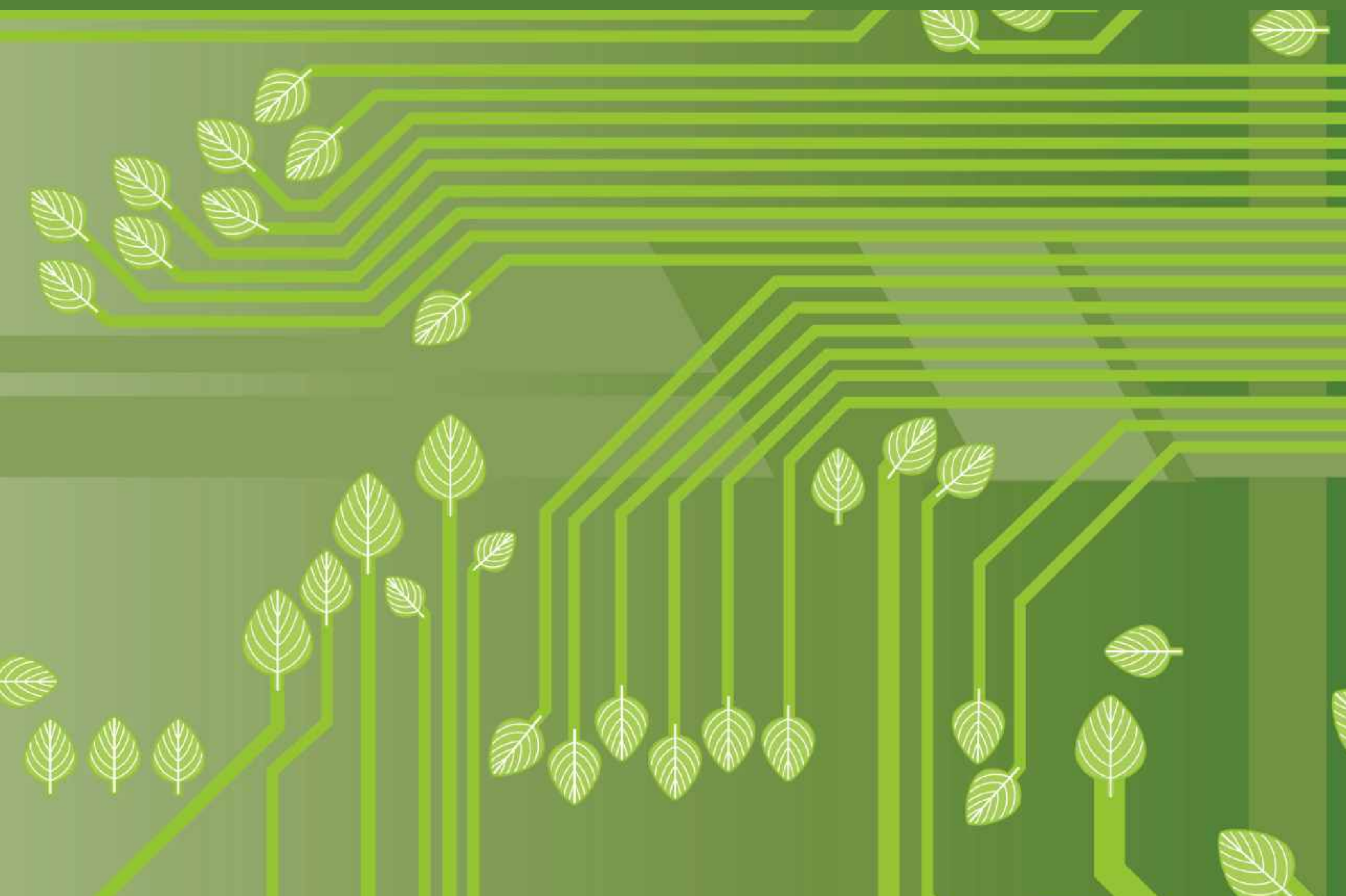
Partnership to Advance Clean Energy - Deployment (PACE - D)
Technical Assistance Program

Smart Grids: An Approach to Dynamic Pricing in India



April 2014

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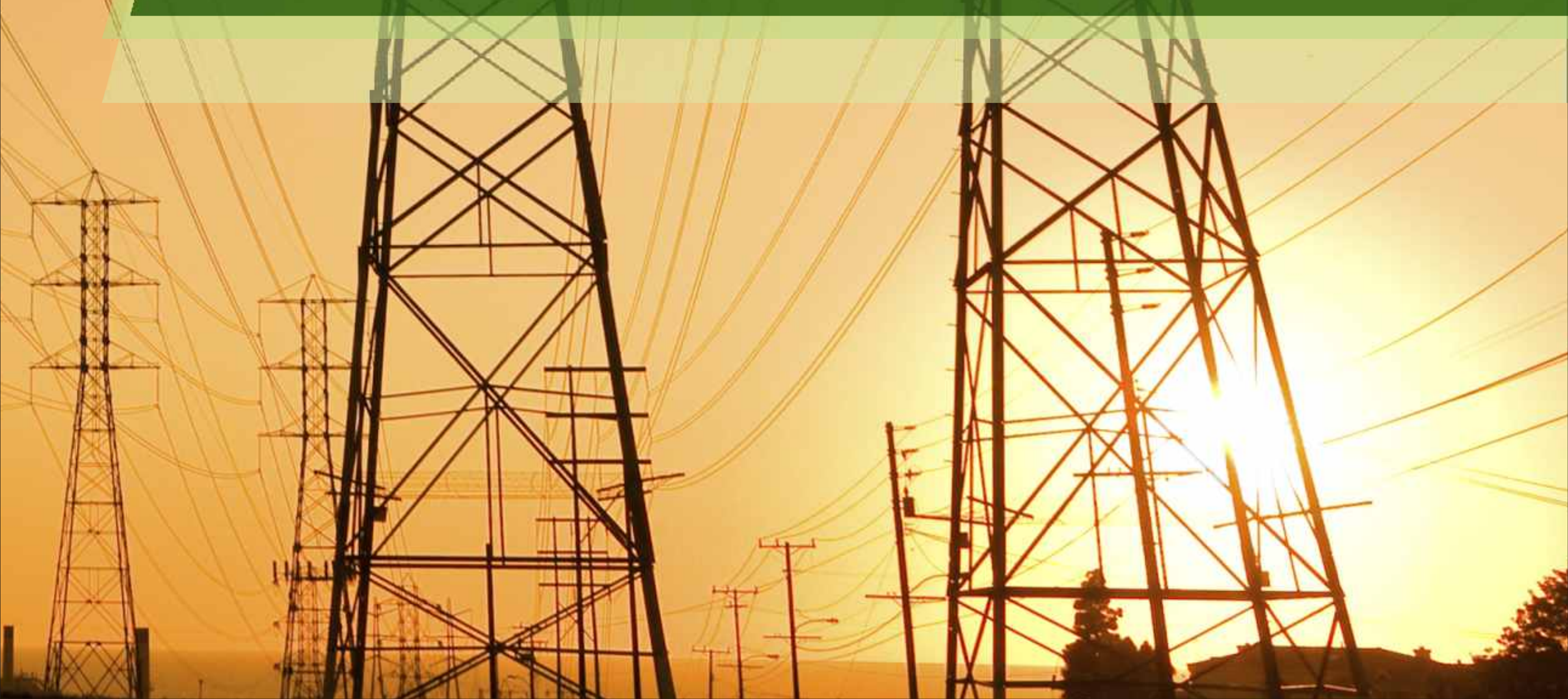

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Executive Summary

This report develops an approach to dynamic pricing in support of the Ministry of Power (MOP) initiative for smart grid pilot projects in India. Dynamic pricing experiments are intended to reveal how consumers respond to electricity prices and identify the most promising mechanisms suitable for wide-scale deployment. Traditional electricity rate structures do not reflect the cost difference of supplying electricity in peak versus off-peak hours. Therefore, the customer has no market incentive to adjust their pattern of electricity consumption.

