Enabling and Motivating Consumers to Manage Their Energy Consumption

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Overview

- The Team
- Value Proposition
- System Concept
- Interface Concept
- Price Sensitivity
- Conundrums
- Future Research

The Team

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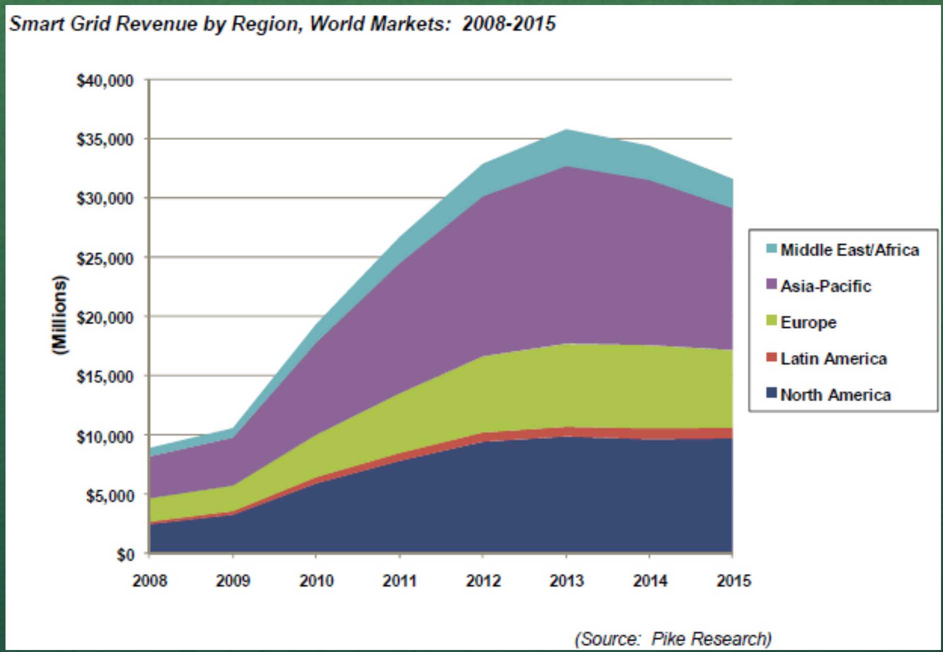
Smart Grid Progress

- The need for an improved electric grid is widely recognized
- Investment in Smart Grid infrastructure is significant and growing rapidly
- The Smart Grid space has attracted many firms producing advanced hardware and software technologies



Anticipated Smart Grid Revenue Growth

Consumer Engagement

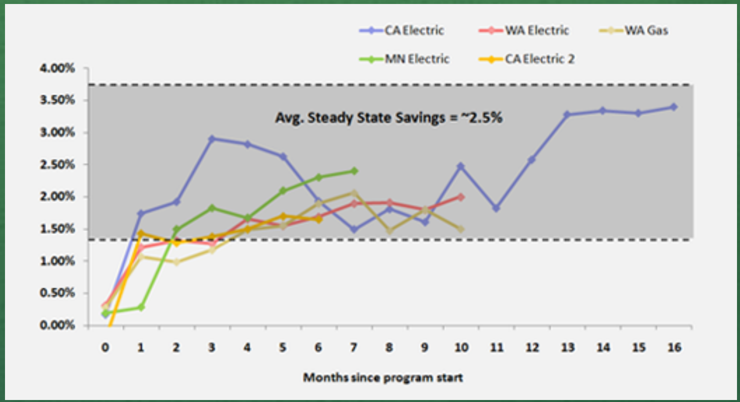
- Smart Grid technologies and standards are nearing maturity, but successful deployment requires consumer consent and participation
- Communities moving to install Smart Grid infrastructure are encountering resistance, as recently seen in California and Maryland
- Smart Grid proponents now recognize the importance of consumer education and communication, leading to efforts such as the Silicon Valley Smart Grid Task Force and the Smart Grid Consumer Collaborative

Enabling and Motivating

- There are many potential approaches to enabling and motivating consumer engagement; a successful solution must:
  - Impart knowledge of opportunities created by Smart Grid technology and likely market outcomes
  - Create financial and social incentives to engage in energy management activities
  - Provide management tools that easily and efficiently communicate consumer preferences to Smart Grid systems
- Before they will participate, consumers must be persuaded to accept the Smart Grid value proposition, outlined in the slides that follow

Primary Consumer Benefits

- The most salient benefit of Smart Grid systems is the potential to reduce consumption, leading to lower energy expenditures
- Smart Grid technologies provide consumption information and management tools that make conservation easier
- Pilot programs have demonstrated reduced consumption from 2-20%, depending on technology

