THE WHARTON SCHOOL, UNIVERSITY OF PENNSYLVANIA
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The Smart Grid: A World of Emerging Technologies

Analysis of Home Area Networks

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Introduction

In this paper, we will analyze the emerging Smart Grid space, and focus on the Home Area Network (HAN) field. The growing HAN market is drawing numerous technology providers, telecommunication companies and appliance manufacturers. Most of the current publications, blogs and experts that analyze the future of the Smart Grid, assume that the development of HAN will be a mandatory step in the process of creating a Smart Grid. However, we would like to take a closer critical look at the viability and development of the HAN field, and it's impact on the companies who are contemplating entering it.

We will analyze the key strategic issues in entering the HAN industry for technology software providers. Microsoft and Google were chosen as the leading software providers that have a significant presence in the consumer market. We will utilize four frameworks, Scenario Planning, Technology Speciation, Assessing Future Markets for New Technologies and Commercializing Emerging Technologies. The major strategic decision both Google and Microsoft need to make is whether to continue developing solutions for the HAN space at the consumer level. Both have entered the market and failed. We will try to analyze why they had failed and come up with recommended strategic decisions.

It is important to note that we gathered the information for this analysis through the official Microsoft and Google websites, Smart Grid blogs and unofficial conversations with company employees and industry experts. We intend the following as a case study for these companies and similar companies contemplating entrance into the HAN field, however do not intend to imply accurate knowledge of these companies' internal strategic decisions.

- **The point of view we will take is that of a technology provider** or company, either already in the Smart Grid space or contemplating to enter it.
- **The time-frame for analysis will be five to ten years**, which we believe will be most relevant for companies planning more detailed or tactical strategies. Due to the fast pace of Smart Grid development, we believe this time frame will capture the most critical phase of the emerging technology's molding, commoditization and development.

- **The geographical scope of our work will focus on the United States**, yet within a global context.

We will conclude by taking a stance on our view of this market and our recommendation for companies in the HAN industry.

Smart Grid – An Emerging Technology

What is Smart Grid?

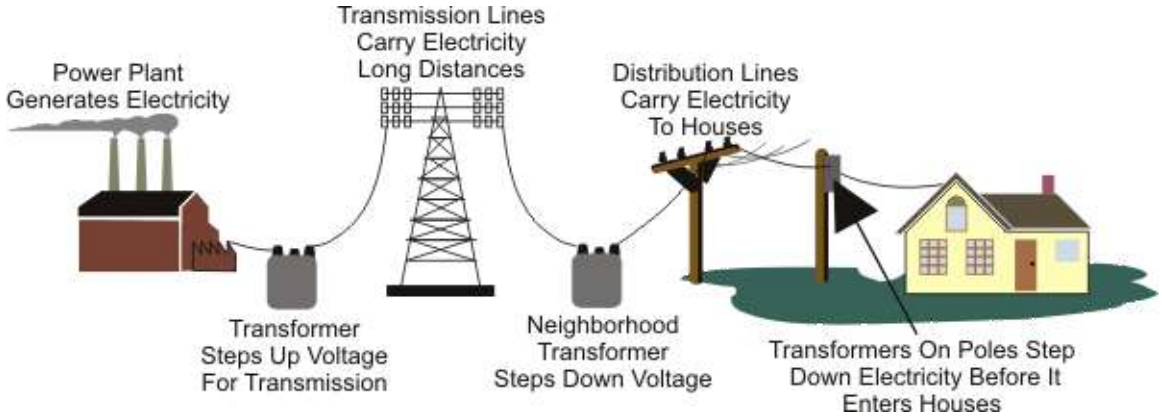
"If Alexander Graham Bell were somehow transported to the 21st century, he would not begin to recognize the components of modern telephony –cell phones, texting…–while Thomas Edison, one of the grid's key early architects, would be totally familiar with the grid." [1]

The current electric grid structure and components have not seen any major changes since the electric grid's inception more than 100 years ago. The term "Smart Grid" is a rather generic term, currently used as a reference to the general upgrade and modernization of the grid. "Smart Grid" is not one specific technology or method, but rather encompasses many new technologies and applications that interact to create a more secure, reliable and cost effective power grid.

Smart Grid technologies can be divided into verticals that align with the electric grid's value chain. The electric grid is traditionally divided into three stages: generation, transmission and distribution (see Figure 1). Generation is the stage that the electricity is created, for example, a power plant. Transmission is the stage that transfers the electricity across great distances from the generation location to an area of demand, and is comprised of high-voltage cables, step-up sub-stations and step-down sub-stations. The distribution stage includes transferring electricity from a sub-station to the end consumer. The electric grid has an inter-connected mesh structure whereas major populated areas and generation plants are interconnected via more than one path, creating necessary redundancies.

[1] US Department of Energy, The Smart Grid: An Introduction

Figure 1 – Electric Grid Layout



Source: www.goldenutilities.com

The Smart Grid upgrade successfully addresses three main weaknesses of the current grid structure:

1. Limited flow control and monitoring: The current grid does not have a granular-level electricity directing, switching or monitoring capability. Monitoring of voltage and current levels is done mostly at the generation stage, to some extent over the transmission stage, and almost not at all in the distribution stage. Thus, when a power-outage occurs, the utility has very little information regarding the nature and location of the outage, and usually does not have the capabilities to remotely repair it.

2. Centralized generation: The current grid structure cannot accommodate distributed generation, i.e. "uploading" electricity to the grid at end- or mid-points. Some of the end-users on the grid, such as factories or residents, are expanding their ability to generate electricity, mostly using renewable energy. Though these users may generate more electricity than they consume, there is no infrastructure in place allowing them to become a provider of electricity, effectively resulting in an unnecessary waste of resources.

3. Low utilization: The current grid induces waste of energy resources as a result of three main issues: (1) Many grid components are not efficient in creating and transferring electricity, for example, about 7% of the electricity generated is lost due to resistance in the transmission stage. (2) There are currently no scalable energy

storage solutions at wide use throughout the grid. Hence, the intermittent nature of renewable generation (i.e. windfarms) results in wasted energy when energy is generated at a rate higher than it is consumed. (3) As mentioned above in "Centralized generation", redundant energy generated at the consumer level goes to waste since there is no infrastructure to accommodate it.

The Smart Grid conceptually consists of three main layers. First, **the infrastructure layer** includes the physical enhancements and changes that need to be installed onto the current grid to enable Smart Grid capabilities. Second, **the communications layer** includes the establishment and implementation of communication protocols and hardware that will provide the capability to monitor and control the flow and usage of electricity throughout the grid. Finally, **the applications layer** refers to the applications that can be installed once the Smart Grid infrastructure and communications layer are in place. Some examples of applications are Demand Response programs and self-healing algorithms. These allow for shifting of load during peak hours and self-maintenance of the electric grid, which provides better reliability of power.