Dynamic pricing options such as time of use (TOU), critical peak pricing (CPP), critical peak rebate (CPR), real time pricing (RTP), and variable peak pricing (VPP), that reflect time-varying cost of electricity supply, have been in use worldwide to encourage peak load management and demand reduction.

A global review of dynamic pricing pilots reveal that its success lies in customer engagement together with the type of pricing options, enabling technology, and market segment chosen, as well as the reliability of service. While success rates have been higher in smaller size test markets, larger sized test markets have also been successful with the help of strong coordination and stakeholder commitment.

Based on the research and pilots reviewed, it is recommended that a smaller size pilot be initially selected for a residential test market with homogeneous income group (and similar consumption patterns) in urban areas with TOU, CPP, and CPR pricing options.

Successful introduction of smart meters and time-based dynamic electricity pricing requires a well-planned social marketing campaign to help raise awareness and give customers the information and support they need to become more energy efficient. More sophisticated dynamic pricing experiments will require the same levels, if not more, of infrastructure and customer education. The infrastructure requirements can be met by the anticipated smart grid pilots in India. The benefits of such pricing programs may be larger than TOU pricing. In the long run, it may be more efficient to move directly to such a program rather than first moving to TOU pricing and then to a more sophisticated dynamic pricing program.

Currently, the power system in many developing countries is ripe for Advanced Metering Infrastructure (AMI), supporting efforts to reach 100 percent metering of loads. With progress in metering of loads, AMI can be supplemented by implementing relatively straight-forward and transparent TOU pricing.

For any such experiment, a cost–benefit analysis and full-scale rollout should be performed and updated as better information becomes available. If the cost-benefit analysis does not show an overall benefit for full-scale implementation, it may not make sense to spend the effort on the smaller scale experiment.

An Approach to Dynamic Pricing in India

Background

The Governments of the U.S. and India signed a Memorandum of Understanding on November 24, 2009, creating the Partnership to Advance Clean Energy (PACE) to enhance cooperation on clean energy, energy security and climate change. PACE has two interlinked components: a Research Component, known as PACE-R, and a Deployment Component, known as PACE-D.

USAID's PACE-D Technical Assistance Program is a part of the overall PACE-D initiative and builds upon USAID/India's previous energy programs. It aims to accelerate India's transition to a high-performing, low-emissions, and energy-secure economy. The five-year program will support institutional strengthening and development of an enabling environment by providing technical assistance to formulate and implement policies, regulations, and strategies for clean energy deployment.

A key component of the program focuses on deployment of smart grid electric system. Under this program, the activities are closely aligned with the work being undertaken by the MOP through the India Smart Grid Task Force (ISGTF). The program aims to support and strengthen smart grid initiatives in the country through focused technical assistance, technology exchange and access, knowledge sharing, training and capacity building, and access to financing. The technical assistance provided under PACE-D TA Program supports the goals of establishing smart grids in India to increase power availability, reduce aggregate technical and commercial losses (AT&C), and improve utilization of renewable resources for sustainable growth.

The Government of India has selected 14 electricity distribution utilities to implement smart grid pilot projects. These projects will contribute toward India's pressing priorities of providing broader access to electric power supply, reducing energy losses due to infrastructure and power theft, integrating renewable energy, and improving energy efficiency and reliability. Pilots will be evaluated for technological and commercial benefits and for the potential of being scaled up.

Dynamic Pricing in Smart Grid Pilots

Time-based or dynamic pricing refers to the provision of a service or commodity in which the price depends on the time when the service is provided or the commodity is delivered. The rationale of dynamic time-varying pricing is to reflect changes (expected or observed) in supply and demand over time and their impact on costs. Time-based pricing includes: (i) fixed time-of use rates for electricity and public transport,(ii) dynamic pricing reflecting current supply-demand situation; or (iii) differentiated offers for delivery of a commodity depending on the date of delivery (futures contract).

Traditional electricity rate structures do not reflect the cost difference of supplying electricity in peak versus off-peak hours. Therefore, the customer has no market incentive to adjust their pattern of electricity consumption. This report develops an approach to dynamic pricing to support the MOP initiative for smart grid pilot projects in India. Dynamic pricing experiments are intended to gather information about how consumers respond to electricity prices and identify the most promising mechanisms suitable for wide-scale deployment.

For example, dynamic pricing programs have the potential to make longer term impacts as plug-in hybrid electric vehicles (PHEVs) become prevalent. These types of pricing programs and the charging times for PHEVs provide another opportunity to address the significant disparity between peak and off-peak demand. In an analysis of the potential impacts of PHEVs in 2020 and 2030 in 13 regions of the U.S., researchers at the Oak Ridge National Laboratory found that charging PHEVs at 10 p.m. instead of 5 p.m. would make a significant difference in total generation costs (reference #1).

In the U.S., the Energy Policy Act of 2005 (EPAct) adds several new federal standards to the Public Utility Regulatory Policies Act of 1978, including time-based metering and communications. Section 1252 of EPAct, smart metering, covers these federal standards and defines the following time-based pricing methods:

- **Time of use (TOU) pricing:** Under TOU pricing, the electricity prices are rates set for specific hourly time periods on an advance or forward basis. Prices paid for energy consumed during these periods are pre-established and known to consumers in advance, thus allowing them to vary their usage in response to these prices and manage their energy costs by shifting usage to a lower cost period or reducing their consumption overall.

- **Critical peak pricing (CPP):** TOU prices are in effect except for certain critical peak days when prices may reflect the exceptionally high costs of generating and/or purchasing electricity at the wholesale level.

- **Real time pricing (RTP):** Electricity prices may change hourly, or even sub-hourly, with price signals provided to the user shortly in advance, reflecting the utility's cost of generating and/or purchasing electricity at the wholesale level.

- **Peak load reduction credits:** For consumers with large loads who enter into pre-established peak load reduction agreements that reduce a utility's planned capacity obligations.