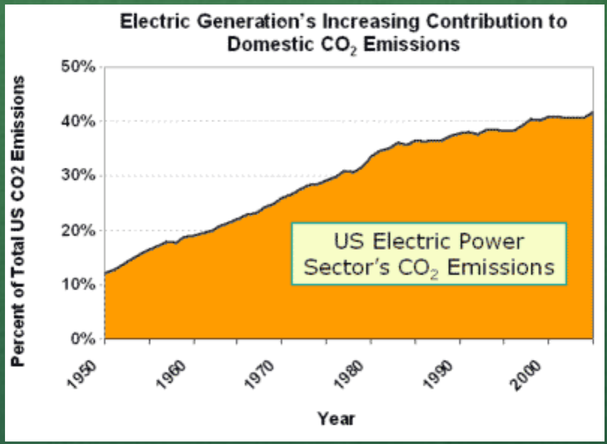


OPOWER: Savings From Paper Reports Alone

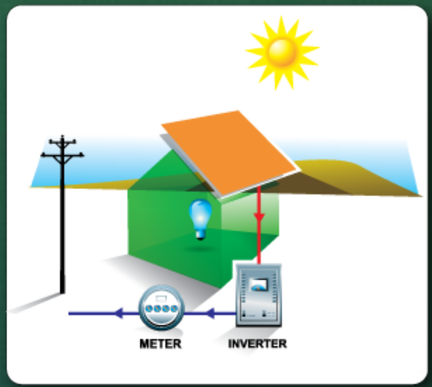
OpenPeak Energy Management Interface

Other Consumer Benefits

- In addition to financial savings and ease of consumption management, Smart Grid systems deliver:
  - Social status and personal satisfaction associated with conservation
  - Reduced environmental impact from energy generation
  - Better electric service reliability and performance
  - Potential profit from distributed generation and supply



Energy Generation Carbon Emissions



Selling Power to the Grid

Consumer Cost Comparison

- There are costs associated with Smart Grid systems, but these are tempered by the costs of continuing under the traditional system as energy demand increases:

COST TYPE	SMART GRID COST	STATUS QUO COST
Financial Burden	Consumer share of Smart Grid installation expenses	Consumer share of capacity expansion expenses, higher rates
Behavioral Accommodation	Adapting to new rate structures and learning to use management tools	Adapting to higher rates with little management flexibility
Personal Freedom	Concerns over privacy and data ownership	Lack of control over energy expenses and consumption
Future Market Uncertainty	Unknown future market conditions buffered by management tools	Unknown future market conditions with few alternatives

- The relative magnitude of costs is unknown, but consumers will likely fare better under a Smart Grid system, and will certainly have more flexibility to respond to evolving conditions

Utility Benefits and Costs

- It is important for consumers to be aware of the value tradeoffs faced by utilities as Smart Grid systems are deployed:

TRADEOFF TYPE	UTILITY SMART GRID BENEFIT	UTILITY SMART GRID COST
Capital Requirements	Reduced need for future capacity expansion	Utility share of Smart Grid infrastructure investment
Operating Revenues	Gains from improved grid control, monitoring, maintenance, and repair	Reduced income due to consumer energy conservation
Business Model	Creation of new advanced energy services market	Disruption of established rate structures
Future Market Uncertainty	Improved alignment between energy prices and generation cost	Possible negative changes in customer relationships as market evolves

- Utilities stand to gain from the introduction of Smart Grid systems, but these gains are not without costs, which must be balanced for utilities to participate

Consumer Incentives

- To ensure that consumers engage and receive benefits, Smart Grid systems should provide compatible incentives:

CONSUMER INCENTIVE	REQUIREMENT FOR REALIZATION
Engagement yields financial benefit	Utilities should design rate structures that adequately reward consumers for conservation
Potential benefits are known	Smart Grid proponents should initiate consumer education efforts and actively pursue communication of benefits
Desired conservation strategy is easy to implement	Consumption management tools should be flexible and intuitive
Social and competitive pressures to conserve are present	Management tools should make conservation visible to others where possible, and should provide rewards meaningful in other contexts
Regulatory environment is trusted	Data management and regulation should be transparent and consistently applied

- Individuals are more likely to participate when these incentives are perceived to apply

Utility Incentives

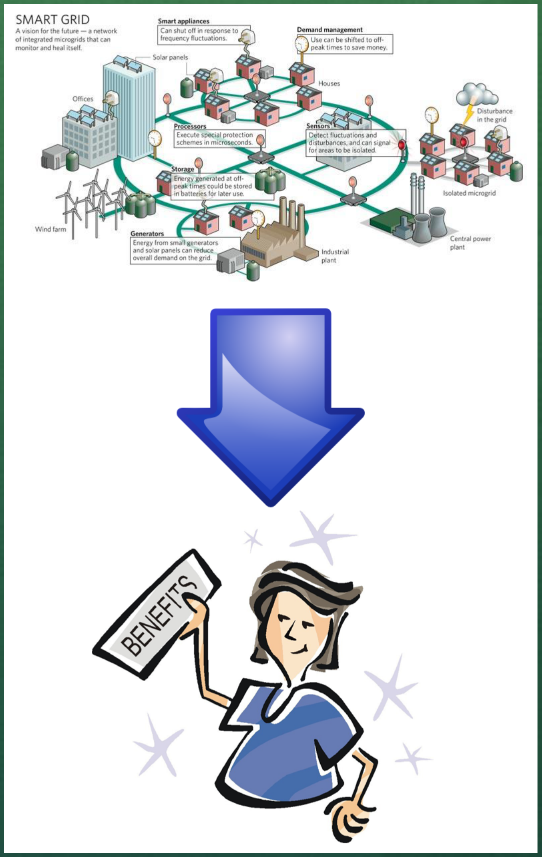
- As with utility benefits and costs, it is instructive for consumers to be aware of utility incentives for Smart Grid participation:

UTILITY INCENTIVE	REQUIREMENT FOR REALIZATION
Peak and long-term demand is reduced	Smart Grid implementation and rate structures should allow utilities to reduce capacity expansion requirements
Grid operation parameters are improved	Implementation should provide utilities with improvements in grid control, monitoring, maintenance, repair, and security
New market mechanisms maintain profitability	The combined effects of Smart Grid should allow utilities to continue operating profitably

- Utilities should not be expected to undertake Smart Grid investments or implement new rate structures without the presence of these incentives

