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Challenges to Smart Grid Technology

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***Abstract*—Smart Grid Technology is the key for efficient use of distributed energy resources the ever-increasing price of petroleum products climate change becomes an important issue the whole world is currently facing clean energy issues.**

This study aims to investigate the barriers that affect SGT. This review provides more insight into energy expert and managers about the critical challenges to clean energy technology.

This research outcome will provide a theoretical basis and simultaneously can be used to analyses SGT development.

***Index Terms*—SGT, barriers, clean technology**

I. INTRODUCTION

Modern Grid Initiative, a smart grid integrates advanced sensing technologies, control methods and integrated communications into current electricity grid transmission and distribution levels [23].Smart grid is envisioned to meet the 21st century energy requirements in a sophisticated manner with real time approach by integrating the latest digital communications and advanced control technologies to the existing power grid rapid advancements in control, Information and Communications Technologies (ICTs) have allowed the conversion of traditional electricity grid into smart grid that ensures productive interactions among energy providers (utilities), consumers and other stakeholders [17].

What holds energy-efficiency technology deployment back is a combination of various energy technology transfer gaps. Barriers to improving energy-efficient technology may be divided into three broad categories: economic, organisational, and behavioural obstacles. In addition, some barriers may be classified as institutional and technological barriers.

The limiting factors for technological transformation are not primarily technical but are instead part of the social, economic, political, and cultural milieus in which technologies are developed, diffused, and used [2].

II. BARRIERS SMART GRID TECHNOLOGY

Different types of factors stress the development, investments, and implementation of clean energy technologies such as SGT which are both energy efficient and cost-effective. Below is the discussion of the various barriers.

i. Technology barriers including standards, interoperability, cybersecurity and data privacy: even though technical solutions often exist at the component level, large scale system experiments are needed to validate "system solutions" such as the management of generation intermittency and to promote standardization and interoperability of the technology solutions which will reduce deployment costs [12]. Potential technological barriers to implementation of demand response include the need for new types of metering equipment, metering standards, or communications technology. These are generally related to customer perceptions of demand response programs and a willingness to enroll [13].

ii. Information: Lack of adequate, accurate and imperfect information about potential energy-efficient technologies inhibits investments of energy-efficient technologies. Consumers, vendors, manufacturers, banks and policymakers often have inadequate knowledge about energy efficiency technologies and their costs and benefits. Though many organisations are working to address this challenge, a harmonized framework for technologies and source of comprehensive information on energy efficiency does not yet exist. As a consequence, consumers and firms are frequently unaware of cost-effective practices and techniques available to save energy [32].

iii Security, cybersecurity, and privacy concerns: Installation of "smart" devices gives potential hackers new targets for exploitation. As these devices monitor and collect large amounts of information, the messages contain information about customer usage, billing and other private customer data [39] There is a concern that customer privacy could be at risk. Since advanced metering infrastructure often relies on wireless technologies, hackers could infiltrate the computer systems to extract recorded information, insert malicious software, identify network authentication keys, and then access other parts of the system using the grid's communication systems. Additional consumer privacy concerns surround the role energy usage information may play in crime enforcement and the potential for energy information to be sold to outside vendors without consumer consent. There is also concern over effective deployment of malicious software causing significant infiltration of sensitive information (including intellectual property) and potential for disruption of critical information systems/services.

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iv. Supply infrastructure limitations: Another barrier concerns supply infrastructure limitations where the availability of new energy-efficient technologies may be limited to particular geographic regions of the country representing an illustrative example of where limitation in the energy supply infrastructure constitutes a barrier to energy efficiency.