As a result of EPAct 2005, the U.S. Federal Energy Regulatory Commission report "Assessment of Demand Response and Advanced Metering" was published in 2006 and updated in 2008. This report assesses the status and potential electric demand response resources of the U.S. (by region) from all consumer classes. Among other topics, it reviews the following:

- The saturation and penetration rate of advanced meters and communication technologies, devices and systems;
- Existing demand response programs and time-based rate programs.

Dynamic-pricing programs that charge higher electricity prices during peak demand periods are conceived as an effective tool to shift electricity consumption from peak to off-peak hours. In this report, dynamic pricing refers to any of the time-based pricing methods for electricity, including but not limited to those listed above. Many utilities, worldwide, have incorporated some form of dynamic pricing (such as TOU pricing) in their rate structures and are experimenting with the incorporation of further dynamic pricing (such as RTP and associated demand response programs) in smart grid initiatives in order to create a mechanism for improving market efficiency through demand response. Dynamic pricing leads to different electricity prices at different times of the day and year to reflect the time-varying cost of supplying electricity.

Dynamic Pricing in the Indian Context

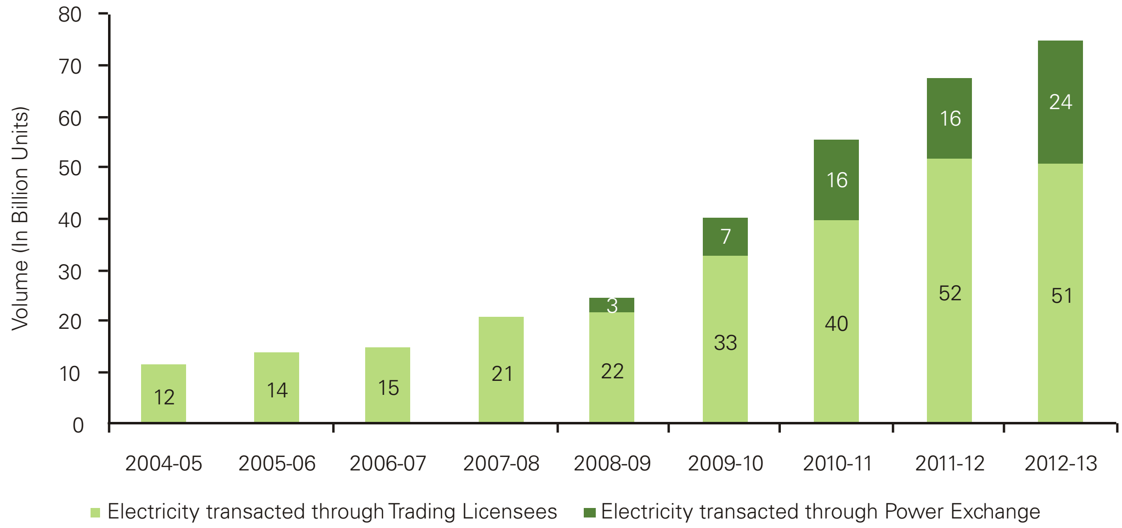
The power market structure in India can be categorized based on the tenure of the contract between the distribution utility and the generator. These categories are as follows:

- Long term (7-25 years)
- Medium term (1-7 years)
- Short term (less than 1 year)

Long term procurement constitutes the majority of the utilities' power purchase portfolio and serves as its base load. However, due to increased demand, utilities are inevitably exposed to the power market to procure electricity to meet their medium and short term needs. In several cases this procured power is at very higher cost, or often subject to a high level of volatility.

As seen in Graph 1 and 2, procurement from short term has increased significantly over the past few years at the national level.

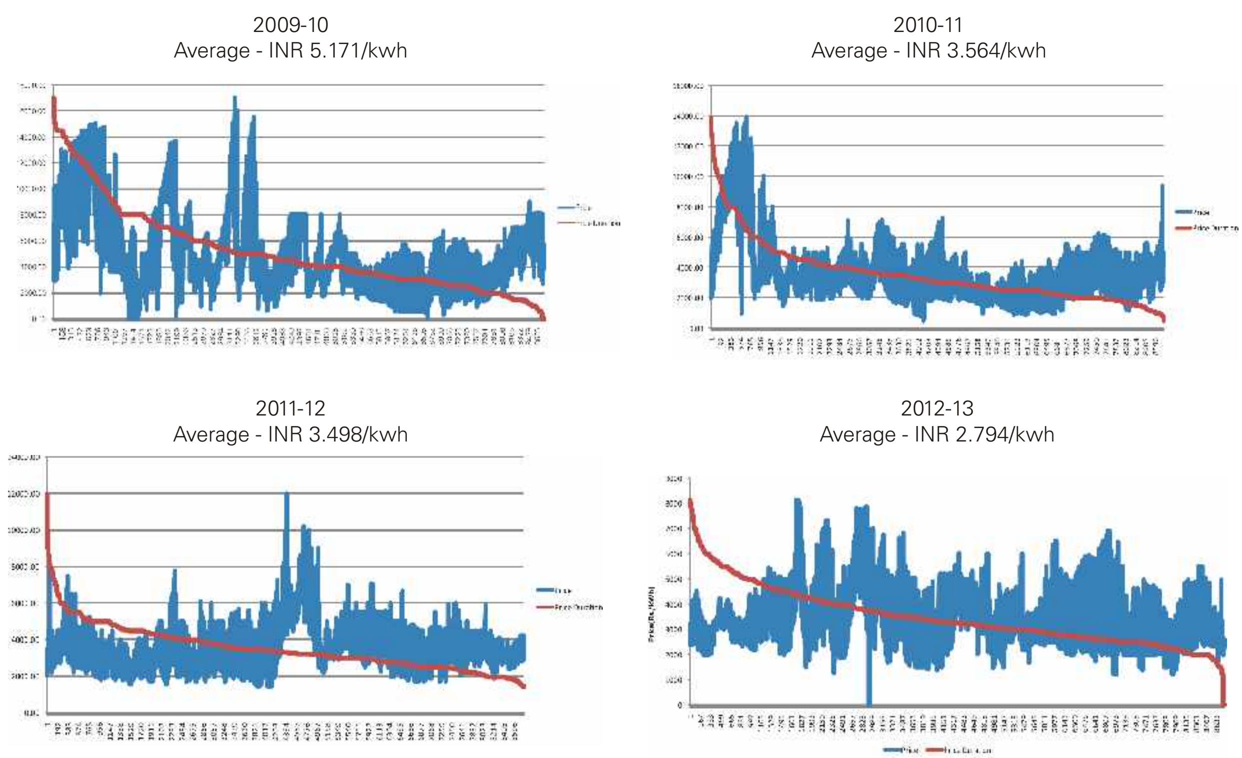
Graph 1: Volume of Electricity Transacted through Over the Counter (OTC) and Power Exchange



Source: CERC Monthly Market Monitoring Reports

Similarly, prices in the short term (ST) market have also exhibited volatility, as is illustrated by the graph below.

