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FIVE-YEAR TRANSMISSION RESEARCH AND DEVELOPMENT PLAN

Public Interest Energy Research Program
Energy Systems Integration Team

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Table of Contents

Executive Summary ……. 1
Introduction …….…….. 4

1 The Problem ……..……... 4
2. Public Interest Criteria for PIER Funding ……...……..... 5

3. Relationship between Public Interest, Regulated and Competitive R&D … 6

4. Transmission Research Assessment and Gap Analysis …..……..... 7
4.1 Current Transmission R&D Projects ……... 7
4.2 Gap Analysis ……..... 9
4.3 Opportunities for PIER ……... 10

5. Scenario Analysis ……..... 11
5.1 Developing Scenarios ……..... 11
5.2 Transmission Technologies ……..... 17
5.3 Assessment of Public-Interest Transmission R&D ……..... 18
5.4 Recommended Priorities ……..... 19

6. Research and Development Committee Workshop ……... 19
6.1 Comments Following Workshop ……..... 20

7. Staff Analysis of Transmission Research Initiatives ……..... 20
7.1 Process ……..... 20
7.2 Selection Criteria ……... 20
7.3 Draft Five-Year Transmission R&D Plan ……... 21

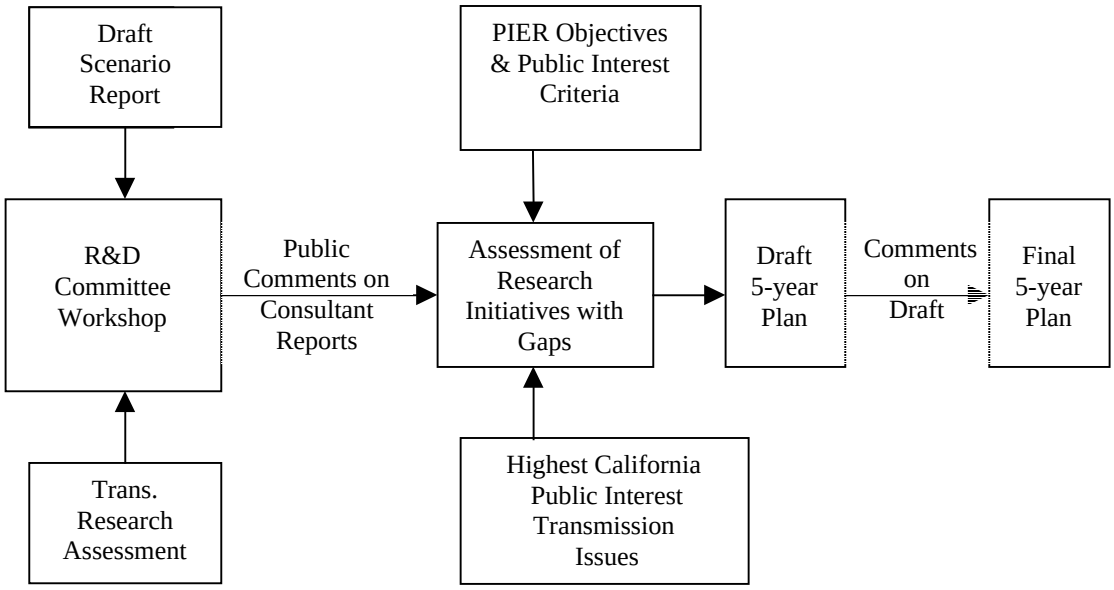
8. Final Research Initiatives ……..... 21
8.1 Descriptions of Research Initiatives ……..... 21
8.2 “First Priority” Initiatives and
Transmission Research Plan Implementation ……..... 24

Executive Summary

Expansion of the California transmission system has not kept pace with demand over the last 20 years. This has resulted in congestion, reliability problems, and higher costs related to insufficient transmission infrastructure which threatens the integrity of the system and the health of the economy. In California it is estimated that a major upgrade to the bulk transmission system can take from five to seven years to complete and now requires planning to begin ten years in advance. Major obstacles to building new transmission lines include: demonstrating need, securing environmental permits and right-of-ways, securing regulatory approval for publicly-owned utilities and federal agencies, and local opposition due to visual and environmental impacts, as well as concerns about property values.

The California Energy Commission, Public Interest Energy Research (PIER) Energy System Integration (ESI) program, recognizing the importance of these critical transmission problems, developed this Five-Year Transmission Research Plan. The plan will be used to guide and coordinate the program's public interest research activities and focus the research on the highest public interest transmission issues. The process that was used to develop this plan includes: identifying California's short and longer term transmission issues and needs; a review of existing research initiatives; and consideration of potential future electricity system scenarios and their research implications. Staff then solicited comments from the public and key stakeholders and applied public interest and PIER criteria to determine what research is appropriate for PIER to fund and include in a research plan. See Figure 1.

Figure 1. PIER Process for developing a Five-Year Public-Interest Transmission R&D Plan



Two consultant reports were developed for PIER to provide the needed transmission R&D background and prospective. The reports are: "Electricity Transmission R&D

Assessment and Gap Analysis" prepared by Navigant Consulting, Inc., and "California's Electricity System of the Future Scenario Analysis in Support of Public-Interest Transmission System R&D Planning" prepared through the Consortium for Electric Reliability Technology Solutions (CERTS), by Joe Eto, Lawrence Berkeley National Laboratory and John P. Stovall, Oak Ridge National Laboratory.

The transmission research assessment and gap analysis began by searching the literature and interviewing private and public sector representatives to determine what research was being done and planned for the future throughout the country. This information was used to determine where there were research gaps and what research initiatives would address these gaps. PIER Public Interest Criteria were applied to these research initiatives to identify transmission research and development (R&D) that would not be appropriate for PIER to fund. The qualifying research initiatives were identified in the Navigant report as transmission opportunities for PIER to consider.

The scenario analysis identifies four scenarios that describe different possible future evolutions of the California electricity system and what transmission R&D would be needed to address issues associated with each. The scenarios that were developed and analyzed were:

- Continuation of Current Trends (Muddling Through)
- State-Mandated Solutions
- Greater Regional Coordination
- Local Solutions

Also considered were the roles and responsibilities of stakeholders and government agencies in the California electricity market and how they might change or evolve in the future. The research needs associated with the respective scenarios were reviewed using the PIER Public Interest Criteria for supporting transmission R&D in California. Ranges of high to low public-interest R&D priorities are identified in the report.