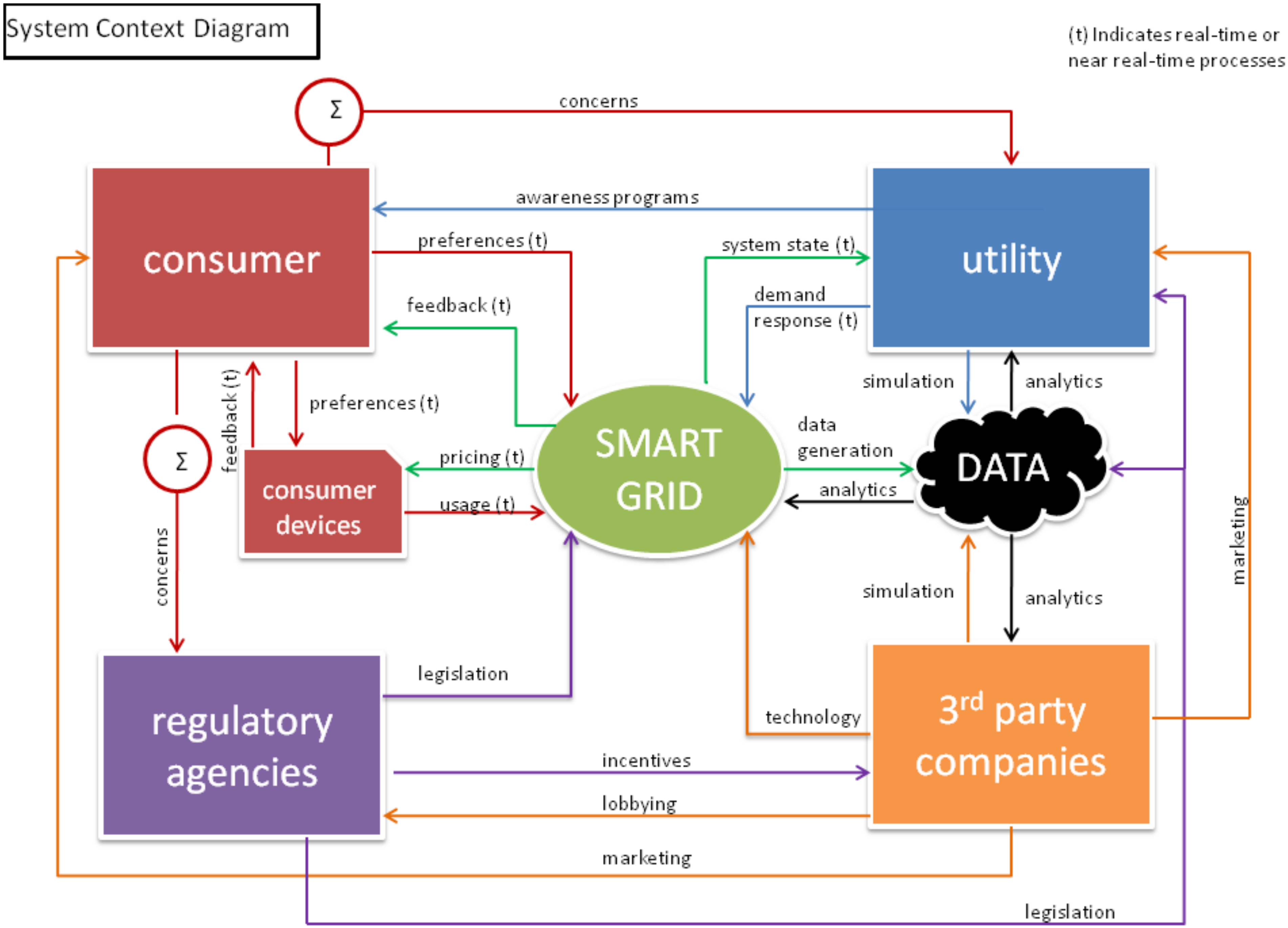
Integrated Approach

- When both consumers and utilities have incentives to participate, a Smart Grid can deliver mutual benefits
- The extent and distribution of these benefits depends on implementation details
- To maximize consumer engagement, an integrated approach must provide appropriate management tools and pricing schemes