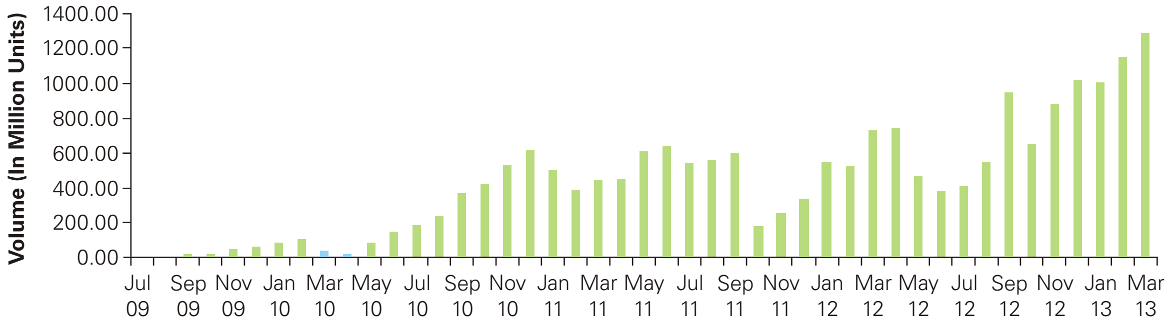
Graph 2: Price of ST Transactions of Electricity on Indian Energy Exchange (IEX): FY 2009-10 to FY 2012-13



Source: IEX Data

For a long time in India, electricity has been considered as social commodity, to be provided at a low cost to the citizens. Despite significant increases in load, electricity tariffs have changed very little. This has led to inefficient use of energy and electricity distribution utilities incurring significant financial losses, which in turn has slowed down investments in the necessary infrastructure. This has further affected industries where reliability of electricity supply is of paramount importance. Additionally, the industrial and commercial sectors have been impacted by high electricity tariffs while the residential consumer segment has been less impacted. With the introduction of open access regulations, industrial consumers are increasingly purchasing power from the market, which is at times less expensive than the tariff set by the utility and is more reliable. Thus, there is an automatic price signal sent to the participating industrial customers with the evolution of the wholesale markets. As observed from the following graph, 40-45 percent of overall trades on the day-ahead markets are from direct customers availing themselves of open access. While relatively low in overall terms, the volumes are significant (annually about 6-7 BU), constituting close to 0.8 percent of the overall electricity supply in the country.

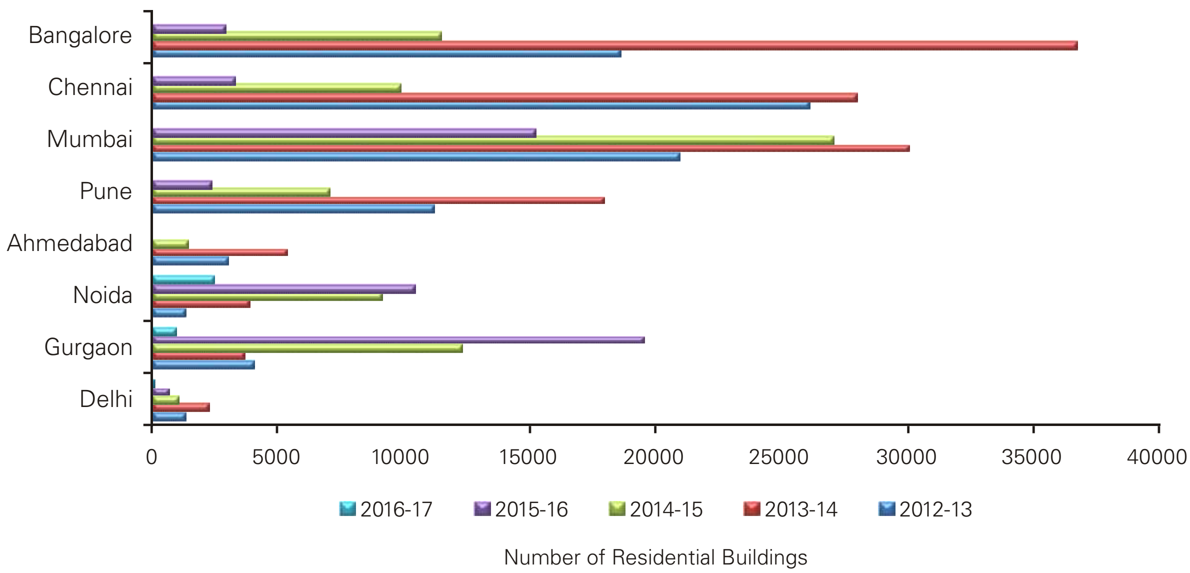
Graph 3: Volume of Participation of Open Access (OA) Consumers in Day Ahead Market



Source: IEX (till March 2013)

With increasing price volatility and higher costs for peak power, it becomes important to communicate price signals to consumers who may be otherwise used to them. Such signals through dynamic pricing are likely to create benefits in the form of avoided generation, transmission and distribution costs. These consumers are both commercial and residential in nature. Graph 4 indicates the growing stock of residential buildings across key towns in India.

Graph 4: Estimated Growth in Residential Stock



Source: Data collated from www.magicbricks.com, www.makaan.com, www.99acres.com and www.magicbricks.com

The pricing design has to be differentiated from conventional TOD pricing since the peaks are much more volatile than in the past and the prices can vary radically between days of the month and between seasons.

Demand response is typically reliability-based (customers reduce their consumption in response to system conditions), or price responsive (customers change consumption behavior in response to a financial incentive). The key difference between reliability-based demand response and dynamic pricing is that demand response targets relatively fewer but larger customers, while dynamic pricing targets more customers however with less consumption. For price-responsive demand response, dynamic pricing and demand response are complementary to each other.

In this regard, it is essential that an in-depth review of the current pricing programs that have been piloted or implemented in different countries be conducted prior to developing an approach for dynamic pricing that would be applicable to Indian smart grid pilot projects. It is expected that a review of past pilot programs on dynamic pricing will provide the following insight:

i. Key factors to the success of dynamic pricing programs

ii. Understanding of why customers do or do not accept or change their usage behavior in response to various treatments

iii. Correlation of program success to enabling technology

iv. What are the most effective incentives to the customers?

v. What are the key considerations for a successful incentive design?

vi. How important is market segmentation for the pilot implementation?

vii. Is there a trend worldwide in the popularity of the dynamic pricing options?

viii. What are the key contributing factors affecting the shift in demand?

ix. Customer engagement options that significantly impact the success of dynamic pricing programs.

To help answer these questions, this report includes a review of current dynamic pricing methods and options worldwide, lessons learned from current dynamic pricing programs, and a discussion that will lead to the development of an approach to dynamic pricing experiments in India.

Dynamic Pricing Options

There are four widely used types of dynamic pricing options:

- TOU: Prices vary by rate period and day of week, but do not change based on system conditions (technically, not a dynamic rate option). TOU prices and time periods are generally fixed at least one year in advance. TOU offers consumers the lowest reward-risk profile.

- RTP: Prices change on an hourly or sub-hourly basis to reflect the true cost of supply in the wholesale market. The volatile nature of RTP can harm consumers and may discourage participation in voluntary dynamic pricing programs, although RTP offers consumers the highest reward compared to traditional flat-rate pricing, but at the highest risk.