On March 12, 2003, the California Energy Commission Research and Development Committee held a workshop to receive public comments on both the above consultant draft reports. These consultant reports, as well as public comment, provided background on issues and problems facing transmission owners and operators, as well as information on a wide range of potential transmission R&D investment opportunities that would be appropriate for PIER.

Using this information, staff determined which research initiatives addressed the highest public interest issues and best fit the objectives of the PIER program. These initiatives form the basis of the transmission plan and are grouped under the following four descriptive focus areas:

Focus Area I: Existing Component Optimization

1) Use actual system conditions in place of worst case conditions to increase thermal and stability limits
2) Develop advanced materials that enhance the durability of current components

3) Develop modular equipment designs/novel configurations to manage failures and enable rapid system restoration under catastrophic circumstances
4) Apply storage technologies to enhance transmission capabilities

Focus Area II: New Capacity Infrastructure

1) Increase the capacity of the conductors
2) Develop new methods and/or practices to mitigate the environmental and health impacts of power line corridors on sensitive habitat and wildlife (e.g. conservation banking to mitigate species impacts)

Focus Area III: System Operations

1) Improve real-time grid data and performance tools
2) Improve the quality and availability of real-time data so system operators can manage region-wide dynamic loadability constraints
3) Develop systems to carry out complex control orders in real-time

Focus Area IV: Planning Tools

1) Refine and develop transmission expansion planning tools and approaches that can be used in a restructured electric utility industry to: assure transmission reliability is maintained in a cost effective manner; the environment is protected; avoid unnecessary duplication of facilities; reduce congestion; and provide for coordination with all parties involved in transmission operation and use.

It should be noted that the above research initiatives are in no particular ranked order. Final versions of the two consultant reports, workshop transcript, comments from the public related to the development of the initiatives can be found at:

http://www.energy.ca.gov/pier/strat/strat_research_trans6.html

Because timeliness is important when trying to apply research to critical problems, two of the 10 initiatives listed above (Focus Area I – 1 and Focus Area IV -1) have been determined to have near-term applications, high potential benefits, and directly address critical transmission issues and will be developed immediately to launch the research program.

Finally, PIER will secure a Program Administrator (PA) to provide the needed infrastructure to fully engage all stakeholders as the new transmission plan and program are implemented. PIER will then establish a Policy Advisory Committee that will help shape the development of the remaining research initiatives identified in this plan.

Introduction

The California Energy Commission Public Interest Energy Research (PIER) program, through legislation, has the responsibility to administer and conduct public interest energy research that seeks to improve the quality of life for California citizens by developing environmentally sound, safe, reliable, and affordable electricity services and products. Public interest energy research includes the full range of R&D activities that advance science and technology and are not adequately provided by competitive and regulated markets.

The PIER program has six legislatively defined subject areas. One of these subject areas is the Energy System Integration (ESI) program area which was established to conduct cross-cutting research critical to the improvement of California's electricity infrastructure. Transmission R&D to improve the efficiency, reliability and adequacy of the transmission system is part of ESI's focus.

In the fall of 2002, PIER staff began developing this 5-Year Transmission Research and Development (R&D) plan, which prioritizes the highest public interest transmission research initiatives for funding through PIER.

The plan is divided into eight sections following the introduction.

- Section 1 states the problems with the electric transmission system
- Section 2 discusses the public interest criteria that supports PIER's transmission R&D
- Section 3 discusses regulated R&D
- Section 4 provides results of the transmission research assessment and gap analysis
- Section 5 explains the electricity system of the future scenario analysis and final priorities
- Section 6 describes the transmission R&D public workshop
- Section 7 explains the staff analysis of the transmission research initiatives and development of the draft research plan
- Section 8 describes the final transmission research initiatives

1. The Problem

Expansion of the California transmission system has not kept pace with demand over the last 20 years. This has resulted in congestion, reliability problems, and higher costs related to insufficient transmission infrastructure which threatens the integrity of the system and the health of the economy. Major obstacles to building new transmission lines include: demonstrating need, securing environmental permits and rights-of-way, securing regulatory approval for publicly-owned utilities and federal agencies, and local opposition due to visual and environmental impacts, as well as concerns about property values.

During the hot summer months, maintaining system reserves can be precarious and the increasing frequency of system emergencies are a result, in part, of inadequate transmission infrastructure. During heavy summer peak load periods, critical transmission paths in the state are often constrained. These constraints can make it impossible to transfer adequate power from one area of the state to another and restricts the import of less expensive power from out-of-state. This leads to less efficient plants being run to meet demand, as well as missed opportunities for Californians to secure lower wholesale prices for electricity.

Two major urban areas in the state are severely constrained due to limited generation and transmission capacity that restricts their ability to import power from outside their area. Unfortunately, the addition of new transmission capacity in these areas is still years away.

In 2002, the Legislature established a renewable portfolio standard to support and encourage the strategic placement of renewable resources throughout California to support electric system reliability. The ability to identify, evaluate, and develop transmission infrastructure to support these resources requires statewide transmission expansion planning tools that are not currently available.

In California it is estimated that a major upgrade to the bulk transmission system, from the time it is proposed, can take from five to seven years to complete and now requires planning to begin ten years in advance.

The transmission plan presented here focuses on research initiatives that will help solve the problems described above.

2. Public Interest Criteria for PIER Funding

All research initiatives that were considered for inclusion in the plan were screened on several levels. The first criteria applied were drawn from PIER's enabling legislation and the "Five-Year Investment Plan, 2002 Through 2006, for the Public Interest Energy Research (PIER) Program**."** These criteria, often referred to as public interest criteria, are used to determine which transmission R&D efforts are appropriate to be considered for PIER to fund. Research initiatives and projects must meet all three criteria.

Criterion 1. R&D activities that improve the quality of life for California citizens.

- Improvements in environmental quality; public health and safety; energy cost/value; and electricity system reliability, quality, and sufficiency are all in California's interests.

Criterion 2. R&D activities that advance science or technology.

Criterion 3. R&D activities that are unlikely to be adequately provided by the competitive or regulated research sectors.

- Criterion 3 specifically addresses social and public interests that are not accounted for by market pricing mechanisms. Pure public interest R&D refers to efforts to develop basic information that is non-exclusive and cannot be appropriated by the research sponsor. Applying criterion 3, however, requires considerations that extend beyond "Pure Public Interest" R&D.

