Industry Partnership

CCSI developed a no-fee industry partnership program founded on prior industry-government research program experience and several innovative approaches. The CCSI Industry Advisory Board includes Energy Technology Providers (Babcock & Wilcox, General Electric, Alstom, ADA-ES), Design and Construction Companies (Fluor, URS, and previously Burns McDonald), Power Companies (Southern Company, Southern California Edison, American Electric Power, and previously Duke Energy), Oil and Gas companies (Chevron, ExxonMobil, Phillips 66), Chemical companies (Eastman, Air Products, and previously DuPont), Software companies (AspenTech, PSE, Ansys, Schneider Electric) and others (EPRI and previously Boeing).

CCSI and laboratory leadership identified a suite of initial partners who participated in the initial design of the overall program. This initial set of partners and program leadership then identified other suitable partners involved in carbon capture technology development who were subsequently recruited into the partnership. Membership generally included high level technical management of the partner companies (Vice-President Technology level and direct reports) as well as technical level leaders more familiar with the working level development of CCSI products.

Expectations were focused around industry partners providing substantial input to the program concerning program relevance, content, progress and directions. Where strong matches of technical interests occurred between partner companies and the Program, partners were further expected to provide collaborators to contribute directly to the technical program by working closely with specific technical teams. An outline describing the role of the IAB was developed at the beginning of the program and served to inform potential partners of their expected role and function.

Key features of the CCSI Industry Engagement program include:

- Early Involvement: Key partners were identified during the program formulation stage and were involved in the design of the overall project, the technical program, industry challenge problems and the form of industry engagement.

*Because NETL is a Federally operated national laboratory, the IAB interacts through the contractor-operated labs, reporting directly through LBNL, to meet the requirements of the Federal Advisory Committee Act (FACA).

- Targeted Partner Identification and Recruitment: The initial industry partners and CCSI Technical and Program leaders collaborated in identifying and recruiting additional partners at the start of the Program.
- Multi-level Participation: A tiered structure was developed that included senior technical management of industry partner organizations (referred to as the "Advisory Board" to support overall programmatic level progress and strategic direction guidance) as well as technical staff ("Collaborators") to engage directly with the CCSI development teams within the Labs. This tiered structure served to provide multiple levels of contact between partner companies and CCSI to facilitate feedback and review, while also ensuring continuity of partner company support and engagement (i.e., IAB interactions were not dependent on a single champion within the companies).
- Continual Interaction: In addition to collaborator involvement directly with the development teams at the working level, a monthly conference call process was implemented open to all industry participants. These calls allowed industry partners the opportunity to have regular exposure to detailed updates of individual program components, to provide regular direction and feedback, and to support planning and execution of the bi-annual program reviews.
- Regular Complete Program Reviews and Product Demonstrations: Bi-annual face-to-face programmatic reviews provided industry partners with a view of progress in all areas, an opportunity to test new product releases and interact with the tool developers, and the opportunity to recommend shifts in program direction and emphasis.
- Direct Input to the Initiative's Directions and Priorities: Industry participants are an integral part of overall program planning and at the individual technical task level, providing feedback and recommendations to CCSI Leadership and the technical teams. Examples of their input include selection of technology focus areas ("Industry Challenge Problem"), such as the initial decision to focus demonstration of the CCSI Toolset on solid sorbents followed by the decision to expand into conventional and advanced solvents. In addition, they provided input on the computer and software platforms that would maximize industry uptake and impact. To ensure compliance with the Federal Advisory Committee Act (FACA), IAB input occurs through LBNL since NETL is a Federally operated laboratory.
- Intellectual Property Flexibility: Considerable improvement of transfer of CCSI products to industry was enabled by an innovative approach to Intellectual Property (IP) management that involved a single contract and single point of contact for industry to license all program products, and secured shared property rights to CCSI products for all the partner laboratories while allowing for follow-on technology developments resulting from the utilization of the products to be owned by the users of the tools. This encourages uptake and use of the tools to improve capture technology and avoids the potential for intellectual property "contamination" that concerned many industry users.
- Creation of Pathways to Deeper Partnerships: CCSI worked closely with industry partners to identify the specific technology development programs that could be accelerated by the application of CCSI tools and developed cooperative relationships to further apply CCSI tools to these programs. While the opportunity for deeper partnerships was available to all of CCSI's industry partners, only some companies have elected to pursue

