DEMAND RESPONSE AND ADVANCED METERING INFRASTRUCTURE

IN CALIFORNIA:

A PROBLEM, A SOLUTION, AND A PROGRAM

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ABSTRACT

This paper identifies specific issues that could be improved in the regulatory guidelines provided for California's deployment of an Advanced Metering Infrastructure, recommends appropriate goals, key strategies, and critical objectives in solving those shortcomings, and outlines a practical program, identifying key tasks and necessary expert capabilities, to accomplish that solution in a timely and affordable manner.

FOR FURTHER INFORMATION

Please contact any of the contributors to discuss any of the topics addressed in this paper.

ENDORSEMENTS

Individuals or organizations wishing to formally endorse the principles and opinions set forth in this paper may contact Anthony Mazy at telephone (925) 785-5178, or with a message to ***a.mazy@ieee.org***.

EXECUTIVE SUMMARY

California's AMI involves millions of devices that must effectively interact with many business entities. A critical contribution to the State's energy infrastructure, it must have open-systems architectures, visibly rigorous engineering approaches, lifecycle economies, and interoperable equipment from many manufacturers. Without an appropriate level of technical rigor, the deployed systems could, instead of adding value, undermine public confidence and public security, and could cost the State, its utilities, ratepayers, and taxpayers alike, significant time, money, and opportunities.

The proposed AMI deployments demonstrate that the imperative for Open Systems architectures —well recognized by all parties—was not sufficiently documented by the State nor adequately conveyed to utilities. Nor are important Demand Response functionalities being consistently identified or implemented, security issues clearly developed, nor best-practice systems engineering applied to proposed implementations. Most importantly, a minimum level of State level functional integration and interoperability has not been accomplished, which could have enabled consistent management, data access, and security policies implemented across independently deployed systems.

This is not to criticize the CPUC, CEC, or the IOUs, but to recognize their institutional limitations in the face of evolving technology and the technical complexity of implementing completely new concepts such as demand response. But, these very serious omissions must be addressed promptly if the State's objectives are to be realized.

Fortunately, a clear path to addressing these issues in a well defined, timely, and affordable manner is available. An independently supervised, open standards-based process (not necessarily a full, "National Standard" work product), expedited with on-call experts to provide clarity, continuity, problem solving, and all documentation, is proposed. By relieving public working groups of time-consuming research and documentation, this effort can be can be underway within as little as two weeks of authorization and completed with significant and valuable within as little as four months. Despite an aggressive schedule, this effort can be accomplished for about an additional one-tenth of one percent of the AMI program's current projected costs.

The end product would be a peer reviewed Technical Report, published by the Institute of Electrical and Electronics Engineers, comprising identified or developed guidelines, recommended practices, standards, and other specifications addressing specific issues necessary for State- and industry-level integration of AMI systems. Early leadership in this effort by California would assure a high level of conformity between the State's initial implementation and any ultimate National Standard.

The State's role in determining policy and the IOUs' role in determining physical implementations suited to their territories are not usurped, but supplemented with standards- and performance-based criteria for key interfaces of any AMI architecture, assuring viability of policy, lifecycle economy, and good engineering.

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Concerned for the functional and engineering integrity of California's AMI program, Mr. Mazy recruited the following industry experts for their opinions and advice:

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This paper is the result of those discussions.

Mr. Hughes is acknowledged for preparing the original draft of this paper, along with significant contributions from Mr. DeBlasio and Mr. Malme to Tasks 1 and 2, respectively.

Joseph Koepfinger, Director Emeritus of the IEEE Standards Board, and Frances Cleveland, President, Xanthus Consulting, are also acknowledged for providing extensive review comments.

This is published and endorsed as an informational "white paper" by the individual Contributors and by any individuals and institutions indicated in a subsequent Appendix.

NOTICE

Unless specifically identified as endorsers in the Appendix, the names of any and all institutions with which any individuals are affiliated are provided only for identification purposes and the opinions expressed in this paper are solely those of the individuals named and do not necessarily represent the opinions of their affiliated institutions or their managements.

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I. THE PROBLEM

A. Overview of California's AMI Problems

In joint proceedings, the California Public Utilities Commission (CPUC), California Energy Commission (CEC), and the California Consumer Power and Conservation Financing Authority (California Power Authority, or CFA) have undertaken to research and develop State planning and regulatory policies for the development of Demand Response (DR) programs and the Advanced Metering Infrastructure (AMI) by which those programs might be accomplished.

The CPUC has issued Decisions and other associated documents to guide the utilities in the development of their proposals to put into place AMIs throughout California, together with various electric power metering, demand response, billing and tariff enhancements. The major California IOUs have responded to the CPUC direction with individual deployment applications. [1] However, the specific proposals in those applications differ substantially in both approach and content.