Advanced Metering Infrastructure (AMI)

Today, more than ten states in the US are already in the process of establishing the Advanced Metering Infrastructure (AMI). The AMI is the first major step in turning the current electric grid into a Smart Grid, and consists of the platform that will enable the communication and control between the utility and the electric grid's components and stages. One of the visible components of AMI are Smart Meters that are installed on the end-consumer's premises. The Smart Meter will replace the traditional analogue meter, and further to its capability to monitor the flow of electricity, it has several advanced capabilities. Most of the Smart Meters currently installed provide the utility with remote electricity monitoring and control capabilities, enabling the electricity provider to turn off supply to an end consumer over the communications network.

Home Area Network (HAN)

According to emeter.com, an industry information aggregator, "virtually all smart meters being installed in the US come with a second built-in radio — the Home Area Network interface — that can send information to one or more devices in the home."

The Home Area Network (HAN) will further enhance the Smart Grid capabilities into the home domain, and enable users to monitor and control electricity usage of appliances such as HVAC, refrigerators and washing machines. The HAN uses a local wireless communication network to provide the user with an interface to monitor and control appliances, and thus achieve optimal control of energy usage and efficiency.

HAN can refer to varying levels of monitoring and control. Simple solutions include monitoring general residence electricity usage via the smart meter and displaying the aggregate information on a display. Advanced solutions include control of appliances such as setting the defrosting cycle in the refrigerator, adjusting HVAC thermostats and running the dryer.

Analyzing HAN Using Scenario Planning and Technology Speciation

Framework Description – Scenario Planning

Scenario planning is a framework that can help predict the future of an emerging market or technology. The question to be answered is, where will this technology be, in terms of development and adoption, in 5-10 years. This framework takes into account the uncertainties and trends around a given technology and tries to predict the outcome. The steps for using this framework are:

1. Identify the forces – find the fundamental drivers that will impact the future of the industry and rate them. For each force, identify if it is predictable ("a trend") or unpredictable ("uncertainty").
2. Build the scenarios – select the two central uncertainties and build a 2x2 matrix with the possible extreme outcomes of each. For each of the four outcomes, create an understanding of how the industry would look should the scenario materialize as described.

Each scenario is then analyzed in detail, including its impact on market players and technology speciation. It would also be helpful to rate the probability of each of the four scenarios – though a specific scenario will have a miniscule probability, it would be helpful to rate the relative weights among the four scenarios that we find, such that weight would appropriately reflect likelihood and impact. The probabilities for these scenarios is based on interviews with market experts and players in the HAN field, yet are only given as a general estimate and do not presume to be accurate.

Framework Description – Technology Speciation

"Sometimes the overnight success in emerging technologies has been in development for decades. The revolution of emerging technologies is often not a result of a major scientific breakthrough as much as a shift in the domain of application of the technology."[2]

[2] Wharton on Managing Emerging Technologies, 2000, page 57.

In many cases, an emerging technology is not based on a technological or scientific innovation, but rather on applying an existing (and possibly mature or obscure) technology to a new market or segment. Often, the widely known application of these technologies is very remote from the original application or goal for which the technology was developed. Thus, for example, radio broadcasting was originally developed for facilitating communication between ships at sea.

Some technologies experience a process of *convergence and fusion*, similar to biological evolution:

1. A technology T1 is developed for a certain (narrow) market and segment A1.
2. Another technology T2 is developed similarly for application A2.
3. It is then discovered that T1 and T2 can be combined (sometimes by developing a minor technology or protocol to facilitate the combination) to address a much broader application A3, which becomes widely used and known as a new major emerging technology, T3.

Managers tasked with strategically choosing which technologies to focus on and which application to target face the following implications:

- Focus on the intersection of markets and applications
- Focus on selecting market contexts for a product
- Understand market heterogeneity
- Expand selection criteria
- Focus on lead users
- Be careful where you look for market insights
- Learn by doing
- Look for opportunities for convergence and fusion
- Accelerate the evolution

Background

One of the most debatable fields in the Smart Grid space in 2011 is the HAN market and its business viability. The HAN market currently attracts multiple players such as Google, Microsoft and Cisco on the one hand and an array of start-ups on the other hand. The HAN and home energy management markets are estimated to grow nearly 90% from $400 million in 2011 to over $750 million in 2015, according to Green Tech Media[3]. However, further research is required to determine whether the adoption rate of the end users will fulfill these skyrocketing forecasts. Will the benefits justify the costs? Which entity (e.g. utilities or technology providers) will push HAN adoption forward? Will the tipping point for consumer adoption commence at the residential or industrial scope?

These are questions that may impact the decisions and strategies of a player in this market. we will use the scenario-planning framework to analyze some of the emerging technologies in the HAN space and outline possibilities for the point it may reach take in five to ten years.

There are numerous new technologies that the developing Smart Grid would either require or enable. For example, the Smart Grid initial rollout requires the development of a dedicated communication platform, which can become an inflection point in the evolution of current communication technologies. Another example is the development of renewable energy technologies on a large scale. The Smart Grid would enable the acceleration of new technology development for scalable consumer-level renewable energy generation solutions.

Thus, the Smart Grid would bring new applications and markets, which would provide a cultivated soil for emerging technologies. It may be helpful for companies that plan to enter into the Smart Grid space to analyze these new applications.

Major Stakeholders and Actors

The development of the HAN market is based on the interplay between many different industries and actors. Following is a list of entities that can influence this process:

[3] http://www.greentechmedia.com/articles/category/home-area-networks/

- **Governmental Stakeholder and Decision Makers**

  The electricity grid and its extensions are directly impacted by the public sector. Federal and state lawmakers can enforce the adoption of HAN by users, through regulation or subsidies.

- **Utilities and State Regulators**

  Utilities and regulators control the Demand Response (DR)[4] mechanisms that are fundamental to the wide adoption of HAN.

- **Technology/Telecommunication Companies and Startups**

  The development of the HAN industry relies on technology and telecommunication companies to invest and develop cheap, secure and pliable solutions to create HANs.

- **Appliance Manufacturers**

  Appliance manufacturers are swiftly moving into the HAN space, developing Smart Appliances that are an essential part of HAN creation.

- **Residential and Industrial Consumers**

  The consumers would need to buy in to the idea of HAN and would drive the profitability and viability of this field.

Trends and Uncertainties

The main forces in the HAN space were initially identified by reviewing the most recent published research and following green energy and smart grid blogs (see Appendix for list of sites). Next, we conducted interviews with industry experts, VCs in the clean-tech space and technology companies in the HAN space. These discussions and interviews catalyzed the most impactful forces, and helped in characterizing the trends and uncertainties.