3. Relationship between Public Interest, Regulated and Competitive R&D

For more than 20 years, the government, the private sector and the state's regulated utilities collaborated to ensure that energy-related R&D activities provided both public and private goods for the benefit of California's citizens. Prior to and after restructuring of the electricity services industry in 1998, investment in both regulated and public interest R&D by utilities had declined. This, in part, was the reason the Energy Commission was given the responsibility to develop and fund public interest research, but it was assumed the utilities would continue to pursue some level of funding for regulated R&D through California Public Utilities Commission (CPUC) ratemaking proceedings. However, though nothing in legislation precludes the CPUC from increasing funding authorizations for regulated R&D programs of California's IOUs, most have either been eliminated or dramatically reduced in size.

As noted in the prior section, public interest research refers to research that is not being adequately provided by the competitive and regulated market. From a societal perspective, pure public interest R&D should result in public benefits that cannot be appropriated by individual firms. Environmental research falls into this category. An example is surveying the state and investigating where sensitive habits are located. The information developed is in the public domain and would provide no private benefit to the researcher. A few projects meet these pure public interest criteria. However, often the benefits are shared. For example, an individual firm may be able to appropriate cost benefits, but additional environmental benefits may require public investment. Hence the challenge for PIER is to balance public and private benefits. This balance requires judgment. When doing transmission research that improves hardware or system operation, benefits accrue to both the asset owner and to ratepayers if the research results in cost reductions that are reflected in their bills. PIER is required to identify and balance these benefits when developing and selecting projects to fund.

In the coming months, PIER will implement this transmission plan. We will build on the 50 transmission and distribution projects already initiated by PIER. Because the transmission infrastructure in California is inadequate and in need of upgrades and expansion, the need for research to address these problems continues to increase.
The goal of the rescoped program will be to identify and focus all research efforts on the highest public interest R&D that will benefit all California IOU ratepayers.

4. Transmission Research Assessment and Gap Analysis

When planning how to collect the information necessary to do a comprehensive transmission R&D plan, staff reviewed the whole spectrum of private and public sector transmission research being done throughout the country and beyond to assure our research efforts are not duplicative. PIER contracted with Navigant Consulting, Inc, to assess the status of transmission research activities and to determine where there are research gaps.[1]

4.1 Current Transmission R&D Projects

Navigant first reviewed the existing literature to determine past, present and planned research activities in the private and public sectors. They then interviewed representatives of utilities, industry, non-profit, and government representatives who were involved in transmission R&D efforts. In all, they identified and examined 190 projects. What they found was that transmission technologies and the associated R&D in this area are often quite expensive, resulting in a predominance of consortium projects. The following projects are illustrative of the types of research being performed and who is supporting that research. The examples are organized by focus areas used in the Navigant report.

I. Component Optimization

- **Real-Time Ratings for Path 15 (CEC, Valley Group, Niskayuna Power Consultants, Power Delivery Consultants, PG&E and CA ISO):** This project examines the feasibility of providing real-time transmission line ratings by monitoring the conductor tension and environmental factors for a multiple transmission line path and communicating the real-time data to PG&E and the ISO. This project also provides a calculated real-time rating for the path directly to the system operators.

- **Optical Voltage & Current Sensors Demonstration (BC Hydro and NxtPhase):** This project verified the performance of NxtPhase Corporation's optical sensors in a substation environment. The sensors provide high accuracy measurements of voltage and current at lower cost compared to conventional equipment, and can be used for metering, equipment protection and power quality management.

II. Capacity Additions

- **Rights-of-Way Environmental Issues in Siting, Development and Management (EPRI, CEC and various contractors):** This program develops and delivers scientific information and innovative approaches to help rights-of-way (ROW) owners/users contain costs while responding to the competitive marketplace and practicing environmental stewardship.

- **Design And Cost Estimates For Novel, Low-Cost Overhead Transmission Lines (EPRI):** This project aims to lower transmission capital costs and construction time by using the latest best practices for design, low cost materials,

procurement, and quick construction. This project will develop a Handbook delineating best practices for such transmission line capital improvements.

- **Superconductivity for Electric Systems (DOE, 27 manufacturers, 8 labs, 10 utilities, and 19 universities):** The DOE Superconductivity for Electric Systems program is the leading US federal effort in High Temperature Superconductors (HTS) research involving world-class industry/ government/ university teams focused on developing and commercializing electric power applications of HTS.

III. Advanced System Operations

- **USAT MOD-2 Satellite Communication System (CEC, Edison Technology Solutions):** The purpose of this project was to promote development of the USAT satellite communications system to deliver high-reliability communications for utility supervisory control and data acquisition (SCADA) systems under all types of weather conditions.

- **Power Quality-Based Transmission Asset Optimization Tool (EPRI):** The project will develop a methodology for a power quality transmission asset optimization tool that will allow energy companies to prioritize investment in T&D assets and to determine the cost optimized solution between utility side investment and customer side improvement. The specific power quality determinants that will be used in the value based reliability model are voltage sag and the associated economic impact of voltage sags on sensitive customers.

- **Real-Time Reliability Management Tools (CERTS, NERC, California ISO, and Electric Power Group):** Key activities include development and demonstrations of prototypes for: 1) new near-real-time reliability adequacy tools for operators, 2) real-time monitoring, performance tracking for system area control error, and area interchange errors for security coordination, and 3) wide-area information visualization systems for monitoring the grid accurately, identifying root causes of problems, and taking swift action to remedy abnormal situations.

IV. Planning Tools

- **London Economics for the California Independent System Operator (CAISO):** The purpose of this project was to develop a methodology to determine and evaluate the positive and negative economic impacts of proposed transmission projects. Analytical principles, a new methodology, analytical tools, and a decision framework were developed.

- **California Wind Energy Consortium (CEC and UC Davis):** The purpose of this project is to provide the initial impetus for establishing the forum or consortium of parties and the recognition that is needed at the state level. Investigative white papers will be prepared that offer plausible approaches to optimizing wind plant facilities including transmission infrastructure issues.

- **Power Market Simulator for Wholesale Energy Markets (EPRI):** The Power Market Simulation Software, now under development, will be used to simulate hedging strategies in electricity markets before they are put into practice. It will account for market contingencies in market operations and production.

