New Homes with Load Shapes to Make an Electric Utility Drool: How to Integrate Multiple DSM Strategies to Achieve Long Term Energy Performance Goals

Bruce Ceniceros and Bruce Vincent, Sacramento Municipal Utility District

ABSTRACT

The idea of "Zero Energy Homes" may be appealing to homebuyers, but electric utilities may be more interested in zero peak homes. This paper describes the process that the Sacramento Municipal Utility District is following to define the most desirable home performance characteristics for the utility, evaluate technology and design options to create a single-family home design that performs in this manner while delivering attributes desired by homeowners and builders, and develop an action plan to make such homes a reality in a next-generation residential new construction program. The process is driven by long-term performance goals for new homes rather than the usual incremental approach of assessing the impact of individual measures. The resulting home design will be a unique marriage of energy-efficient design features, roof-integrated photovoltaics with net metering, automated peak shifting strategies and built in demand response capabilities. This design is expected to deliver demand side benefits to homeowners, the utility and the environment that are much greater than possible from conventional utility new construction incentive programs that focus only on energy efficiency.

Background

The Sacramento Municipal Utility District (SMUD) is the sixth largest municipal electric utility in the country and generates, transmits and distributes power to a 900-square-mile service area that includes Sacramento County and a small portion of Placer County. SMUD serves 580,000 meters, including 515,000 residential meters. SMUD's peak demand hit a new high of 2,959 megawatts on July 15, 2005. During the past five years SMUD's customer base has gown by 12 percent, and over 70 percent of the District's load growth is attributed to new homes added to the District. Sacramento County is projected to add one million people by 2050, for a total population of 2.3 million (CCSCE 2002).

SMUD's service territory lies in the middle of California's vast Central Valley, which has a unique climate. The winters are relatively mild with an average January low temperature of 39°F and highs in the 50s. Summer high temperatures frequently top 100°F. But due to the unique on-shore "delta breeze" that brings cool marine air to Sacramento by the evening hours, the area experiences large diurnal temperature swings. Even on the hottest days temperatures will drop down to the mid-60s or low 70s by midnight making night ventilation cooling an attractive option.

This combination of unique climatic factors causes SMUD to have a load factor of about 40%, one of the lowest in the country among electric utilities.

Production builders dominate the residential new construction market in Sacramento. Until recently, several discrete programs directed at the residential new construction market have operated independently at SMUD, with different objectives and insufficient coordination:

- The Advantage Homes Program is the mass-market energy efficiency program for residential new construction that has captured over 50 percent of the market.
- The "Zero Energy Home" (ZEH) program, in partnership with the U.S. Department of Energy's (DOE) Building America program, supports subdivision scale demonstrations of more extensive energy efficiency measures integrated with photovoltaic generation. While the goal of current "zero energy" homes is to use 60% less energy than a conventional home, the ultimate goal is homes that annually produce as much energy as they use. Three ZEH subdivisions totaling over 200 homes have been completed or are under construction in the Sacramento area.
- The ReGen Program is SMUD's renewables R&D program, partially funded by the California Energy Commission's Public Interest Energy Research Program. The ReGen program develops and demonstrates new renewable technologies and designs to ensure viable pathways to commercialization.
- The Customer Advanced Technology (CAT) program evaluates and demonstrates emerging or underutilized demand-side technologies and products.

Why a New Approach is Needed

In June of 2005, staff from the four SMUD departments that run the programs outlined above formed the "Residential New Construction Collaborative" to coordinate and focus SMUD resources and expertise on the task of strategically planning the next-generation residential new construction program. The team's findings included:

- SMUD's current portfolio of separate energy efficiency, demand response, and zero energy home programs lacks coordination and a common vision.
- The residential new construction market continues to drive SMUD's growth in summer peak demand.
- As California's Title 24 energy efficiency standards continue to become more aggressive, conventional energy efficiency programs for residential new construction yield diminishing returns. Energy savings for SMUD's Advantage Homes relative to the applicable version of Title 24 have fallen from 50 percent at the program's inception in 1993 to 20 percent (with 30 percent cooling savings) in 2006. After the next Title 24 upgrade in 2008, these programs may no longer be cost effective. SMUD must move beyond small, incremental annual changes to the same program models.
- The program should be tailored to complement SMUD's load-serving requirements in order to generate greater benefits for the utility.
- The California Solar Initiative recently provided for a $2.8 billion investment in solar over 11 years, creating an unprecedented opportunity for the development of a strong local photovoltaic market (CPUC 2005).