Many utilities engaged in smart grid projects find that they are spending significant portions of their project costs on communications and IT infrastructure rather than physical intelligent grid components. Creating a nationwide broadband infrastructure and allowing the smart grid to leverage it could have benefits for both the communications and electric power sectors. Utility executives continue to view the need for new and upgraded infrastructure as the most critical issue impacting the current and future state of the industry.

v. Codes, Protocols, and standards: The Smart Grid needs consistent standards worldwide. Many of those standards are in development now in various places around the world. Codes, protocols, and standards are usually viewed as instruments of change and not as barriers. Despite that, the process of setting and revising rules and codes is often slow, cumbersome, and dominated by special interests. Because laws and standards take a long time to adapt and modify, they sometimes specify obsolete technologies, thereby inhibiting innovation. Completing them, stabilizing them and normalizing them planet-wide are a process that will take years of additional development, testing and negotiation.

Limiting the deployment of this SGT is the lack of consistent standards and protocols. There currently are no standards for these technologies. This limits the interoperability of Smart Grid technologies and limits future choices for companies that choose to install any technology. Most systems can communicate only with technologies developed by the same manufacturer. Regulators and utilities have been hesitant to adopt SGT since it is evolving and, like any computer software, can often require costly upgrades. It also currently lacks standards and industry-wide consistency -- all of which could be quite costly to consumers if companies choose technology that becomes obsolete.

Lack of technology standards" as a major obstacle to smart grid deployment. Uncertainty about interoperability and technology standards present the most significant risk to utilities, who do not want to purchase components that will not work with new innovations down the road [20].

vi. Concerns about Technological Obsolescence and Cost Recovery: Despite increasing investment in AMI, some regulators and decision-makers still have concerns about the useful life of smart meters, as well as the risks that the technology could shortly be replaced with something better. Ultimately, these concerns contribute to doubts about the ability to recover the cost of these investments before they need to be replaced. As there is uncertainty surrounding the price and enabling technologies, this poses a barrier to full-scale deployment [13].

vii. Lack of Cost-Effective Enabling Technologies: There is a diverse menu of technologies that can improve customers' ability to provide demand response, but these technologies are not yet all cost-effective. Examples of enabling technologies include smart thermostats that respond to high prices with an automated adjustment to their setting, whole house gateway systems that allow multiple devices to be similarly made price-sensitive, advanced energy management systems in commercial buildings and process control systems in industrial facilities that can reduce load when needed. Customer awareness of these technologies is low, and given the low level of market penetration, the cost of the techniques is high.

III. Economic Barriers

Economic barriers refer to situations where the market and non-market which are financially related. Market barriers are obstacles that are not based on market failures, but which nonetheless contribute to the slow diffusion and adoption of energy-efficient measures. Numerous market failures and barriers contribute to the efficiency gap. "Market failures" occur when there is a flaw in the way markets operate. Barriers which may be categorized as market barriers are, for example, hidden costs, limited access to capital, risk and these barriers.

Split incentives and lack of apparent market signals/ Lack of Sufficient Financial Incentives to Induce participation: whereas the investments in Smart Grids fall largely on the network operators, the benefits are largely with other stakeholder's society, electricity system, customers, generators etc.). This is not considered by current regulation schemes: present incentives are not sufficient for network operators to invest, neither in extra R&D nor in large scale demonstration or in the deployment of the new technology.

[2] mentioned that homebuilders and developers often do not include cost-effective energy technologies because real estate markets lack adequate means to quantify resulting energy savings and efficiently recoup the added capital cost from buyers. Similarly, landlords require incentives to invest in more efficient appliances if their tenants will be paying building energy costs. The same problem accounts for the fact that many electronic devices consume unnecessarily large amounts of power even when turned off or in standby mode. Manufacturers have no incentive to reduce these losses when the resulting impact on energy use and operating costs is invisible to the consumer at the point of purchase [18].

[13] emphasized that for some customers, demand response programs may not provide a sufficient financial incentive to participate. If customers place a high enough value on being able to consume as much electricity as they want, when they want it, then the financial incentives to participate in demand response programs may not be large enough to justify their participation.

