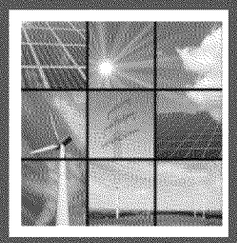

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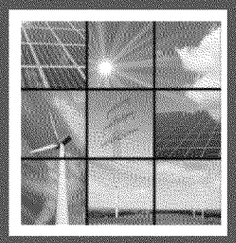
California Energy Systems for the 21st Century

California Energy Systems for the 21st Century Workshop

February 20, 2013



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CES-21 Workshop Agenda

- Welcome: Brian Cherry
- Introductions: Brian Cherry
  - CES-21 Board of Directors: Jane Yura, Doug Kim, Jeff Nichols, Dan Kammen, Mani Chandy, T.J. Glauthier
  - Liaison to Board of Directors: Ed Randolph
- Overview of Workshop Objectives: Erik Jacobson
  - Discussion of the proposed research and priorities
  - Review the business case for proposed research
- Research Area Presentations + Q&A
  - Electric Resource Planning: Redacted (PG&E) & Tom Edmunds (LLNL)
  - Electric Operations: Robert Sherick (SCE) & Liang Min (LLNL)
  - Gas Operations: Redacted (PG&E) & Lee Glascoe (LLNL)
  - Cyber Security: Corey McClelland (SDG&E) & John Grosh (LLNL)
- Next Steps: Erik Jacobson
  - Updates to CES-21 research projects and business cases
  - Next CES-21 Board Meeting
- Adjourn: Erik Jacobson

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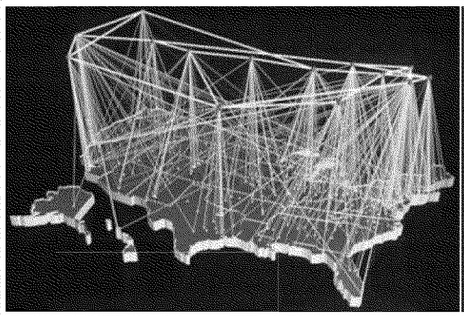
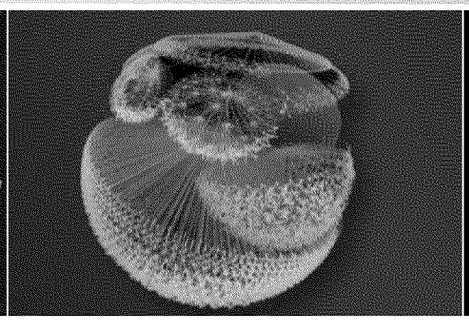
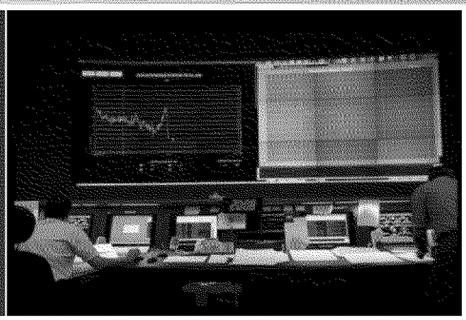
CES-21 is built around areas of collaboration

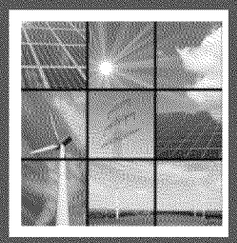






Electric Resource Planning	Electric and Gas System Operations	Cyber Security
▪ Planning (day to years ahead) simulations at scale ▪ Wind and solar forecasting ▪ Impact of intermittency associated with renewables	▪ Operations (seconds to minutes ahead) simulation at scale ▪ Storage and demand response ▪ Real-time diagnostics and control	▪ Analytics and situational awareness of the grid ▪ Efficient algorithms to effectively capture, analyze, and share data on demand

Advanced Computing Services



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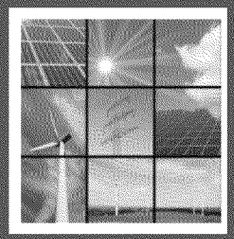
CES-21 Potential Projects

CES-21 Potential Projects – Year 1	Estimated First Year Costs	Total Cost/Duration
Electric Resource Planning		
• Ensemble Weather Forecasting	$2.7M	$9M/3 years
• Cyber-Physical Support of Hydropower Generation	$1.3M	$9M/5 years
• Flexibility Metrics and Standards	$3.3M	$9M/3 years
• Planning Engine	$4.6M	$21M/5 years
Electric System Operations		
• Distribution Modeling and Optimization	$3.0M	$6M/2 years
• Real Time Hybrid Digital Simulation	$3.8M	$15M/5 years
• Integrated Transmission and Distribution Model	$2.8M	$9M/3 years
• Electric System Monitoring and Control	$3.3M	$14M/4 years
Gas System Operations		
• Geographic Data Integration for Risk Management	$1.7M	$5M/3 years
• Advanced Modeling and Simulation Environment	$2.2M	$12M/5 years
Cyber Security		
• Advanced Threat Analysis Center	$7.2M	$36M/5 years
• Modeling and Simulation	$5.1M	$27M/5 years



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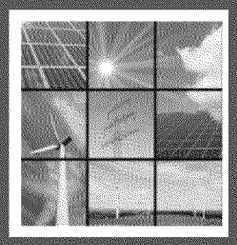
Electric Resource Planning

Integrate high resolution weather and electric resource models to improve accuracy and uncertainty definition of weather-based generation, reduce operating costs, and improve planning and investment decisions given RPS and other structural changes under way

Redacted (PG&E)

Tom Edmunds (LLNL)



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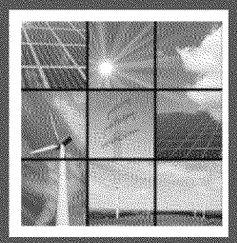
Electric Resource Planning proposed projects

- Ensemble Weather Forecasting of Wind/Solar Generation
  - Develop an ensemble-based forecasting system to improve forecast accuracy and provide uncertainty bounds for wind and solar generation
- Cyber-Physical Support of Hydropower Generation
  - Develop hydrographic data network and predictive modeling toolbox to support hydropower planning and operations activities
- Flexibility Metrics and Standards
  - Define operating flexibility metrics and targets based on a probability measure of the occurrence, the magnitude, and the duration of ramping shortages at different time intervals. Develop models to estimate flexibility deficiencies
- Planning Engine
  - Develop higher resolution, larger-scale models of transmission and alternatives to integrate renewable generation such as demand response, and energy storage



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Electric Resource Planning

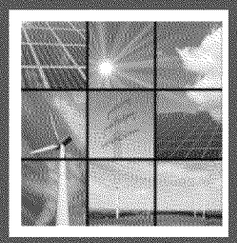
Ensemble Weather Forecasting

Need:

New forecasting approaches are needed to integrate large amounts of weather-based electricity generation. New forecasts must improve the prediction and uncertainty measurement of weather parameters and renewable generation

Objective:

- Determine the optimal weather forecasting approach for renewable power generation
- Improve renewable generation predictions and uncertainty of weather and renewable generation for operation
- Deliver real-time ensemble-based forecasts for CAISO and utilities to compare the ensemble-based forecast to existing forecasts



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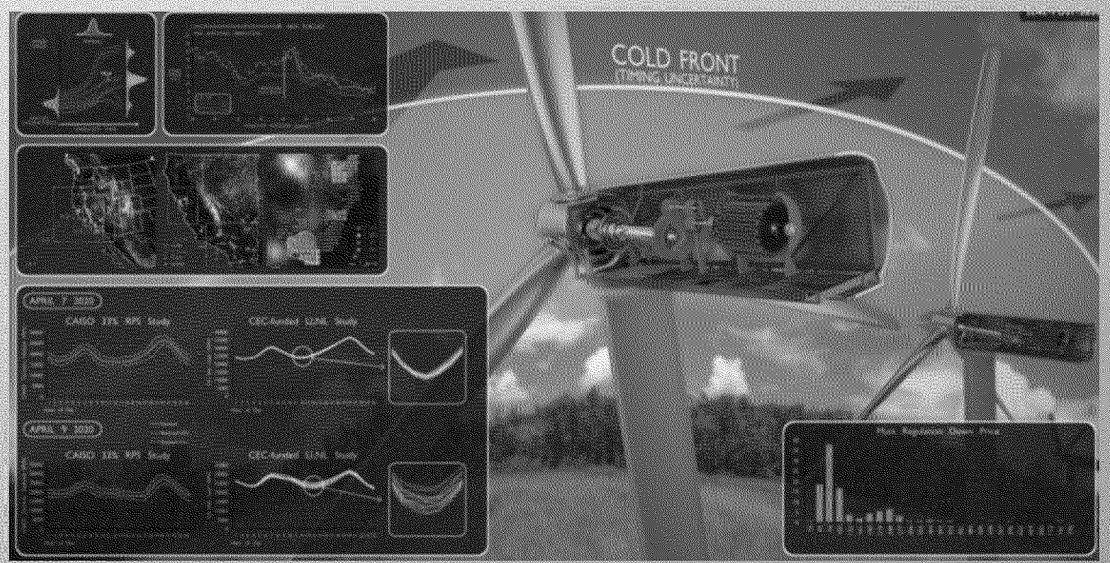
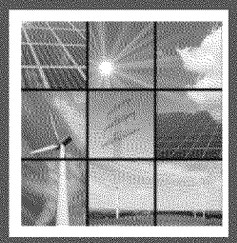
Electric Resource Planning