them. These have been pursued through a combination of cooperative research and development agreements (CRADAs) and nondisclosure agreements (NDAs) between individual companies and the required subset of the CCSI Technical Team needed to pursue the work. These mechanisms provided opportunities for partners to engage at a deeper level, better protect data and IP while continuing to utilize program talent, products and relationships. Specific results from these deeper partnerships benefit the companies involved and remain protected; however, the broader results, such as models validated at large scale, bring benefits to all members of the consortium by improving the overall CCSI Toolset.

CCSI Intellectual Property and Licensing

CCSI operates under a unique Intellectual Property Management Plan (IPMP). Implementation of the IPMP is one of the clearest reasons for the success of both the development of the CCSI Toolset and its ongoing transfer to industry partners. The IPMP is an innovative, integrated plan designed to facilitate a cohesive, collaborative technical team and enable a single point of contact for industry to license the toolset. The IPMP was created with the goal of enabling the collaborative nature of CCSI and mitigating the barriers that arise based upon eventual conflict over intellectual property rights. By agreeing up front to share any royalties equally among laboratories and giving each laboratory equal IP rights to everything developed under the project, the technical team could easily function as a single, unified team without worrying who was contributing to a project.

Additionally, the licensing terms state that any works derived from using the Toolset that contain a company's proprietary information will be owned by the company, clearly allowing industry to have rights to IP generated from their usage or modification of the Toolset. This element was essential to enable evaluation and use of the Toolset without concern of contamination of a company's IP as often occurs with software made available via certain Open-Source licenses.

To facilitate industry adoption of the tools, two mechanisms were put in place. First, the plan establishes a single lead laboratory as the primary licensing agent who also serves as the project's IP Lead. This provides a single point of contact for industry and other potential licensees without the need to negotiate separate agreements with each laboratory. Second, each laboratory has the right to use and modify all of the components of the CCSI Toolset for subsequent projects and has the right to license subsets of the Toolset. In addition, if the IP Lead does not secure commercial licenses within five years after the conclusion of the project, each lab has the right to license the entire Toolset. The primary licensing agent leads an IP Council, which includes representatives from all the lab's technology transfer offices. Together, they coordinate software disclosures and joint copyright assertion. The lab serving as primary licensing agent can be changed if necessary. This approach helps ensure that the technology developed through this effort will continue to be used, adapted, and expanded upon in the future.

The IP Management and Licensing Principles are summarized below. This list is organized on the basis of importance for the success of the partnership.

1. All source code developed under CCSI, will be available under a **common CCSI license**, which will enable the following:
    a. All labs will have equal access to all of the source code of CCSI Toolset during and after the project.
    b. All labs will have the right to modify and use the source code and the compiled components of CCSI Toolset, including the right to distribute it (as described in #2).

    This is an essential component ensuring that there are no barriers to cooperation and collaboration during the development of the CCSI Toolset. This enables each lab to contribute and accept assistance from any member of the CCSI Technical Team, regardless of lab affiliation, as necessary.
2. The **IP lead is responsible for licensing the CCSI Toolset**, for usage and/or distribution. The royalties derived from such licenses minus an administration fee will be equally divided among the five labs. Five years after the completion of the project, if distribution licensing of the CCSI Toolset has not yet occurred, the individual labs may negotiate non-exclusive distribution and end-user licenses for the CCSI Toolset or its components.