- **Costing and Pricing of Ancillary Services (PSERC, TVA, ConEd, and WAPA):** This project investigated methods for establishing justifiable costs for ancillary services. The work focused on the issues of costing reactive power and voltage control. It addressed questions of what it costs to maintain voltage; what it costs an energy provider to use an exciter; what operating costs can be allocated to voltage control; and how these services might affect a third party.

- **Develop Transmission Pricing Methods Sensitive to Reliability (BC Hydro):** This project is designed to develop transmission pricing methods which are sensitive to reliability and provide price differentiation for different customers with different levels of reliability, price signals to improve overall system reliability, and incentives to properly locate future generation and load.

The results of the literature search and interviews provided essential information that helped identify the most critical issues facing electric transmission owners and operators, regulators and the public in California. The information was consolidated and examined for common themes. It formed the basis for identifying what research initiatives would be needed to address the most important problems affecting the California transmission system – improving reliability and coordinating infrastructure planning to facilitate the timely development of new transmission capacity.

4.2 Gap Analysis

Before recommending needed these research initiatives as options for PIER to consider for inclusion in its research portfolio, it had to be determined what research initiatives were already in progress. The following framework used by Navigant for the assessment, allowed staff to evaluate what information or value PIER investment would add to any ongoing research activity.

There is a significant gap if:

> *Few companies or entities are adequately pursuing a research strategy at a level that will likely ensure the strategy has a reasonable chance of success to help resolve the issue it is addressing. This could indicate an area that has been overlooked or just emerging as a viable research initiative. However, it could be an initiative that is not appropriate or feasible to pursue at this time.*

There is a moderate gap if:

> *Continued and additional research activity is likely required to ensure the research has a reasonable chance of success to help resolve the issue it is addressing.*

There is little or no gap if:

> *Little additional work beyond what is currently funded is necessary. There are many companies and/or entities pursuing this initiative. The current level of activity is likely appropriate to ensure the research strategy has a reasonable chance of success to help resolve the issue it is addressing.*

When the analysis was completed, Navigant found that there was a range of gaps among the transmission research initiatives that they evaluated. Initiatives that had little or no gap were determined to be a low priority and dropped. Staff also evaluated how gaps would change if PIER discontinued funding any of the projects it now supports.

4.3 Opportunities for PIER

The remaining research initiatives were then evaluated using the public interest criteria described earlier in this document. The initiatives that met the criteria are presented as opportunities for PIER to evaluate for inclusion in its research plan. The final list includes initiatives from all four focus areas, including component optimization, capacity additions, advanced system operations and markets.

Table 1. Research Initiatives That Meet Energy Commission Public Interest Criteria

Component Optimization	• Use actual system conditions in place of worst case conditions to increases thermal and stability limits • Develop new operating techniques • Develop self-healing networks • Develop novel equipment/configuration designs to manage failures and rapid system restoration • Develop mechanized/automated repair techniques • Develop materials to increase efficiency of system components (e.g., conductors, ceramics, carbon fiber) • Apply storage technologies to enhance transmission capabilities
Capacity Additions	• Increase operating voltage • Increase/simplify the application of DC transmission • Develop novel phase configurations to increase capacity • Develop novel configurations to reduce environmental/public impact (e.g., aesthetics, EMF, wetlands, wildlife)
Adv System Ops	• Develop enhanced communications architecture • Integrate and streamline operations database and information systems • Develop expert systems to carry out complex control orders

Markets	• Develop mechanisms to value and assign capacity rights • Determine appropriate ancillary services • Develop modeling tools to test and simulate markets • Identify ISO and Transmission Ownership requirements • Develop systems to ensure transaction compliance • Develop rules and systems for congestion management • Determine how to encourage adequate investment in transmission • Determine the best way to regulate transmission • Determine optimal ownership of transmission • Develop transmission value network

5. Scenario Analysis

Recognizing that the Navigant assessment of transmission R&D would only capture what was happening in the present, PIER wanted to get a sense of what might affect transmission R&D priorities in the future. The financial uncertainty and institutional conflict that developed as a result of the "electricity crisis" of 2001, remains a factor that is affecting the amount of investment in transmission technology and R&D today, but if that were to continue or change, how would it affect PIER's research plan?

5.1 Developing Scenarios

To get a sense of some of those possibilities and recognizing that our research plan must be robust and able to adapt as the future unfolds, PIER directed the Consortium for Electric Reliability Technology Solutions (CERTS) to analyze plausible future scenarios for the evolution of California's electricity system to see how public interest research needs could change under those possible futures. The full details of this analysis can be found in "California's Electricity System of the Future, Scenario Analysis in Support of Public-Interest Transmission System R&D Planning."[2]

The time horizon for the scenario analysis was set at five years to coincide with the research plan. Four scenarios were developed that described different possible evolutions of the California electricity system and identified transmission R&D needs for each. It is important to note that the scenarios developed for this report are not predictions, nor did PIER designate any as preferred. The four scenarios that were developed for this report by CERTS are presented below.

Scenario 1 - Continuation of Current Trends (Muddling Through)

Central Features:

- The financial uncertainty, institutional conflict, and lack of resolution resulting from the California "electricity crisis" of 2001 continue. As an example, Pacific Gas and Electric Company (PG&E) is unable to emerge from bankruptcy in a timely fashion because of on-going conflict with the California Public Utilities Commission (CPUC). Similarly, FERC decisions on refunds for energy

overcharges in California in 2001are delayed and, once made, are challenged, leading to additional delays. There is incomplete resolution of differences in vision between FERC and the state over the structure and organization of wholesale electricity markets. Federal energy legislation on electricity does not clarify FERC jurisdictional roles, leading to ongoing state challenges of federal authorities regarding the organization of electricity markets.

- Merchant generators are slow to return to financial health. As a result, construction on many merchant plants is halted, and other plants are cancelled. Significant public opposition and lack of clarity about roles and economic benefits is successful in blocking the siting of new power plants and major new transmission lines, or leads to protracted delays in projects. For example, growing public concern regarding health risks of high-voltage electricity transmission continues unabated. Local groups organize successfully to create a hostile environment for would-be power plant developers.

- Regional demand growth is moderate, consistent with recent trends (2001 is considered an exception). California demand growth lags behind regional growth because of a continuing depressed economy and state budget crisis. Supply is unable to keep pace with demand. Efforts to use pricing approaches to ration supplies during tight periods are mired in ideological (and sometimes misleading) debates over alleged wealth transfers among customer classes.