Ensemble Weather Forecasting

Approach:

- Build infrastructure for computations, data analysis, and data sharing (PM1 -12)
- Produce and provide ensemble forecasting to CAISO and IOUs (PM6-33)
- Evaluate statistical performance of forecasting methodology (PM30-36)
- Report benefits of approaches. Recommend how prototype operational forecasting tools can be implemented by vendors, CAISO or IOUs (PM36)





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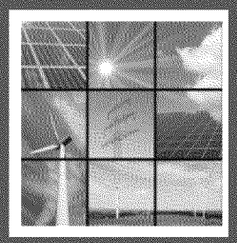
Electric Resource Planning

Ensemble Weather Forecasting

Research or service needed	Potential Collaborators
Experience evaluating the use of ensemble forecasts in an operational setting	1. CAISO 2. Vendors of weather and generation forecasts
Extensive experience in ensemble forecasting, especially multi-analysis forecasting, developer of WRF	1. NCAR
Wind and solar resource data sets	1. CAISO 2. NREL 3. Vendors of weather and generation forecasts
End user of wind forecasts, experience in making weather-to-power conversions	1. Infigen 2. Cool Earth Solar
Expertise in solar tracking and short term prediction	1. UCSD



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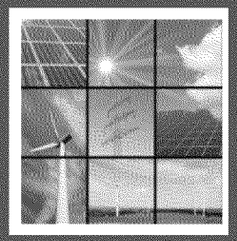
Electric Resource Planning

Ensemble Weather Forecasting

Potential customer benefits

1. The CAISO can better predict net load, ramping and new flexibility reserves like load following requirements
   - Purchase the necessary reserves to account for the net load uncertainty faced on a daily basis.
   - Purchase additional reserves for days when the net load forecast is highly uncertain, thereby reducing the chance of over/underproduction and the expenses associated with them.
2. The IOUs and other wind/solar generation owners benefit from improvements in the overall accuracy and uncertainty of predicted generation
3. Customers ultimately benefit from lower cost of electricity and increased reliability ($30 million per year by reducing load following costs per CES-21 application)



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Electric Resource Planning

Cyber-Physical Support of Hydropower

Need:

Better knowledge of snowpack, snow water content, runoff, and groundwater discharges to enhance use of hydro generation.

Prediction, planning, and management of hydropower resources relies on accurate and timely knowledge of water availability for generation stations.

Objective:

- Improve hydrologic data and modeling, and scheduling capabilities to more effectively manage limited hydro resources. (The initial research will be based on PG&E's East Branch of the upper North Fork Feather River hydroelectric system.)

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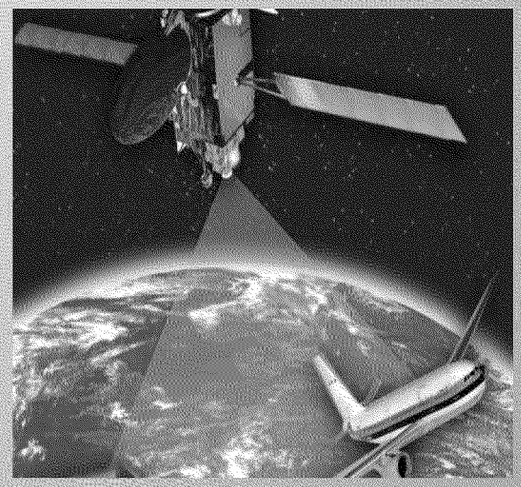
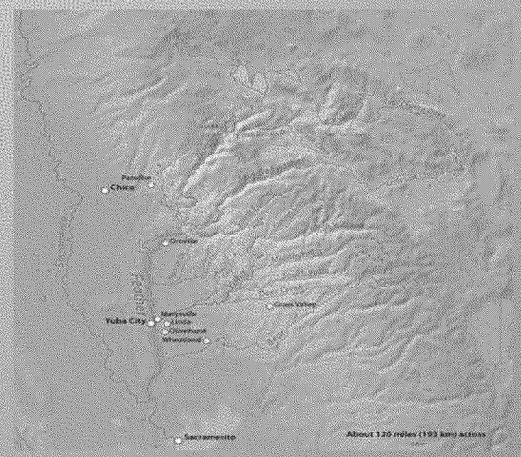
Electric Resource Planning

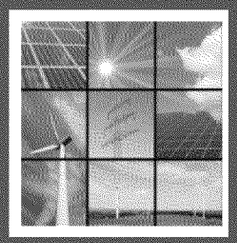
Cyber-Physical Support of Hydropower

Approach:

- Develop Information Management System to retrieve data daily (PM1-8)
- Develop and implement a network of ground-based sensors (PM12-36)
- Develop Modeling Toolbox for forecasting water availability (PM1-36)
- Improved decision making tools (PM30-60)







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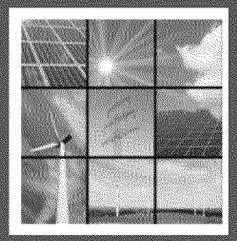
California Energy Systems for the 21st Century

Electric Resource Planning

Cyber-Physical Support of Hydropower

Research or service needed	Potential Collaborators
Flexible information-management capabilities for hydrologic data	1. UC Merced (Sierra Nevada Res. Inst.) 2. UC Berkeley (CITRUS)
Satellite snow cover products	1. JPL/NASA
Expanded ground-based hydrologic sensor networks	1. State of California, DWR 2. State of California, CEC (EPIC)
Support for PRMS operational model used by PG&E	1. USGS 2. UC Merced (Sierra Nevada Res. Inst.)



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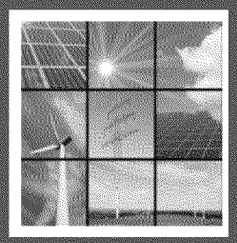
California Energy Systems for the 21st Century

Electric Resource Planning

Cyber-Physical Support of Hydropower

Potential customer benefits

1. Less lost water – Reduction in water spills
2. Higher value of hydro generation
3. New decision making tools – transferable to other watersheds
4. Non-quantifiable safety benefits, flood protection and management
5. Benefit quantification:
   - $__ million/year illustrative benefits from reduced lost energy
   - $__ million/year illustrative benefits increased value of hydro capacity and energy



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Electric Resource Planning

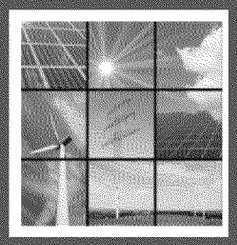
Flexibility Metrics and Standards

Need:

New operating flexibility metrics and targets are needed for long-term resource planning in California. Improvements to methodology and models are also needed to determine resource need for increased operating flexibility requirements

Objective:

- Review existing flexibility metrics and tools now in use and under development to identify resource needs
- Define flexibility metrics, such as insufficient ramping capacity
- Use high performance computing to operationalize flexibility metrics for planning purposes, as new flexibility metrics or modified reliability metrics
- Use LLNL's expertise to develop new or improved models that incorporate flexibility metrics with traditional production simulation and reliability models



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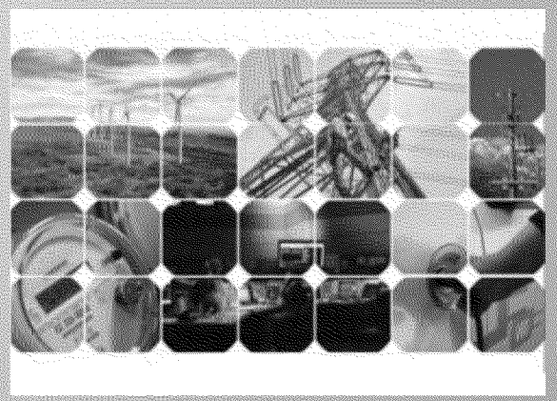
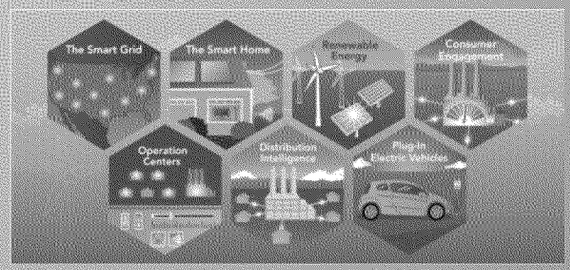
Electric Resource Planning