[4] Detailed description of DR can be found in U_2

Following is a list of the trends that are either directly part of the HAN field, or have a substantial impact on it. We established each of these forces as a trend after finding concrete evidence showing that the force has either already started to materialize, or has a high probability of doing so. We then go on to list the uncertainties impacting the HAN space. Forces were defined as uncertainties, either after discovering conflicting evidence regarding their outcome, or if the timing and result of their impact is currently debatable. For each uncertainty, we provide a range of outcomes.

Trends

T_1 – AMI is approved and established in a growing number of states in the US; wide scale Smart Meter installations are rolled out across the country.

Today, over 10 million Smart Meters have already been installed in the US. Most states have either approved, or are considering the approval of, a statewide rollout of AMI. These programs consist of installation of Smart Meters and a communications network, enabling the utility to monitor and control the flow of electricity. AMI has both a direct impact on HAN by providing the users with HAN capabilities (see T_2 below) and an indirect impact by providing the users with incentives to save energy (see T_4 below).

T_2 – Establishment of HAN communication standards: Wifi and Zigbee protocols emerge as the ultimate standard for HAN; virtually all Smart Meters include Wifi or Zigbee capabilities.[5]

Many competing technologies were sought to be established as the standard technology used for HAN, such as Zigbee, Wi-Fi and Bluetooth, among others. While industry-wide accepted standards have not been instated, the vast majority of the Smart Meters installed in the US are wifi- and Zigbee-enabled, which has helped to establish a standard de-facto.

The establishment of a communication standard is a critical step in the HAN evolution, since the HAN relies heavily on the cooperation of several different providers and entities in order to work seamlessly. For example, in a HAN-enabled home the utility can remotely control the user's HVAC via the Smart Meter and turn it off during peak hours; in this

[5] "Over 99% of US smart meters that include a HAN interface use ZigBee — with total installations nearing 10 million meters. Furthermore, utilities have committed to tens of millions more ZigBee-enabled meters" (www.emeter.com/2010/smart-appliances-wifi-vs-zigbee-communications-the-great-debate/)

example, the HVAC would not be able to communicate with the Smart Meter hadn't there been an established protocol.

Since most Smart Meters installed include built-in capabilities to start a HAN, end-users already have the basic capability to start their own HAN.

Figure 2 – LG's HomBot, robot vacuum cleaner, now with video streaming capabilities.

T_3 – Appliance manufacturers market and create prototypes for network-enabled appliances targeting the home consumer.[6]

LG and GE, to name two, are appliance companies that have come out with "smart appliances" in 2010. Smart appliance capabilities include remote communication, monitoring and control via Wi-Fi. Pike Research estimates that the global Smart Appliance market will grow from $3.06 billion to $15.12 billion, from 2011 to 2015[7], however, there are still some uncertainties around the Smart Appliance market in making such skyrocketing growth a reality (see U_1 and U_5). First, the price point of these products is still unclear; will these products be affordable to the general public? If not, how long will it take for prices to ramp down? Second, though companies are providing new products with Smart capabilities, there are no viable solutions that would connect current products that were already purchased into Smart ones.

[6] HAN enabled appliances were displayed by GE and LG in the 2011 CES.
[7] http://www.reuters.com/article/2011/01/31/idUS172908065220110131

T_4 – Utilities role out DR mechanisms in order to control peak-load management.

AMI is being approved and rolled out by utilities across the US, a process that is largely supported by the government co-funding and stimulus plans. The AMI is the first step in giving the utility the ability to control user consumption and peak demand using Demand Response (DR) mechanisms. Utilities will incentivize consumers to shift their energy consumption to off-peak hours using pricing plans such as Time Of Use (TOU) pricing.

DR mechanisms are a major driver for the development of the HAN market, as consumers will look for better control of their appliances' energy consumption in order to benefit from the pricing incentives. This trend goes hand-in-hand with the uncertainty around the savings the consumer will be able to achieve using a HAN and the viability for purchasing HANs (U_1).

T_5 – Technology and telecommunications providers are investing in R&D in the HAN space.

Companies such as AT&T, Verizon, Comcast and Cisco are investing in solutions in the Smart Grid space. This trend also supports the development of the HAN market.

Uncertainties

U_1 – Will inexpensive HAN solutions be available? Would HAN-enabled end-user electricity savings enabled by HAN justify the costs for purchasing and setting up HAN devices?

This is a major uncertainty in the HAN space. Today, the cost for the basic technology creating a HAN is almost negligible, as utilities provide HAN-enabled Smart Meters (see T_1 and T_2) and telecommunication companies provide HAN capabilities using standard routers. However, the consumer needs to invest in several components in order to utilize this network to monitor and control appliances. Specifically, these investments include purchasing Smart Appliances or a technology for enabling remote monitoring and control for non-Smart appliances. Moreover, the user would need an interface for monitoring appliances, either using a dedicated monitor (such as Cisco's Home Energy Controller) or specialized software that could run on a computer or hand-held device.

These investments would need to be justified by the savings the consumer would achieve in better management of her energy consumption. These savings, in turn, rely on the DR mechanisms enforced by utilities (see T_4). Though DR mechanisms will be applied once the AMI is rolled out, it is still unclear to what extent users would be able to save on their bills by adhering to energy management and efficiency. Currently, utilities have been expressing savings of between 3% and 30% on each electric bill, which for the average bill of $50-$200, results in savings of $1.5 - $60 per month. Obviously, such a large range is not helpful in determining the viability of the HAN solution from an economical standpoint. Users may still partly or fully achieve these saving without using a HAN, simply by self-monitoring and adjusting their electric consumption behavior (i.e. manually running the washing machine at night, instead of programming it to run then or remotely controlling the washing machine using a network and Zigbee interface).

U_2 – Will utilities roll out DR mechanisms that make use of HAN?

This uncertainty is closely linked to U_1. The extent to which the customer will be able to save, and as a result the customers' willingness to pay for a HAN, relies on the type of incentives that the utility provides. Such incentives are very uncertain today, since the type and extent of savings are not set by utilities yet. Even though it is quite certain that utilities will enforce dynamic pricing (T_4), the type of the pricing model will impact the customers' need to purchase a HAN to adhere to it. Currently, utilities are considering three types of pricing schemes:

1. Pre-set TOU (Time of Use) rates that are determined on a daily, weekly or monthly schedule. For example, this type of pricing scheme may include only two rates – a lower one for evenings (7pm-7am) and a higher one for daytime. In this case, consumers can simply adjust their behavior and shift any energy consumption to the nighttime, potentially eliminating the need for an automated system to shift the consumption for them.
2. A complex pricing system that updates rates hourly, directly matching cost to price, and publishing hourly rates over the AMI or the internet. Due to the dynamic nature of prices in this case, the consumer may not be able to utilize better rates without an automated system such as a HAN.
3. A hybrid of the two pricing systems – constant rates throughout most of the year, and only a few select dates when pricing is dramatically changed (typically during

peak hot summer days). Though the exact timing of the pricing change is unpredictable by the user, the viability of maintaining a HAN that will be utilized only a few days per year is unclear.