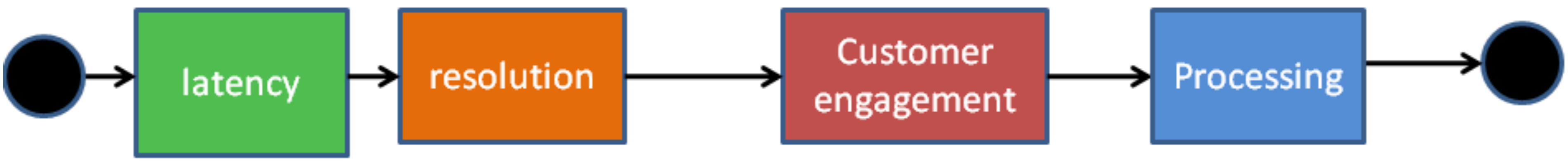


System Concept

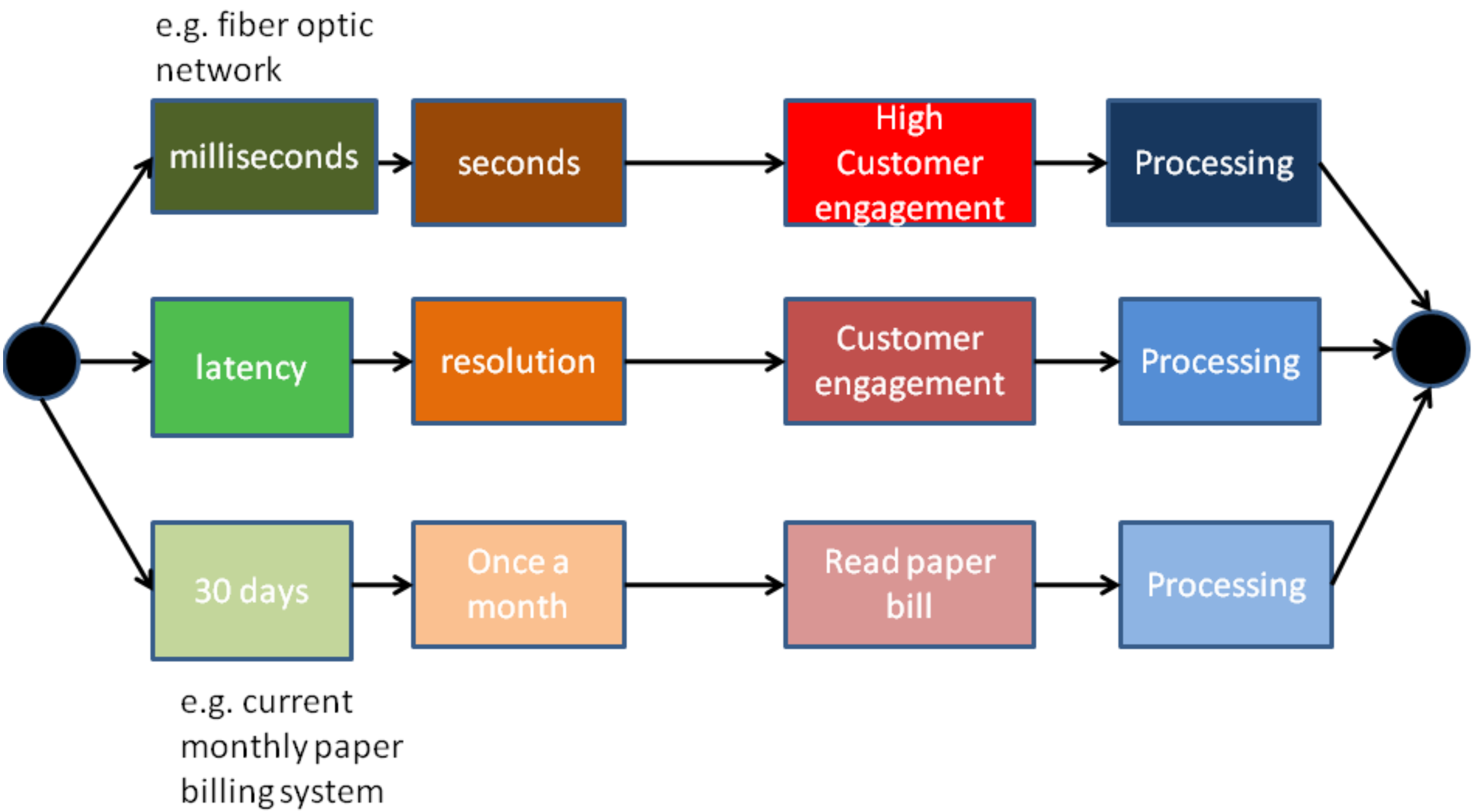
- System Context Diagram
- Customer Engagement Dependencies
- Smart Grid System Diagram
- State of the Smart Grid


System Context Diagram
(t) Indicates real-time or near real-time processes
Σ
concerns
consumer
awareness programs
preferences (t)
system state (t)
utility
demand
response (t)
feedback (t)
feedback (t)
preferences (t)
simulation
analytics
Σ
SMART GRID
data
generation
DATA
pricing (t)
consumer devices
usage (t)
analytics
concerns
simulation
analytics
marketing
regulatory agencies
legislation
technology
3rd party companies
incentives
lobbying
marketing
legislation

Utility sends signal	Relevance of signal to consumer depends on latency of network infrastructure	Resolution is dependent on sampling apparatus i.e. Smart Meters	Customer Engagement is dependent on latency (relevance of signal), resolution, HAN requirements and interface devices , ancillary functionality as well as innate desire for engagement.	Processing time determines 'age' of data (relevance to utility)	Utility receives signal and the cycle continues.