Proposed Solution

As SMUD adapted the Advantage Homes Program to the new baseline of the 2005 Title 24 standards, it quickly became clear that the program needed to move towards the Zero Energy Homes model by integrating PV with advanced efficiency measures. The Collaborative theorized that we might be able to improve upon the ZEH homes built to date, which still had a

pronounced peak during the last two hours of SMUD's critical peak period (4:00-7:00 pm on summer weekdays) due to declining PV production in the late afternoon. Furthermore, if the average ZEH homes were to actually achieve the long term Building America goal of zero net energy use but still draw significant demand, other ratepayers would essentially be subsidizing the infrastructure and peak supply costs to serve these homes since they would provide no revenue. The team wondered: should the program goal instead be a "zero peak home" with zero average energy consumption during the utility's on-peak period?

Technology Opportunities

The technologies are available or on the horizon that are capable of making zero peak homes a reality, but a number of them must either be further developed or made acceptable to production builders. These include:

- Load-management techniques to minimize peak electrical demand.
- Building shell technologies that are better insulated and/or incorporate large amounts of exposed thermal mass that can be thermally "charged" during off-peak hours.
- Improved HVAC technologies such as indirect-direct evaporative cooling, radiant heating and cooling, and ductless mini-split systems.
- Passive solar architectural features.
- New demand response strategies such as off-peak overcooling, appliance load control, and the use of the battery storage in plug-in hybrid vehicles when they are garaged.
- Advanced control systems.
- High-efficacy lighting fixtures for all types of lighting.
- Lower-cost and higher-performance PV systems. A number of revolutionary PV technologies are now under development, including PV materials that are made using semi-conventional printing processes, carbon nanotubes, modular rooftop concentrators, PV fabrics, and hybrid PV/space heating systems.

An integrated design approach or systems approach can magnify the benefits of these strategies (EDR 2006). For example a high-performance building envelope will reduce heating and cooling loads and allow both the HVAC and PV systems to be reduced in size, resulting in substantial capital cost savings.

Table 1. Examples of Possible Zero Peak Home Measure Packages

Package 1: Resembles conventional home	Package 2: More radical design package
• Evaporative condensing AC or geothermal heat pump • Ducts in conditioned space • Reduced wood volume wall-framing • Defect-free polyisocyanurate wall insulation with a foam wrap and R-40 ceiling insulation • Advanced control system for HVAC and lighting • Double sheet rock with off-peak pre-cooling, compressor lock-out during critical peak period • Nighttime ventilation with improved control • Higher-efficacy light fixtures and lamps • Roof-integrated PV	• T-Mass walls with a four-inch layer of concrete on conditioned side of insulation • Nighttime ventilation • Passive solar architectural features • Radiant heating and cooling • Integrated control system combining internet-based security and demand-response capabilities • Concrete tiles with cool roof properties • High-efficacy light fixtures throughout with light emitting diode lighting for selected applications • High efficiency appliances, table lamps and floor lamps • Charge management and remote dispatch capabilities for plug-in hybrid electric vehicles • Real-time pricing or critical peak pricing rate structure • Roof-integrated PV

Table 1 shows two possible measure packages. The first is intended to minimize obvious changes to the look and feel of the home. The second is a more radical design concept that would require a major adaptation by builders and homeowners before it is likely to be accepted.

How to Get There: Creating a Utility Roadmap to a High-Impact Residential New Construction Program

After reviewing available data and discussing the tremendous potential for innovative construction techniques in the residential new construction market, the SMUD Collaborative launched an effort to test the hypothesis that zero peak homes were technically and practically achievable. The team is implementing a short-term research plan and will document the results in a strategic roadmap to achieve high-performance, zero-peak new homes. The roadmap will articulate common goals for all of SMUD's residential new construction activities and the roles and contributions needed from each program. While SMUD's program plans and budgets generally look out only one to three years, the roadmap will cover five to 10 years, allowing SMUD to leapfrog the business-as-usual approach and incorporate emerging technologies and change construction practices.