Most of the utilities today are leaning towards the first pricing scheme - simple TOU (time of use) mechanisms with 1-2 tiered pricing levels pre-set by hours throughout the day. Simplicity and transparency are a catalyzor of adopting such a pricing scheme. However, most utilities have not yet announced specific pricing plans, and those may still change over the next few years, as utilities trial to find the optimal pricing scheme.

U_3 – Who will push or subsidize HAN purchasing? Utilities, governments or technology/telecom providers?

Some industry experts envision the utility becoming a provider of HAN services, similar to the US cable and television companies, who have turned into internet service companies that provide the infrastructure, rental equipment and servicing for the consumer. In this case, the utility will undertake the initial HAN costs and may make it more viable for the consumer to purchase them.

Another main driver behind HAN adoption may be state or federal subsidies that will motivate consumers to purchase HANs. Such a program is similar to the CARS (formerly known as Cash for Clunkers) government subsidized program to encourage users to trade in older cars for more fuel-efficient ones. No such program currently exists.

Technology, telecom or appliance manufacturing companies may also push for HAN products. Today, it looks like appliance manufacturers are marketing HAN enabled products in conjunction with other advanced capabilities (such as built-in inventory management for refrigerators or remote real time video capturing and streaming for automatic mobile vacuum machines), as a premium high-end product, not targeted at the average consumer. However, upon changing the manufacturing costs for Smart Appliances as a result of increased demand, this situation may change. Telecom and technology companies are also investing in researching the HAN area and may move into it as service providers.

The extent and speed of HAN adoption are greatly impacted by the entity that will actively drive HAN adoption.

U_4 – B2B vs. BTC: Which of the industrial or residential consumer markets will first widely adopt HAN?

Most industry experts and blogs, as well as the appliance and technology providers, focus on the residential segment as the main and initial segment that will drive HAN adoption. However, the industrial segment may be much more suitable as the first adopter of HAN solutions. Industrial customers are more price sensitive to electricity price changes, as they typically consume electricity at much higher relative rates, and a HAN may be a much more cost effective solution for industrial customers that need to run a complex environment of appliances and machines.

U_5 – Smart appliances vs. smart chip adapters: will an interface be made available for non HAN-enabled appliances to create HANs without the need to purchase new appliances?

As detailed in T_3, Smart Appliances are already being manufactured and marketed to consumers. However, for many consumers, the cost of replacing current appliances with new smart ones is unreasonably high. A more viable solution may be technologies such as smart chip adapters that will be able to connect to non-Smart enabled appliances and allow for remote control and monitoring capabilities. One example of a chip with such capabilities is NXP's EM773, which is designed to be built into devices and allow self-reporting[8]. These technologies are still being developed and it remains to be seen which type of offerings would be available in this area in ten years. Cost-effective solutions for creating a HAN interface for non-Smart appliances would greatly induce the adoption of HAN.

[8] http://www.smartgridnews.com/artman/publish/Technologies_Metering_News/Smart-grid-trend-alert-Smart-appliances-will-soon-proliferate-3138.html

Figure 3 – Cisco's Home Energy Controller.

U_6 – Will cloud-based AMI and HAN services comply with cyber-security standards?

AMI and HAN are a source of concern for cyber-security experts. These wireless networks, which provide the user access to monitoring and controlling of electricity supply and appliances at home, can be the vehicle of great damage if breached. The security and reliability of these networks will greatly impact the adoption rate of HANs by consumer. It is premature to measure the extent to which HANs will comply with acceptable security standard. However, the AMI that is currently rolled out has already proven to be under performing in this area. A worm displayed in the 2009 BlackHat conference was able to take control of 22,000 Smart Meters within 24 hours and shut off their electricity supply altogher[9]. These kind of security breaches could be used both as a destructive weapon by causing grid instability and burning out power plants, and as a tool for residential criminals to break into homes or remotely control appliances.

[9] http://gigaom.com/cleantech/smart-meter-worm-could-spread-like-a-virus/

Scenario Matrix

The main uncertainties revolving around the HAN field's development were identified as U_1 – whether the HAN costs will justify the savings, and U_2 - whether the utilities will roll out DR programs that will promote HAN.

These were found to be the most critical of uncertainties that would impact the development of the HAN and the technology service providers, as the other four uncertainties are either closely correlated to these two, or will have such a secondary impact on the forecast of this industry. U_3 – which entity will push for HAN adoption, will not greatly impact whether HAN will be adopted, but rather how quickly and how wide-spread. U_4 – whether HAN will start in the residential or industrial space is, again, less impactful in whether the HAN will really become a large-scale field. U_5 – the development of Smart chip adapters vs. new appliances with built-in HAN capabilities has a direct correlation with U_1 – whether the HAN will be cost effective or not. U_6 – security standards for HAN is an issue that is unclear, but will be driven by the wide-spread adoption of HAN, i.e. if HAN is widely adopted, the investments will most probably be made to create solutions to all the security issues.

U_2 - Utilities' DR Implemention ?	**U_1 – Will inexpensive HAN solutions be available?**	
	Tech. Unaffordable P=45% ⇔ Inexpensive Solutions P=55%	
Dynamic Pricing P=20%	(1) A Tool for the Rich P=9%	(3) HAN in Every Home P=11%
⇔ Simple TOU P=80%	(2) No Market for HAN P=36%	(4) In Search of a New Purpose P=44%

Note: P – the probability of each scenario

For each of the above scenarios, we will include the appropriate outcome for the other four uncertainties:

	A Tool for the Rich P=9%	**No Market for HAN** P=36%	**HAN in Every Home** P=11%	**In Search of a New Purpose** P=44%
Who will push HAN adoption?	Appliance Manufacturers	N/A	Utilities / Appliance Manu	Tech Companies / Appliance Manu
Which consumer will adopt HAN?	Industrial Consumers	N/A	Residential Consumers	N/A
An interface for non-smart appliances?	No	No	Yes	No
Will HAN be secure?	Yes	No	Yes	N/A

Following is a description of each scenario, giving an idea about how it will evolve ten years from now, what the industry is likely to look like and the perspective of each of the major stakeholders. The details for each scenario are, of course, fictional, and are delineated in order to give the reader a sense of the way that specific scenario could "play out". In select scenarios, we will delineate the process of Technology Speciation (see Framework Description – Technology Speciation on page 9 for a description of the tool).