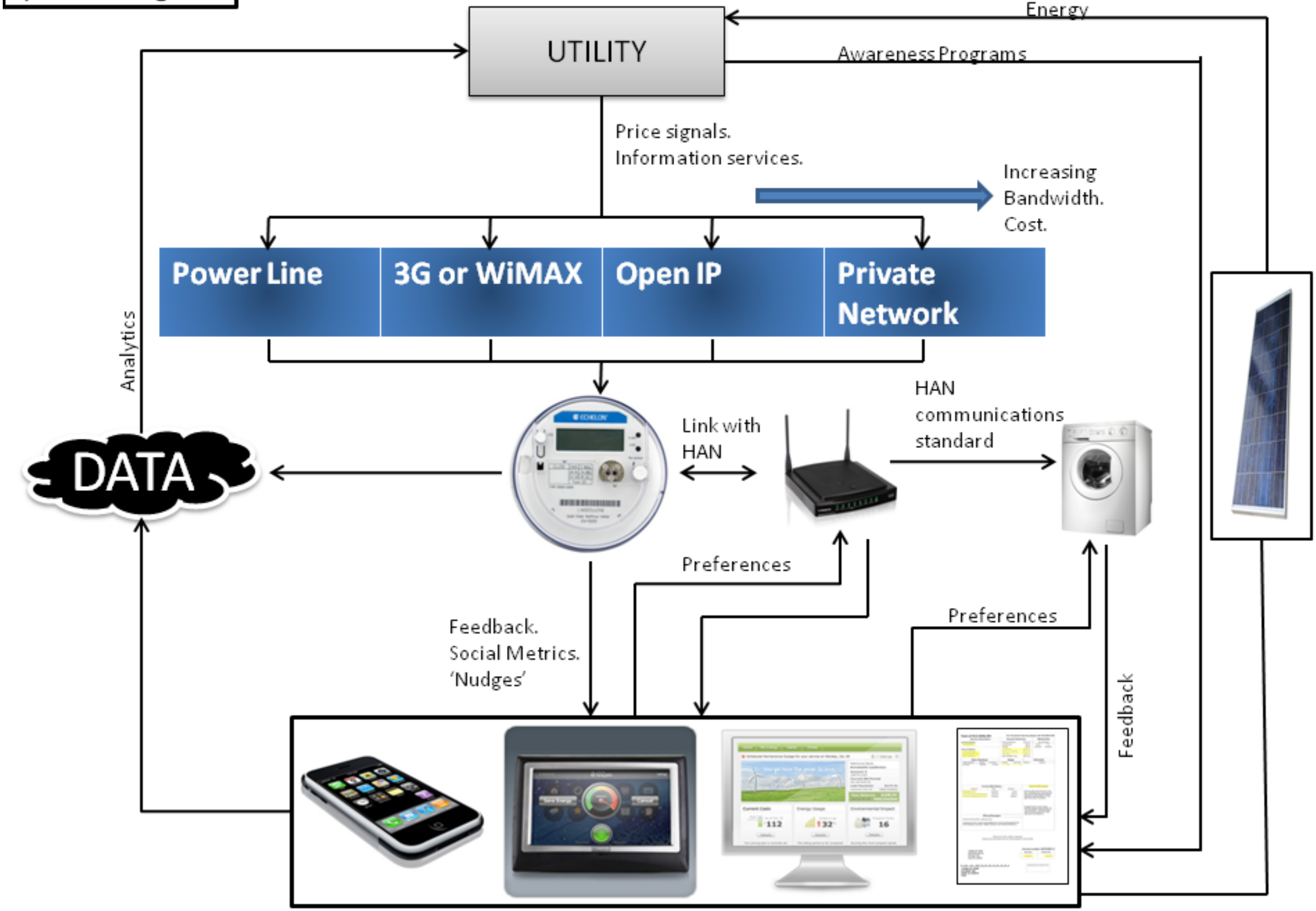


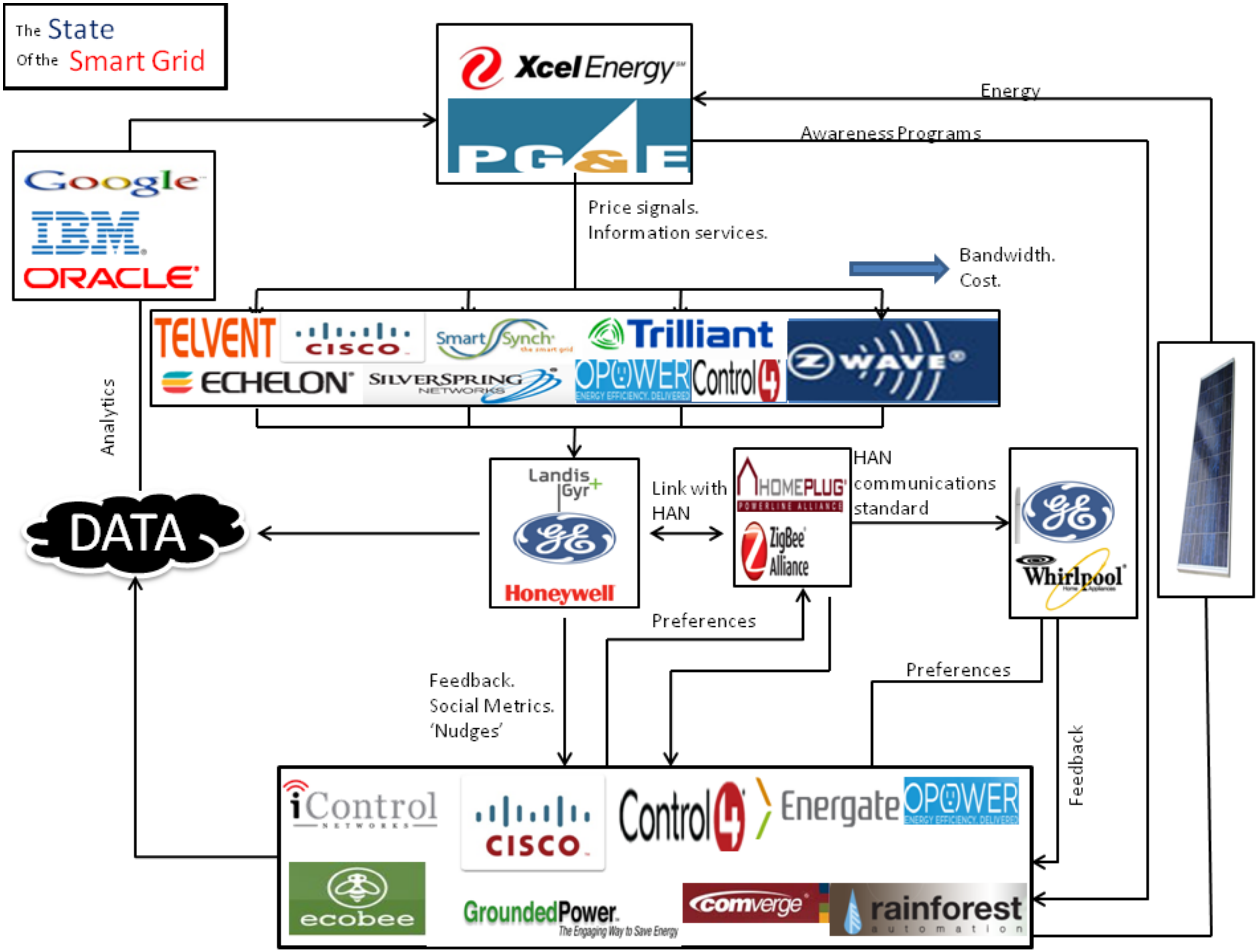
The appropriate level of customer engagement is dependent on upstream investment that determines the latency and resolution of the network infrastructure