What follows is a step-by-step description of the process the Collaborative has laid out to develop a program for the residential new construction market, driven chiefly by performance goals. The process is described in a general manner that should be applicable to any electric utility, with examples from SMUD's effort.

Step 1: Identify Resources and Form Interdisciplinary Team

The first step is to identify the resources and expertise available within your organization and form an interdisciplinary team that is capable of performing the required analysis, planning and execution.

SMUD's Residential New Construction Collaborative includes staff from energy efficiency, renewables and research and development programs. The team will also require input and participation from individuals charged with energy supply, energy purchasing, transmission and distribution planning, and rate design responsibilities.

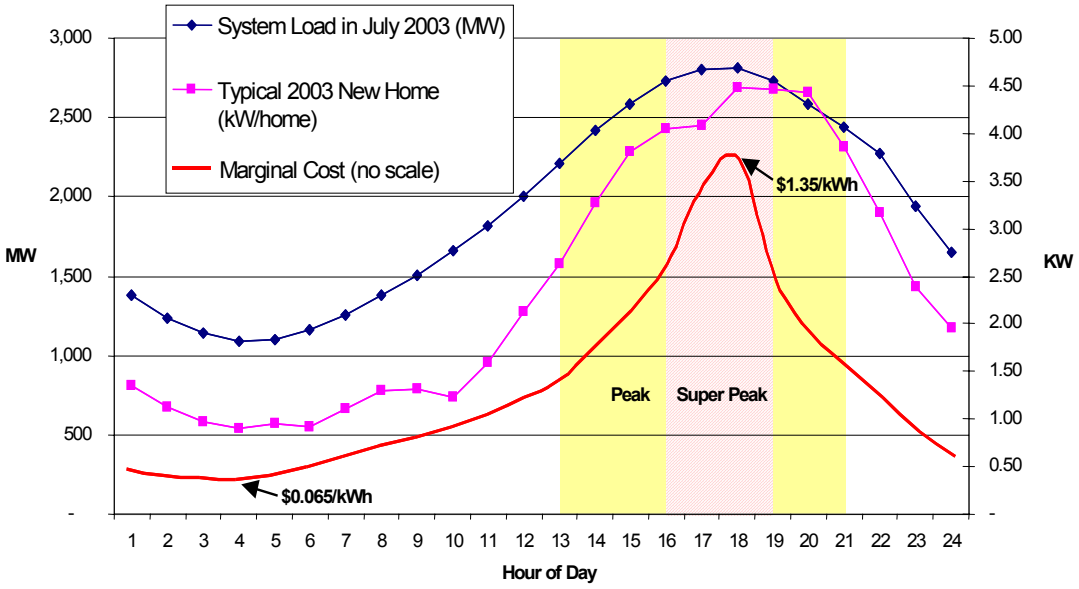
The Collaborative agreed on common objectives and roles for participants and documented this in a short-term action plan. The plan articulates how the activities of each workgroup will be aligned and coordinated to achieve common objectives and provides resources for a core "Technology Transition Team" for the residential new construction market. After the Collaborative has developed a long-term development plan, the Technology Transition Team will implement the steps of the long-term plan.

Step 2: Understand Load Serving Needs

It is important to understand the utility's load serving needs today and over the projected life of the measures. This includes an analyses of the current system load curve and how it will likely change in the future, how the demand curve breaks down by sector with particular emphasis on the target market, and the marginal costs associated with providing power at different times of the day and year.

Figure 1 shows SMUD's system load curve and marginal cost of electricity for a peak day in July. The top ten hours of peak demand each year add 130 MW to the maximum supply capacity required at all other hours, incurring an average marginal cost of $0.82 per kWh—ten times the average marginal cost for the year. The top 100 hours add 536 MW (19 percent of SMUD's peak demand) at a marginal cost of $0.35/kWh. Nearly all of these high-priced hours occur during SMUD's critical peak period of 4:00-7:00 pm on summer weekdays, making consistent demand reductions during these hours highly valuable (SMUD 2006a).