1. A Tool for the Rich

   LG and other appliance manufacturers go to market with Smart Appliances. A typical appliance in the HAN space would be a $30,000 refrigerator that has its own inventory management system and electricity efficiency program. This directly feeds from Smart Grid data through the Smart Meter. Though solutions for interfacing between the HAN and non-Smart appliances exist, these are abandoned, given their high prices prevent a wide market penetration: while it is too expensive for low-end consumers, high-end consumers prefer to purchase new appliances with other enhanced capabilities rather than upgrade old appliances.

Utilities roll out extensively complicated DR pricing plans, which include hourly updates to electricity rates. **Most consumers** are able to obtain these rates via the internet or by connecting a monitor to their Smart Meter. The "Colored Orb" becomes a popular household item – placed at the center of the home, the orb is connected to the Smart Meter and glows red when electricity prices are high, warning household members to try to cut down on their electricity usage.

Technology companies are still in a race to find a way to solve the interface problem between HAN and non-Smart appliances. The industry has become more crowded, with utilities rolling out dynamic pricing plans. If a vendor is able to create a cheap product that would serve as an interface between existing appliance and the HAN, with a price tag that is viable for the consumer, they will win a great market (see scenario 3).

The HAN market is stunted, limited to only high-end consumers, and only reaches 10% of its predicted size a decade ago.

Technology Speciation – the desired breakthrough has not been accomplished in the HAN space. Perhaps the sister technology has not been developed yet. However, it may well exist in a different market, waiting to be transported to fill this immense market gap in the smart grid space. Technology managers who follow the guidelines Technology Speciation - Select Analysis for HAN Players on page 26 may benefit by being the first to capture and transfer the technology.

2. <u>No Market for HAN</u>

Appliance manufacturers have discontinued the HAN enabled appliance lines, such as their Zigbee-enabled refrigerators. They have diverted all their R&D efforts to other lanes, such as inventory management, self-cleaning and mobility.

Utilities roll out simple TOU pricing DR models and have found them to be very effective. Surveys continuously show that consumers are happy with the current pricing and are confused by more complicated rates. This is a win-win situation for

both the consumers and utilities, which don't need to deal with complicated pricing for electricity.

After initial resistance, **consumers** have gotten accustomed to TOU pricing, and have been able to permanently shift their electricity consumption patterns to match the pricing scheme. Consumers find that there is no real need for sophisticated systems to manage their energy consumption. It is now common for washing machines to operate at night and for families to cluster into a single air-conditioned room during the hottest of summer days, instead of cooling the entire house.

Technology companies have dropped or cut investments in HAN-related R&D. The only technology that was developed involved major partnerships and was not cost effective. Some of the original HAN technologies, such as Zigbee protocol-enabled environments, have been diverged into other fields, such as hand-held mobile devices.

The HAN market is simply non-existent, with hardly any players left in the field. The startups have disappeared, and the larger companies have diverted their attention elsewhere.

Technology Speciation – the HAN is a dead-end for technology evolution.

3. <u>HAN in Every Home</u>

The majority of the product lines put out by **appliance manufacturers** are Smart and HAN-enabled; only the low-end models do not have these capabilities. Appliance prices are still in the same range as a decade ago, and the incorporated HAN chips and technologies are at almost no additional marginal cost for the manufacturer. Companies such as GE and LG that had invested in developing HAN capabilities a decade ago have emerged as winners, and have been able to minimize the learning curve, leaving other companies in the dust.

Utilities roll out complex DR models and have found them to be very effective. Some utilities have made successful partnerships with appliance manufacturers and technology companies in co-marketing HAN solutions, resulting in a win-win situation. Regulators are watching closely to ensure that HAN solutions are available at a reasonable price for the public, who need them to effectively make use of the dynamic electricity prices.

Consumers are at a new age of electricity management – everything is set to work automatically with minimal intervention. Some consumers even venture beyond electricity usage management, utilizing the HAN in their home for other capabilities.

Technology companies that had invested in HAN solutions are booming. Many synergies are found between HAN and wireless internet routers; companies are working together to continue finding cheaper solutions to create a state-of-the-art "connected home" at a cheap price. Solutions have been found for interfacing between the HAN and non-Smart appliances, opening up nascent markets to the HAN space. The winners are the chip-manufacturers for HAN-enabled appliances, specifically the ones that were quickly able to make them cheaper. All HAN solutions adhere to the strictest of security standards.

The HAN market has grown beyond any proportions imaginable just a decade ago. There is literally a HAN in almost every US home.

Technology Speciation – wireless routing technology has found a new application in connecting appliances in the home. This new market has expanded well beyond the initial intention of energy consumption management and a decade's ago technologies in the wireless space (mobile telephony, wifi, 4G networks) have merged into one standard. While a unified standard has merged, the carriers have multiplied over the years increasing the competition in the market. Companies like Comcast and Time Warner have entered the mobile phone space, creating unified solutions for mobile phone and data, combined with control and management of the home. This new market, initially tapped by utilities' support of the HAN, created a market for the development of interactive home management systems. Viable and

cheap solutions for "home computers" have emerged, led by Microsoft and Google, enabling control of all appliances, light fixtures and electric devices in the home.

4. In Search of a New Purpose

Due to low consumer interest, **appliance manufacturers** have discontinued the HAN enabled appliance lines, though they are still developing other capabilities, such as inventory management, self-cleaning and mobility.

Utilities roll out simple TOU pricing DR models and have found them to be very effective.

Consumers have been able to change their behavior to accommodate TOU pricing, and only an insignificant minority of "technology geeks" uses HAN to manage energy consumption. Consumers find that there is no real need for sophisticated systems to manage their energy consumption for them.

Technology companies have shifted the focus of their original HAN-related R&D. Amazing technological breakthroughs have been happening all over the industry, including cost effective solutions for creating and maintaining HANs, as well as interfacing with various appliances. Security and communication standards exist, yet the market doesn't. Technology companies are seeking new markets for an existing, almost perfect, technology.

The HAN market, as we knew it a decade ago, does not exist anymore. However, the technology is alive and kicking. The real winners are those who are able to utilize the technology to unlock whole new markets.

Technology Speciation - Partnerships between technology companies and utilities result in micro-grids and a blossoming new market for renewable energy generation on a consumer level. HAN technology has been diverted into new markets since it is not needed in the home to control appliances, it can be utilized to manage energy consumption and generation on a macro level for the home user. Thus HAN

technology made way for, and then gave in to, micro grid and user-generated power technologies. Consumers have found that energy generation is a viable way for cutting power costs. Large technology companies, such as Google and Oracle have obtained renewable generation capabilities following a wave of acquisitions. Technologies for optimizing networks and distribution have evolved and are utilized for running micro-grids in residential areas.