- The upgrade of Path 15 continues to be delayed, and outages in the corridor sever Northern and Southern California for extended periods. CAISO must again implement rolling blackouts.

Organization and operation of the transmission system is characterized as follows:

- CAISO continues to operate transmission assets owned by IOUs. Municipal utilities continue to operate their transmission assets independent of CAISO.

- Wholesale market design means that CAISO will transition to Market Design 2002 (MD02), yet there is significant reliance on price caps in lieu of more basic, structural remedies.

- The incentives for IOU transmission investment are determined initially by FERC's authorized, regulated return on equity (ROE). However, although FERC has increased these rates modestly in recent years (and considers even greater incentives to promote certain structural and investment activities), the effect of these incentives is mitigated by CPUC-authorized retail tariffs. A politically popular retail rate freeze, in the absence of other cost cutting by the utilities, undercuts the effect of higher FERC-authorized ROEs.

- Moreover, because of reliance on an ROE approach for rewarding transmission investment, there is no relationship between the impact of transmission limits on market operations and incentives to upgrade the transmission system. IOUs focus on generation interconnection and local reliability upgrades. Transmission projects needed for market efficiency continue to face an uncertain future

particularly because the resultant higher consumer costs are a "pass-through" item for the transmission owning utilities.

- Transmission planning continues using the current the process led primarily by IOUs. There is growing awareness of the need to account for economic efficiencies, yet there are no widely accepted planning tools to support these assessments. State oversight is limited. The process is dominated (and utility staff are overwhelmed) by generation interconnection requests (increasingly, for plants that fail to materialize). Regulatory policy direction is inconsistent regarding priorities of economic efficiency versus reliability. There is still no coordinated regional process for addressing approval of multi-jurisdictional lines.

- Reliability management continues with the present form of NERC/WECC oversight, in which financial penalties for non-compliance are minimal. Information-sharing among operators for reliability management is negotiated on a bilateral basis; operators have limited access to information about conditions on neighboring systems.

Scenario 2 - State-Mandated Solutions

Scenario 2 can be viewed as one possible reaction to or transition from Scenario 1. In Scenario 2, strong state leadership results in increased coordination of electricity planning and operations within the state yet leaves unresolved many coordination issues in the West as a whole.

Central Features:

- State actions and final bankruptcy court rulings allow IOUs to return to financial health. The state actively supports long-term transmission investments to increase reliability as well as a revamped, integrated resource planning process. This process includes renewed emphasis on energy efficiency and renewable energy sources. The focus of planning efforts is on increased reliance on in-state resources to enhance reliability as well as continued access to regional markets and out-of-state resources.

- FERC defers to state-led decisions on wholesale electricity market organization and structure. FERC rulings on refunds contribute to renewed financial health of IOUs. Availability of imports is reduced somewhat because of unresolved market inconsistencies between California and the rest of the West, which further increases the need for and justifies the construction of additional in-state generation.

- A state-directed integrated resource planning processes facilitates the siting of in-state generation in locations that relieve intra-state transmission bottlenecks. Transmission system enhancements emerging from the process give greater consideration to reliability-enhancing investments over those that might facilitate increased interstate trade for economic purposes. The state orders IOUs to build needed transmission projects and further streamlines regulatory processes, leading

to greater coordination among state agencies for approval and siting of new generation and transmission facilities.

- Demand growth continues at modest 1990s levels, moderated somewhat by state-directed energy efficiency and local DER (including customer-owned, locally sited renewables) programs, which, together, reduce the total demand for electricity that must be met through the high-voltage transmission system. Increased reliance on in-state resources versus lower-cost (at least, in the short-term) out-of-state resources leads to moderate electricity price increases. However, there is no major reform of retail tariff structures (i.e., limited movement toward real-time pricing); thus, there is no significant demand response to dampen wholesale market price volatility. In any case, the final cost of electricity to customers is significantly decoupled from wholesale market prices because the bulk of customer demand is met through long-term (fixed-priced) contracts.

- Stringent local air quality restrictions limit utilization of conventional back-up generation and fossil fuel-fired DER, so DER development is limited.

Organization and operation of the transmission system is characterized as follows:

- CAISO, with a state-appointed board, continues to operate transmission assets owned by IOUs; municipal utilities continue to operate their transmission assets independent of CAISO. MD02 is fully implemented. Reliance on price caps is eased because greater state involvement (e.g., directing and streamlining the process for construction of needed power plants) reduces in-state supply-demand imbalances. Aggressive market monitoring sharply limits opportunities to unfairly exploit market power.

- FERC-regulated ROE is coordinated with CPUC to ensure meaningful opportunities for recovery under regulated tariffs. For example, CPUC issues Certificates of Public Need based largely on CAISO recommendations, thereby lowering IOUs' uncertainty regarding cost recovery for transmission investments.

- At the same time, there is an evolving mixture of private and public ownership of the transmission system. State-led directives to expand transmission may be carried out by third parties operating under long-term contracts with IOUs, or new transmission facilities may even be owned by the state.

- Transmission planning emerges as one element of the state-led integrated resource planning process, which is tightly coordinated with the Energy Commission's supply and demand assessments. Opinions differ regarding assessment of the economic efficiency and reliability benefits of increased transmission and evaluation of tradeoffs with alternatives (local generation, DR, etc.) There is still no coordinated regional process for addressing either planning or approval of multi-jurisdictional lines.

- Reliability management is reformed through the creation of the North American Electric Reliability Organization (NAERO). There are meaningful financial

among system operators for reliability management continues to be negotiated on a bilateral basis.

Scenario 3 - Greater Regional Coordination

Scenario 3, in which greater coordination and leadership for electricity planning and operations emerge among the Western states, can be viewed as a distinct reaction to or transition from Scenario 1. Nevertheless, unresolved issues remain regarding how coordination is actually implemented.

Central Features:

- An ostensibly unified market design for the entire WECC is supported through the creation of three large western-states RTOs. There is substantial region-wide trade among wholesale power producers and load-serving entities.

- Harmonization of interests increases (but is not complete) among states as well as federal land management agencies and Native American tribes. Jurisdictional conflicts are reduced (but not eliminated) under greater FERC oversight.