Figure 1. System Peak Day Load Profile Versus Demand for Average New Home[1]



Source: SMUD Rates and Pricing Group

Residential energy consumption is a major contributor to SMUD's peak demand and is largely responsible for extending the system peak well into the evening hours. The average demand profile for new homes built in 2003 is included in Figure 1, showing that these homes peak between 6:00 and 8:00 pm—later than the system peak.

SMUD's next step will be to perform end-use monitoring to learn how energy is being used in new homes. This will allow us to identify which end uses should be targeted for peak demand reductions. It will also help us better understand the current growth in energy consumption of plug loads—particularly standby losses.

It is also important to understand SMUD's mix of supply side resources used to meet system loads. SMUD's 2005 power mix included 35 percent hydroelectric generation and 12 percent from renewable sources, most of which is SMUD-owned. However, 45 percent of SMUD's supply was fueled by natural gas. Given the recent price volatility of natural gas and long-term projections for significant price increases, this is the most vulnerable part of SMUD's supply-side portfolio.

SMUD's power mix is changing rapidly as it races to attain the District goal of 20 percent renewable generation by 2011. The Residential New Construction Collaborative plans to analyze the complementary characteristics of wind, solar, hydro and natural-gas generation and how

[1] Data for SMUD system load on July 22, 2003. Marginal cost forecast is for 2008 and includes generation capacity, supply, transmission, and distribution costs for the last increment of capacity.

planned changes in the power mix will alter the economics of demand side alternatives to new generation.

Step 3: Identify Potential Benefits to Changes in System Load Curve

If air conditioning load in half of all new homes could be altogether eliminated during the critical peak period, this would impact about 80,000 homes over the course of 20 years and reduce SMUD's system peak by more than 200 MW. This would single-handedly improve SMUD's load factor by as much as four percent, significantly reducing price volatility and emissions, improving reliability, and helping keep rates low for all customers. In green-field developments, a larger number of homes could be served by a given number of substations and distribution system assets, reducing infrastructure costs. The Collaborative plans to quantify these benefits, but initial estimates put the capacity value alone at several thousand dollars per home.

Step 4: Understand Dynamics of Target Market

It is vital to understand what motivates the key actors in the target market in order to successfully move new technologies and approaches into the market. It is clear that energy efficiency is not a significant motivator for most homebuyers (Hanson & Bernstein 2006).

SMUD's experience in working with builders on several ZEH developments has yielded some interesting lessons:

- Production builders are extremely risk-averse when it comes to new technologies.
- Production builders believe that zero energy homes are too expensive and, therefore, will not readily sell.
- Excellent aesthetics are vital. Off-the-roof PV systems are not acceptable to production builders.
- Homebuyers care about things like cost, floor plan, location, curb appeal, image, and comfort—but not energy. Few are aware of residential photovoltaics and zero energy homes. Successful marketing of advanced homes will hinge on our ability to tie the unique features of these homes to the benefits homebuyers care about.
- Energy consumption patterns of the occupants vary wildly from house to house.
- If PV is a mandatory feature in a subdivision, the sales staff will market it well. If it is optional, the sales staff will rarely market it effectively (SMUDb 2005).

The SMUD Collaborative will conduct targeted market research to gain a more in-depth understanding of builder and buyer preferences and market trends.