e.g. fiber optic network
milliseconds
seconds
High Customer engagement
Processing
latency
resolution
Customer engagement
Processing
30 days
Once a month
Read paper bill
Processing
e.g. current monthly paper billing system

Smart Grid System Diagram




The State
Of the Smart Grid
Energy
Awareness Programs
Price signals.
Information services.
Bandwidth.
Cost.
Analytics
DATA
Link with
HAN
HAN
communications
standard
Preferences
Preferences
Feedback.
Social Metrics.
'Nudges'
Feedback

Interface Concept

- Types of Interfaces
- Current Interface
- Interface Requirements
- User Interface
- Feedback

Types of Interface

Mobile

- Interact with meters and provide information on how customers use their energy
- Helps to control home appliances anyplace anytime when mobile device is connected to communication network. (3G, Wi-Fi, and etc)

In-home

- Interact with meters to provide information on how customers use their energy

Web

- Develop solutions to encourage energy savings through social forces and demographic observations
- Interact with meters and provide information on how customers use their energy

Paper

- Provide information from utility providers on how customers used their energy weekly or monthly

SMART GRID

Types of Interface

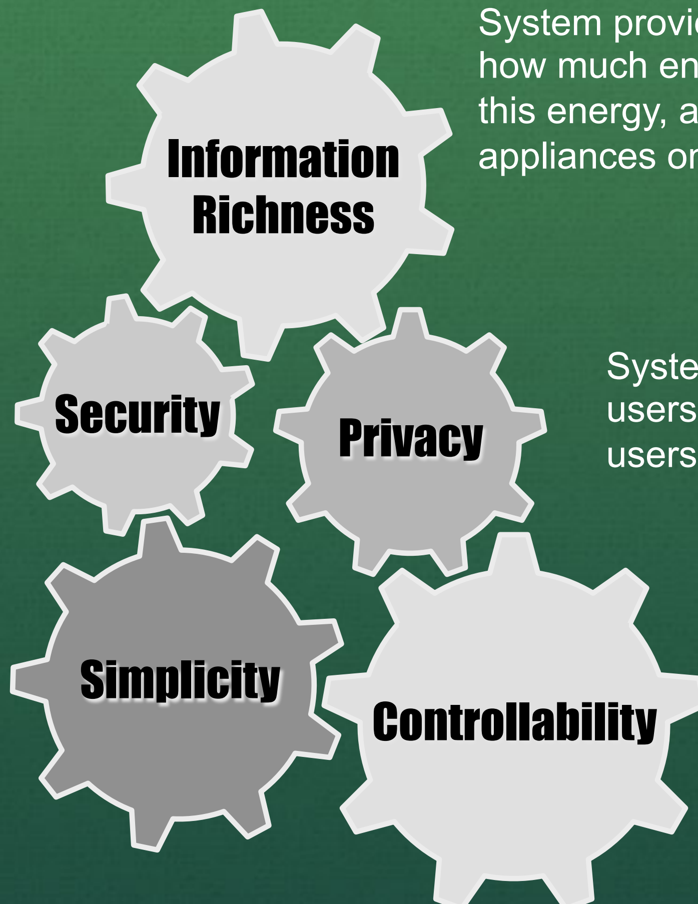
- **Mobile**: Control4, iControl Networks, Tendril (The Power is Yours)
- **In-home**: ecobee, HAI smartgrid solutions, GroundedPower
- **Web**: Google powermeter, OPOWER (Energy Efficiency. Delivered), Microsoft hohm beta
- **Paper**: Georgia Power (A Southern Company), Southern Company

SMART GRID

Current Interface

- Means of providing electricity usage information
  - Mobile devices
  - In-home devices
  - Web solutions
  - Paper bills
- Home automation systems already enable users to set rules and control appliances automatically
- Advanced metering infrastructure can measure customers' energy usage and enable utilities to provide customers recommendations for managing energy consumption
- Users will be able to compare their usage with neighbors which, perhaps via social technology, may lead to sharing of energy conservation practices

Interface Requirements



System provides real time information on how much energy is being used, the cost of this energy, and the implications of switching appliances on or off.

System is secured against many different interruptions that can occur during communication or control of household appliances

System requires personal data of users and outgoing information from users is protected by the system.

Simple and comprehensible interfaces make users feel more comfortable using the system.

Interface elements allow users to communicate their preferences efficiently and accurately.