According to [8] if the potential adopter of an energy efficiency investment is not the party that pays the energy bill, then information about available cost-effective energy efficiency measures in the hands of the potential adopter may not be sufficient adoption will only occur if the adopter can recover the investment from the party that enjoys the energy savings. This is a deterrent to the use of energy-efficient technologies those which have higher initial costs but lower life-cycle costs than conventional technologies

[13] asserted that financial disincentives have a

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significant impact on utilities. Without specific regulatory mechanisms in place, utilities generally have a disincentive to pursue programs that will reduce sales. While this problem is most pronounced with energy efficiency programs, it is also present with plans to encourage demand response.

afar of Customer Backlash: This has been cited as a concern by some utilities who feel that heavily-used dynamic pricing could cause customer fatigue, cause them to feel exploited if bill savings were small, or trigger a "revolt" in response to the higher critical peak prices. However, others think that a well-designed program, coupled with effective marketing and educational efforts, could prevent this from becoming a significant barrier [13].

b. Risk Aversion: A significant barrier to customer participation in dynamic pricing options is risk aversion. According to [13] (the Momentum Market Intelligence study showed that, when selecting a pricing option, customers focus more on the downside risk that their bills might go up if they go on the rate, then on the upside potential that they can save money either by virtue of having a favorable load shape already or by reducing or shifting load from high cost to low-cost periods, or both. This risk aversion is one of the primary reasons why default pricing options will lead to much higher customer enrollment than will opt-in enrollment. Research also shows that customers who experience time varying rates have high levels of satisfaction and, when offered the option of staying on such standards, most will do so and will also recommend such tariffs to their friends [13].

limited access to capital: Energy-efficient Technologies are often more expensive to purchase than alternative technologies. Furthermore, obtaining additional capital to invest in energy-efficient technology may be problematic. The financing barrier, sometimes called the liquidity constraint, refers to significant restrictions on capital availability for potential borrowers. Economic theory tells us that, for a risk-adjusted price, the market should provide capital for all investment needs Although it typically pays for itself in a few years, grid modernization certainly costs more than doing nothing at all. Many developed nations are struggling to pay for a renewal of all of their major infrastructure whiles many developing countries have financial challenges. Oftentimes costs for new energy-efficient technologies are too high to afford. The adoption of high-capital-cost technologies like smart grid deployment is slow due to capital constraints.

d. High Cost/Uncertainty in Costs/ Hidden costs: The high cost of smart meters and related equipment relative to conventional technology has inhibited greater utility spending on SGT. A smart meter typically costs three times as much as a traditional meter. High incremental costs have become particularly problematic in the context of high wholesale power prices and utility preoccupation with cost recovery. The high degree of risk-aversion exhibited by utilities has resulted in minimal investment in new technologies such as those required for the smart grid. With a few notable exceptions, questions and uncertainties about new systems have prevented utilities from moving beyond the pilot phase of SGT deployment. This has led some observers to describe current circumstances in terms of a "pilot plague."

The high speed of technical innovation in the smart grid space has discouraged spending on equipment that may become obsolete in a short period. The twenty-year depreciation rate has run counter to the rapid pace of technological advance and turnover that characterize smart grid innovations. This brief "shelf life" acts as a disincentive to investments in SGT that can only be recovered over the long term. The lifetime cost is too high for existing DER devices to compete with traditional alternatives (investment, operation, maintenance, fuel, etc.). Advances in R&D and commercialization are needed to make it more competitive with conventional generation.

According to [8] regarding risk and uncertainty in costs revealed that while smart grid may reduce total electric grid costs through labour savings and potential efficiency improvements, the high cost of implementing the system can erase some of those savings. Because smart grids rely on sophisticated technology for communication and control activities, significant investments in infrastructure are needed. Decision-makers must, therefore, weigh the expected benefits against the likely costs. However, there is a large degree of uncertainty regarding costs, making it difficult for decision-makers to assess how much it will cost to implement a smart grid system. Unlike traditional utility infrastructure such as power plants and their pollution control technologies, which can operate with minor or no modifications for decades, smart grid technologies may need to be upgraded every few years. Though managers know what the capital cost is for an energy efficiency investment, uncertainty about the long-term savings in operating costs means the venture is a risk. Also, the industry and commercial entrepreneurs are unsure whether installing new equipment will disrupt operations and whether the original equipment will increase downtime or reduce productivity during operation. Such concerns are very important to decision-makers.