    This element similarly maximizes the potential for the CCSI Toolset to be licensed and utilized by industry following the end of the project, by providing (initially) a single point of contact. If that is unsuccessful, then all participants are free to license the toolset and/or components as desired.
3. Any **IP generated from the usage and modification of the CCSI Toolset by an IAB member (or other licensee) is owned by that IAB member** and need not be contributed to the Toolset. If the company chooses to contribute the IP, then the IP will fall under CCSI license.

    This element is essential to enable industry to use the tools without concern of 'contaminating' their own IP. It has enabled the rapid evaluation and use of the tools by IAB members.
4. The CCSI Toolset consists of the simulation and experimental data, verification & validation hierarchies, models, software, application programming interfaces, and best practices documentation developed by CCSI Team. The entire CCSI Toolset will be **available for download from one official CCSI location**.

    Providing a single source for the tools ensures that users know where and how to obtain the software and also enables the technical team to manage the release process that includes project-level source code management, version control and rigorous beta testing. Code review and release management is coordinated by a Product Deployment team that is an integral part of the project. Additional review occurs through software disclosures prior to copyright assertion. The system also enables tracking of bug reports and feature requests from licensees and the technical team. During the project period, the technical team can respond to requests from licensees to help install and use the Toolset.
5. The CCSI Toolset will require complementary software (e.g., FLUENT, Aspen Plus, gPROMS, etc.) that is licensed under separate commercial licenses. These are not part of the Toolset and will continue to be licensed by their respective owners.

This element and elements 6-7 clearly indicate that related software that works with the CCSI Toolset is not part of the CCSI Toolset.

6. Non-commercial complementary software (e.g., MFIX, PSUADE) will be separately available from their developers and is also not necessarily part of the Toolset, although it may be available via a link from CCSI website or directly from the CCSI website (if such redistribution is compatible with the license terms).
    a. Enhancements made to complementary software with CCSI funding can, at the discretion of the developer, be contributed to the complementary software for distribution under that software's license.
7. Existing software packages (libraries, etc.) can only be included in components of the CCSI Toolset if their license permits redistribution. Otherwise they will be termed complementary software.
8. The CCSI Toolset will be classified at the lowest level of export control (EAR99). If content that needs to be export controlled is disclosed by a developer, the export controlled component will be distributed separately under a special license for export controlled content.

Technical Scope

CCSI is developing, demonstrating and deploying advanced computational tools and models to accelerate the development of next generation technologies, specifically the development of cost effective carbon capture technologies. This CCSI Toolset will (1) enable promising concepts to be evaluated more quickly based on an optimized process, (2) reduce the time for design and troubleshooting by integrating process and device scale simulations to better predict performance and more effectively resolve scale up issues, (3) quantify technical risk to enable more focused scale up activities, and finally, (4) stabilize the costs during commercial deployment by having a more comprehensive understanding of the process and underlying behavior of the system.

CCSI is organized around tasks that correspond to the activities involved with the development of a new chemical process, such as a carbon capture system. This includes the development of submodels for basic data, such as thermodynamics and kinetics, and using those submodels within process models to synthesize and optimize a process design. The next major activity is identifying promising device configurations to serve as the basis for more detailed computational fluid dynamics (CFD) simulations, then pulling all the information together to assess project risk and determine whether or how to proceed. Unique within CCSI is the integration of uncertainty quantification (UQ) among the simulation scales. To effectively design a new *process* with new technology, each of these tasks is important and must interact to achieve an efficient, cost effective system. The CCSI Toolset consists of several product categories: basic data submodels, high resolution filtered submodels, validated high-fidelity CFD models and uncertainty quantification (UQ), steady-state and dynamic process models, process optimization & UQ, dynamics & control, and crosscutting integration tools.