Interface Technologies

- Real-time information, e.g., of consumers' usage
- Advanced graphical displays, including animation.
- Voice recognition, e.g., of consumers' preferences
- Pattern recognition, e.g., of energy usage
- Predictive models, e.g., of costs of usage patterns
- Geographical information systems, e.g., weather forecasts
- Social technology, e.g., for sharing practices

Feedback

Type	Description	Pros	Cons
Direct Feedback PowerCost Monitor Kill-A-Watt, TED	* Real-time feedback on energy use and costs * Devices interface with utility electric meter	Users able to receive real-time feedback from their meter via a mobile monitor	Low willingness to pay relative to device cost
Indirect Feedback Positive Energy, BC Hydro's Power Smart	* Processed feedback via mailed reports or online interface * Opportunity to incorporate comparative data/feedback	Provide comparative feedback, showing a customer's performance relative to their neighbors; power of social norms	Utilities must be careful in targeting and crafting their messaging in order to minimize potential negative effects
Dynamic Feedback Smart Meter	* Protocols that allow for different rates to be charged based on time of use * Enabled by advanced metering infrastructure and two-way communication between the utility and customer	Utilities are better able to match prices to energy production and/or purchase costs	Costly infrastructure investment requiring substantial resources to install meters and develop integrated IT platforms

Price Sensitivity

- Variable Pricing Strategies
- Consumer Price Elasticity
- Demand Response Models
- Recent Studies

Variable Pricing Strategies

- TOU (Time of Use) Only
- CPP (Critical Peak Pricing), CPP-F rate, CPP-V rate
- RTP (Real-Time Pricing or Dynamic Pricing)
- RCTOU (Time of Use + Critical Peak)
- DPP (Dynamic Peak Pricing)
- Peak Load Reduction Credits
- PTR (Peak Time Rebate)
- Regulated Price Plan
  - TOU (RPP TOU)
  - RPP TOU rates with a CPP component (TOU CPP)
  - RPP TOU rates with a Critical Peak Rebate(TOU CPR)
- Increasing-Block Pricing

Consumer Price Elasticity

- Real-Time Pricing

Table 12- Elasticity Estimates from ESPP

Time of the Day	Elasticity Estimate
Daytime (8 a.m. to 4 p.m.)	-0.02
Late afternoon/evening hours (4 p.m. to midnight)	-0.03
Daytime+ High-Price Notification	-0.02
Late Daytime/Evening+High-Price Notification	-0.05

- Time-of-Use Pricing

Type	Season	Peak Own Price Elasticity	Peak to Shoulder Cross Price Elasticity	Peak to Off-Peak Cross Price Elasticity
Residential	Summer 2006 Winter 2006	-0.30 to -0.38 -0.47	-0.07 -0.12	-0.04 -
Business (less than 40 MWh)	Summer 2006 Winter 2006	-0.16 to -0.18 (ns) -0.2 (ns)	-0.03 -	- -
Business (40 MWh to 160 MWh)	Summer 2006 Winter 2006	-0.03 to -0.13 (ns) -0.02 to -0.09 (ns)	- -	- -

Demand Response Models

CES (Constant Elasticity of Substitution) Demand System

$$\ln\left(\frac{Q_p}{Q_{op}}\right) = \alpha + \sigma \ln\left(\frac{P_p}{P_{op}}\right) + \delta(CDH_p - CDH_{op}) + \sum_{i=1}^{N} \theta_i D_i + \varepsilon$$

$$\ln(Q_d) = \alpha + \eta_d \ln(P_d) + \delta(CDH_d) + \sum_{i=1}^{N} \theta_i D_i + \varepsilon$$

Parameters	Definition
Q_p	average energy use per hour in the peak period for the avg. day
Q_{op}	average energy use per hour in the off-peak period for the avg. day
Q_d	average daily energy use per hour
σ	elasticity of substitution between peak and off-peak energy use
P_p	average price during the peak pricing period
P_{op}	average price during the off-peak pricing period
P_d	average daily price (e.g., a weighted average of the peak & off-peak)
δ	measure of weather sensitivity
CDH_p	cooling degree hours per hour during the peak pricing period
CDH_{op}	cooling degree hours per hour during the off-peak pricing period
CDH_d	cooling degree hours per hour during the day
θ_i	fixed effect coefficient for customer i
D_i	binary variable equal to 1 for the ith customer, 0 otherwise
η_d	price elasticity of demand for daily energy

Demand Response Models

VES (Variable Elasticity of Substitution & Other Customer Characteristics)

$$\ln\left(\frac{Q_p}{Q_{op}}\right) = \alpha + \sum_{i=1}^{N}\theta_i D_i + \sigma \ln\left(\frac{P_p}{P_{op}}\right) + \delta(CDH_p - CDH_{op}) + \lambda(CDH_p - CDH_{op})\ln\left(\frac{P_p}{P_{op}}\right) + \phi(CAC)\ln\left(\frac{P_p}{P_{op}}\right) + \varepsilon$$

Other customer characteristics, such as income, household size, and number of people in the household, may also influence the elasticities in the CES model. They can be included in the specification by introducing additional price interaction terms in a similar manner to the CAC and weather terms shown

$$\ln(Q_D) = \alpha + \sum_{i=1}^{N}\theta_i D_i + \eta\ln(P_D) + \rho(CDH_D) + \chi(CDH_D)\ln(P_D) + \xi(CAC)\ln(P_D) + \varepsilon$$

$$\text{ES} = \sigma + \lambda(CDH_p - CDH_{op}) + \phi(CAC)$$

The composite daily price elasticity in this model is a function of three terms : Daily= $\eta+\chi(CDH\ D)+\xi(CAC)$