[23]. Also, point out risk as a barrier to energy efficiency as accurate estimations of the net costs for the implementation of energy efficiency measures depending on future economic conditions in general, and, on future energy prices and availability. Energy prices have fluctuated in the past, leading to perceptions of uncertainty about future prices.

[17]. Wrote on Hidden costs inciting that there are costs associated with information seeking, meeting with sellers, writing contracts etc., which are higher than the actual profit from implementation and thus inhibit SGT investment. Accordingly, cost-effective measures may not be cost-effective when such costs associated with the investment are included. In a study by [15]., for example, it was found that the hidden prices in large energy-intensive industrial firms ranged from three to eight per cent of the total investment costs. In smaller, non-energy intensive firms, such charges are likely to be even higher. The "hidden cost" argument says that potential technical studies fail to account for either reduction in benefits associated with investments in energy-efficient equipment or additional costs not considered in the analysis of cost-effectiveness [33].

upfront Consumer Expenses: In the responses of 200 utility managers to a 20015-survey conducted in USA.42

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percent cited "upfront consumer expenses" as a significant obstacle to the smart grid as revealed in [19]. These concerns were confirmed by consumer responses in which 95 percent of respondents indicated they are interested in receiving detailed information on their energy use; however, only 1 in 5 were willing to pay an upfront fee to collect that information. Regulatory approval for rate increases needed to pay for smart grid investments is always tricky, and the receptiveness of regulators varies from state to state. While there are many connections between these barriers (for example, high cost and high risk-aversion are mutually reinforcing, as are high risk-aversion and rapid innovation), each one represents a unique impediment to the broader adoption of advanced meters and other smart grid technologies.

f. Investment: Before a utility installs an advanced metering system, or any smart system, it must make a business case for the investment. Some components, like the Power System Stabilizers (PSS) installed on generators are very expensive, require complex integration in the grid's control system, are needed only during emergencies, but are only useful if other suppliers on the network have them. Without any incentive to install them, power suppliers don't. Most utilities find it difficult to justify investing a communications infrastructure for a single application. Due to this, a service must typically identify several forms that will use the same communications infrastructure – for example, reading a meter, monitoring power quality, remote connection, and disconnection of customers, enabling demand response, etc. Ideally, the communications infrastructure will not only support near-term applications but unanticipated applications that will arise in the future. Regulatory or legislative actions can also drive utilities to implement pieces of a smart grid puzzle. Each utility has a unique set of business, regulatory, and legislative drivers that guide its investments. This means that each utility will take a different path to create their smart grid and that different utilities will create smart grids at different adoption rates.

Some features of smart grids draw opposition from industries that currently are,or hope to provide similar services. An example is a competition with cable and DSL Internet providers from broadband over power line internet access. Providers of SCADA control systems for grids have intentionally designed proprietary hardware, protocols, and software so that they cannot inter-operate with other systems to tie its customers to the vendor.

difficulty in Measuring Benefits: Pilot programs are useful in evaluating many features of utility smart grid implementations; however, they provide limited support in determining peak period load savings for the entire utility service area over time. The ability to evaluate costs and benefits over time is especially important with these investments because smart grid initiatives require years to complete and benefits of the investments accrue mainly in the future [36].

Many of the benefits of a smart grid come from expected changes in consumer behaviour. However, it is difficult to predict how customers will react to price signals accurately. It is possible that customers may not change their electricity demands much, even when faced with different prices at different times of the day.