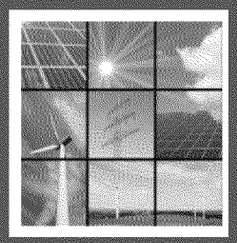
Flexibility Metrics and Standards

Approach:

- Define problem and characteristics of tools to needed to address the problem (PM1-3)
- Select base model (PM3-5)
- Develop the infrastructure to generate multiple weather dependent data (PM6-10)
- Develop the infrastructure to automate the running of many scenarios in batch mode through the optimizer (PM10-16)
- Develop Flexibility Metrics (PM16-20)
- Develop a prototype model to quantify flexibility metrics (PM20-30)
- Integrate the flexibility metric prototype with the base model (PM30-33)
- Document new or improved model (PM34-36)







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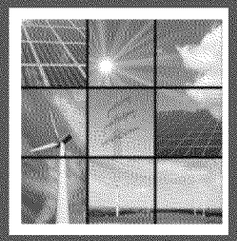
Electric Resource Planning

Flexibility Metrics and Standards

Research or service needed	Potential Collaborators
Simplified representation of weather uncertainty and its impact on load, wind and solar generation	1. CAISO 2. Consultants (Energy Exemplar, E3) 3. Vendors of weather and generation forecasts
Dynamic representation of flexibility requirements as weather uncertainty evolves during operating horizon	1. CAISO 2. Regulators (CPUC, FERC) 3. Research organizations (LBNL, EPRI, Dublin and other universities)
Ability to evaluate simplifications to representation of weather uncertainty and other inputs to production simulation models	1. CAISO 2. Consultants (Energy Exemplar, E3) 3. Research organizations (LBNL, EPRI, Dublin, other universities)
Ability to measure operating flexibility deficiencies, and contribution of resources to meet system needs	1. CAISO 2. CPUC 3. Parties to LTPP and RA proceedings



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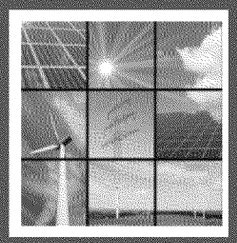
Electric Resource Planning

Flexibility Metrics and Standards

Potential customer benefits

1. More accurate estimate of flexibility requirements given a resource mix and operating policies for unit commitment and dispatch
2. Quantification of resource need
3. Identification of cost effective additions to provide flexibility
4. In CES-21 application these were estimated at a value of $552 million through improved resource planning



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Electric Resource Planning

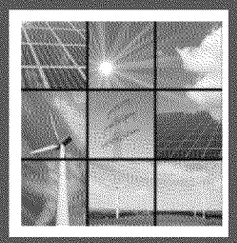
Planning Engine

Need:

Higher resolution models with improved solution algorithms are needed to analyze systems with many intermittent generators and millions of distributed resources and improve generation and transmission investment decisions

Objective:

- Better model resolution of transmission system to identify preferred location of resource additions and desired transmission reinforcements
- Inputs to transmission reliability models that incorporate the weather uncertainty associated with variable generation
- Closely coupling of generation and transmission investment decisions
- Methodology and analytical tools to evaluate the feasibility and effectiveness of potential new demand response, energy storage, and other resource additions to satisfy operating flexibility metrics and standards



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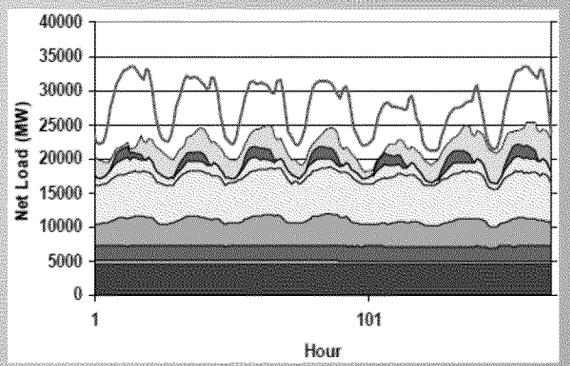
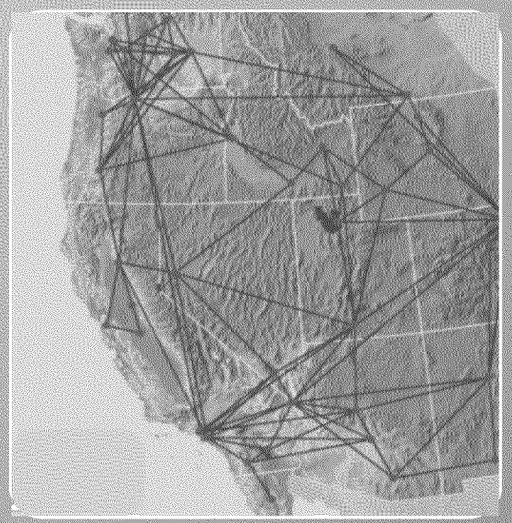
Electric Resource Planning

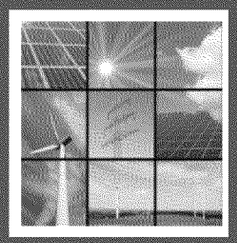
Planning Engine

Approach:

- Common building block and potential synergies from close coordination with other business cases (PM6)
- Enhanced representation of the transmission system in production simulation models (PM1-36)
- Enhanced inputs to transmission system planning models (PM12-48)
- Design and test tools for evaluation of demand response programs, energy storage and other alternatives for renewable integration (PM12-24)
- Investment and market analysis tools (PM12-24)
- IT infrastructure planning (PM24-45)







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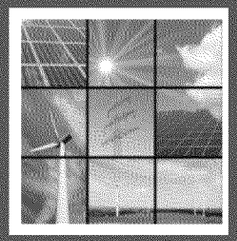
Electric Resource Planning

Planning Engine

Research or service needed	Potential Collaborators
Better model resolution of transmission system to identify the preferred location of new resource additions and grid reinforcements	1. CAISO 2. Regulators (CPUC, FERC) 3. Vendors (Plexos, GE)
Inputs to transmission reliability models that incorporate the weather uncertainty associated with variable generation	1. CAISO 2. Research organizations (EPRI) 3. Software vendors
Methodology and analytical tools to evaluate the feasibility and effectiveness of demand side programs, energy storage and other alternatives for renewable integration	1. CAISO 2. Regulators (CPUC, FERC) 3. Consultants (Energy Exemplar, E3) 4. Demand response suppliers



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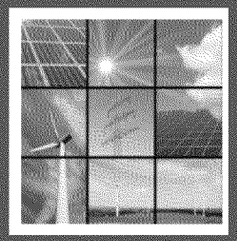
Electric Resource Planning

Planning Engine

Potential customer benefits

1. Improved planning tools to identify cost effective generation and transmission additions
2. Lower operating costs and emissions with more effective algorithms for unit commitment and economic dispatch
3. Understanding how demand response, energy storage and other flexible resources can contribute to renewable integration
4. Improved reliability with better representation of weather uncertainties, transmission limitations
5. Benefit quantification:
   - $__ million illustrative benefits from reduced cost or enhance effectiveness of demand response programs
   - $__ million illustrative benefits from better location of resources or reduced need for generation



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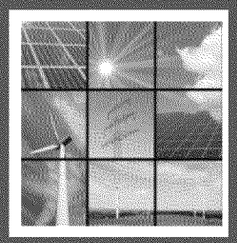
Electric System Operations

High fidelity models of multiple grid components will be developed, and then integrated to inform system-based simulations of grid operations. These simulations will inform operational decisions and shape the design of future monitoring and control systems.

Robert Sherick (SCE)

Liang Min (LLNL)



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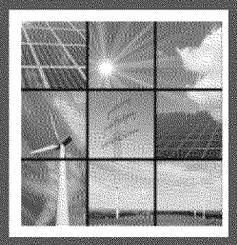
Electric System Operation potential projects

- Distribution Modeling and Optimization
  - Develop a detailed model of the distribution grid, analyze various emerging technology adoption scenarios, determine market and control mechanisms that would optimize the balancing of resources and demand, and review the impacts on grid infrastructure
- Real Time Hybrid Digital Simulation
  - Develop high-performance hybrid digital simulator supporting integrated electromechanical and electromagnetic transient simulations to evaluate impacts from intermittent resources on system stability
- Integrated Transmission and Distribution Model
  - Develop an integrated transmission and distribution model to analyze reliability impacts of increased renewable penetration in the distribution network and identify restoration capabilities during large scale system outages
- Electric System Monitoring and Control
  - Develop tools and methods to analyze synchrophasor patterns and system events to improve transmission system monitoring; identify mitigation strategies to improve the stability of the transmission system during stress conditions



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Electric Operations potential project

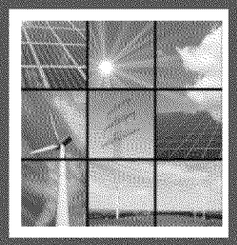
Distribution Modeling and Optimization

Need:

Emerging technology devices (e.g. photovoltaic panels, controllable thermostats, plug-in electric vehicles, storage) are being interconnected to the distribution grid allowing new opportunities to balance resources and demands. These devices are presently encouraged through a series of incentive programs that are intended to increase the adoption of the technology, but there is no mechanism to optimize across the technologies.