- CPP: CPP captures the true cost of power generation during peak demand periods (i.e., top 100 to 200 hours a year). In exchange for paying very high prices during those peak hours, customers receive a discounted rate for all remaining hours of the year. The actual times in which the CPP will be in effect are identified on a day-ahead (and sometimes day-of) basis, depending on the demand–supply balance.

- Peak Time Rebate (PTR): PTR is similar to CPP, but instead of higher prices during peak periods on selected days, customers are paid to reduce load (technically, not a rate, but a pay-for-performance program). PTR allows customers to remain on their current flat rate while receiving a cash rebate for each kilowatt hour (kWh) of energy usage they reduce from their baseline usage during the peak hours. Thus, PTR provides an opportunity to customers to save money on their monthly bill.

Lessons Learned from Dynamic Pricing Programs

Time of Use Rates

TOU pricing of electricity is the most widely used dynamic pricing method in power systems today. In the U.S. and Canada, it has gone well beyond the experimental pilot project stage and has been widely adopted. TOU pricing was instituted in Ontario, Canada, in 2006 by the Ontario Electric Board, and today covers 90 percent of residential customers. In California, at the direction of the California Public Utilities Commission, businesses are moving to a full time-based TOU electric rate structure and while TOU rates are optional for residential customers.

TOU rates require the functionality of interval meters or TOU meters that has existed for years in older technologies and is included today within the features of smart meters. Interval and TOU meters that have been installed historically to measure commercial and industrial customers with time-based rates often lacked automatic meter reading. In California, since 2006, nine million smart meters have been installed for Pacific Gas and Electric Company customers and five million smart meters have been installed for Southern California Edison customers.

A smart meter is an electrical meter that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes. Smart meters extend the functionality of interval meters or TOU meters in addition to automatic meter reading. Smart meters usually involve real-time or near real-time sensors, power outage notification, power quality monitoring, and generally can support two way communications as part of AMI in a smart grid implementation.

These additional features of smart meters enable more than simple automated meter reading. Smart meters enable two-way communication between the meter and the central system. An AMI with smart meters differs from traditional automated meter reading in that it includes increased functionalities enabled by communications with the smart meters. Unlike home energy monitors, smart meters can gather data for remote reporting. While home energy monitors and smart meters can be installed together, these are distinct devices with different functions that should not be confused.

Smart Meters and Time of Use

The American Council for an Energy-Efficient Economy reviewed more than 36 different residential smart metering and feedback programs internationally. They published their results in 2010 (reference #3). Their conclusion was: "To realize potential feedback-induced savings, advanced meters [smart meters] must be used in conjunction with in-home (or on-line) displays and well-designed programs that successfully inform, engage, empower and motivate people." Their results call for a national social marketing campaign to help raise awareness of smart metering and give customers the information and support they need to become more energy efficient, and raise customer awareness regarding changes they must make to realize the potential of smart meters.

While TOU rates and smart meters are widespread, their implementation has often been controversial. For example, while in Ontario, Canada, 90 percent of residential customers pay TOU rates and almost every household and small business now has a smart meter, in British Columbia, Canada, the situation is more complicated. In British Columbia, TOU electric rates are opposed by the provincial government and do not accompany smart meters.

BC Hydro had set a goal of implementing smart meters to all customers by the end of 2012. However, after smart meter installations were associated with several fires, the Union of British Columbia Municipalities voted in favor of a moratorium on smart meter installations in British Columbia, and many BC municipalities passed motions opposing the installation of smart meters. BC Hydro is not obliged to abide by these municipal decisions, and the provincial government insists that installations will proceed based on global standards. In January 2013, when smart meters were installed in 90 percent of customer homes, BC Hydro announced that smart meters will not be installed at any home unless the company has the customer's permission, and headlines read "BC Hydro Smart Meter Installation Not Mandatory."

Italy and the Netherlands present two somewhat contrasting European examples of smart meter installation. In Italy, the world's largest smart meter deployment was undertaken by the utility Enel SpA with more than 30 million customers. Between 2000 and 2005, Enel deployed smart meters to its entire customer base. These smart meters are fully electronic, all solid-state, with integrated bi-directional communications, advanced power measurement and management capabilities, and an integrated, software-controllable disconnect switch. They communicate over low voltage power line using standards-based power line technology to data concentrators, at which point they communicate via IP to Enel's enterprise servers, demonstrating that smart grids do not require wireless devices. The system provides a wide range of advanced features, including: the ability to remotely turn power on and off; read usage information from a meter; detect a service outage; change the maximum amount of electricity that a customer may demand at any time; detect "unauthorized" use of electricity and remotely shut it off; and remotely change the meter's billing plan from credit to prepay, as well as, from flat-rate to multi-tariff.

In the Netherlands, as part of a national energy reduction plan, the government proposed in 2007 that all seven million households in the country should have a smart meter by 2013. The roll out of these meters was delayed in August 2008 for several reasons including difficulties registering small-scale local energy production (such as by solar panels), and then again in April 2009 after consumer groups raised privacy concerns. As a result, the government decided to make the use of smart meters voluntary.

Dynamic Pricing Pilot Projects

Smart meters enable and support various time-based dynamic pricing methods in addition to TOU electricity rates. Most current smart grid experiments with dynamic pricing study time-based pricing options that go beyond TOU rates.

Most analyses of pilot show that customers do respond to dynamic pricing rates by lowering peak usage, and the response varies depending on the intensity of the price signal. The response improves when enabling technologies are added. Pilot projects in the U.S. have demonstrated that the dynamic pricing does not hurt low-income customers; on the contrary, it provides benefit to many low-income customers. In the U.S., the PowerCentsDC program has been highly successful, as demonstrated by the fact that 89 percent of the participants would recommend it to their friends and neighbors, and 93 percent preferred dynamic prices to flat rates (see Graph 3, also references # 10 and 11).

Categories for Defining Dynamic Pricing Research Objectives

In its Dynamic Pricing and Consumer Behavior Studies Webinar (April 20, 2010), the U.S. Department of Energy addresses the following four categories which are important for defining dynamic pricing research objectives:

1. What to test?
   a. Pricing option – Each pricing option can have several attributes such as:
      i. Price levels by rate period – will higher peak prices generate more impact?
      ii. Number of rate periods – how many rate periods would have more impact?
      iii. Length of peak period – will shorter period have more impact?
      iv. Timing of rate period – will seasonal rate periods be more relevant?
      v. Combination of options as overlays on existing pricing tiers.

   b. Enabling technologies - Enabling technologies such as direct load control, home area network, programmable communicating thermostats, message alerts, in-home displays (IHD), and web portals are anticipated to have an impact on the end users.