If customer demand is not notably affected, then the costs of smart grid implementation may outweigh the benefits. Putting into place proper, complementary policies (such as funding broader programmatic efforts to educate and encourage customers to save energy and adopting fair rates and interconnection standards for distributed generation) are therefore critical for successful implementation of a smart grid [34].

h. Adverse selection& Market Structure: Adverse selection means that producers of energy-efficient equipment will in general be much better informed about the characteristics and performance of equipment than prospective buyers, i.e. the information between the two parties engaged in the transaction is asymmetric. A central theme is that asymmetric information is widespread in real world markets so inefficient outcomes may be the rule rather than the exception [35]

k. The market structure barrier refers to product supply decisions made by equipment manufacturers. This barrier suggests that individual powerful firms may be able to inhibit the introduction by competitors of energy-efficient, cost-effective products.

IV. BEHAVIOURAL BARRIERS

There are also several barriers derived from behavioural sciences that include the form of information, credibility and trust, values, inertia, and bounded rationality. These barriers are presented below.

a. Form of information: One barrier to energy-efficient technology is that the form of information does not receive as much attention as people (often) are not active information seekers but rather selective in attending to and assimilating information. Research in the field points out some characteristics in the way information is absorbed. People are more likely to remember information if it is specific and presented in a vivid and personalised manner and comes from a person who is similar to the receiver [6]. Focus on individuals with their values and attitudes towards energy conservation. Obstacles may occur as lack of attention towards energy consumption, lack of perceived control or a missing link between attitude and action. Social norms and lifestyle patterns may also hinder individuals to use energy more efficiently. Individuals may act as private subjects or in social roles, such as members of the political party or business managers [7].

b. Values: Values are another type of barrier to energy efficiency. Values such as helping others, concern for the environment and moral commitment to using energy more efficiently are influencing individuals and groups of individuals. However, studies of households indicate that norms only have a strong impact on cost-free energy efficiency and energy conservation measures and show weaker correlation to low-cost measures [33] With high uncertainty about energy prices and lack of trust in formal information sources, interpersonal influences like imitation of behaviour are likely to have more significant impact on people's behaviour as friends and colleagues implementing energy efficiency equipment or conservation behaviour acts as a vivid example and because information from close associates are outstanding [9].

c.Lack of trust credibility and trust: Arises due to lack of confidence between two parties at different levels within an organisation. The owner of an industry, who may not be as well informed about the site-specific criteria for energy efficiency investments, may for example demand short pay back rates/high hurdle rates on energy efficiency investments due to his or her distrust in the executive's ability to convey such investments leading to the neglect of cost-effective energy efficiency investments [10].

V. Organizational & Structural Barriers

There are also barriers, for example, power and culture, which are sprung from organisational theory [32].

These barriers are presented below.

a. Power: Lack of control is put forth as an explanatory variable to the ‘gap'. Energy management typically has low status within organisations leading to constraints when striving to implement energy efficiency measures [32] b.Culture: Culture as a barrier to energy efficiency is closely connected to the values of the individuals forming the culture. An organisation's culture may be seen as the sum of each individual's values where the executives' values or the values of other workers who influence within the organisation, may have more significant impact on the organisation's culture than ‘lower status' workers [30].

c. Distortions in fuel prices: Distortions in fuel prices means that the prices that consumers pay for fuels do not fully reflect all the environmental and social costs associated with fuels' production, conversion, transportation, and use. Energy prices would, in turn, lead to lower pay-back periods for energy efficiency investments and thus plausibly increase the chances of implementation.