The State direction for these proposals was technically brief and open-ended resulting in a diversity of utility technical proposals. This should not be seen to criticize the State but rather to recognize that it is not a part of their regulatory practice to maintain the depth of expertise necessary to specify and build systems such as that implied by AMI. In a similar manner, IOUs tend to be somewhat risk-adverse, and reluctant to go too far ahead of CPUC direction.

Inspection[2] of the AMI deployment applications filed by California's large investor-owned electric utilities (IOUs) with the CPUC reveals that, among other things, Open Systems architectures and DR functions have not been implemented consistently and security issues are not discussed to any meaningful degree.

There is no indication whatsoever that best-practice system engineering have been applied to any of the proposed implementations. There is no indication that IOUs have mutually discussed or independently attempted any state-level integration of common issues, such as data communication with the California ISO or their own regulatory agencies, such as the CEC and the CPUC.

A review[3] of the regulatory background shows that the imperative for Open Systems architectures —seemingly well recognized within both institutions— was not adequately conveyed in the CPUC's Assigned Commissioner's Ruling (ACR) of February 11, 2005, nor sufficiently documented within the California Energy Commission (CEC) workshops.

Most importantly, no minimum level of state-level integration was required of the IOUs in the proceedings of either agency. State-level integration would enable consistent management and security policies to be implemented across independently deployed systems. It would also ensure consistency, for example, with data management and communication, for stakeholders such as consumers, regulators, and the ISO.

Again, these observations are not intended to imply any undue criticism of the CPUC, CEC, or the IOUs, but to recognize their institutional limitations in the face of complex and rapidly evolving technology and identify shortcomings that must be corrected if the State is to maintain its stated expectations for these infrastructure deployments.

Moreover, these very serious oversights must be addressed quickly if the State's objectives are to be realized within the schedules laid out. Fortunately, these issues can be addressed and remediated in a timely and affordable manner.

The utilities proposals are understandable based on the direction provided by the State thus far. The State of California could consider a midcourse correction in its plan to create an AMI, using the approach suggested in this paper to augment the programs already proposed by the utilities.

As will be shown, a solution to these problems is straightforward, and a program to accomplish that solution can be outlined that is well defined, timely, and affordable.

The solution suggested does not propose to supplant the roles of the CEC and CPUC in the determination of public policy nor that of the IOUs in the determination of physical and organizational implementations, but to supplement those activities with the standards-based documents to define, on a state-of-the-art basis, performance-based criteria for the key interfaces of any AMI architecture, to help assure the viability of stated public policy, life-cycle economics, and good engineering practices.

B. Specific Issues

1. *Technical Scope and Objectives*

State guidelines give little direction in technical scope, objectives or approach. A scope that includes technical development to support State-level integration and governance should be included in an AMI systems development processes. The scope of the AMI systems development needs to be more clearly defined at the State and industry level. Minimum levels of State-level governance for management should be included in systems development processes.

2. *Technical Approach to Complex Systems*

AMI systems are large, complex and multi-disciplinary systems that need to be developed using industry-level architecture development principles for large-scale integration, for which systems engineering and architecture development is reasonably mature and the recommended practice for their specification and construction. These principles are well accepted in the information industry as ultimately the most cost-beneficial methods, but require significant coordination and up-front design efforts involving all stakeholders.

3. *Higher Levels of Integration*

The State's direction does not include higher levels of integration across the State. Integration of CAISO operations, regulatory oversight and governance and consistency in consumer systems integration should all be considered as a part of California's AMI system.

4. *Security*

Few provisions for security are addressed. An AMI system will constitute a substantial public infrastructure that should have a minimum of required protection against cyber attack and unauthorized intrusions. Several stakeholder communities are developing security policies having implications for AMIs, which should be addressed. End-to-end security requirements should be included in the AMI specifications, and the corresponding security measures should be implemented from the beginning.

5. *Interoperability*

The patchwork of proprietary and single purpose systems allowed by the State's current non-rigorous guidelines would result in systems that cannot interoperate across vendor products, or must be manually patched together, leading to one-of-a-kind, unreliable, and expensive systems. Vendors might not be motivated to maintain these orphan systems, thus leading to greater maintenance and upgrading expenses over time. Utilities could be "locked" into the one vendor supporting the proprietary technologies, thus might not be able to take advantage of less expensive and/or more capable products from other vendors over time. Systems that are not based on open standards may be based on incomplete requirements and, even if they can be integrated, must be manually patched together. Worst-case scenarios include systems that are designed and deployed that must be upgraded by a wholesale change out of millions of meters and other customer-site equipment.