      The following questions will be relevant in the development of a dynamic pricing experiment:

      i. What technologies are to be tested and what selection criteria should be used?
      ii. Customer eligibility criteria for using the technology, if any.
      iii. Cost impact.

   c. Enrollment options – Enrollment options could be mandatory, opt-in, or opt-out. It is important to know how enrollment varies across different customer segments, rates, enrollment options, and marketing strategies. Issues that need consideration include:
      i. Desired enrollment model for the full-scale roll out.
      ii. Attrition mitigation measures (e.g., bill protection) for a full-scale role out.
      iii. Mitigation models for the trial/pilot phase.

   d. Marketing strategy – It is important to decide which features (e.g., message, package, incentive, mode of communication, etc.) are to be included in the marketing offer. Issues that need consideration include:
      i. Relative importance of marketing features.
      ii. Offering different incentives across different customer segments.
      iii. Consideration of unconventional marketing methods.

2. What population to reach? There are several target markets to choose from:
    a. Residential customers (low/median/high income, etc.).
    b. Commercial customers (size and type of business).
    c. Industrial customers (timing of processes, size).
3. What impact to measure?
    a. Changes in peak demand and energy use by time period and resultant savings.
    b. Differential acceptance/enrollment/attrition rates for each option and market segment.
    c. Changes in consumer behavior underlying the changes in energy use.

Summary of Dynamic Pricing Pilot Projects

Based on the study of 17 pilots listed in Graph 5, the following inferences can be drawn:

- Based on the fact that more than 70 percent of the pilots reviewed were experimented on residential customers, it may make more sense to start the pilot with residential test market.
- Out of five most successful pilots (reference #, 2, 11, 12, 16 – Graph 5), four were tested on residential customers.
- Based on the data in Graph 5, the size of the test market does not seem to have a strong correlation with the success of the pilot. However, three out of five most successful pilots were conducted across a smaller cross-section of customers (1,000 or lower). It seems a smaller size of test market will be more manageable from resource- and cost- containment perspective.
- A homogenous market mix would help establish a definite trend in the outcome. It may also make sense to test the pilot in more than one test market for any differentiation purposes.
- Pilots must provide enabling technologies (e.g., IHD, smart thermostat) to the customers in the chosen test market.
- Based on the pilots reviewed, CPP and TOU pricing with a combination of CPR was more successful.

Considerations for Dynamic Pricing Design

Below is an outline of important considerations for the program design process adapted from the American Electric Power, Texas experience (reference #4).

- Begin with a soft launch: A soft launch is a limited release of a program which is essentially a feedback process that provides a preview of the response and pre-validation of assumptions before incurring significant resources on the program. A soft launch enhances the probability of success of the program. A typical soft launch may be conducted with a goal of reaching about 10 percent of the target population.

- Define the population and align the sample to maximize external validity: The population in this context is the electricity consumers/end users (also known as the treatment group) that would benefit most from the program design. The external validation ensures that the results of the program can be extrapolated from the target to larger population.

- Include a control group to maximize internal validity: A control group is similar to the treatment group in electricity consumption, but without dynamic pricing option. Internal validity will determine the impact of dynamic pricing on the electricity consumption of the target population.

- Design treatment groups to isolate impacts of research variables: The evaluation will be more meaningful if the dynamic pricing program is designed in a way not to combine with any other program.

- Recruit sufficient sample to achieve analysis goals: Size of the treatment group or sample is important for making the outcome of the program meaningful. However, this could be a key cost driver. Appropriate balance has to be made by weighing benefit versus cost in determining the sample size. Statistical calculations can be employed in determining the optimum sample size.

- Over-recruit to account for dropouts: In order to ensure the availability of adequate data for the analysis, it is important to recruit more participants than required to mitigate participant drop outs. Over recruitment and drop outs will vary depending on several factors such as:

    - Ease of the program interface for the participant

    - Length of the evaluation period – Some participants may not want to be tied up for too long

    - Participants' particulars – Renters/home owners etc.

- Plan for an assessment period sufficient for evaluation of long-term impacts: Short-term programs may not adequately reflect long-term impacts. Also, response may be initially slower due to the learning curve.

- Combine various data sources to improve understanding of impacts: Provision should be made to collect additional data that may impact energy consumption (e.g., weather data, power outages, etc. will be helpful for the analysis).

Designing Future Dynamic Pricing Pilots

The following observations drawn from the completed dynamic pricing pilots are useful in designing future dynamic pricing program:

- Customers respond better to dynamic pricing with planned communication and education.

- Enabling technologies (e.g., smart meter, smart thermostat, IHD) play a key role in the success of a pilot.

- Pilot design and roll-out must mirror a utility's full deployment approach as much as possible.
- Low-income customers with a flat load profile do benefit from dynamic pricing.
- A variety of choice offerings (CPP, RTP, TOU, etc.) may help determine the most effective option for the selected treatment group.
- In some situations, RTP may not be popular with some customers, due to exposure to high risk. Customers may accept higher risks if there a corresponding reward to go with it.
- In order for the results to be demonstrative, both the treatment and control groups should have a similar consumption pattern.

Summary of Results from Dynamic Pricing Pilots

The 2013 ISGAN Issue Brief (reference #5) discusses a TOU tariff simulation study and concludes that "the net impact on consumer bill on account of aforementioned TOU charges will be almost negligible if the consumer does not make any change in consumption pattern".

As indicated in this report, results from international pilots exhibit varying impacts from the tariff schemes and a degree of sensitivity to the way in which customers interact with the tariff (for example, via in-home devices). Graph 5 displays the varying impacts experienced by the U.S. and Canada utilities due to different tariff schemes and consumer interaction methods. Further information on the U.S. and Canada time-based tariffs can be found in reference #6.