- The state further streamlines its regulatory processes, allowing for meaningful coordination with regional planning and siting bodies for approval and siting of new generation and transmission facilities. However, these regional bodies are still in their formative stages. Procedural steps and coordination between/among them and state and federal agencies are not yet seamless.

- There is a healthier climate for private investment in new generation relative to the climate in previous years, which leads to an improved overall regional supply-demand balance. Still, as a result of the meltdown of 2001, financial markets remain slow to provide capital to the once-vibrant merchant power plant sector.

- Demand growth increases to 1980s levels as the economy responds, in part, to the renewed health and increased stability of wholesale electricity markets.

- Locational marginal pricing of transmission creates tangible incentives to locate generation closer to load and provides one element for a more comprehensive framework for enabling greater DR. There is a significant increase in the fraction of customers exposed to prices that more closely reflect time-varying, wholesale market conditions than has been true under past tariff practices.

Organization and operation of the transmission system is characterized as follows:

- CAISO and publicly owned transmission facilities within California are subsumed into one of the three large, western-states RTOs. The current mixture of private and public ownership of transmission continues. Limited, but growing, merchant transmission investments take place along certain high-value corridors into the state.

- FERC's Standard Market Design (SMD) is implemented. Aggressive market monitoring sharply limits opportunities for unfair exploitation of market power in

wholesale electricity markets.

- Performance-based ratemaking (PBR) for IOUs provides meaningful financial rewards to transmission owners for investments and other operational improvements to reduce congestion costs and losses. FERC's regulatory decisions provide greater certainty than is the case currently for recovery of merchant investment.

- Transmission planning occurs, in principle, within the context of overall resource planning that is conducted though a regional process with significant coordination among state planning agencies and transmission owners. In reality, the newness of the processes, despite the historic familiarity of the major players with one another, leads to false starts.

- Reliability management evolves with the transformation of NERC to NAERO. RTOs actively manage intra-RTO reliability issues. There are meaningful financial penalties for non-compliance with reliability rules governing inter-RTO movements of power. There is a significant increase in region-wide sharing of operational information for reliability management.

Scenario 4 - Local Solutions

Scenario 4 can be viewed as a possible reaction to or transition from Scenario 1 or as representing a situation that might coexist with all three of the previous scenarios. In Scenario 4, overall dependence on the transmission system is reduced because electricity services are increasingly provided and managed on a local basis. As a result, the focus of this scenario depends less on the features of transmission system and more on the features of the distribution system. We draw principally on Scenario 1 for the features of the larger electricity system in which increased local action to provide electricity service takes place.

Central Features:

- Local governments and organizations assume a significant role in energy planning, leading to increased reliance on distributed generation, locally sited renewables, and energy efficiency. There is movement toward municipalization of IOU assets in selected metropolitan and regional areas across the state.

- Low-cost fuel cells and other new small-scale generation technologies are successfully commercialized within five years. Technical costs of interconnection are lowered significantly relative to today's costs.

- State policies promote reliance on small-scale generation. Regulatory utility and local environmental barriers to DER are successfully reduced. Local building inspectors and code officials adopt a proactive posture toward on-site generation facilities.

- Significant public opposition is successful in blocking the siting of new, large generating stations and major transmission lines, in part because smaller, local

solutions have become more viable as alternatives to reliance on large, centralized power sources and systems of delivery.

- Differences continue between FERC and the state regarding the structure and organization of wholesale electricity markets. This conflict contributes to impending wholesale supply shortfalls because of underinvestment in generation and transmission at the state and regional levels.

- Demand growth continues at 1990s levels, moderated somewhat by locally directed energy efficiency programs and local DER programs.

- There is a significant increase in the fraction of customers exposed to dynamic prices, including self-generation (which provides additional demand elasticity). This leads to increased volatility in loads served by transmission system.

- Negative health effects of transmission lines are conclusively proven, reinforcing public sentiment against construction of new high-voltage transmission lines. Similarly, strong public opposition prevents opening of new or reinforcing of existing transmission corridors through environmentally sensitive or otherwise protected regions.

- Stringent environmental restrictions on greenhouse gases are enacted. The state supports additional movement toward renewables and clean, locally sited DER.

Organization and operation of the transmission system is characterized as follows:

- Same as for Scenario 1.

The authors of this report consulted and met with Staff on several occasions to develop and discuss these scenarios. When they were set, staff's attention turned to discussions of the technologies that would be considered for inclusion in the analysis.

5.2 Transmission Technologies

For this report, unlike the Navigant report that did not limit the technologies considered, it was decided to focus on eight technology categories that included nineteen technologies. These technologies, as shown in Table 2 below, were based on a list of transmission technologies that were studied and reviewed by the U.S. Department of Energy in the National Transmission Grid Study.[3] Staff felt that this list would be comprehensive and relevant. Additionally, as a pragmatic consideration in assessing R&D priorities, the authors of this report applied an annual upper limit of roughly $10-20 million for transmission R&D. This placed an important upper bound on the scale (and scope) of research activities that were assumed possible for PIER in this study.

Table 2. Technologies Considered in the Scenario Analysis

Technology Categories	Technologies Included
A. Real-time grid/asset monitoring and analysis tools for reliability management.	1. Dynamic Transmission Line and Transformer Monitoring and Systems 2. Real-Time Direct System-State Monitors and Wide-Area Measurement Systems

Technology Categories	Technologies Included
	(WAMS) 3. Real-Time Grid Operations and Performance Monitoring Tools 4. Grid Analysis Tools 5. Communication Systems for Transmission and Distribution (T&D) Systems
B. Transmission power-flow control technologies, including energy storage.	6. Flexible AC Transmission Systems (FACTS) 7. Energy Storage
C. Transmission hardware technologies.	8. Ultra-High Voltage Alternating Current (AC) 9. High-Voltage Direct Current (DC) 10. Underground Cables 11. Transmission Tower Design Tools 12. Advanced Composite Conductors 13. Standardized, Modular Transformers
D. Advanced transmission hardware technologies.	14. High-Temperature Super-Conducting Technologies 15. Polyphase Transmission Line Configurations
E. Advanced real-time control technologies and approaches.	16. Advanced Real-Time Control Technologies and Approaches
F. Market design, monitoring, and analysis tools.	17. Market Design, Performance Assessment, Analysis, and Monitoring Tools
G. Transmission expansion planning tools and approaches.	18. Transmission Expansion Planning Tools and Approaches
H. Public health, safety, and environmental issues.	19. Assessment and Mitigation of Public Health, Safety, and Environmental Impacts of Electricity Transmission