6. *Economics*

The State's direction implies the benefits of using industry open technical standards without actually requiring them; thus, a strategic pathway to minimum levels of interoperability cannot be assumed. Inconsistently designed and implemented systems will not stimulate the marketplace to build products to open standards that interoperate, but rather will encourage the marketplace to push more proprietary equipment that may be lower priced initially but would be more costly to utilities and ratepayers over its life cycle. Without a clear and compelling policy for such open systems interoperability, and the independent supervision and review necessary for ensuring the use of standardized interfaces, desired levels of cost reductions from a competitive marketplace will just not happen. The resulting systems would inevitably incur the higher costs of proprietary systems that do not yield the benefits a mature, competitive and open market place.

II. THE SOLUTION: A MID-COURSE CORRECTION

A. Overview of the Solution to this Problem

The foregoing situation can be rectified with additional direction provided by the State. These additional directions range from clarification of functions to the enhancement of the technical approach. Policy-making can be improved with greater access to current technical information addressing both emerging opportunities for and the implications of such policy-making. Implementations by California's utilities can be improved with a more rigorous systems engineering approach, with particular attention to security issues and open, standards-based architecture.

The following sections highlight the technical points that could help the State improve the development of these technical systems. These improvements are not mere embellishments, but necessary repairs to help ensure cost-competitive equipment and systems that can be integrated, and maintained and managed over the long term.

An independently-supervised, national standards-based process[4] is defined and available on rather short notice for the CPUC to use to tie up these loose ends in a manner fully consistent with the public workshop venues typically employed by the State agencies involved.

Backing up and facilitating these workshops with a body of on-call technical expert consultants can also support expedience. Such expert consultants can be used to provide clarity, continuity, and problem-solving, together with all of the necessary documentation that is responsible for much of the delay typical in such proceedings, when left to the care of well-intentioned, but over-worked volunteers who cannot afford the time necessary for focused and thorough analysis.

An AMI needs to be viewed as an integral part of an overall energy and power system strategy and operation. It should not be viewed as an isolated system for collecting billing data, but rather an important set of resources that can be used by a wide variety of stakeholders, including but not limited to Independent System Operators/Regional Transmission Operators, transmission, distribution, generation, distributed energy resources, customers, and third party operations. This development of a higher level of integration of AMI across the state and the industry-at-large is a key missing element in the State's direction.

Similarly, all of the functional requirements of an AMI need to be rigorously clarified and documented, if they are to be effectively accomplished in a technical system.

The State's direction to its utilities can be further enhanced by encouraging the deployment of systems that are appropriately secure against both physical and cyber intrusion or attack.

For instance, many of NERC's CIP 002-009 security standards, although focused on utility operations, are also conceptually applicable to AMI systems. Recommended technical practices for today's systems require adherence to security policies that, first, adequately value the assets to be protected and then develop protection mechanisms commensurate with the valuation.

These and other methods to help ensure consistent protection for California consumers need to be provided. The lack of adequate direction from the State means that security functions, as well as security policies, are likely to be inconsistently applied by the technologies developed or used by the utilities. Moreover, recommended minimum levels of security, now under development by key stakeholder organizations may be left out of system requirements.

If systems are built without adequate security functions, they can potentially harm commerce, consumer privacy, and have the potential to endanger public and worker safety. Inadequately specified and installed systems may have to be replaced prematurely, forcing the public to incur additional capital costs for system upgrades.

Briefly, these techniques would take the State's functional requirements for the overall AMI, once clarified and fully documented, and apply industry-level system architecture methods to insure integration with all stakeholders and their related technical systems. Security issues would need to be thoroughly addressed, and all requirements considered from the perspective of available, relevant, open technical standards, to ensure multi-vendor procurements at two critical interfaces, those at customer premises and those at the data head end.

These and other technical issues must be spelled out in rigorous technical terms if the systems' functional capabilities are to be provided consistently, on an end-to-end basis, and accessible at key interfaces.

This is not just a theoretical approach. A specific, practical program to put these solutions into effect is laid out in the next section. Objective methodologies are available and this work will contribute to expediting the key standards-development processes that are a necessary foundation for interoperable metering and demand response equipment development. This work should be integrated with utility project work in progress to form a more complete technical foundation for DR objectives and necessary implementation functionalities, and in the more thorough systems engineering of implementation architectures for security and interoperability, competent and proven experts are readily available.

Through the use of an off-the-shelf, yet flexible, procedural methodology, this effort can be underway within as little as two weeks of authorization. And, by relieving the voluntary participants of the necessarily public working groups of the time-consuming research and documentation tasks involved, it can be produce significantly useful results within as little as four months.

Despite such an extremely aggressive schedule, this proposal can still be accomplished while incurring no more than only an additional of one-tenth of one percent (0.001) of the AMI program's current projected costs.

Furthermore, this effort does not propose, and should not be interpreted, to supplant the roles of the CFA, CEC and CPUC in the determination of public policy or that of the IOUs in the determination of physical implementations suited to their service territories, demographics, and physical terrain. Rather, it is intended to, and can succeed in, supplementing those activities with standards-based documents to define, on a state-of-the-art basis, performance-based criteria for the two key interfaces and the end-to-end functionality of any AMI architecture. In doing so, the viability of stated public policy, beneficial life-cycle economics, and good engineering practices, could be assured.