Objective:

- Develop a detailed model of the distribution grid
- Build adoption scenarios for renewable generation, plug-in electric vehicles, demand response, and storage
- Analyze impacts to customers and the grid of different adoption scenarios
- Identify market mechanisms to enable interaction amongst devices to optimize resources and minimize consumption



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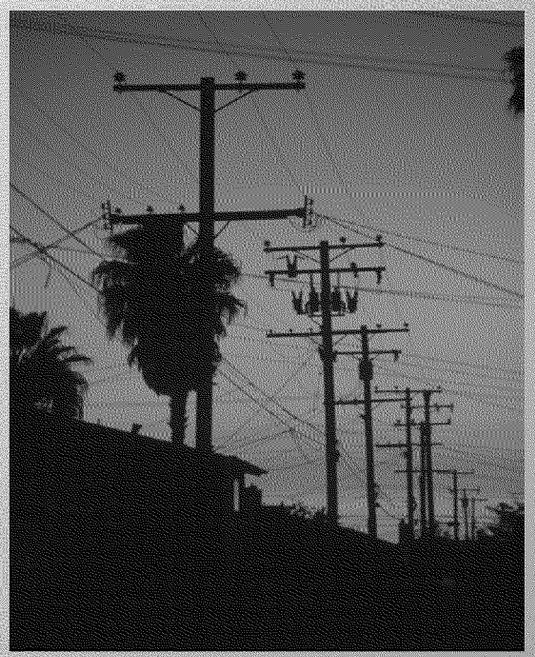
California Energy Systems for the 21st Century

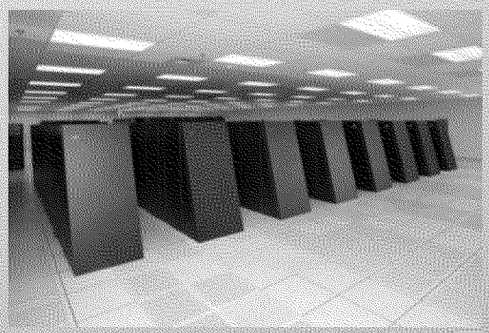
Electric Operations potential project

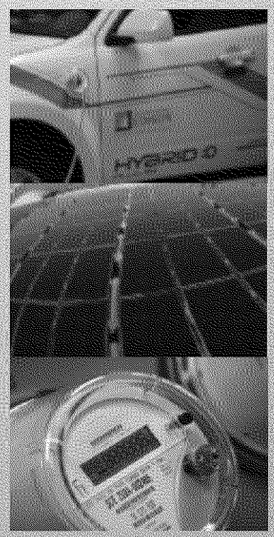
Distribution Modeling and Optimization

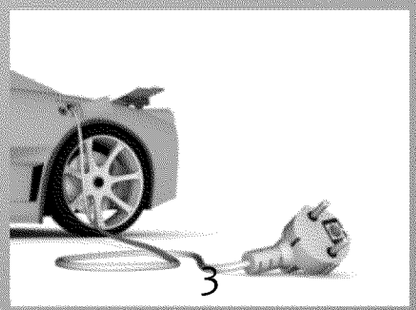
Approach:

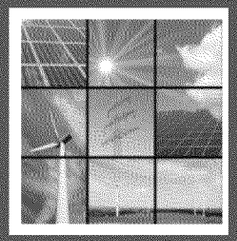
- Modeling Framework and Model Development/Validation (PM1-12)
- Computational Runs, Analysis, Recommendations (PM13-24)











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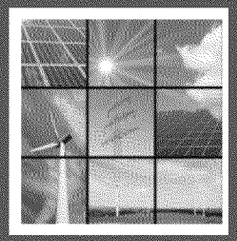
California Energy Systems for the 21st Century

Electric Operations potential project

Distribution Modeling and Optimization

Research or service needed	Potential Collaborators
Distribution grid modeling tools	1. Pacific Northwest National Laboratory 2. EPRI 3. CYME 4. ETAP
Market Optimization	1. California Institute of Technology



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California Energy Systems for the 21st Century

Electric Operations potential project

Distribution Modeling and Optimization

Potential customer benefits

1. Improved understanding of technology adoption scenarios across the state
2. Identify Energy Efficiency opportunities across the state
3. Identify Demand Response opportunities across the state
4. Identify rate impacts to different customer classes and technology adopters
5. Evaluate voltage and VAR control and implementation strategies
6. Quantify the value derived from control of smart inverters
7. Identify impacts on distribution infrastructure, mitigation strategies, and cost allocation methods
8. Identify market and control systems to optimize resources and demand within a region

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California Energy Systems for the 21st Century

Electric Operations potential project

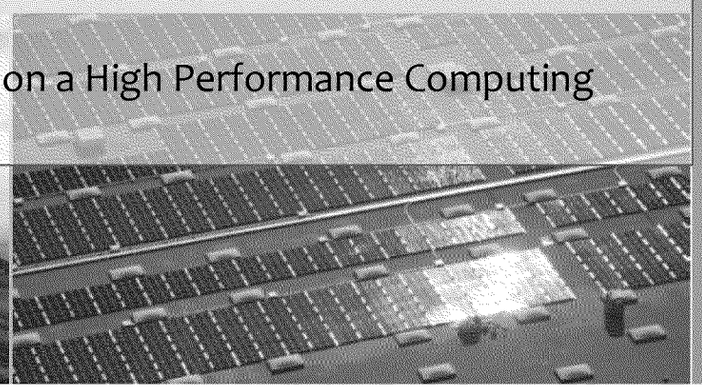
Real Time Hybrid Digital Simulation

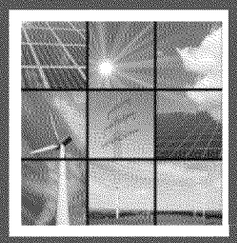
Need:

The stability of the grid's frequency has traditionally relied on the mechanical inertia resulting from rotating machines. Recently, an increasing proportion of energy from PV and wind generation in California feeds the grid through solid-state, switch-controlled electronics which lack the mechanical inertia from rotating machines and whose dynamic behavior does not inherently stabilize the grid.

Objective:

- Develop high-performance hybrid digital simulator that integrates electromechanical and electromagnetic transient simulation
- Leverage existing tools and models developed on the EMTP-type simulator at the California IOUs
- Leverage speed and memory available on a High Performance Computing platform





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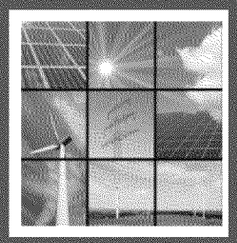
California Energy Systems for the 21st Century

Electric Operations potential project

Real Time Hybrid Digital Simulation

Approach:

- Prototype coupled software simulator (PM1-12)
- High Performance Dynamic Stability Assessment Tool (PM3-30)
- Hybrid Simulator Algorithms (PM12-54)
- Software Development and User Interface Development (PM30-54)



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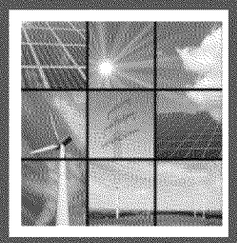
California Energy Systems for the 21st Century

Electric Operations potential project

Real Time Hybrid Digital Simulation

Research or service needed	Potential Collaborators
Modeling tools	1. GE 2. EPRI 3. PowerTech Lab 4. Manitoba HVDC Research Center
Real-time digital simulator	1. RTDS Technologies 2. OPAL-RT technologies
Energy grid research	1. PSERC 2. University of Tennessee CURENT 3. Florida State University FREEDM



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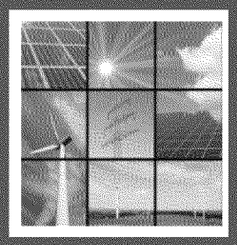
California Energy Systems for the 21st Century

Electric Operations potential project

Real Time Hybrid Digital Simulation

Potential customer benefits

1. Improved real time simulation capability related to integration of renewable resources that are critical to meeting California' Renewables Portfolio Standard
2. Reduced wide-scale blackouts and avoid customer costs of outage through real-time simulation capability
2. Improved visibility of the health of the system and precision to locate risks and reduce the incidence of blackouts and associated societal costs
3. Improved planning to reduce instances when operators mitigate for worst-case scenarios, avoiding potential overbuilding and reducing overall costs



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California Energy Systems for the 21st Century

Electric Operations potential project

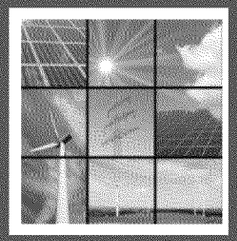
Integrated Transmission and Distribution Model

Need:

The existing models used in transmission reliability assessment include models for the transmission network only. These models include an accurate representation of generation connected at the transmission level. However, the distributed generation is typically modeled as a reduction in load. With the increase in the distributed renewable penetration, there is a growing need to accurately capture the impact of the distributed generation on transmission reliability.