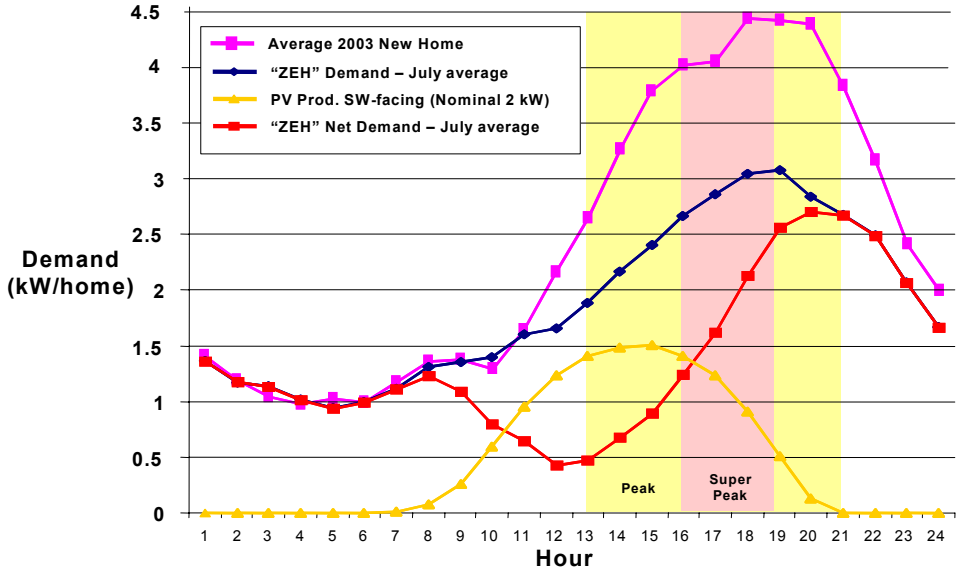
Step 5: Develop Initial Performance Goals for Target Market

Based on the results of the analyses of the system load, system benefits and market research develop preliminary goals for the performance of buildings in the target market.

Figure 2 shows the electrical demand profiles for the typical new home and an average Premier Gardens ZEH home, including the impact of PV production on the net load of the home.

While the maximum peak for the ZEH homes has been reduced by about 1.8 kW (40 percent), they still peak during the last two hours of SMUD's peak period.

Figure 2. Demand Profile for Average Premier Gardens Zero Energy Home on Peak Day[2]



Source: SMUD/Consol 15-minute interval data

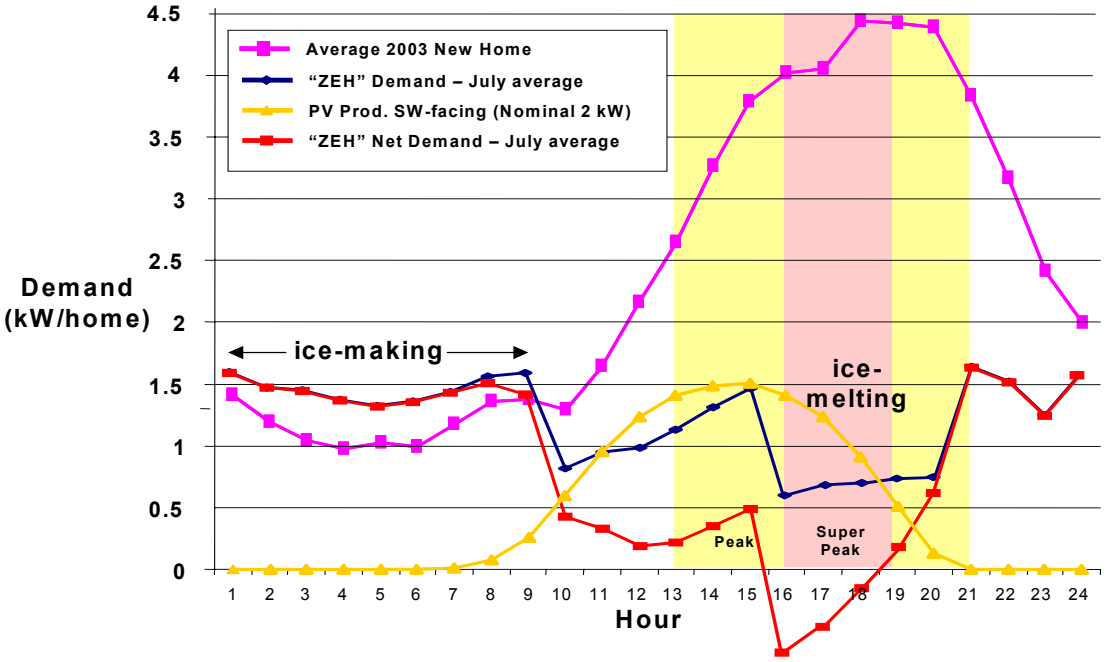
Therefore the first priority is to further reduce the demand of these homes during the super peak period and preferably until 9:00 pm. An ultra-efficient envelope and HVAC system would effectively lower the demand curve and reduce the peak another 10 to 30 percent. Increasing the internal thermal mass by a factor of ten or more and pre-cooling it by several degrees up until 4:00 may make it possible to shut down the air conditioner from 4:00-7:00 pm. The same objective could be achieved with a residential ice storage system. Figure 3 illustrates the potential impact of a 10 ton-hour ice storage system when integrated with the other ZEH features. These homes could be net power producers through the super-peak period. With high efficiency equipment, high thermal mass or ice storage, and advanced load limiting controls a goal of net-zero peak for SMUD's 1 pm to 9 pm peak period appears technically achievable.