Funding

CCSI is funded through the DOE Office of Fossil Energy (FE). An initial $10M of funding was provided in 2010 via the American Reinvestment and Recovery Act (ARRA). The remaining

funding of approximately $40M is from FE's Crosscutting Research Program. NETL's Office of Research and Development leads the program and initially funded the university collaborators. Funding to the other four national labs was initially agreed to be split evenly to enhance collaboration among the organizations by mitigating competition among the participants. This was achieved by matching the breadth of CCSI's technical needs with the diversity of technical capabilities that the participating labs offered and helped to ensure a unified, integrated development team.

Following the current CCSI project, two potential funding mechanisms are being planned to enable ongoing support of the Toolset. A subsequent project, Carbon Capture Simulation for Industry Impact ($CCSI^2$), has been planned and includes proposed funding for Toolset maintenance. In addition, FE's Crosscutting Research Program has issued a Funding Opportunity Announcement (FOA) (DE-FOA0001238) to enable the Toolset to be commercially supported, integrated with the existing modeling and simulation tools, offered as a commercial product, and demonstrated on multiple advanced energy systems.

The IAB is strictly advisory in nature and has no membership fee. Membership is based on interest and a willingness to commit between 10 and 20 working days per year to participating in monthly teleconferences, two annual program review meetings each year, and other interactions with the CCSI Technical Team. A document describing these expectations as well as potential benefits was distributed while the IAB was being formed. This type of no fee membership was deemed the most appropriate for the early state of development of CCSI at its inception and is evolving toward more participatory and cost-sharing approaches as the technology matures and draws greater application interest with specific partners for specific purposes.

Partnership Governance

The partnership has an integrated technical structure that includes a technical leadership team reporting to a Technical Director. Overall technical leadership is provided by NETL. As described previously, an executive committee provides high-level management of the program and a BoD, comprised of the Chief Research Officer from each participating lab, meets annually to review the program and offer guidance. Leadership of particular tasks is shared among labs and universities. Membership in each technical team crosses institutional boundaries, with the structure of the IPMP removing many of the barriers to such cross-institutional teams by sharing all IP across all institutions. Industry stakeholders interact with the leadership and technical team through the IAB as described above.

The CCSI Technical Leadership Team meets weekly via teleconference/web meeting to review progress, update milestones and revise plans. Each technical task team meets regularly, usually weekly, via teleconference/web meeting. Prior to each IAB program review meeting, the technical teams meets in person to review activities across the entire project. In spring 2014, the regular IAB program review meeting was replaced by a 2-day technical team meeting to allow a more focused engagement among team members at separate institutions. In addition, each technical task team regularly reviews ongoing work internally, gaining additional value from the diverse perspectives possible with researchers from multiple institutions.

Every 6 months, the IAB as well as the executive committee and representatives from DOE HQ review the program's progress over a two day period which includes presentations, software demonstrations and posters by nearly all the members of the CCSI Technical Team. The IAB provides written and verbal feedback and suggestions. The BoD formally reviewed the program in early 2012. Since then, the BoD review has primarily occurred in conjunction with IAB meetings. In addition, CCSI has participated in Merit Reviews conducted by the Strategic Center for Coal. An initial program review was conducted by DOE-HQ with a panel of reviewers that included members of the National Academy of Engineering. Over the course of the project an effective balance between oversight and the time burden has been obtained by focusing project review efforts on the two annual meetings with the IAB. An ongoing challenge has been reconciling the project level reviews with the review requirements associated with each organization involved in the program to avoid duplicative review activities.

The program is continually adjusted based on feedback from the IAB, DOE and other stakeholders to ensure that it achieves its goals and has significant impact. The leadership team meets annually to review feedback from the previous year and develop the detailed plans and milestones for the following year. This schedule enables the detailed plans to adjust to actual funding available.