Parameters	Definition
χ	the change in daily price elasticity due to weather sensitivity
ξ	the change in daily price elasticity due to
	the presence of central air conditioning
CAC	if a household owns a central air conditioner, 0 otherwise

Recent Studies

- Fifteen recent empirical studies of the residential dynamic pricing programs found that usage response depends on
  - Magnitude of the price increase
  - Presence of central air conditioning
  - Availability of enabling technologies
    - For example, two-way programmable communicating thermostats that allow multiple remote end-use control
- Measured usage responses
  - TOU induced a drop in peak demand from 3 to 6 percent
  - CPP induced a drop in peak demand between 13 to 20 percent
  - CPP plus enabling technologies induced a drop of 27 to 44 percent
- Demand response programs that blend together customer education initiatives, enabling technology investments, and carefully designed time-varying rates can achieve substantial demand impact

Conundrums

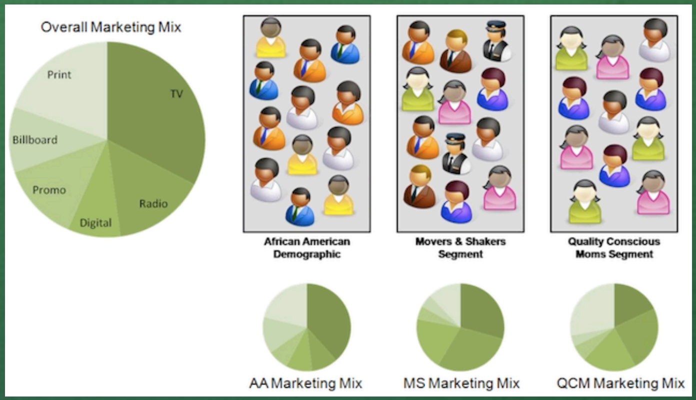
Conundrum	Issue
Cost & Profit	**Who Pays**: Utility Companies, 3rd Party companies, Government, Customers: who pays for required Smart Grid investments?
Utility Companies Engagement	**Why Change**: Inertia to change in the utility industry vs. the need for consistent regulation and innovation in energy offerings. Distributed generation forces utilities to decentralize yet extend transmission infrastructure to energy source.
Market & 3rd party Companies	**Who Wins**: Variety of Smart Grid related devices, software, technologies and companies, dynamic market vs. Interoperability and standardization. Competing and overlapping standard protocols must be standardized. Who will survive? Why?
Customers Engagement	**Why Play**: Different types of consumers, e.g., price-sensitive, energy-conservative, how to get them all involved? Consumers reluctant to pay upfront costs for uncertain benefit while efficiency and conservation are anti-business model for utilities.
Security	**When Safe**: Grid optimization allows more points of entry for breaches of security to grid. Smart Grid devices and communication infrastructure bear the risk of being attacked vs. Infrastructure complexity and investment.
Privacy	**Who Knows**: Dynamic pricing and optimal energy saving strategies vs. Energy usage data can invade privacy creating a backlash against Smart Grid implementation
Storage	**Where Stored**: Peak demand reduce, renewable resource vs. energy storage feasibility, stability and cost

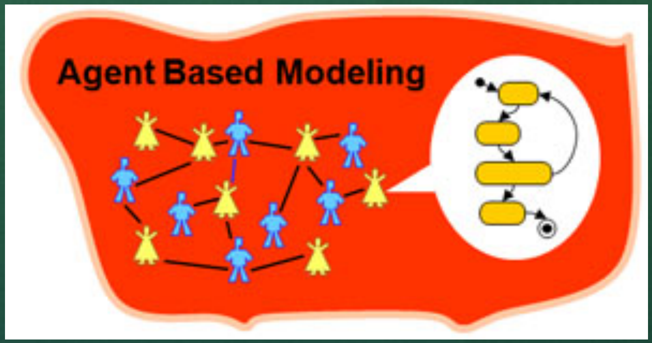
Future Research

- Market Simulation
- Consumer Modeling
- Token Economies or Games

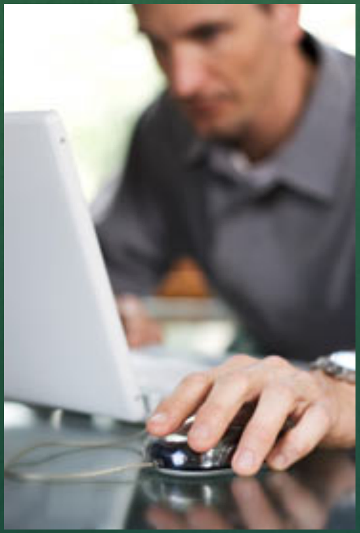
Market Simulation

- Smart Grid firms can benefit from simulations that assume a variety of consumer agents and predict the outcome of pricing schemes and market conditions
- Data generated by pilot programs allow validation and refinement of simulation results
- Given preferences generated by the tool on the next slide, accuracy of agent models can be improved





Consumer Modeling



- Need for tools that interact with consumers to build personalized preference models
- Preference models can drive automated conservation management algorithms
- Potential use in simulations that inform users of likely individual benefits from energy consumption management
- Could help persuade consumers to accept Smart Grid if available free on the web

Token Economies or Games

- Use of token economies or games to motivate additional engagement
- Pseudo currency conservation rewards redeemable in a virtual marketplace
- Game advancement and bonuses tied to conservation performance
- Visibility and competition through real-time integration with social networks

Summary

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