Objective:

- Develop an integrated transmission and distribution model
- Analyze interactions across the two systems
- Identify system restoration plans utilizing the integrated transmission and distribution system



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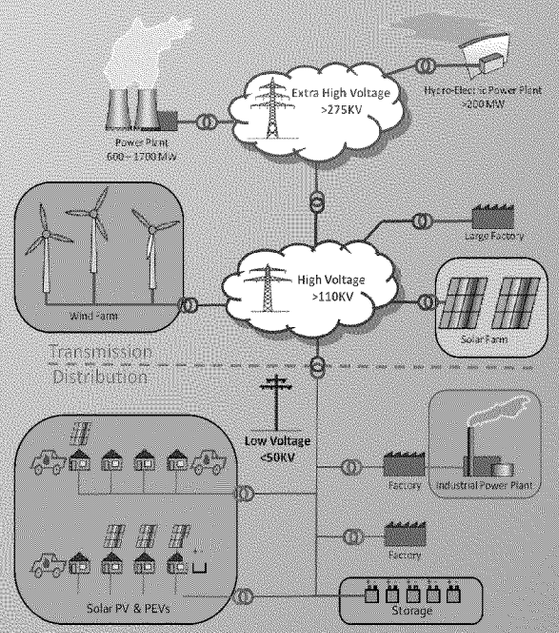
California Energy Systems for the 21st Century

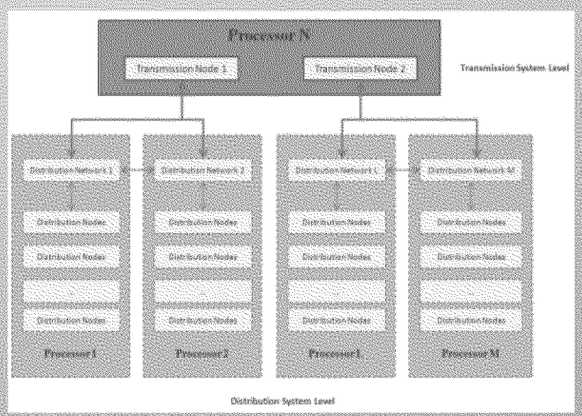
Electric Operations potential project

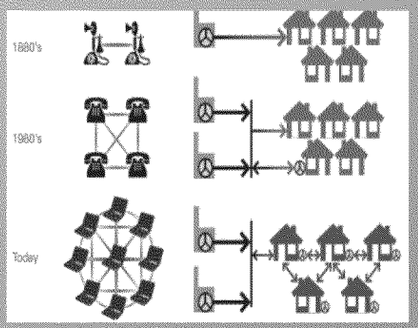
Integrated Transmission and Distribution Model

Approach:

- Integrated Transmission and Distribution Steady-state Model Development (PM1-15)
- Integrated Transmission and Distribution Dynamic Model (PM16-36)
- Restoration Capabilities in Extreme Scenarios Title (PM13-30)
- Integrated Electric Grid and Information Network Simulation (PM12-36)







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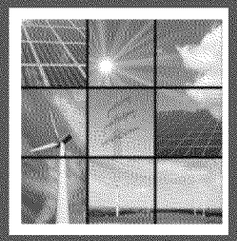

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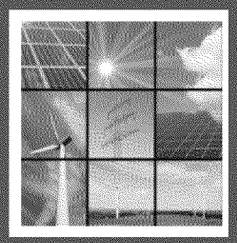
California Energy Systems for the 21st Century

Electric Operations potential project

Integrated Transmission and Distribution Model

Research or service needed	Potential Collaborators
Transmission modeling tools	1. GE 2. Powerworld
Distribution modeling tools	1. Pacific Northwest National Laboratory 2. EPRI 3. CYME 4. ETAP



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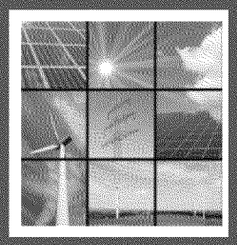
California Energy Systems for the 21st Century

Electric Operations potential project

Integrated Transmission and Distribution Model

Potential customer benefits

1. More comprehensive utilization of already purchased and deployed technology (i.e. Smart Meters)
2. Leverage the existence of data to reduce outages and costs through efficiency
3. Enable a smoother integration of distributed energy resources
4. Avoid potentially unnecessary redundant capacity buildup as more accurate planning becomes available
5. By identifying restoration impacts and weaknesses, strategies regarding upgrading/ investing in infrastructure, procuring, building, replacing generation can be improved
6. With improved strategies, restoration time will be shortened beyond standards and requirements set by NERC requirements improving customer satisfaction



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California Energy Systems for the 21st Century

Electric Operations potential project

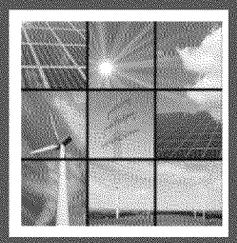
Electric System Monitoring and Control

Need:

One of key operational issues faced by California utilities is the ability to manage intermittent resources effectively while utilizing grid assets efficiently. With the increasing amounts of intermittent resources, stability analysis becomes more critical. Detailed system data (e.g. synchrophasors, digital fault recorders, SCADA) is collected and analyzed for discrete events, but large scale correlation and pattern recognition have not been employed due to the quantity of data.

Objective:

- Develop a predictive engine based on data mining and pattern recognition algorithms
- Develop system stability monitoring and mitigation system using predictive engine
- Increase transmission path capability through reliable use of actual system conditions



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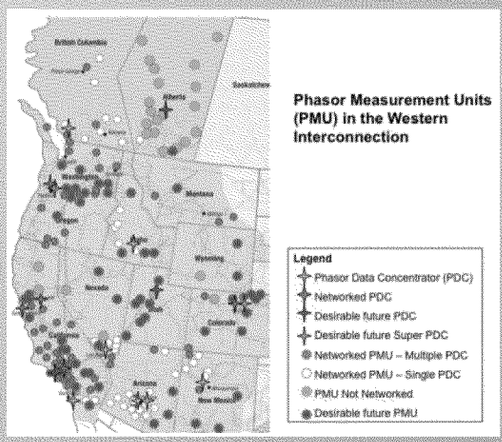
California Energy Systems for the 21st Century

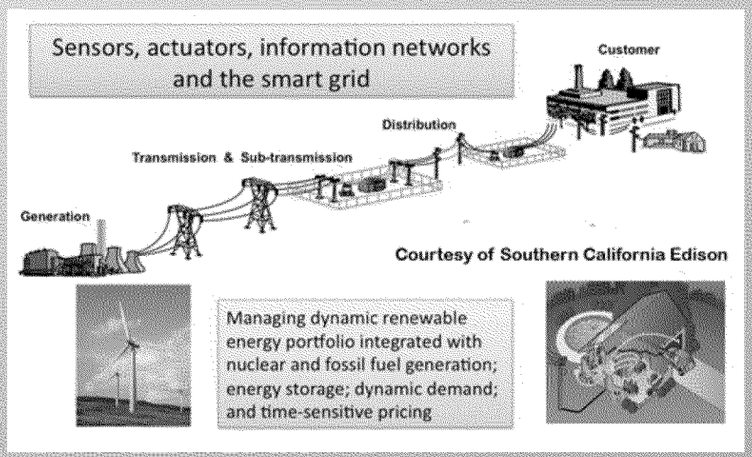
Electric Operations potential project

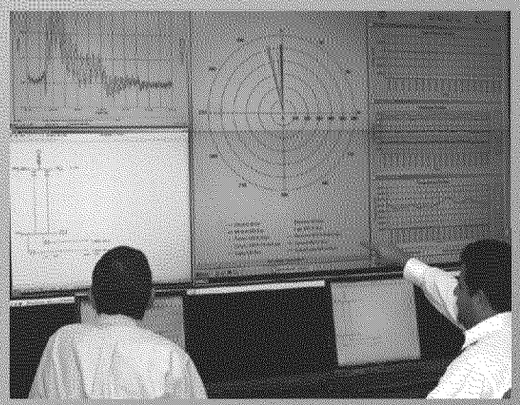
Electric System Monitoring and Control

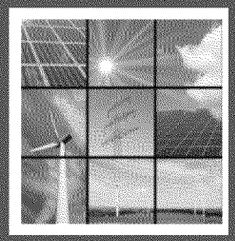
Approach:

- Situational Awareness (PM1-PM39)
- Adaptive Protection and Control (PM16-27)
- Dynamic Transmission Paths Capability (PM28-39)
- Final Report, Documentation, and Technology Transfer (PM 40 - 45)









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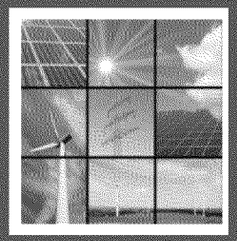
California Energy Systems for the 21st Century

Electric Operations potential project

Electric System Monitoring and Control

Research or service needed	Potential Collaborators
Monitoring and control tools	1. Grid Protection Alliance 2. Electric Power Group 3. GE Energy 4. Alstom
Data management	1. OSI Soft
Grid research	1. Power System Engineering Research Center 2. University of Tennessee's CURENT center



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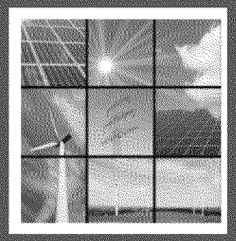
California Energy Systems for the 21st Century

Electric Operations potential project

Electric System Monitoring and Control

Potential customer benefits

1. Improved monitoring capability and system dynamics understanding to reduce overall system outages through early warning and mitigation plans
2. Reduced generation and load dropping on special protection schemes
3. Increased wide area system awareness and understanding to increase transmission capacity
4. More detailed modeling capabilities and longer dynamic analysis to increase overall understanding of interplay between transmission and distribution systems with substantial amounts of intermittent generation



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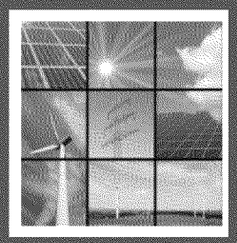
California Energy Systems for the 21st Century

Gas System Operations

Advanced system modeling along with collection, extraction, fusion and analysis of multiple data sources that characterize the gas pipeline network and its operation will inform advanced risk analysis processes to ensure the safety and reliability of the gas pipeline system.

Redacted (PG&E)

Lee Glascoe (LLNL)



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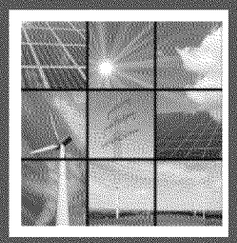
California Energy Systems for the 21st Century

Gas System Operation potential projects

- Geographic Data Integration for Risk Management
  - Develop and demonstrate tools that enable the integration of large amounts of both traditional (paper records) and non-traditional (electronic data and models) forms of gas infrastructure and environmental information to support comprehensive integrity assessments
- Advanced Modeling and Simulation Environment
  - Develop and demonstrate tools to enable comprehensive parametric simulations of the transmission and distribution gas system including a quantified uncertainty framework to enhance modeling accuracy as well as the level of understanding and confidence in modeling results



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California Energy Systems for the 21st Century

Gas System Operation potential project

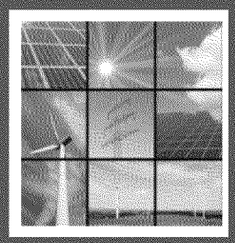
Geographic Data Integration for Risk

Need:

Risk assessment for Integrity Management requires historical and current information on the state of the natural gas system and its surroundings, including previous repairs and population distribution. All of this information must also be integrated into a single database for comprehensive risk assessments.

Objective:

- Transform the understanding and quantification of risk from and to natural gas infrastructure by using detailed information
- Implement population modeling tools with higher time and spatial resolution
- Create digitization framework for historical (paper) records of pipeline maintenance activities to allow processing of millions of records
- Integrate both traditional (e.g. records) and non-traditional (e.g. population modeling) sources of information to Improve the understanding of risk from and to natural gas infrastructure



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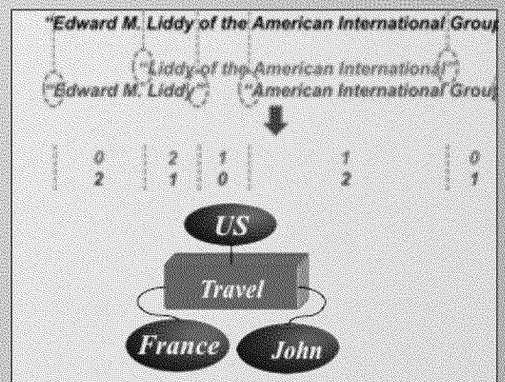
California Energy Systems for the 21st Century

Gas System Operation potential project

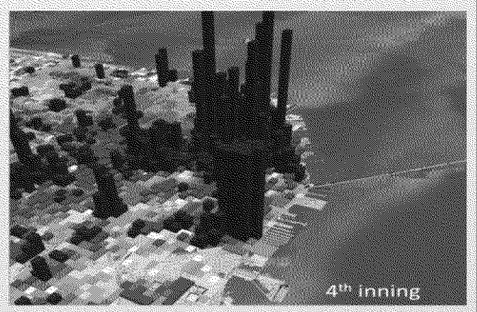
Geographic Data Integration for Risk

Approach:

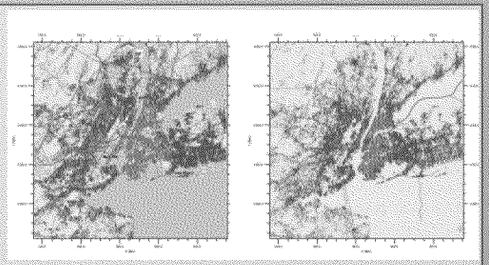
- Spatially and temporally explicit assessment of risk associated with population distribution (PM1-36)
- Computer assisted extraction of geographical information from historical maintenance records (PM1-24)
- Methods for System-Wide Risk Assessment of PG&E's Natural Gas System (PM24-36)



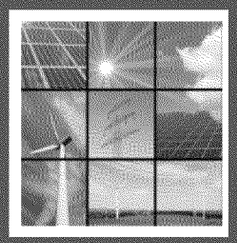
RECORDS EXTRACTION



Dynamic population modeling in San Francisco



DAYTIME VERSUS NIGHTIME POPULATION



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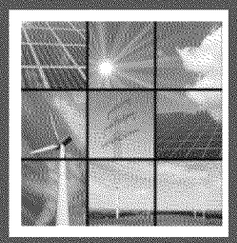
California Energy Systems for the 21st Century

Gas System Operation potential project

Geographic Data Integration for Risk

Research or service needed	Potential Collaborators
GIS provider	1. ESRI
Risk assessment	1. Lawrence Berkeley & Sandia National Laboratories 2. University of California, Berkeley, Santa Barbara, Los Angeles 3. Stanford University 4. EPRI 5. PRCI 6. Gas Technical Institute
Population dynamics	1. Oak Ridge National Laboratory 2. Sonoma State University
Energy informatics	1. University of Southern California
Optical character recognition	1. Adobe 2. OmniPage
Document management	1. EMC Documentum 2. Xerox Docushare



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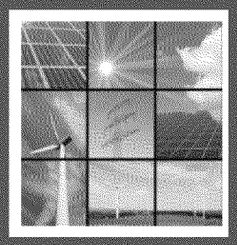
California Energy Systems for the 21st Century

Gas System Operation potential project

Geographic Data Integration for Risk

Potential customer benefits

1. A high resolution understanding of time dependent impact to the public in case of a potential pipeline failure that will support a cost effective risk-based assessment to prioritize system improvements such as shut-off valve installation, inspection and maintenance
2. Leveraging databases and models developed for a broad range of security and business applications by the National Laboratories provides a reliable solution at a minimal cost
3. Enabling new possibilities in operation and resource management to minimize response time, reduce costs, and improve safety
4. Exploring how population movement and density forecasts can be used to optimize work and investments on the pipeline network
5. Providing a reliable, fast and cost-effective method to process very large numbers of historical records of assets for pipeline maintenance and risk assessment
6. Accelerating the development of understanding quantitative comprehensive risk-based integrity management plans that are currently limited by the lack of accurate and reliable data



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California Energy Systems for the 21st Century

Gas System Operation potential project

Advanced Modeling and Simulation Environment

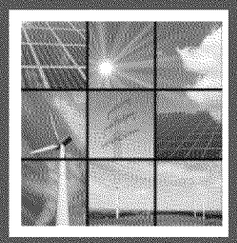
Need:

Natural Gas planning needs are evolving due to the integration of renewable energy sources and the availability of substantially more monitoring data on the transmission and distribution networks.

Enhanced system simulations have the potential to improve system operations by providing tools to guide complex real time decisions, provide insight into complex "what if" scenarios, and potentially to detect leaks or other equipment failures.