d. Different perspectives on energy: The different views on power thus make energy politics, and energy efficiency, in particular, an intricate matter and a strong emphasis on one perspective, deviating from the energy efficiency issue, may lead to a lower priority on for example energy efficiency policies. Models of organisational barriers define firms as social systems influenced by goals, routines, organisational structures, etc. Barriers to energy efficiency in organisations may result from an asymmetry of information, a trade-off with non-energy specific goals or missing responsibility concerning energy consumption. Obstacles may occur in budgeting, in the acquisition of new equipment, or in operation service and maintenance [8] Market conditions strongly depend on institutional constraints and prerequisites. An ideal market is defined as a system of transactions with well-informed unbound individuals and prices reflecting the unbiased balance of demand and supply. The existence of a monopoly, lack of information or subsidies may be an obstacle [7].

e. Lack of widespread understanding: Because smart grid is still a new concept and the technologies that enable it are rapidly evolving, there is misunderstanding amongst consumers, regulators, policymakers, and businesses about what its costs and benefits are. Stakeholders that are generally aligned may reach different conclusions based on a different understanding of the smart grid.

f. Government fiscal and regulatory policies: Increased energy prices would, however, be assumed to result in more attention being paid to energy efficiency issues but, as stated previously, this is not always the case. A variety of government policies, practices, and programmes, thus implicitly affect decisions regarding the purchase and operation of energy-using equipment.

The American authors [8] write that: Unfortunately, these government actions tend to favour increased energy use rather than greater energy efficiency this means that lack of energy end-use policies may be an institutional barrier to the adoption of energy efficiency measures.

[13] argued that many parts of the world regulate electric power through policies originally developed. Although appropriate for those times, many of those regulations are now outmoded. Regulatory barriers are caused by a particular regulatory regime, market design, market rule, or the demand response program itself.

The regulation barrier referred to miss-pricing energy forms (such as electricity and natural gas) whose price was set administratively by regulatory bodies. These procedures and the cost structure of the industries typically result in different prices depending on whether they are set based on average costs (the regulated price) or marginal costs (the market price). This shift has given rise to contentions that the price of electricity now provides an incentive to overinvest in energy efficiency [31].

Many of the obstacles to a smart grid are regulatory issues. The patchwork of regulatory structures and jurisdictions is only loosely coordinated, and final authority on many decisions can be unclear, as projects are subject to multiple levels of review. Local (municipality, county), state-level, and federal jurisdictions overlap, and conflicting decisions can result in regulatory lead times of several years. Some regulatory choices can also be challenged in court, resulting in more potential delays at each level. This series of setbacks add significantly to the cost and regulatory risk of pursuing a smart grid project.

g. Coordinating authority’s/ Conflicting agendas among stakeholders: One of the significant challenges in implementing a smart grid is the coordination required between the Energy Regulatory Commission and each of the states involved. Although Energy Regulatory Commission has authority over domestic issues, the responsibility for the construction and maintenance of power generating plants and transmission lines primarily resides with the state Public Utility Commissions (PUCs), which also have authority over electricity distribution systems and the rates paid by retail customers.

VII. Research method

This paper is based on a systematic literature review, conducted on journal papers, conference papers, and books on SGT, particularly focusing on key themes such as clean energy. These themes were used as keywords is searching for related journal articles, conference papers and books from electronic online repositories. The barriers are classified as organizational, technology, structural, behavioral and economical.

VIII. Conclusion

Smart grids promise significant returns for energy efficiency and cost savings, but at the risk of consumer

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privacy. Privacy concerns have already caused pushback that has significantly delayed smart grid deployment and increased costs Smart grid technologies in the coming years hold the promise of significant benefits to end-users, utilities, and to the functioning of economy. However, this promise will be realised only if all barriers are eliminated to the full implementation of SGT are eliminated. New technologies for improving the efficiency of energy use are often not adopted as quickly or as extensively as might be expected based on cost-effectiveness considerations alone. Despite profitable business opportunities and a large potential market, actual investments in energy-efficient technology have not reached economically optimal levels according to many experts.

Action is needed at national levels to remove potential barriers to technology transfer. Such work includes implementing fair trade policies, removal of technical, legal and administrative obstacles, creating stable macro-economic conditions and transparent, enforceable regulatory frameworks.

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