B. Goals

Generally, there are a number of specific attributes that any AMI architecture development endeavor should obtain:

- A vendor-neutral Open Standards development processes that can enable multiple suppliers of interoperable equipment;
- Clear and comprehensive development and documentation of the functional, security, performance, and other management requirements,
- An appropriate level of integration of functional, security, management, and policy requirements across California State programs;

- Synergies from sharing of infrastructures across multiple State institutions and stakeholders;
- A rigorous, systems engineering approach; and
- Coordination and continuity with standards and industry programs.

1. *Open Standards Development Process*

Open Standards development processes must be identified and employed to ensure an independently-supervised, open systems/architecture development process. This process will ensure that all selected *interfaces* between vendor products are based on standards and open technologies that are vendor-neutral, published, and freely available while meeting all performance, security, flexibility, and life cycle requirements. Vendors are then free to develop proprietary products with market-driven value-added capabilities, while still remaining interoperable with all other AMI systems.

Highly expedited forms of these processes must be identified and employed to prevent undue disruption of established program schedules.

This work should build upon and contribute to key existing open technical standards necessary for the construction of interoperable equipment and mature markets.

2. *Clear and Comprehensive Functional Requirements*

The functional requirements for the various Demand Response programs and an Advanced Metering Infrastructure must be developed comprehensively, stated clearly and rigorously, and well documented if they are to effectively support State policy and be integrated into key stakeholder operations.

These requirements define what the systems must do for the stakeholders and define the system management functions that must be in place, such as to ensure public protection against cyber intrusions and protect customer privacy. These requirements also enable consistency across key stakeholder communities that will play a role in the deployment and use of these systems.

3. *California State-Level Integration and Coordination across Programs*

California programs, such as Demand Response programs and the Advanced Metering Infrastructure to support those programs, together with other, appropriately related customer service or utility operations programs, should be integrated and coordinated at a State-level for key policy as well as functional, security, performance, and management requirements.[5]

4. *Synergies from Sharing of an Integrated Infrastructure Statewide*

Mutually beneficial synergies can be obtained among utilities, State institutions, and other stakeholders by the sharing of an integrated AMI infrastructure statewide. These synergies could result not only from the sharing of physical systems and communications, but also from sharing engineering developments, security technologies, and management of systems. The key functional requirements for demand response programs and an advanced metering infrastructure must also be specified to a State level of integration in order to consistently implement management of AMI systems across the various stakeholders operating under state jurisdiction and to determine the appropriate potential for infrastructure sharing and synergy between utilities and other stakeholders

5. *Rigorous Systems Engineering*

Systems engineering methods must be applied to AMI development to help ensure that the systems will in fact meet present and future stakeholder needs. AMI systems are large, complex and multi-disciplinary physical infrastructures that cannot function without a very high level of objective automation. Fortunately, the systems engineering and architectural development methodologies needed are reasonably mature and unquestionably recommended practice for specifying and constructing such large systems.

6. *Coordination and Continuity with Standards and Industry Programs*

Work products should be expected to serve as the straw man draft for follow-on to relevant Standards Development Organizations[6] (national and international) and industry consortia to effectively move the development of key open standards forward.

C. Strategies

This proposal employs three key strategies:

- Use of an established, peer-reviewed, open standards development processes;
- Clarification, integration, and definition of Functional Criteria; and
- Rigorous application of systems engineering principles.

It should be noted that these strategies involve significant iteration in any specific methodology.

1. *Use of Established Open Standards Development Processes*

First, it is essential to use independently supervised, national and international standards development processes to ensure the "openness" essential for recognition within either the technical or regulatory communities.

Collaborative projects, under prevailing processes, can apply consistent approaches to systems development and enable true multi-vendor environments for AMI and Demand Response systems. Collaborative efforts with the key stakeholder communities could build from work that is ongoing in the industry, and allow the derived work products to be adopted by other States and be embraced by institutions throughout North American through the use of emerging international standards.

Existing standards development communities and user groups garner significant expertise that can further assist California's development of AMI and work on technical interoperability agreements and product testing to help ensure interoperability.

2. *Clarification, Integration, and Definition of Functional Criteria*

Desired system capabilities to be served by the specified systems and architectures must be thoroughly clarified, integrated across multiple stakeholder and operational domains, and formally defined. This "functional domain" will effectively capture the attributes and requirements of those desired applications in a manner that will translate well into meaningful architectural requirements.