Technology Speciation - Select Analysis for HAN Players

The HAN space is still nascent, and may take any of several directions, as we have seen in the scenario analysis. This evolving field is predicted by many experts to grow to $750M in revenues by 2014, and companies that invest in HANs area today may emerge as winners. However, as we have seen via the scenarios above, HAN may not emerge as a major field, as it is heavily reliant on several factors such as utility pricing schemes and technology affordability. Technology companies will do well to closely monitor market trends and ***focus on the intersection of markets and applications.*** It may be that the technologies developed for the HAN market will be better utilized and better monetized in other tangent markets. Technology and telecommunication vendors will do well to ***focus on selecting market contexts for a product***, doing so actively, and not just following current "hot" market trends.

The early adopters of HAN technology are likely to be affluent consumers, interested in the management capabilities beyond electricity efficiency. Technology companies should ***focus on lead users***, and watch carefully for the type of usages that these users apply. Ideas for potential markets may emerge. Companies should also ***understand market heterogeneity***, and while there may be market pressure for lowering of prices (see scenario analysis above), technology companies should watch out from burying themselves in a specific market segment.

Look for opportunities for convergence and fusion – HAN technologies development demand cooperation between companies and industries. Today, the HAN is an intersection point between communication protocols, appliances, wireless data transmission, efficiency algorithms and data storage and management. Companies developing in this space should

embrace the partnerships, rather than develop on their own, while choosing their partners carefully. We are already seeing many partnerships emerge in the HAN space, such as Tendril with EnergyAxis and Landis+GYR, and Control4 and EcoFactor with Texas utilities.

Analyzing HAN by Assessing Future Markets and Commercializing Through Complimentary Assets

Framework Description – Assessing Future Markets for New Technologies

"The challenge of assessing future markets for new technologies is to determine the demand for products that don't exist from customers who don't yet know about them."[10]

When creating a technology with a novel application, there are many unknown market factors that the company has to deal with. For example, the market size is unclear as well as the rate the new technology will be adopted. This framework suggest three approaches for assessing future markets for new technologies:

1. Diffusion and Adoption.

   The rate that a new technology is adopted is largely impacted by: (a) the perceived advantages; (b) the perceived riskiness; (c) barriers of adoption and (d) opportunities to learn and try. The diffusion of a technology can be stimulated through (a) innovation – R&D, which is usually spurred by rivalry; (b) price – the decline in price is caused by experience effects (i.e. increase in productivity and decline in costs) and the squeezing of margins; (c) collective investments in education and access – investments should be made to lead customers through the adoption process: awareness -> knowledge -> interest -> evaluation -> trial -> adoption. A company's diffusion speed (i.e. the concept spreads throughout the market) is dependent on adoption rate (i.e. how quickly users start using the product). There are five types of adopters, according to the stage in which the technology is adopted (innovators, early adopters, early majority, late majority and laggards), and a successful product should move seamlessly from one segment to the next.

[10] Wharton on Managing Emerging Technologies, George S. Day and Paul J. H. Schoemaker, The Wharton School

2. Exploration and Learning.

The process of exploring a new market is iterative. A company that is entering into a new market needs to start by framing the inquiry, and then interpret the results and act. The process is iterative and needs to be corrected: framing the inquiry -> collecting market information -> disseminating information to management -> interpreting -> making decisions.

3. Triangulation for Insights.

There are various ways of gaining knowledge of a new market. A company contemplating entering into a market should gather information using multiple market research tools, and at the same time stay open to novel implications the customers themselves do not envision.

Lead users are helpful in finding out future uses for and problems with the technology, and can be found either directly using the product or in analogous or similar markets.

Latent needs are found through several methods: (a) problem identification – frustrations the current users are facing; (b) story-telling – listening to customers; (c) observation – monitoring the use of products by customers.

Anticipating inflections in the character of demand, the "take-off" point and the "onset of aggressive competition", can be done using (a) methodical guesswork – basing calculations on assumptions; (b) tracking leading indicators – such as the experience of lead users, customers' perception of adoption barriers and risk, rate of new market entrants and the progress in building infrastructure and complementary products.

Diffusion modeling using the Bass model, for example, can help predict where in the product cycle we currently are.

Information acceleration – introducing focus groups to future technologies and applications and garnering their reaction.

Predicting the adoption of a new technology is challenging and this framework provides companies with some systematic steps to take in order to plan and understand the new markets they are penetrating.

Framework Description – Commercializing Emerging Technologies Through Complimentary Assets

Commercializing faces three challenges:

(1) Change in complementary assets – commercializing an innovation is dependent upon complimentary assets such as distribution, service capability, customer and supplier relationships and complimentary products. Some new technologies make the company's complimentary assets more valuable while others make them obsolete.

(2) Change in customers – new technologies often create new customer segments, which need to be effectively serviced. Building bridges from old technologies to new ones can help preserve market position.

(3) Changes in competition – emerging technologies reshape the competitive landscape and the company needs to adapt to the new environment.

Diffusion and Adoption

While there is a growing base of consumers with installed Smart Meters, HAN is still a nascent industry. Only a handful of products exist that can offer the full HAN environment in a home (i.e. hubs, smart-enabled appliances, controlling and monitoring software), and the wireless protocols are not yet standardized.

Perceived Advantage

The major perceived advantage for the user is cost savings. The reduction in the user's energy-bill should justify the cost of creating a HAN. However, the average annual electricity bill in the US is around $1,200[11], and though both Google and Microsoft sites promise HAN savings of 15% ($180 annually), users testify to savings closer to 3% ($36 annually), though some have achieved 30% ($360 annually). If a user purchases Smart Appliances for her HAN, the average life is about 10 years. The NPV over 10 years of the HAN cost savings are between roughly $3,000 (for 30% savings) and $300 (for 3% savings). In both cases, the

[11] http://www.motherearthnews.com/Energy-Matters/Average-Electric-Bills.aspx

additional costs for Smart Appliances (about double the price for a regular appliance today) far exceed the savings, even when excluding the networking and software costs. Hence, without lowering costs for the user via competition, cheaper technology or government subsidies, the HAN would not justify the savings.

Perceived Riskiness

The major perceived riskiness from the users' perspective in HAN technology is the security. An insecure HAN can expose the user to dangers ranging from personal information leakage to a malicious cyber attack. Another risk is losing the investment in HAN technology, if it becomes obsolete.

Barriers to Adoption

The most expensive part of the HAN is the upgrade to smart appliances, hence the barrier is highest for those. The Smart Meters are usually subsidized by the utility, and the software and networking services are relatively cheap. The main barrier for a service company is getting into the user's home by proving viability, and garnering continuing use of the product. It is clear from blogs and user testimonials the consumers prefer hands-off solutions for their energy consumption software.