Partnership Results

Due to positive feedback from the IAB members, and an expressed desire to use the software as soon as feasible, the first version of the CCSI Toolset was released in 2012, a year ahead of the originally scheduled release date. A second generation Toolset was released in 2013 followed by a third generation release in 2014. Many of the improvements were the result of feedback from IAB members. The Toolset has been offered to the partnering companies under a Test and Evaluation License since 2012. Under this license, the industrial partner is granted use of the software for 18 months without charge, but under the stipulation that thorough feedback on the use of the Toolset is provided. This provides the companies a method of communicating which aspects of the software are problematic, which they found to be effective, and to suggest features that would improve the toolset. After 18 months, if the company provides detailed feedback, they are able to renew the license for a subsequent 18 months, an arrangement that incentivizes further interaction with the development teams. Currently nine companies have signed licensing agreements.

The third generation of the CCSI Toolset, which was released on October 31, 2014, included new capabilities needed by industry to help scale up and develop next generation carbon capture technologies. A total of thirty "products" are currently available. General new capabilities include more streamlined workflows to help industry users take advantage of the advanced capabilities, new models with quantified confidence and rigorous, statistically-based uncertainty bounds. Specific new capabilities include a pulverization model, which builds on the capabilities of the previously released validated particle attrition model, a new advanced process control framework that utilizes dynamic reduced order models created using the CCSI D-RM Builder Tool, and a new Data Management Framework that tracks provenance from experimental data to kinetic model to process model to optimized system. In addition, the Framework for Optimization, Quantification of Uncertainty, and Surrogates (FOQUS) provides

significant new capabilities, many of which were requested by members of the industry advisory board. These include a unified user interface for simulation-based and surrogate-based optimization as well as the ability to manage multiple simulations on a single desktop computer. The tool for automatic learning of algebraic models for optimization (ALAMO) has been integrated with FOQUS and includes the capability for constrained regression, allowing physical constraints and knowledge of a system to be incorporated into the resulting algebraic surrogate models making them more accurate. This release also includes a new oxy-combustion boiler model and a model to predict wetted area of a solvent on a surface, an important capability for predicting the behavior of advanced carbon capture solvent systems. The final release of the completed toolset is planned for January 2016.

Three companies (ADA, GE, and B&W) are currently involved with the technical team through CRADAs or other information sharing arrangements to increase the success of their carbon capture development projects. Such opportunities are available to all the industry partners. These projects serve as examples of how CCSI technology will be used by industry to accelerate carbon capture technology development, and their successful completion will result in the early direct impact of CCSI on carbon capture technology development. Thus, while these partnerships assist the companies, they also assist the whole consortium by providing real opportunities to validate the CCSI Toolset. In addition, Southern Company, through the National Carbon Capture Center, has provided valuable data to use for model validation.

In order to promote the use of the toolset, educational sessions have been offered to train current and future engineers in the use of the CCSI Toolset. Members of the CCSI development team have visited industry sites to instruct their employees on the capabilities of the Toolset and have conducted web meetings to demonstrate how to use the technology. Through these methods, the Toolset will continue to be developed with a heightened awareness of industry needs, based upon the systematic implementation of dialogue between the research teams and the ultimate end-users of the technology.

Commercialization of the technologies available in the toolset is expected to provide significant economic impacts because the implementation of these tools holds the potential to reduce technology development time by 25 percent and costs by $500 million for each carbon capture technology scaled up utilizing the CCSI Toolset. Industry has enthusiastically embraced the releases of the CCSI Toolset, and nine companies currently hold test and evaluation licenses for the technologies: GE, Alstom, Phillips 66, B&W, Chevron, EPRI, WS Corporation, ESI North America, and Clean Energy Systems. Even though many of these companies do not have immediate plans for carbon capture, they recognize the value of these new computational tools to revolutionize their process optimization and modeling capabilities across multiple technology areas. To help track the impact of the CCSI Toolset on industry, one of the licensing terms requires reporting on the impact the CCSI Toolset has on their development activities. While not quantitative, such information will help measure the extent to which the CCSI Tools have changed current practice.