A core of requirements development common to the utilities is necessary to ensure consistent implementation of critical capabilities. The deployed AMI systems need to be planned to last for decades; this requires that the system be robust enough to not only meet today's needs, but support future needs as well. This category of requirements, termed "robustness", means the ability to meet unstated needs, and must be designed into a system from the start; it cannot be retrofitted after installation. Robustness is also necessary to enable flexibility in State policy implementation.[7]

State-level integration enables consistent management and security policies to be implemented across independently deployed systems. Current plans do not enable consistent responses to State governance. State-level integration also ensures consistency, for example with data management, for stakeholders such as consumers, regulators, and the ISO. Currently, consumers with sites across the state are forced to evaluate data from each site in differing forms. The ISO could be faced with developing data interfaces from each type of system and developing the means to integrate the information to evaluate on a statewide basis.

3. *Rigorous Application of Systems Engineering Principles*

Third, it is essential to use a system engineering approach based on the current methods for complex system designs. This involved a more in-depth analysis of functional requirements to develop system architectures with appropriately identified and specified capabilities, interfaces, and subsystems. This the initial step in developing industry-level requirements and architectures but does not intend to include specific device designs or physical system implementations.

Systems engineering methods can guide the development of core requirements and analysis as well as design, construction, testing and management. The details of this series of tasks can be worked out with the key stakeholder organizations through the collaborative development effort. The outcome of this is to develop systems that share minimum levels of interoperability and to enable appropriate levels of data sharing and management functions for applications that cut across the stakeholder communities.

Utilities can still develop specific designs and implementations necessary to integrate with their existing systems and other functions that may be specific within a given utility.

D. Specific Objectives

There are four specific objectives that must be accomplished:

- Establishment of a formal, Open Standards development venue;
- Identification and Documentation of comprehensive Functional Requirements;
- Identification or development, documentation, and adoption of appropriately systems-engineered, Open System, architectural specifications; and
- Stakeholder Outreach: Promulgation of architectural specifications to all audiences.

1. *Establishment of a Formal, Open Standards Development Venue*

An appropriate Open Standards development process must be identified and an appropriate venue must be established in California.

Open System Architecture is not just a vision; it is a defined objective of specific, existing, authorized programs developed under national and international technical supervision, with demonstrated value. The IEEE offers some of the most well developed programs for open, consensus industrial standards, among which is that of an IEEE Technical Report.

Despite their establishment and definition, standards development processes can be difficult to manage in a timely manner. So, while there is no substitute for the independence and acceptability of these established standards programs, they must be intensively assisted with competent technical experts in order to produce needed results on an expedited basis. Such a process can also contribute to the usefulness of the final work product, in both its near-term serviceability and its long-term conformity with any emerging national standards.

2. *Identification and Documentation of Comprehensive Functional Requirements*

The business- and policy-based performance capabilities of desired systems must be comprehensively identified, clarified, integrated across the most appropriate set of geographic and operational domains, and documented in a manner that supports the necessary follow-on work. These requirements would include the functional requirements for different types, configuration, and levels of AMI deployments, with the interoperable interfaces clearly identified. In addition, all performance, security, management, maintenance, upgrade, and life cycle requirements must be clearly defined.

3. *Identification or Development, Documentation, and Adoption of Appropriately Systems-Engineered, Open Systems, Architectural Specifications*

The business- and policy-based performance capabilities of desired systems must be translated into technically-meaningful specifications, recommended practices, and guidelines and reviewed for internal consistency with one another and for external consistency with existing standards development programs.

The end products of this effort would be a peer reviewed set of open standards development-based documents (not necessarily full, "National Standard" documents) published by the Institute of Electrical and Electronics Engineers (IEEE), comprising identified and/or developed, performance-based standards, recommended practices, guidelines, and other specifications and recommendations for the implementation of Open Systems architectures for AMI. While necessarily provisional and regional in scope, these products would be fully sufficient for practical application in California and should be fully suitable as draft documents for follow-on expedited acceptance as formal ANSI national standards and IEC international standards.

4. *Stakeholder Outreach: Promulgation of Architectural Specifications to All Audiences*

The formally published work products of the Open Standards development venue must be appropriately presented, explained, and promulgated to key stakeholders and all other appropriate audiences.

Left to themselves, consensus Industrial standards have an indeterminate efficacy. These documents must be formally adopted by an appropriate Authority Having Jurisdiction (AHJ)[8] and communicated to entities under its formal authority. They must also be promulgated among other stakeholders, promoting their intent, suitability, and benefits among California's industrial, professional, and academic communities. California's early leadership role in such proceedings would almost certainly assure a high level of compliance between the ultimately adopted standard and California's initial implementation.