Opportunities to Learn

HAN components are not currently widely available. Smart appliances were displayed this year in tradeshows and are starting to be available to consumers, but at a high price. HAN networking solutions are still nascent, as well as services. There is no top-to-bottom solution available, and a user would need to patch and create her own network.

Conclusion – Slow Growth

Taking into consideration the above four factors, we conclude that the HAN industry will be facing slow growth in the near future, and if there won't be a major change in the industry, diffusion may take years.

Diffusion Stimulation and Adoption Rate

From the above analysis, we derive that technology service companies should actively stimulate diffusion in order to create a market for HAN. Specifically, it seems that there

would be a need for *profound R&D investment* to create a cost-effective, efficient and user-friendly solution. Though there is not much rivalry in the HAN space today, companies would still need to find ways to lower prices, as refraining from using a HAN would provide a "good enough" solution for most users today (i.e. they would be able to achieve cost savings without the technological advancements of a HAN, simply by curbing their energy consumption). Since the willingness to pay for a HAN is low, we conclude that products will *go to market with fairly squeezed margins*, resulting in less rivalry in the future as well. There should be great emphasis on *education and access for users*, since according to multiple blogs in the space, there is much confusion and misinformation among users regarding the perceived safety and cost savings of HANs. Service would need to overcome the initial negative perception of users. The current adopters of HAN are the *innovators,* yet the market has not expanded much beyond this small group of typically tech-savvy environmentally aware users. Service providers would need to take steps to push the technology through the next stages of user adoption. It appears that most HAN products are not able to push through the "awareness" phase into the "interest" and "evaluation" phases.

Exploration and Learning

With Microsoft's and Google's recent entry to and exit from the HAN field with their PowerMeter and Hohm products, it appears that they have already started iterating and probing the market. However, their products were apparently premature and did not provide enough added-value to the consumer. Service providers, such as Microsoft and Google, would need to continue iteratively exploring the market before extending their products.

Triangulation for Insights

There are abundant blogs and testimonials of lead HAN users shedding light on both the value and the problems of the current technology. This is valuable information that companies should gather and dissect. For example, many Microsoft Hohm and Google PowerMeter users were getting bored with the product and had stopped using it after less than five times. Their perceived cost savings did not justify the time spent using the products, and it seemed that their awareness of energy-savings had been raised enough so as to generally lessen their energy consumption without the use of software monitoring solutions, rendering the products obsolete. Frustration among users included the inability

to remotely control their appliances without upgrading the smart appliances. Observation of the markets by both Google and Microsoft showed a slower-than anticipated adoption rate[12]. It may be perceived that both Google and Microsoft anticipated a larger market for their Smart Grid products in the consumer space, and as both were negatively surprised, their assumptions and calculations should be revised. Tracking lead indicators show that hidden beneath the excitement over the new products, there was much talk and worry among customers concerning security issues as well as savings' viability.

Commercializing Through Complimentary Assets

Entering the HAN field requires software companies to invest in R&D and the development of new technologies. However, there is also a need to invest in other assets in order to survive the competition.

Change in Complementary Assets

Both Microsoft and Google have significant presence in the consumer segments with other software products. However, this is clearly not sufficient for succeeding in the HAN space, as was proven by the failure of Microsoft Hohm and Google PowerMeter. Their failure should serve as a red flag for smaller companies that a network of complementary assets should be in place before introducing a new product for the HAN space. The HAN and Smart Grid value chain is very different from traditional software fields, in that it includes the utilities and regulators as major players and enablers. Software companies, such as Microsoft and Google, must form fast alliances and partnerships with utilities in order to help push their products. This was done to some extent with Hohm and PowerMeter, but definitely not enough: Microsoft had only partnered with four utilities, none of which were US market leaders. Moreover, the relationship with utilities should be handled with care, as big brands like Microsoft and Google may threaten the utilities' delicate and evolving relationship with their customers, following the build-out of the controversial Smart Grid.

[12] Paraphrased from both Google and Microsoft official sites (http://googleblog.blogspot.com/2011/06/update-on-google-health-and-google.html?m=0, http://blog.microsoft-hohm.com/news/11-06-30/Microsoft_Hohm_Service_Discontinuation.aspx)

Other complimentary assets include partnerships with appliance manufactures and alliances with wireless hardware companies. As the standards for communication have not been set yet, these relationships may shape the industry in the future.

Change in Customers

HAN customers can be varied – from the residential consumer via the utility to the industrial consumer. As the HAN technologies develop, the appropriate market segment can change. Software providers need to find ways to bridge between current products to their HAN offerings.

Changes in Competition

Rivals in the software service HAN space include wireless software and hardware providers, startup companies and the utilities themselves. Another "competitor" for software service in the HAN field is the current status-quo (without the software solution) being a "good enough" solution, i.e., there is no urgent need for this technology and it is the providers' challenge to prove the viability of their products.

We will analyze the development of the HAN industry and transitions using the four possible future scenarios we developed in Analyzing HAN Using Scenario Planning and Technology Speciation on page 9.

Transition Dimension	A Tool for the Rich P=9%	No Market for HAN P=36%	HAN in Every Home P=11%	In Search of a New Purpose P=44%
Change in Complimentary Assets	**Significant** Strong alliances with appliance manufacturers may be the driver behind Smart Grid solutions.	**Not Significant** With simple TOU pricing and expensive technology, it may not be viable for companies to offer this service.	**Significant** Strong alliances with utilities to push software management products; brand name and access to the residential consumer	**Moderate** Simple TOU pricing can still utilize monitoring software for the consumer.
Change in Customers	**Significant** Focus on high-end residential customers and industrial customers.	N/A	**Moderate** Larger than current customer base; includes customers with no internet access.	**Significant** Customer segment shift to a small, yet dedicated, group of micro-grid users.
Change in Competitors	**Significant** Smart Meter companies and appliance manufacturers.	N/A	**Significant** Rivalry from software providers, startups (tablet apps..), Smart Meter companies and appliance manufacturers.	**Moderate** Environmental and green companies; clean energy startups.

Conclusions – Strategic Analysis for Google and Microsoft

HAN and Smart Grid technologies are drawing much attention from venture capitalists and large technology companies, such as Google and Microsoft. It is a promising field, however, a closer look at the prospects via **Scenario Analysis**, reveals that the outcome of the HAN market development is unclear. A major loophole in this potential market is the substantial dependency on external and independent drivers. Specifically, the utilities and their choice of pricing plans hold the key to unlocking the consumer HAN market. If a utility decides to utilize simple TOU pricing models, the need for a HAN to manage consumer energy consumption drops drastically.