5.3 Assessment of Public-Interest Transmission R&D Priorities

Once the scenarios were developed and the range of technologies to be considered were established, the criteria and how they would be used were detailed. In the report, the authors attempt to understand, "why the market might undervalue certain R&D activities." To do this, they looked at the principal California market players: the California Independent System Operator, investor-owned utilities, municipal utilities, water districts, publicly-owned utilities (POUs), the Western Area Power Administration (WAPA), marketers, generators, merchant transmission owners, and equipment manufacturers. They also included California state agencies (excluding the Energy Commission's role in managing PIER), the Western Electricity Coordinating Council (WECC), and the North American Electric Reliability Council (NERC), the Federal Energy Regulatory Commission (FERC), and the U.S. Department of Energy (DOE).

In each scenario, organization and operation of the transmission system was characterized followed by a projection of what transmission R&D needs would result. The interests and incentives of the market players and stakeholders listed above were evaluated before concluding what transmission R&D priorities would require public-interest funding from PIER in each particular scenario.

5.4 Recommended Priorities

The report concluded that the highest priorities for public-interest R&D – i.e., those that emerge as priorities in more than one scenario, are:

- Real-time grid/asset monitoring and analysis tools for reliability management
- Advanced real-time control technologies and approaches
- Market design, monitoring, and analysis tools
- Transmission planning expansion tools and approaches
- Public health, safety, and environmental issues

The report also concluded that there is an immediate need to focus public-interest R&D support on all of the above activities that relate to system reliability and market efficiency. Specifically, they all relate to market design, monitoring, and planning tools as well as advanced controls. The authors point out that these are all areas where roles and responsibilities in California are still evolving and for which there is no existing, established research process or funding mechanism.

Research activities that emerge as lower priorities in this report are:

- Transmission power-flow control technologies, including energy storage.
- Transmission hardware technologies.
- Advanced transmission hardware technologies

The authors indicate that these activities represent important areas in need of R&D support, but from the standpoint of PIER, they are ranked lower in priority because they tend to be higher in cost compared to expected budgets assumed for this study. Also, these activities emerge as priorities in scenarios where it is assumed that California utilities are financially able and motivated to take the lead in pursuing these research activities as regulated R&D in the 5 year timeframe of the plan. In these scenarios, it is assumed that PIER's role should be supporting or as a strategic partner, not a leader.

6. Research and Development Committee Workshop

On March 12, 2003, the Energy Commission Research and Development Committee held a workshop to present and take comments on the two consultant reports detailed earlier in this document. The workshop was also webcast for the benefit of those that could not attend in person. Each consultant explained the methodological approach that was used to develop their reports and reported initial results. Questions were raised and answered and verbal comments and suggestions were noted. The opportunity to provide written comments for consideration was also extended to workshop attendees and any other interested parties.

6.1 Comments Following Workshop

Extensive comments on the reports were received, considered and used to revise both the Navigant research assessment and the CERT Scenario Analysis. There was almost unanimous agreement among commenters that research on electric transmission-related environmental issues is very important. Both consultant reports identify research in this area and indicate its importance. Interest was also indicated in demonstrations of superconductors; relating transmission research to attaining California's new Renewable Portfolio Standard; and the concept of developing virtual Regional Transmission Organizations, as well as other technology suggestions. Where applicable, this information was included in both final consultant reports. Additional information about new emerging R&D technologies has been noted and will be useful as we begin discussions on R&D technologies and projects. All comments from the workshop, along with the transcript, final versions of the transmission research assessment, gap analysis, and scenario analysis can be found at:

www.energy.ca.gov/pier/strat/strat_research_trans6.html

7. Staff Analysis of Transmission Research Initiatives

7.1 Process

With the completion of the two consultant reports, PIER staff studied the research opportunities identified in both consultant reports. The research initiatives in the Navigant report provided an in-depth view of the universal scope of research technologies that are available to address transmission research problems. On the other hand, the scenario analysis developed research priorities that were based, not only on public interest criteria, but on the R&D interests and capabilities of the players and stakeholders in the California electricity market.

It was decided that in order to address these issues, a balance of research initiatives would have to be selected that included system hardware, environmental mitigation, system optimization tools for real-time operation of the grid, and transmission expansion planning tools.

7.2 Selection Criteria

Using Energy Commission staff experts from ESI, the Transmission Planning Program and the PIER Environmental Program, each research initiative was evaluated against the following list of PIER program objectives.

- Improve the environment, public health, and safety
- Improve electricity reliability, quality, and sufficiency
- Improve energy cost/value
- Address important RD&D gaps
- Provide greater choices for California consumers
- Connect to near-term market applications

The goal of the process was to determine which initiatives were strategically aligned with PIER and state objectives and would provide the most value to California ratepayers.

Twenty-eight initiatives were considered. Several initiatives that focused on research to understand markets were eliminated because this work is not directly related to the PIER objectives. Other considerations included:

- Applicability to highest public interest transmission issues
- Near-term benefits
- Value to ratepayers
- Pragmatic assumptions about probable budget limitations
- Assessing risk associated with technology development, as well as time and path to market
- Balance of research across all four research focus areas

7.3 Draft-Five Year Transmission R&D Plan

Through an iterative process, staff selected ten research initiatives that would address the highest California public interest research issues and have the potential to provide significant value to California IOU ratepayers in the next five years. Staff decided to include all priorities recommended in Scenario 1 – Continuation of Current Trends and Scenario 2, State-Mandated Solutions, because they provide a good starting point to launch our transmission research work. Finally, staff created names for the focus areas of their research portfolio that would clearly convey the nature of the research that was planned. The four focus areas are: Existing Component Optimization, New Capacity Infrastructure, System Operations, and Planning Tools.