III. A PROGRAM

A. Overview of a Program to Implement the Solution

The proposal outlined below is to demonstrate a practical means to effectively integrate advanced meter reading and demand response systems across key stakeholder organizations within the discipline of established Open Standards development protocols. The success of such an effort would critically depend upon the accomplishment of its four specific objectives:

- To employ a highly expedited form of Open Standards development programs, in this case, administered under the auspices of the Institute of Electrical and Electronics Engineers, to establish and maintain the legitimacy of the program as an open standards process without undue impact on the deployment schedules of the involved utilities.
- To fully articulate the functional and integration requirements of AMI architectures for deployment in the California market,
- To define the systems engineering requirements necessary for that set of functional requirements, and
- To effectively promulgate these architectural requirements among stakeholders and all other relevant audiences.

In order to achieve these objectives within the time believed to be available, and without undue impact upon existing deployment schedules, the work products of this expedited effort must be conceived of as provisional and/or regional statements of functional specifications, recommended practices and/or guidelines, as appropriate, suitable for near-term use within California, and which can be accomplished in a limited amount of time.

While all aspects of this proposal necessarily involve vetting through open, public workshops, an intense program of on-call consulting specialists must be maintained to expedite the deliberative process and its documentation, consistent with the desired schedule.

B. Specific Program Work Plan

Task 1: Establish Venue with IEEE Expedited Protocols

This task would involve the establishment through the development and acceptance of the appropriate authorization document(s), of a formal relationship between the entity sponsoring this program[9] and the IEEE.[10] Then, a series of public workshops, all set within California, would be convened and executed. The technical work product(s) developed within this venue would then be managed through the final editing and publication process(es).

Task 2: Functional Domain Development

This task would establishes a common operational context for all stakeholder communities relative to future processes and programs that would use the AMIs being deployed by utilities under the standards developed in this project.

Functional stakeholders include those that have a stake in the capabilities or performance of the system such as the operational and financial managers of user enterprises, their system administrators and security management personnel, individuals from regulatory or other oversight bodies, electricity consumers, electronic and electrical equipment manufacturers, energy service providers as well as others.

Most importantly, it must be understood that this task seeks to assist, on an iterative and interactive basis, public agencies, such as the CPUC and CEC, in their policy-setting roles, and not to usurp those roles. This process can assist that policy-making process by ensuring that decision makers are fully apprised of emerging opportunities for, and the technical consequences and implications of, their policy choices.

This task would employ a subset of the workshops to examine current processes and programs to be deployed in the subject markets, characterizing the "as built" systems as a baseline for evaluating proposed future enhancements enabled by industry architectures.

This task would also explore the functional characteristics of new intended processes and programs and the potential scope of programs that may be introduced in the future that the architecture must support, as well as review case studies of DR programs deployed in other locations to gain an understanding of lessons learned and best practices.

Lastly, this task would consider the scope of state-level integration, across various operations and industries that might be appropriate. In consideration of the potential difficulty involved in distinguishing between levels of integration that might be considered "operational" and those heavily imbued with policy ramifications, iterative referral back to appropriate state agencies might be necessary.

Task 3: Initial Applications Scope and Stakeholder Identification

This task defines the initial applications' scopes in cooperation with stakeholder communities. The intent behind this task is to identify key distributed computing applications categories that are central to achieving the levels of integration desired with stakeholder organizations. This task may develop an applications hierarchy that addresses both present and future industry business drivers and technical organizations. This task identifies, organizes and describes the boundaries of the follow-on requirements elicitation process.

Task 4: System Requirements Development

A requirements development[11] process would be used to draw out the detailed technical capabilities, modeled generally in Task 3, of completed systems implied by the functionality requirements developed in Task 2.

While Task 2 documented "requirements" from business and policy perspectives, Task 4 translates those requirements into the technical criteria meaningful to designers. Requirements should be as complete as possible and accommodate inputs from key technical stakeholders of the systems, such as direct users like systems operations engineers, as well those from the systems manufacturing, service, and standards development communities.

These requirements would cover issues such as interoperability, security/privacy, performance, information management, system maintenance, system life cycle management, and deployment.

Task 5: Requirements Analysis and Model Development

The technical requirements developed in Task 4 must be examined more closely, and as a whole, to develop architectural requirements for entire systems.

This process is explicitly iterative as opposed to sequential, and enables system analysts to look for potential synergies and possible technical limitations and conflicts. This analysis takes the process further down a systems integration development path in which a limited set of generic, interoperable architectural models begin to emerge.

Task 6: Define Set of Systems Architectures Alternatives and "Views"

Define the technical requirements of overall communications and application architectures, so that a limited set of high level, different alternative implementations can be developed. While there may be, conceivably, many implementations that could co-exist and interoperate, there must also be limits to the choices available to implementers, some of which may appear rather arbitrary[12], but, without which, California could be exposed to chaos.

Architectures also enable the development of a variety of "views" of systems which permit different stakeholders to plan their differing interactions with those systems: e.g. utilities need overall management, vendors need access to their equipment, customers need to establish preferences, and regulators need appropriate audit information.