Graph 5: Varying Impact of Tariff Scheme

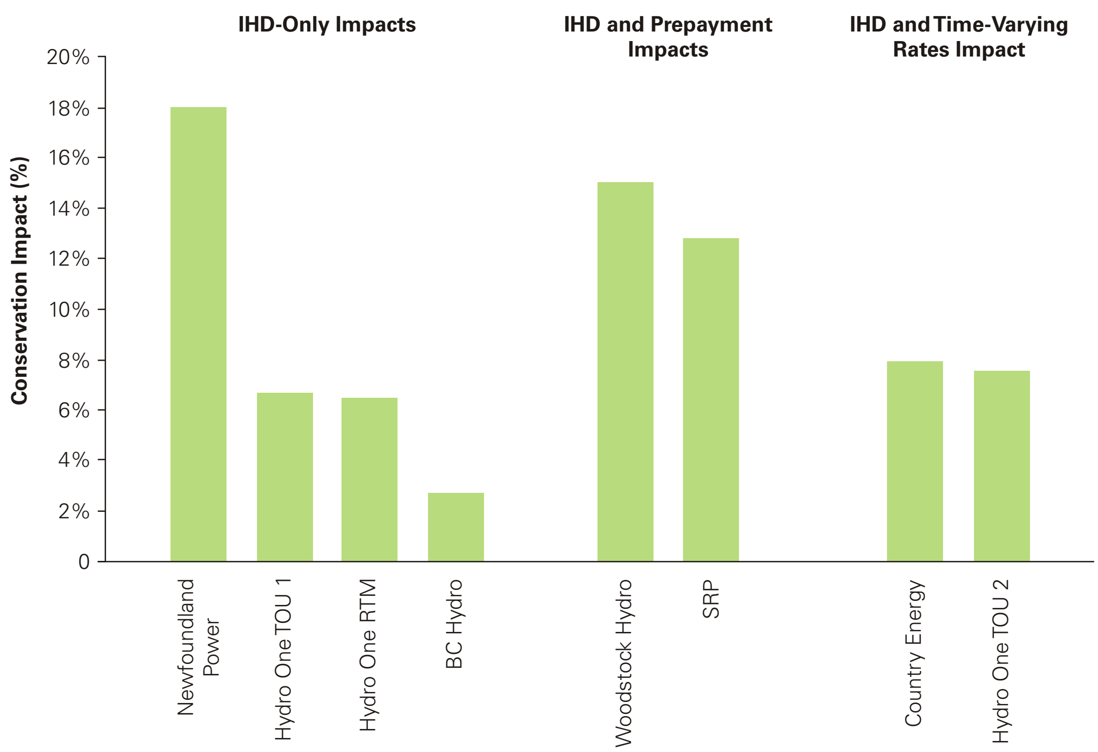


Table 1 includes data and observations from 17 dynamic pricing pilots. The data used in the table are based on information provided in reference # 7.

Additional sources of information on international smart grid pilot projects and dynamic pricing are found in references # 5 and 6.

The observations listed in Table 1 indicate that the consumption pattern will change if:

- The ratio of peak/off peak rate is high – it is important to note that the energy savings may not translate into a proportional direct cost savings.
- There is a price limit hedge (or announced maximum price) for the program participants.
- Enabling technologies are employed so that:
    - The consumers can monitor their electricity usage from IHD.
    - Smart meters and smart thermostats are in place to automate data collection and control of appliances - ONCOR, Inc.'s Smart Texas program applied a monthly surcharge for program participants towards installation of the smart meters.
- The program produces consistent results with minimum error – Pepco, who conducted one of the most successful dynamic pricing pilots in the U.S.(PowerCents), conducted a sample test on each production run of smart meters before installation to ensure accuracy.
- The end users have adequate training and knowledge of the program.
- The program is limited to a homogeneous mix of participants.

Questions that the various programs tried to address in designing their dynamic pricing program include:

- Would people be willing to participate in the program?
- How much money would consumers with central air-conditioning save, and how would this compare to consumers without central air-conditioning?
- How comfortable is the treatment group in handling technologies such as IHD, smart meter, and smart thermostat?

Table 1 - Dynamic Pricing Pilots

Sl. #	Company/ Program	Test Market	Dynamic Pricing Option	Changes in Peak Demand	Dollar savings	Consumer Savings	Customer Communication/ Education	Other Issues/ Observations
1	Potomac Electric power Co. (PEPCO)/ Power Cents DC, Washington, DC, 2008–2009, 2010–2011; Program Budget - N/A.	280,000 Residential with smart meter.	CPP- prices 7 times the normal price for 60 peak hours/year; CPR - rebates earned for lower consumption in peak hours; HP - hourly change in price based on wholesale prices.	CPP - 30% -13% (summer /winter); CPR - 13% - 5% (summer/winter; HP - 4% - 2% (summer/winter).	CPP - 2%; CPR - 5%; HP - 39%.	Overall 8% bill savings over 2 years.	Program brochure, and explanation in bill.	Smart thermostats were used in houses with electric heating; Low income participant's demand reduction was smaller; Billing system testing was essential.
2	Southern Company/ Georgia Power/Power Rewards, Georgia, 2008-2009, Program budget N/A.	1,000 Residential customers already having AMI.	CPP - Rewards based difference between actual and projected usage (required 30 hours of admin time per event). It was difficult to predict consumption behavior of residential customers.	Program reduced peak energy demand.	35¢/ kWh of energy saved, with a maximum CPP period of 50 hours/ year.		Customers were notified at least one day before CPP event via phone/e-mail.	Customer education and energy management advice, and enabling technology are important for the acceptance and satisfaction of end users as well as program reliability; Payout to customers higher than the highest RTP (88¢/kWh vs. 29¢/kWh) indicating flaw in the incentive design.
3	CenterPoint Energy, /In Home Display Pilot, Houston, Texas, 2010, Program budget N/A.	500 Residential customers given smart meters, IHD.	TOU	NA	NA	NA	Advertising, direct communication, internet, media relations, and collateral materials.	Periodic meter checking and automating routing transactions are important for accuracy and reduction in routine service visits.
4	ISO-NE/DR Reserve Pilot, New England, 2006-10, Program budget N/A.	109 Commercial customers.	RTP, VPP, TOU, Flat rate.	35% load reduction of enrolled participants.	NA	NA	NA	Base line adjustments in calculations negatively impacted load reduction performance. Performance of load reduction assets always less than the demand response reserve contract amount.

Sl. #	Company/ Program	Test Market	Dynamic Pricing Option	Changes in Peak Demand	Dollar savings	Consumer Savings	Customer Communication/ Education	Other Issues/ Observations
5	ONCOR, Inc./Smart Texas Program, Dallas, Texas, 2009-12, USD Budget - 7.3 million.	3.4 million customers from all sectors, with smart meter, IHD.	TOU	NA	NA	NA	Web site devoted to informing consumers about saving energy (includes links to compliance reports); Advertisements; Door hangers; Hosted 8 Mobile Experience Center events.	Monthly surcharge for smart meter installation (USD 2.19/month); Benefit not fully realized since TOU pricing is not wide spread; DLR pilot using smart meters will measure congestion relief and extrapolate potential economic effects in the overall Oncor service area.
6	SDG&E Smart Meters, San Diego, California, 2009-11, USD Budget - 572 million.	1.4 million customers from all sectors with smart meter, smart thermostat.	CPP	NA	NA	NA	Web site devoted to informing consumers about saving energy; SDG&E has met with more than 25 stakeholder groups in academia, business, customer advocacy, and government since late 2010 in order to understand their smart grid preferences.	Utility's focus has been on security/integrity first; Variable-pricing programs employing smart meters have not been utilized, except for business customers; used 9 customer/smart meter metrics.
7	Anaheim Critical Peak Pricing Experiment, Anaheim, California, 2005, Program budget - N/A.	71 Residential customers.	CPP (Rebates are calculated on usage reductions noon - 6 p.m)	12% (reduction is larger on higher temperature CPP	NA	NA	NA	APU paid an average of 7 times more/ KWh for the load reductions achieved during CPP days than the rebate amount.
8	Idaho Power Residential Pilot Program, Idaho, 2005-2006, Program budget - N/A.	85 Residential customers.	Time of Day (TOD)	50% reduction.	0	0	High-price day notification via phone or email when the price of electricity was over USD 0.10 per kWh.	TOD rates with very low peak/off peak rate ratio will have no effect on shifting usage A higher peak/off-peak rates ratio is needed to induce customers to shift usage from peak to off-peak periods.