On June 18, 2003, this information was incorporated into the PIER Draft Five-Year Transmission Plan and posted on the Energy Commission website for public review and comment. Comments were received from diverse stakeholders and individuals. All comments were considered before finalizing the transmission research plan. Specific responses to comments on the draft plan, and all other documents relevant to this process, can be found at:

http://www.energy.ca.gov/pier/strat/strat_research.trans6.html

8. Final Research Initiatives

8.1 Descriptions of Research Initiatives

Following are brief descriptions of the ten research initiatives that make up the PIER transmission research plan, including projected benefits:

Focus Area I: Existing Component Optimization

1) **Use actual system conditions in place of worst case conditions to increase thermal and stability limits.**

Description: Improve sensing, monitoring and reporting technologies to gather real-time system information. This would allow system operators to get more capacity from the system basing operating limits on actual conditions, rather than worst-case assumptions.
Benefits:
- Higher capacity from existing lines and equipment
- Increased reliability that results from better access to resource options in an emergency
- Reduced cost to consumers as a result of greater access to remotely located lower cost sources of power.

2) **Develop advanced materials that enhance the durability of current.**
Description: Apply advanced materials technologies to make system components more durable and less susceptible to damage or failure.
Benefits:
- More reliable equipment, resulting in fewer outages and system failures.

3) **Develop modular equipment designs/novel configurations to manage failures and enable rapid system restoration under catastrophic circumstances.**
Description: Develop new equipment designs and configurations that are easier and faster to repair or replace.
Benefits:
- Faster restoration of power in the event of failure.

4) **Apply storage technologies to enhance transmission capabilities.**
Description: Increase transmission capability by applying storage technology.
Benefits:
- Improves power quality on the T&D system and reduces strain on the system at times of peak demand or during dynamic operational events.

Focus Area II: New Capacity Infrastructure

1) **Increase the capacity of conductors through utilization of new advanced conductor materials to allow more power through new or existing transmission rights-of-ways.**
Description: Increase the current carrying capacity of the conductor by developing new materials that allow high-temperature operation without violating present electrical clearances to the ground and other objects.
Benefits:
- Maximize the use of new or existing transmission infrastructure and transmission rights-of-ways.

2) **Develop new methods and/or practices to mitigate the environmental and health impacts of power line corridors on sensitive habitat and wildlife.**
Description: Design and demonstrate transmission configurations and remedial actions that reduce environmental and visual impacts, require less right-of-way, and are less harmful to flora and fauna.
Benefits:

- Minimize the impact of electric transmission facilities on wildlife and the environment in existing and new transmission right-of-ways.

Focus Area III: System Operations

1) **Improve real-time grid data and performance tools.**
Description: Improve the ability of system operators to determine the condition of the power system using real-time data and simulation models of the power system. Develop new visualization techniques and animation to improve the speed at which operators can respond to system disturbances. Investigate effective schemes to aggregate power system data for presentation in a visual environment. This will improve transmission system operation through improved accuracy in presenting system limits.
Benefits:
   - Improve the ability of transmission system operators to detect power-system disturbances and respond to them quickly.
   - Improve routine operation and greatly improved operations during non-routine events.
   - Increase local and regional system stability and reliability

2) **Improve the quality and availability of real-time data so system operators can manage region-wide dynamic loadability constraints.**
Description: Increase use of faster real-time system state sensors to collect essential data (e.g. key power flows, bus voltages, alarms, etc.) from local monitors located throughout the region. Investigate how to improve tracking and assessment of corrective actions.

   Continue work on Wide Area Measurement Systems (WAMS) using synchronized digital transducers that stream data in real time to operators and (future) automatic controls.
Benefits:
   - Increase speed at which system operators can respond to regional constraints or disturbances.

3) **Develop systems to carry out complex control orders in real-time.**
Description: Restructuring of the utility industry separated the responsibilities for generation, transmission, and distribution. There is a need to ensure that operation of these systems remains coordinated. Research is needed to develop reasonable-cost communication systems to improve generator T&D communications capabilities to multiple points along a transmission line corridor to improve overall system operation. Utilize both hardware & protocols.
Benefits:
   - Improved grid operation that includes minimizing failures and faster response to grid information.
   - Lower overall electricity costs as a result of better optimization of the system.

Focus Area IV: Planning Tools

1) **Develop and Refine Transmission Expansion Planning Tools & Approaches**
Description: Continue to refine and develop the transmission planning and expansion process in a restructured electric industry through development of tailored tools and approaches. This should include updating information on the existing physical infrastructure and developing new information to assure the environment is protected when developing future transmission corridors. These tools should have the capabilities to value transmission for reliability, resource diversity, environmental impact, and access to renewable generation and contingencies in the case of emergencies. Developing information that can help identify how best to address congestion, local area constraints and interconnection of new generation should also be a focus of this research.
Benefits:
- Maintaining reliability in a cost effective manner.
- Identify regional and state-wide economic benefits
- Identifying system limitations.
- Avoiding unnecessary duplication of facilities.
- Providing for coordination with all parties involved in transmission system operation and use.
- Assessment of needed rights-of-way/future transmission corridors.

8.2 "First Priority" Initiatives and Transmission Research Plan Implementation

Staff plans to initiate projects over the next five years in all ten research initiatives outlined above. Yet, after reviewing all research initiatives, rating them for strategic fit with public interest and PIER criteria, staff determined that two research initiatives that focus on using actual system conditions in place of worst case conditions (Focus Area I - 1) and transmission planning tools (Focus Area IV – 1) had specific near-term applications, high potential benefits, and directly address the two critical transmission issues identified in this research plan. These "first priority" initiatives will be developed immediately and will launch the research activities of the program.

Finally, PIER will secure a Program Administrator (PA) to provide the needed infrastructure to fully engage all stakeholders as the new transmission plan and program are implemented. PIER will then establish a Policy Advisory Committee that will help shape the development of the remaining research initiatives identified in this plan.

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[1] Electric Transmission Research Assessment and Gap Analysis, Final Consultant Report prepared for the California Energy Commission, Public Interest Energy Research Program, Energy Systems Integrations Team by Navigant Consulting, Inc. Burlington, Massachusetts, May 11, 2003, P500-03-011F.
[2] California's Electricity System of the Future, Scenario Analysis in Support of Public-Interest Transmission System R&D Planning, Final Consultant Report prepared for the California Energy Commission, Public Interest Energy Research Program , Energy Systems Integration Team by Joseph Eto, Lawrence Berkeley National Laboratory and John P. Stovall, Oak Ridge National Laboratory, April 2003, P500-03-010F.

[3] National Transmission Grid Study, Issue Papers, Advanced Transmission Technologies., U.S. Department of Energy. Washington, DC, 2002, http://tis.eh.doe.gov/ntgs/