These high level views offer more opportunity for review and feedback from stakeholders, and this task should develop the specification of architectures in both the natural language used by "functional" stakeholders[13] and the standardized industry notation(s) appropriate to capture the technical elements of architecture.[14] The use of standardized tools and the sharing of documentation would be developed.

Task 7: Technology and Standards Assessment

A technology and standards assessment should be conducted to determine the extent to which existing industry infrastructure and associated technologies either meet or could be modified to meet the anticipated architectures and systems requirements. This process recognizes the significant amount of work that has already gone into open standards and associated utility industry infrastructure and technology development. This task would be somewhat independent of the requirements and architecture development work, taking a robust view of the future, and this may preclude many devices, technologies, standards and protocols in existence or even widespread use today. This task can help to elucidate potential weaknesses in existing technical standards and serve to identify improvements that may be adopted or developed by the industry.

Task 8: Develop Recommendations for Further Development

This task winds up the project and documents its proceedings, together with any recommendations for follow-on work[15] with key stakeholder communities.[16]

These topics and others resulting from the first seven tasks would be compiled into appropriate documentation for referral back to the State.[17] Outreach to appropriate industrial, policymaking, professional, academic, and civic communities would help establish understanding and acceptance of these work products.

With the other work products of this program, a record would be established suitable as a strawman draft for a follow-on, full national standards development effort. Altogether, these efforts would help ensure both the near-term utility of these work products within California and help ensure the highest possible conformity between AMIs developed in California under these recommendations and any ensuing ANSI national standard and/or IEC international standard.

C. Consultant Capabilities Requirements

As conceived, this program cannot be accomplished without adequate expert assistance. At least three key bodies of capabilities are indicated:

- To direct the expedited standards development process;
- To support the clarification and integration of the AMI functional requirements; and
- To support the systems engineering process for architectural technical requirements.

Additionally, appropriate experts and/or institutions should be recruited to assist with industry, professional, and academic outreach. The necessary role of each expert in the various tasks requires certain key competencies, which are discussed below.

Task 1, Establish Venue with IEEE Expedited Protocols

The Standards Process expert(s) selected for this task should demonstrate:

- Great breadth and depth of knowledge in the development of open, consensus standards;
- Experience as senior manager(s), with a breadth of perspective cultivated through successful assignments in a number of allied fields;
- Capability of overseeing and coordinating the work of several hundred highly technical experts under extremely tight schedule and budget restrictions;
- Direct experience in the management of ANSI/IEEE national standards process;
- Successfully accomplishment of ANSI/IEEE national standards development under greatly limited time schedules;
- Extensive experience and rapport with the IEEE Standards Association Board, given the uniqueness of the anticipated program;
- Familiarity and respect from across the spectrum of stakeholders likely to participate in the anticipated public working groups and capable of co-coordinating the efforts of public participants, with possibly rapidly changing perspectives and priorities, and paid consultants
- Availability to undertake this assignment and be productively underway with public participation workshops within two weeks of appointment.
- Absolute commitment to bringing the program to a successful conclusion within the extraordinary tight budget and schedule limitations.

Task 2, Functional Domain Development

The Functional Requirements expert(s) selected for this task should demonstrate:

- Experience with design and operation of wholesale and retail demand response programs in various market structures, cultures and customer demographics;
- Experience with a structured and documented process for evaluation of markets, determination of demand response potential and valuation, selection of appropriate technology, and overcoming market barriers in varied environments, customer segments;
- Thorough knowledge of the transactions required for data exchange between parties in demand response programs including but not limited to Notification, Interval Meter Data, Baseline Calculations, Near Real Time Performance Monitoring, bidding, modifying, certifying, bid aggregation and comparison to goal, and Settlements;

- Thorough knowledge of the design, interfaces, communications protocols, communications infrastructure options, and use of advanced metering technologies to enable a variety of programs and utility benefits
- Knowledge of the capabilities and experience in the use of public networks (the Internet) for secure and reliable data transmission of energy information;
- Experience in working with and moving working groups or stakeholder groups to consensus on a broad range of technical issues;
- Experience at State, Regional, and Federal levels on the development of demand response policy and programs.

Tasks 3 through 8, Systems Engineering of Architectural Requirements

The Systems Engineering expert(s) selected for these tasks should demonstrate:

- Experience and expert capabilities in systems engineering and requirements engineering;
- Successful experience with large-scale and industry-level system architecture development;
- Successful experience in technical standards development specific to electric industry advanced distributed computing systems.
- Industry-level model development and experience with the Unified Modeling Language (UML), XMI formats and Computer Assisted Systems Engineering (CASE) Tools;
- Technical development of systems and network management infrastructure including next generation cyber security development;
- Energy industry distribution automation, consumer communications and advanced energy services application development.

D. Program Schedule and Budget

Significant contraction of the usual schedule allowed for National Standards development efforts is necessary for the California AMI program, as it is effectively already underway and should not be unduly delayed.