Sl. #	Company/ Program	Test Market	Dynamic Pricing Option	Changes in Peak Demand	Dollar savings	Consumer Savings	Customer Communication/ Education	Other Issues/ Observations
9	Community Energy Cooperative's Energy-Smart Pricing Plan, Illinois, 2003-2005, Program budget - N/A.	1,500 Residential customers.	RTP	3-4% of summer electricity usage.			Energy usage education provided to participants.	Day-ahead (DA) announcement of the hourly electricity prices for the next day and a price limit hedge of USD 0.50 per kWh for participants, meaning that the maximum hourly price set at USD 0.50 per kWh for the participants in the program.
10	Bonneville Power Administration (BPA)/Olympic Peninsula Project, Washington, 2006-07, Program budget - N/A.	112 Residential and Industrial, Commercial.	Fixed; TOU/CPP; RTP.	29.7% for 500-kW (fall), 19% for 750-kW (winter); No measurement provided for 1500-kW (summer) period, which did not need peak management.	Mean savings: TOU/CPP —30%; RTP – 27%; Fixed – 2%.	10% from previous year's bill.	NA	Much of the decline in peak demand can be attributed to automated responses from the smart appliances installed. Default settings, which would shut off appliance usage at critical high price times, were rarely overridden; Users were given an average of USD 150 (which could be more or less depending on energy savings) for participation.
11	PSEG/my Power Sense and myPower Connection, New Jersey, 2006-2007, Program budget - N/A.	379 Residential customers (my Power Sense); 319 Residential customers (my Power Connection).	TOU/CPP (includes off peak, peak, base rates - summer months).	my Power Sense - 17% ; my Power Connection - 47%; for combined impact of TOU and CPP.	NA	NA	Customers were educated on TOU tariff and notified on CPP day ahead.	my Power Connection customers had enabling technology.
12	Ontario Energy Board Smart Price Pilot, Canada, 2006-2007, Program budget - N/A.	373 Residential customers.	Regulated Price Plan (RPP) TOU, RPP TOU with CPP (TOU CPP), RPP TOU with CPR (TOU CPR).	Load shift - 6% (TOU only); 4.7% (TOU CPP); 7.4% (TOU CPR) for full pilot duration.	NA	NA	Monitoring device allows customers to view an estimate of the CO_2 emissions produced as a result of their electricity consumption.	Large average peak reductions under all three of the rate designs, with the TOU CPP impact being the highest, followed by the TOU CPR, and then the pure TOU; Results were achieved without any accompanying incentives or price schemes.

Sl. #	Company/ Program	Test Market	Dynamic Pricing Option	Changes in Peak Demand	Dollar savings	Consumer Savings	Customer Communication/ Education	Other Issues/ Observations
13	Energy Australia/TOU Tariff Program, New South Wales, Australia, 2005, Program budget - N/A.	50,000 (Residential/ customers – 50/50).	TOU/DPP	~20%	NA	~20%	Price signals through Short Message Service (SMS), telephone, email, or the display unit.	Required in house display (IHD) and on line access to data; Large estimation error from heterogeneity of business customers; Day ahead notification was effective, impacts of load shift was seasonal.
14	AmerenUE Critical Peak Pricing Pilot, Missouri, 2004-2005, Program budget - N/A.	89 Residential customers.	TOU-CPP, TOU-CPP-Tech (enabling technology).	TOU-CPP: 12%; TOU-CPP-Tech: 35%.	NA	NA	NA	Enabling technology was a key component for the success of the program for TOU-CPP-Tech group.
15	Impact Evaluation of the California Statewide Pricing Pilot (SPP), California, 2003-2004, Program budget - N/A.	Commercial & Industrial (C&I).	TOU, CPP-F (Fixed period), CPP-V (variable length of peak w/ enabling tech).	CPP-F: 13.1%; CPP-V:~20%.	NA	NA	NA	Comparing the CPP-F and the CPP-V results suggests that usage impacts are significantly larger with an enabling technology than without it.
16	ERDF/Pilot Linky, Touraine and Lyon, France, 2009-2011, budget - ~€4.3 billion Euro.	100,000 (Touraine) and 200,000 (Lyons) Residential customers.	TOU, CPP, CPR	CPP – 16%, CPR – 12%, TOU – 5%.		NA	In-Home Displays (IHD), websites and informative billing.	55% Reduction – Non technical losses; Installed low loss transformers; installed Linky meters for customers to be able to monitor energy consumption.
17	Load Management Pilot Project, ESKOM, South Africa, 2009-2012, Program budget - N/A.	Residential.	TOU	1–1.2 kW (pre winter) & 2.6–3.0 kW (Winter) DR per house for 1.5kW limit.	NA	NA	Provides each customer an electricity demand display instrument (EDDI) that shows the real-time demand of various electrical appliances at work.	Enabling technology limits the amount of electricity supplied to households during high-constraint periods; When a household does not comply with the load limit that was set during the pilot, that individual house is subjected to load shed.

Conclusions

Several conclusions can be drawn from the review of the time-based dynamic pricing methods that have been implemented internationally as also the available data on pilot project dynamic pricing experiments.

There is a scarcity of smart grid dynamic pricing pilot projects outside of North America that go beyond TOU tariffs, compared to the widespread efforts at implementing AMI in smart grid projects internationally.

Successful introduction of smart meters and time-based dynamic electricity pricing requires a well-planned social marketing campaign to help raise awareness and give customers the information and support they need to become more energy efficient. It is also necessary to raise customer awareness on what changes they must make to realize the potential benefits.

At the current stage of power system commercial development in developing countries for which data is available in Asia and Africa:

1. These systems are ripe for AMI to support 100 percent metering of loads.
2. With progress in metering of loads, AMI can be supplemented by implementing relatively straight-forward and transparent TOU pricing.

Dynamic pricing can be an effective complement to wholesale market access and demand response initiatives that are already underway in India. More sophisticated dynamic pricing experiments will require the same levels, if not more, of infrastructure and customer education. The planned smart grid pilot projects in India can provide the required level of infrastructure. The benefits of such pricing programs may be larger than TOU pricing. In the long run, it may be more efficient to move directly to such a program rather than first moving to TOU pricing and then to a more sophisticated dynamic pricing program later on.

For any such experiment, a cost-benefit analysis for the experiment, and full-scale rollout should be performed and updated as better information becomes available. If the cost-benefit analysis does not show an overall benefit for full-scale implementation, it may not make sense to spend the effort on the smaller scale experiment.

Acronyms

AMI	advanced metering infrastructure
AT&C	aggregate technical and commercial loss
BU	billion unit
CPP	critical peak pricing
CPR	critical peak rebate
DP	dynamic pricing
DPP	dynamic peak pricing
DR	demand reduction
EPAct	Energy Policy Act
HP	hourly pricing
IHD	in-home display
kWh	kilowatt hour
MOP	Ministry of Power
NE	New England
PHEV	plug-in hybrid electric vehicle
PSEG	Public Service Electric and Gas Company
PTR	peak time rebate
RTP	real time pricing
SDG&E	San Diego Gas and Electric Company
TOD	time of day
TOU	time of use
VPP	variable peak pricing

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