Demand response strategies can further reduce peak demand during the most expensive 10 to 100 hours of the year. Furthermore, new controls and communications capabilities may soon make it possible to dispatch demand reductions from appliances or other end-uses.

While minimizing peak-period loads is desirable for the utility, homeowners care more about reducing their electricity bills and they will have to be compensated for the peak-period load reductions that their homes provide for the SMUD system.

[2] ZEH demand is average for all Premier Gardens homes. PV data is average system output on July 23, 2005.

Figure 3. Estimated Demand Impact of Advanced Efficiency Measures and Ice Storage[3]



Source: SMUD projections

Based on these observations, the Collaborative established the following initial performance goals:

- Zero average demand between 4:00 and 7:00 pm
- 0.5 W/ft^2 average demand from 1:00-4:00 pm and 7:00-9:00 pm
- Seventy-five percent reduction in energy bills compared to a standard code home.

Step 6: Evaluate Technologies and Design Options

The evaluation process begins with the screening of available and emerging technologies. Technologies will be screened in terms of:

- Their ability to help SMUD meet the performance goals for zero peak homes.
- The market readiness of the technology.
- The cost of the technology.
- Potential for mass-market acceptance by production builders. Factors to consider include reduction in construction time, installed cost, and call-backs.
- Potential for increasing acceptance by homebuyers. Factors to be considered include improved comfort, improved aesthetics, reduced maintenance, and lower operating costs.

[3] Theoretical demand curve based on data in Figure 1, modified by the known circulating pump demand and a/c demand shift of a 10 ton-hour Ice Bear system. Assumes demand at cooling hours is lowered an additional 30% below that of the Premier Gardens ZEH homes through more aggressive envelope and HVAC measures prior to adding ice storage.

- The degree to which a supporting market infrastructure exists. An excellent technology that has no support among manufacturers, engineers and/or contractors has little chance of being adopted by today's complex and highly competitive markets.
- Environmental footprint.

The means of measuring these attributes are currently being developed. Technologies and measures that pass the initial screening will be modeled individually and in combination to assess their impact on building performance. The modeled performance of multiple design approaches for achieving a particular performance goal will be compared.

Target technologies will be chosen and implemented in demonstration projects. The demonstration projects will be monitored and evaluated. Based on the results of the monitoring and evaluation, lists of technical challenges that need to be solved will be prepared.

Step 7: Evaluate Programmatic and Policy Strategies

Looking beyond technology solutions, there are a variety of powerful program and policy mechanisms available to electric utilities to influence the design of new homes. These include beneficial rate structures, innovative delivery strategies, utility hookup incentives or "feebates," local government codes and incentives, and innovative marketing campaigns.

As part of its effort to develop and promote zero peak homes, SMUD will be working with local government agencies to develop policies to expedite the entitlement and permitting processes for projects that voluntarily meet certain energy performance criteria and requirements for minimum energy performance for inclusion in development agreements. An electric utility can offer the incentive of expedited processing of electrical hookup applications and reduced hookup fees, or even impose their own requirements for energy performance as a condition of providing service.