This schedule necessarily bears a very heavy cost of maintaining a suitable staff of appropriately expert consultants available for long periods of time on short notice, to expedite the deliberations, consensus building, and documentation efforts among public participants.

Based on considerable experience, the authors believe the schedule and budget shown in the accompanying Table are feasible.

IV. CONCLUSION

An AMI infrastructure for California will be an unprecedented technical undertaking involving millions of devices that must securely and effectively integrate with a variety of business entities. As envisioned, these systems will be an important and needed contribution to the State's existing and future energy infrastructure.

The efficacy of these systems will depend upon the clarity of their functional criteria, the comprehensiveness of system architectures, and rigorous approaches to manage the entire scope of effort through all the steps of their life cycle.

The success of California's AMI program cannot be simply assumed, but requires a State-level technical integration and architecture development perspective, a perspective uniquely provided by this paper. Its development should be collaborative with a focus on bringing that vision together through open standards that enable interoperable equipment from a variety of manufacturers and industries. The program developed in this paper can help assure the success of that vision.

Much is at stake. If done well, this system would provide substantial value, for all the stakeholders for years to come. However, if done without an appropriate level of technical rigor, the deployed systems could undermine public security and cost the State, utilities, and ratepayer's significant money, time, and public confidence.

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Table: Recommended Program Schedule and Budget

Task	**Name**	**Time (Months)**	**Comment**	**Budget ($1000's)**
1	Coordinate IEEE Standards processes & academic outreach	4		2,000
2	Document Functional Domain Baseline	2		800
3-8	Systems/Requirements Engineering	4		2,700
3	Scoping	1		200
4	Requirements Development	4	Can be done in parallel with 2-7	1,000
5	Analysis	2	Can be done in parallel with 6	300
6	Open Systems architecture requirements	2		700
7	Standards Assessment	4	Can be done in parallel with 4, 5, 6	200
8	Recommendations & Documentation	1		300
	Total	4		5,500

NOTES

[1] A.05-03-016, for PG&E pre-deployment; A.05-03-015, for SDG&E pre-deployment; A.05-03-026, for SCE pre-deployment; A.05-06-028, for PG&E case-in-chief.

[2] Nothing in this paper is intended to evaluate IOU proposals in any context of their regulatory compliance, actual cost-effectiveness of specific implementations proposed, or the reasonableness of expenditures for rate recovery.

[3] Nothing in this paper is intended to advocate specific public policies but, given the contributors' understanding of the public policies actually or effectively in place with respect to open systems architecture, data security, life-cycle economics, etc., to provide information on effective and technically-appropriate means to implement those policies.

[4] Actually, several alternative processes exist within IEEE alone. The approach described assumes an IEEE Technical Report, which is most recommended among the others.

[5] While the work products upon which such programs and systems are to be based must necessarily be conceived as provisional and/or regional, they must nevertheless be suitable for integrating advanced communication systems and intelligent equipment across the entire spectrum of key State policy and stakeholder communities.

[6] The technical Standards Development Organizations include but are not limited to: the American National Standards Institute, the Institute of Electrical and Electronics Engineers, the International Electrotechnical Commission, the American Society of Heating Refrigeration and Air Conditioning Engineers, North American Electric Reliability Council, as well as federal government organizations such as the National Institute of Standards and Technology. Together, these organizations comprise a significant body of industry work that should be considered in the design of AMI systems.

[7] For example, the system should be able to support a wide variety of potential rate structures. Future State policy makers may have different ideas on how to implement dynamic rates or need to address entirely novel issues through rate design. The technology should not be a hindrance to future policy makers.

[8] Such as the Public Utilities Commission.

[9] Most likely the State of California, through one of its agencies, most likely the Public Utilities Commission.

[10] Directly, or through its Standards Association or other functional subdivision, depending on the specific process selected.

[11] The term "requirements engineering" is applied to this process to reflect the rigor with which it should be approached.

[12] Consider the problem of choosing which side of a bi-directional roadway, left-hand or right-hand, on which traffic should maintain.

[13] And, thus, to enable an iterative loop of feedback, by which the developers of systems engineering requirements can validate their understanding of the functional and policy objective presented to them.

[14] The Unified Modeling Language and other such notation should be considered for the deliverable(s) on this task.

[15] Key work areas could include formal standard development, equipment designs, data and device models, and other details that can only be completely investigated through real implementations and testing. In addition, open systems development must include a rigorous set of interoperability/interworkability test suites that evaluate the relevant performance of the equipment to ensure suitability for field deployment.

[16] This could include California IOUs, State and federal government agencies, standards development organizations, and industry technical consortia, but need not be limited to those.

[17] Such recommendations could include both technical and policy matters requiring either validation or adoption by appropriate State agencies.