Another weak point in the viability of this market is the question of whether current solutions are adequate. The main incentive for a user to purchase a HAN in the Smart Grid aspect is to be able to automatically adjust energy consumption of appliances and shift usage to off-peak hours. However, each user has the ability to monitor the general household electricity usage directly using just the Smart Meter that is already supplied by the utility. A user can easily shift electricity consumption to off-peak hours without the use of a HAN. What, then, would the added value of installing a HAN be? If a user's potential savings on each electric bill is $1.5-$60, part of which can be achieved without using a HAN, what would the HAN price point need to be in order to be economically viable for the consumer? Technology companies need to consider and face these questions as they enter the HAN market and develop costly solutions.

Microsoft and Google have both ventured into the HAN market with their Hohm and PowerMeter products in 2009. These products were greeted with much initial excitement, yet in the summer of 2011, both products were announced to be discontinued, due to low consumer adoption rates. Taking a look at the four scenarios we have drawn above, we find that even in 5-10 years, it is most probable that HAN services would be redundant (probability of 36%). The scenarios that would require full automation are far from negligible (probability of 20%), and this is were the highest monetizing potential for Microsoft and Google lies. Hence, it may be worthwhile for Microsoft and Google to continue investing in the development of HAN technologies. We also find that it would be helpful for

Microsoft and Google to strengthen alliances with utilities and appliance manufacturers, as they hold the key to the residential consumer and industrial segments.

When looking at the HAN industry through the **Technology Speciation** prism, it naturally falls into an intersection of markets. As a result, HAN technologies have great potential to evolve into new emerging markets, and large technology providers, such as Microsoft and Google, have much to gain from cross-selling to hard-to-reach markets. For example, industrial consumers may be a lucrative and secluded segment, yet entering via their energy management needs may open doors to products such as Gmail or Microsoft Project. Microsoft and Google should continue their investments in the field and be open to entering new markets and new partnerships in order to capture opportunities that do not currently present themselves.

Software for monitoring and managing electricity consumption alone is not enough to monetize the Smart Grid space. Microsoft and Google should enhance their offering by finding opportunities for convergence and fusion. For example, the utility could use Google's data warehousing and search capabilities to take control of the overwhelming inflow of information from consumer's HANs to the utility (see Scenario (3) HAN in Every Home).

The **Assessing Future Markets** framework revealed the reasons for slow adoption of HAN software that was expensive and not completely hands-off. Microsoft and Google would need to find ways to make their software cheaper and more automated. A major hurdle that needs to be overcome is the communication with appliances – is there a way to wirelessly monitor and control appliances in the home? The company that finds a solution to this pressing issue will break down virtually all the barriers to the residential consumer segment.

Microsoft and Google need to understand and accept that they will be entering a non-competitive market with fairly squeezed margins, and will need to complete internal NPV analysis for the products before approving the investments.

Microsoft and Google could enhance their iterative **exploration and learning** process by defining specific inquiries, such as the following:

- Will the consumer use software to continually monitor energy usage (beyond initial excitement)?
- Are the consumers' concerns of HAN security barring them from trying the product?
- Will a non-tech-savvy consumer be able to run the HAN service?
- What would a full top-to-bottom solution for home electricity management look like for the user? How much would they be willing to pay?
- What other technologies can be combined to provide more hands-free use?

The result of our **triangulation for insights** analysis shows that Microsoft and Google need to gather information about their failed products before they move on – it seems that they were both off-target with market sizing and adoption rate estimations, as well as assessing consumers' needs and issues with energy savings management.

Finally, **Commercializing Through Complimentary Assets** reveals that Microsoft and Google should invest more in complimentary assets before launching another product in the Smart Grid space. The assets they should utilize are their channels to residential consumers, their brands and their proprietary knowledge and development capabilities – their shear size enables them to invest in risky projects such as HAN solutions. However, these assets could be put in danger by entering the market unprepared – the process of entering and exiting the HAN market with immature products resulted in a hit to the Google and Microsoft brands and a larger barrier in consumer perception of accepting a shift beyond Google's and Microsoft's traditional service fields.

As a result of the shift in consumer type, requirements and access-route results in a need to form alliances with utilities and other providers. One of the lessons learned from the failed HAN products was that the strength of Google and Microsoft brand names are not enough to enter and survive in a challenging new market. Significant market penetration can be achieved by displaying clear value-add to the customer and moving through the consumer-adoption phases (11
"innovators" phase. One way to successfully reach a large consumer base would be to partner with major utilities to create opt-out programs for the HAN service offerings. This strategy, coupled with a good product, can bring Microsoft or Google to world-leader status in the HAN space. Microsoft and Google, as the largest software providers, have an inherent

advantage in creating alliances with utilities. It appears that these alliances were either looked-over by Microsoft and Google, or challenging to arrange in past products. However, our recommendation is to create these alliances prior to any further development, as they are key to the success of product adoption.

Microsoft and Google would also benefit from finding *bridging products*, such as Microsoft Project or Google Reader in addition to added value for customers that do not own Smart appliances.

Summary

Our recommendation for Microsoft's and Google's next steps is to continue investing in HAN, given their market positioning and the potential upside of becoming a market leader in this space. However, they would need to build stronger products, partnerships and consumer understanding before re-entry.

Appendix – Resources

Blogs and research groups

- Green Tech Media
- eMeter
- Smart Grid News
- The Brattle Group
- Smart Grid Watch
- Google Blog
- Microsoft Hohm Blog
- Gigaom Blog
- Venture Beat
- Energy Circle
- NIST (www.nist.gov)
- Treehugger
-

Articles and published papers

McKinsey & Co., "McKinsey on Smart Grid"

McKinsey & Co., "Unlocking Energy Efficiency in the US Economy"

GTM Research, "The Smart Grid in 2010"

The Department of Energy – official site

The DOE, "Smart Grid: An Estimation of the Energy and CO_2 Benefits"

The DOE, "The Smart Grid: An Introduction"

NETL and the DOE, "A Vision for the Smart Grid"

Southern California Edison, "Smart Grid Strategy Roadmap"

Karen E, Kalt D. & John L., "Advanced Metering Initiatives and Resedential Feedback Programs: A Meta Review for Household Electricity-Saving Opportunities", June 2010

Carnegie Mellon University, "The Many Meanings of Smart Grid"

Demand Response Coordinating Committee (DRCC), "Demand Response & Smart Grid – State Legislative and Regulatory Policy Action Review: October 2008 – May 2010, An Overview"

Carnegie Mellon, "First Annual Report on Smart Grid Implementation"

Federal Energy Regulatory Commission (FERC), "Demand Response & Advanced Metering"

Interviews

Over the past months we have conducted interviews with representatives from companies and organizations, of which most preferred not to be named.

Following is a partial list of the companies we were able to speak with:

- Google, Microsoft and four other large tech companies
- PG&E, Southern California Edison, and several other utilities
- Three VC funds that specialize in the clean-tech area
- Four industry experts from the likes of Green Tech Media