Objective:

- Automate the costly and time-consuming calibration process for pipeline models
- Increase the accuracy and robustness of calibrated models
- Develop a framework for reporting uncertainty in model predictions
- Provide visualization tools for complex simulations to improve gas system planning and operation



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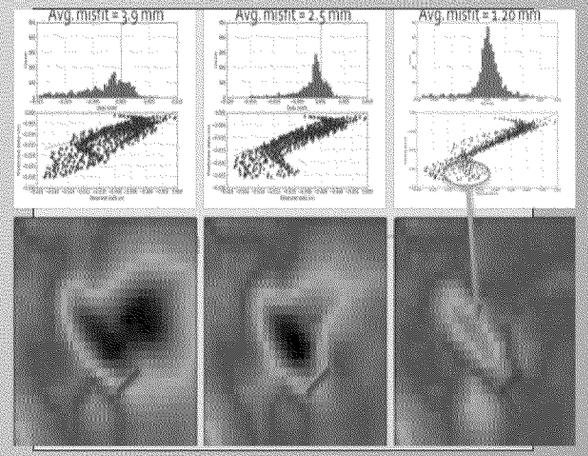
California Energy Systems for the 21st Century

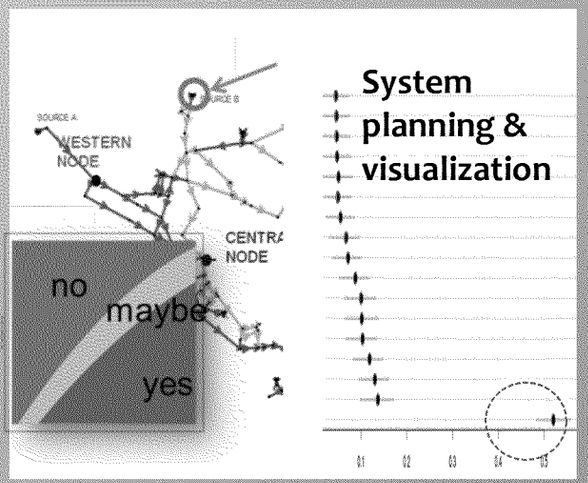
Gas System Operation potential project

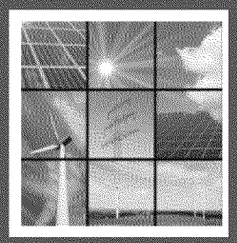
Advanced Modeling and Simulation Environment

Approach:

- Automate the calibration process for models in a way that is compatible with the IOU's existing modeling tools (PM1-24)
- Improve simulation performance and develop visualization tools that allow planners to leverage modeling results for complex decision making. (PM12-36)
- Address more complex networks and the integration of increasing amounts of available data (e.g. Smart Meters) (PM12-36)







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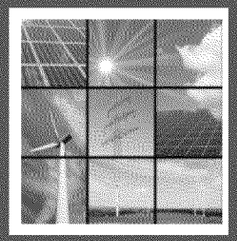
California Energy Systems for the 21st Century

Gas System Operation potential project

Advanced Modeling and Simulation Environment

Research or service needed	Potential Collaborators
Pipeline modeling tools	1. GL Noble Denon 2. Energy Solutions International 3. Gregg Engineering 4. ATMOS International 5. Simulation Software Limited 6. Eucalypt 7. Liwacom
Expertise in pipeline modeling	1. Sandia National Laboratories 2. Lawrence Berkeley National Laboratory 3. University of California, Santa Barbara
Research organization	1. Pipeline Research Council International 2. Pipeline Simulation Interest Group



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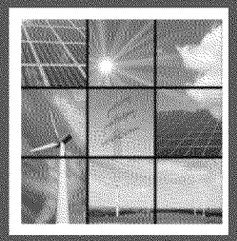
California Energy Systems for the 21st Century

Gas System Operation potential project

Advanced Modeling and Simulation Environment

Potential customer benefits

1. Avoid unplanned disruption (curtailments) of gas service during a Cold Weather Day event or an Abnormal Peak Day event.
2. Diagnose system response to a gas leak with confidence and offer repair solutions that reduce system disruption.
3. Accurate knowledge of system capacity and customer usage to reduce the response time during emergency (such as a gas leak), thereby reducing natural gas emissions.
4. An effective simulation environment results in faster response to planning and operation requests. The benefits are multiplied during emergency scenarios to respond to a gas leak and implement repair alternatives.
5. Fully calibrated and validated high resolution models will allow planners to ensure that system investments are optimized, which will decrease costs.
6. Automate manual processes to increase the efficiency of the hydraulic simulation work, to lower costs and increase result resolution.



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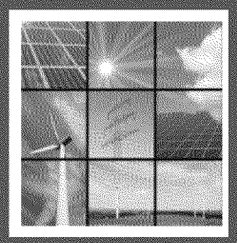
California Energy Systems for the 21st Century

Cyber Security

Collection, extraction, fusion and analysis of grid network and device data will be used to develop models and simulations of cyber event impact to grid operations. These simulations, coupled with advanced analytics of actual cyber-industrial control systems data, will provide the IOUs with the situational awareness and system impact information needed to mitigate, contain, and respond to cyber attacks that may compromise grid performance or ratepayer privacy.

Scott King (SDG&E)

John Grosh (LLNL)



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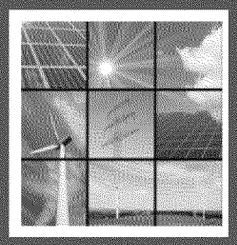
Cyber Security potential projects

- Advanced Threat Analysis Capability
  - Develop tools and algorithms to analyze large amounts of the IOU network data to detect advanced cyber attacks and improve situational awareness; develop tools to determine vulnerabilities in hardware, firmware, and software that support the operation of California's critical infrastructure.
- Modeling and Simulation
  - Build a computational simulation codes that couples the industrial controls systems communication infrastructure with generation, transmission and distribution networks, storage, and loads to simulate cyber attack and defense.



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California Energy Systems for the 21st Century

Cyber Security potential project

Advanced Threat Analysis Capability

Need:

A highly-coordinated and structured cyber, physical, or blended attack on the bulk power system, could result in long-term, difficult to repair damage to key system components in multiple simultaneous or near-simultaneous strikes. Unlike "traditional," probabilistic threats, a coordinated attack would involve and intelligent adversary with the capability to bring the system outside the protection provided by current planning and operating practices. An outage could result with the potential to affect a wide geographic area and cause large population centers to lose power for extended periods.

Objective:

This project includes two key components:

- **Situational Threat Awareness:** Develop tools and algorithms to mine and analyze large amounts of the IOU operational data over long periods of time to discover and implement corrective actions to reduce the impact of advance persistent threats on California's critical infrastructure.
- **Vulnerability Analysis**: Develop tools to determine the extent of cyber vulnerabilities in hardware, firmware, and software that support the operation of California's critical infrastructure.

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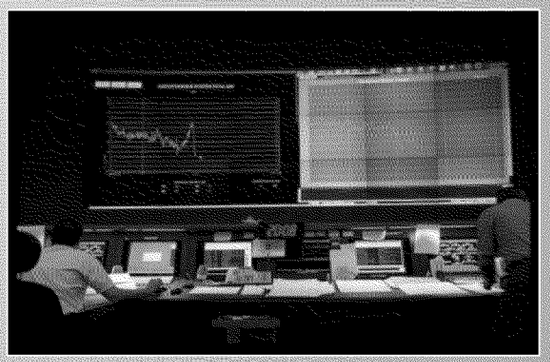
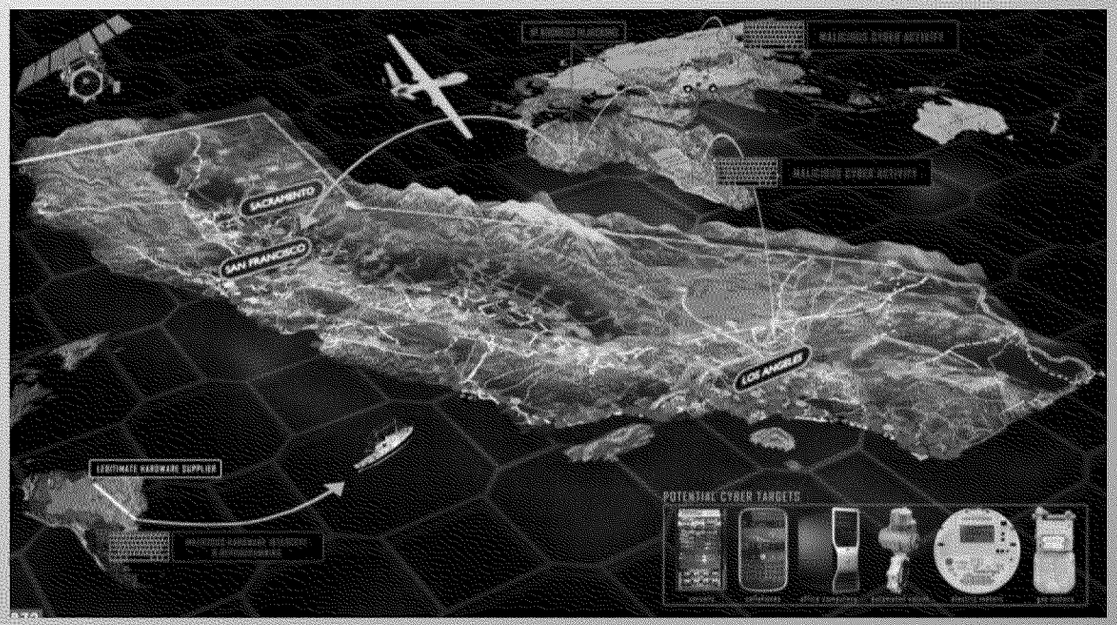
Cyber Security potential project