In addition to the economic impact of CCSI, the initiative enables training of PhD students at regional universities. These students become part of innovative project team and then join the

workforce with industry-specific skills, which will ensure continued expertise in carbon capture technology.

CCSI is scheduled to conclude at the end of January 2016. At that point, the IAB has expressed a desire for the Toolset be licensed and supported by independent software vendors. Discussions have been held with Process System Enterprise (PSE), Chemstations (makers of ChemCAD), GAMS Development Corporation (makers of optimization software) and AspenTech regarding potential licensing and commercialization of the CCSI Technology. PSE and AspenTech remain committed members of the IAB. We anticipate that licensing/commercialization discussions will intensify in 2015 as the CCSI effort draws to a close. As discussed above, FE's Crosscutting Research program has issued an FOA to support commercialization.

We anticipate that the CCSI Toolset will be utilized by industry and industry/lab partnerships to advance the development and scale up of new carbon capture and related technologies. For example, a follow on project, Carbon Capture Simulation for Industry Impact ($CCSI^2$) has been planned to help maximize the learning obtained from large-scale industry pilot programs to enable more cost effective scale up to demonstration scale. Data collected during this project will enable quantitative estimates of actual cost savings and return on investment.

Lessons Learned

If we were starting a new program, we would largely follow the same model for industry engagement as we have had excellent participation and strong interest in product uptake and application. Perhaps, we would include a greater emphasis on developing early joint development programs to utilize the products for specific technology development applications. Tiered industry engagement, regular involvement and reviews, and the IP plan are components that would certainly be propagated forward into any new program.

As we look to future partnerships, we plan to further engage industry partners during early program planning and to use these laboratory-industry relationships to identify shared goals, targeted implementation plans, and other cooperative research and development arrangements as an integral part of program planning and execution. In addition, we hope to create a clearer, shared understanding of the potential value to be delivered to industry partners by program success and pursue that value as directly and as early in the program as possible. Finally, as CCSI moves towards developing more specific collaborations with industry, we have discovered that establishing a streamlined process for developing, approving and executing multi-lab/university CRADAs with industry would be helpful to establish at the same time as the IPMP and other project documents.

Conclusion

United in the goal of developing computational tools that meet industry needs, the CCSI Technical Team has worked closely with each other and its industry partners to deliver a Toolset that successfully addresses challenges related to the scale up of new technologies and will be used to accelerate the development of carbon capture systems. To enable its success, the CCSI Team developed and applied two innovative systems and policies to foster creativity and maximize the contributions of all individuals: (1) a plan for effectively managing IP among multiple organizations, and (2) incorporating potential users of the tools from the very

beginning of the initiative to ensure a successful technology transfer pathway. The IPMP represents an innovative, integrated approach specifically designed to facilitate licensing of technology developed by a partnership of multiple laboratories and universities. The use of a common CCSI license, a single point of contact, and the availability of the CCSI Toolset download from a single web site has made it more straightforward for industry to utilize and reap the benefits of the CCSI Toolset. Industry stakeholders are rapidly adopting the CCSI Tools and clearly recognize its value, as demonstrated by the following quotes:

> *The development of this CCSI Toolset is a major innovation, which will have a significant impact on the way industry develops new technology. We are excited to be among the first to adopt these computational tools. We believe they will ultimately give us a competitive advantage as we incorporate them into our work processes.* Terry K. Leib, Technology Director, GE Global Research
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> *The CCSI Toolset provides a unique set of capabilities not currently available from any other source. We consider these capabilities of great value to our process development activities.* Arnold Smith, Executive Director, Fluor Enterprises, Inc.
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> *Users will license CCSI's advanced simulation tool set because the tool set has capabilities that were not previously accessible to industry and various parts of the tool set can be integrated as stand-alone capabilities within existing evaluation, design and scale-up processes. Additionally, the tool set will be broadly applicable to the development and scale-up of advanced energy conversion and emissions control systems.* Chris E. Latham, Director, Babcock & Wilcox Research Center