Step 8: Identify Necessary Actions to Overcome Challenges

After technological and programmatic solutions have been identified as well as barriers to their application in the target market, identify the necessary action steps to overcome the barriers.

While SMUD's Residential New Construction Collaborative has yet to reach this step, it has identified the following preliminary actions:

Technology development.

- Evaluate new products and load management strategies.
- Solicit proposals for research and development to create new products and functionality to help meet home performance goals.
- Demonstrate integrated packages of measures and monitor their performance.

Market development.

- Integrate new measures and technologies into the Advantage Homes Program as they become ready for mass-market introduction.

- Continue subdivision scale demonstrations of Zero Energy Homes, integrating new measures and technologies as they become ready for pilot testing.
- Build stronger relationships and trust with local builders.

Program/Policy development.

- Institutionalize performance objectives and the long-term corporate commitment needed to accomplish them.
- Develop new program delivery models.
- Work with local governments to develop local policies and ordinances.

Step 9: Reevaluate and Refine Performance Goals

At this stage, it is a good idea to revisit the initial performance goals to ensure that they are realistic in light of the information gathered on available technology, program and policy strategies, and the level of effort that would be required to develop and integrate these tools so that they can be put into widespread use. If the original goals no longer look realistic, it may be wise to scale back expectations. Conversely, new technologies or tools may have been identified that allow more ambitious goals to be set.

Step 10: Identify Resource Requirements

Make an estimate of the resources required to achieve the project objectives. These include:

- Resources from outside organizations that can be leveraged, including programs, research and demonstration projects by other utilities and research organizations.;
- Consulting support;
- Internal staff expertise and workload;
- Monitoring and evaluation support;
- Time required to meet major milestones and the ultimate performance and market objectives;
- Total budget; and
- Determine whether the project will be constrained by the scope, available resources, or time.

Step 11: Identify Risks to Success and Strategies to Avoid or Mitigate Each Risk

It is advisable to list any foreseeable risks to the success of the plan, the circumstances under which each risk would impact the project, the probability that the event will occur, and the consequences if it occurs.

SMUD will assemble a risk management plan that addresses ways to prevent or mitigate each significant risk or mitigate the negative impacts if the risk event occurs.

Step 12: Develop Strategic Market Plan Capable of Achieving Long Term Goals

It is important to document the project purpose, goals, objectives, action steps, team member roles and responsibilities, and other elements.

SMUD will use the information and data developed in Steps 1 through 11 to prepare a strategic market and program implementation plan. The plan will be invaluable for making sure that all team members and management have a common understanding of what needs to be done and why. The plan will need to be periodically reviewed and updated as assumptions are tested and as new technology and market opportunities arise.

Step 13: Adopt and Implement the Plan

The last step is for the whole project team to sign-off on the plan and then secure approval from management for the plan including a commitment for the resources necessary to staff and fund the program.

The SMUD Collaborative expects to complete a five-year market development plan for residential new construction by the end of 2006.

Conclusions

While the SMUD team has only completed the first few steps of the process outlined in this paper as of this writing, use of the process has already resulted in a level of internal coordination, ambitiousness of goals, length of planning horizon, and level of technology and program integration that was heretofore unprecedented. Lessons learned so far include:

- There is potential to increase the utility benefits of residential new construction programs by several-fold through integration of energy efficiency, peak load management, demand response, distributed generation and R&D programs.
- It may be prudent to follow parallel paths to the same performance objective in the event one comes to a dead end.
- The basic approach is applicable to other utilities as performance objectives can be tailored to the local climate, load-serving needs, capacity constraints, and market trends.
- This approach is also applicable to other market sectors such as commercial and industrial new construction, commercial renovation, and residential renovation.
- The power of a utility to achieve its performance goals would be enhanced significantly by looking at opportunities across several market sectors. While a particular building type may not by itself be capable of achieving the broad performance objectives, it may have unique opportunities for load shaping that contribute a critical piece towards meeting the overall goals.

The SMUD team will be implementing the road map over the next five to ten years, and welcomes inquiries and information sharing from other utilities and organizations that are working toward similar objectives in residential new construction or other market sectors.

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