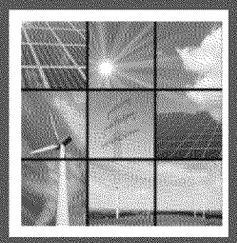
Advanced Threat Analysis Capability

Approach:

- Situational Threat Awareness (PM1-60)
- Vulnerability Analysis (PM1-60)
- Transition to IOUs (PM36-60)







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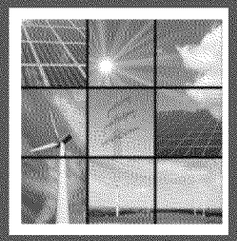
California Energy Systems for the 21st Century

Cyber Security potential project

Advanced Threat Analysis Capability

Research or service needed	Potential Collaborators
Situational awareness tools	1. Invincea 2. Internet Systems Consortium
Device and control testing and evaluation	1. Sandia National Laboratories 2. Idaho National Laboratory



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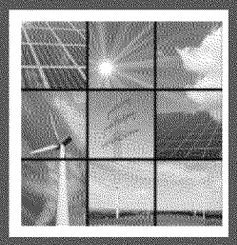
Cyber Security potential project

Advanced Threat Analysis Capability

Potential customer benefits

1. Define and develop "forward looking" technology, strategies and tools that will further strengthen the grid against cyber based attacks.
2. Increase the security of California's critical infrastructure by creating new capabilities to prevent advanced attacks that current commercial technologies do not address.
3. Enable the California utilities to better understand the relationships between vulnerabilities in cyber systems and their impact to critical components within the electric grid.
4. Develop the capability to assess the likelihood of successful grid impacting cyber-attacks, determine the optimal placement of preventative security controls, and reduce the risk of a cyber-attack that would cause large scale grid impacts.



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Cyber Security potential project

Modeling and Simulation

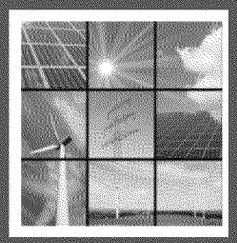
Need:

Emerging cyber threats require detailed models to identify vulnerabilities and develop mitigation strategies. Because the grid is coupled at several levels, a comprehensive model has to be developed to a sufficient level of detail to identify vulnerabilities and paths across those levels. The increasing use of devices with two-way communication creates an emerging threat to grid control systems. These devices and their interaction with utility back office systems and control systems are growing in complexity. Detailed models identifying control characteristics and communication protocols have not been developed for a large-scale analysis across the State of California.

Objective:

We propose to build and successively refine a computational model that couples

- Communication infrastructure
- Primary electric generation and transmission behavior
- Utility distribution networks
- End-user loads and generation
- Utility ICS systems



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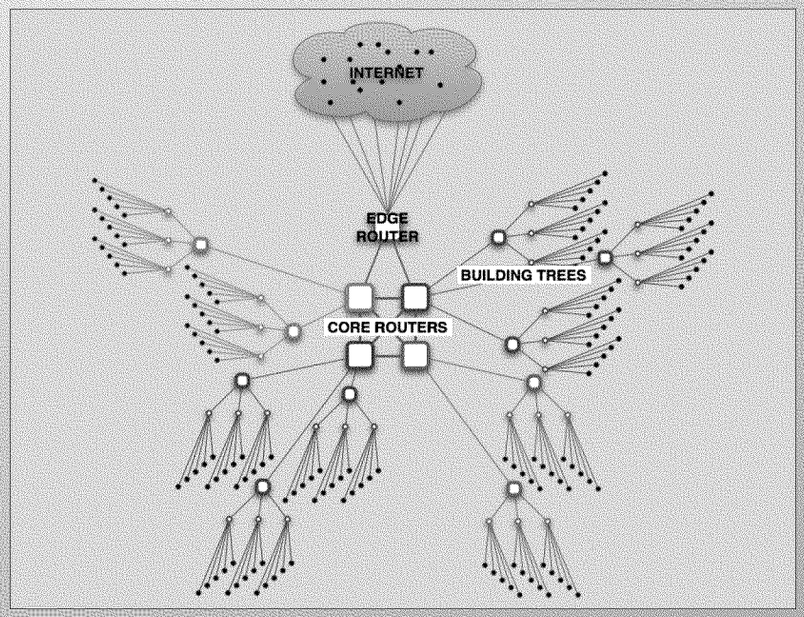
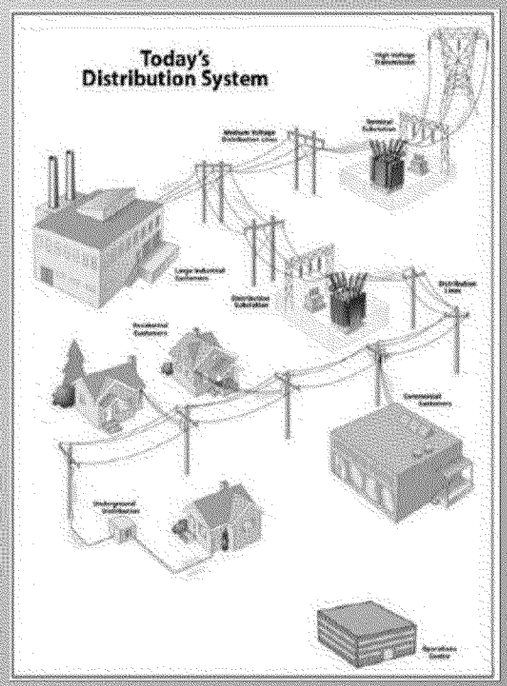
Cyber Security potential project

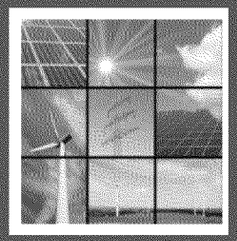
Modeling and Simulation

Approach:

- Baseline Device, Topology and Traffic (PM1-60):
- Coupled Model Development (PM6-44):
- Cyber Attack Scenarios and Modeling (PM18-60):







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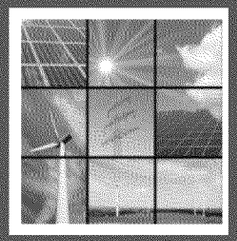
California Energy Systems for the 21st Century

Cyber Security potential project

Modeling and Simulation

Research or service needed	Potential Collaborators
Communication / Grid Modeling and Simulation Tools	1. University of Illinois 2. Pacific Northwest National Laboratory 3. Oak Ridge National Laboratory



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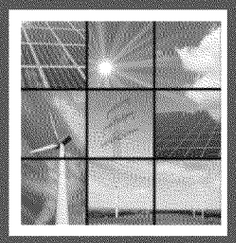
Cyber Security potential project

Modeling and Simulation

Potential customer benefits

1. As a planning tool in assessing operational benefits and risk reduction that could be realized by future grid improvement proposals. Such information would enable rapid quantitative assessment of potential benefits as part of developing future rate cases
2. Explore and evaluate incident response scenarios in advance of need, to improve the time to respond and recover
3. Capability to replay cyber incidents, with variations, to understand the range of risk exposures in similar situations, and the possible consequences of response strategies other those utilized at the time of incident
4. Provide training and exercise capability for incident detection and response



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California Energy Systems for the 21st Century

CES-21 Workshop Agenda

- Welcome: Brian Cherry
- Introductions: Brian Cherry
  - CES-21 Board of Directors: Jane Yura, Doug Kim, Jeff Nichols, Dan Kammen, Mani Chandy, T.J. Glauthier
  - Liaison to Board of Directors: Ed Randolph
- Overview of Workshop Objectives: Erik Jacobson
  - Discussion of the proposed research and priorities
  - Review the business case for proposed research
- Research Area Presentations + Q&A
  - Electric Resource Planning: Redacted (PG&E) & Tom Edmunds (LLNL)
  - Electric Operations: Robert Sherick (SCE) & Liang Min (LLNL)
  - Gas Operations: Redacted (PG&E) & Lee Glascoe (LLNL)
  - Cyber Security: Corey McClelland (SDG&E) & John Grosh (LLNL)
- Next Steps: Erik Jacobson
  - Updates to CES-21 research projects and business cases
  - Next CES-21 Board Meeting
- Adjourn: Erik Jacobson