The Changing Decision Patterns of the Consumer in a Decentralized Smart Grid

Mario Gstrein, Stephanie Teufel
{mario.gstrein, stephanie.teufel}@unifr.ch
iimt, University of Fribourg, Switzerland

***Abstract*—The well-regulated Swiss electricity market is subject to far-reaching transitions towards an intelligent network. These include a shift of responsibility, as the consumer comes to play an active role in electricity management. While previous research suggests that the consumer acts according to rational choice or non-cooperative game theory, this is not a sufficient justification for consumer decision-making in a socio-technological environment. To this end, this empirical research elaborates on the decision-making patterns supported by the technological change. The findings suggest that to a certain extent, diffusion of decentralized generation and storage create new responsibilities for a micro trader apart from consumption. Central for trading is the "security of supply" value and any perceived gains and losses in the value outcome entails switching between risk-averse and risk-seeking behavior.**

***Index Terms*—smart grid management, economic behavior, decision making pattern.**

I. Introduction

Currently, the Swiss electricity market is host to a violent debate regarding the topics of energy efficiency, electricity supply, sustainability, and optimization of electricity utilization. The trigger for deliberations consist of new guiding principles (exit of nuclear power, influx of renewable sources), design criteria (request of an intelligent network) or other requirements (increase in consumption through demographic changes, electrification) [1, 2]. To meet the requirements, the sector is undergoing a transformation, the outcome of which is not yet known. Standards are missing and multiple new players are emerging the field [3]. Furthermore, the transformation path inherits a great deal of uncertainty and ambiguity, which leads to different directions and clashing opinions [4]. Scenarios are useful to reduce the uncontrolled speculations and to support the collaboration of actors, but smart grids scenarios exhibit more decentralized architecture and the integration of manifold small units where the end-consumer (later called the consumer) actively influences the overall electricity management [5, 6]. Currently, the electricity producer and distributors (later called suppliers) enter the discussion with their "traditional" perspective and mind-set of consumers as passive receivers as an inconvenient factor for electricity management. Suppliers argue the overwhelming management efforts of such units are difficult and can cause a loss of stability. Additionally, extra communication infrastructure to control the grid is expensive. Further arguments are the leverage reduction and the profit loss through lower quantity sales. So, suppliers are not necessarily interested in advanced consumer influences within the supply chain as it disrupts their current business models. However, the continuous growth of decentralized generation and storage units provides additional opportunities to optimize the distribution of electricity, and suppliers are accustomed to the idea of the electricity grid decentralizing towards individual or micro grids [7].

Some demand side management models (DSM) focus on managing consumer loads, e.g., control of consumer devices [8], where other models are advanced and profoundly integrate the consumer [9, 10]. These models still impose the subordinated consumer role and assume a rational human that avoids risky options, prefer selfishness and react primarily to monetary incentives. Studies have shown that humans behave inconsequentially and adapt their choices violating the rationality axiom [11]. To generate improved simulation models, consumers need to be defined with other assumptions as well as need to handle adaption of choices to determine the load but also the price of electricity [12]. A challenge is the definition of consumer decision patterns which means dealing with a large number of independent users with various behaviors [13]. Therefore, this paper aims to utilize the prospect theory [11] to determine an underlying consumer decision pattern within a socio-technological smart grid. This paper also considers the effects of consumers becoming a non-business-driven trader and evaluates the gains and losses in the prospective value, specifically the security of supply.

II. Background

Traditional DSM concepts are similar to well-known consumer integration paradigms to reduce costs, e.g., arranging furniture or customizing cars. Single steps, mostly at the end or beginning of a value chain, are made the consumer's responsibility. Though the control is still on the supplier's side, a smart grid goes beyond and extends the idea of a prod-user [14]. Within a smart grid, the consumer abruptly influences the consumption behavior, contributes to the production and supports the stability of the grid. Electricity management happens in the masses rather than at a few isolated points [15]. Consequently, the management becomes a dispute between supplier, government and consumer. However, the consumer role experiences a major shift and still the attitudes of which consumers enter the market are not well defined.

A. The Fourfold Pattern

The gambling metaphor following conclusions based on elementary axioms of rationality is a popular example of decision-making; a preference for one choice outweighs the other to maximize the benefits and minimize the costs [11]. In recent years, intelligent rational decision-makers give rise to doubts as people adapt their risk choices, which violate the rational choice axiom [11]. People act risk-averse in some instances and risk-seeking in others. The shortcoming leads to the development of more sophisticated models where decision-making is applied in the matrix of the prospect changes and probability of occurrence (Fig. 1) [11].

	GAINS	LOSSES
HIGH PROBABILITY Certainty effect	**Risk Averse** *e.g. Bet on the sure thing* Fear of disappointment Accept unfavorable settlement	**Risk Seeking** *e.g. Gamble between bad options* Hope to avoid loss Reject favorable settlement
LOW PROBABILITY Possibility effect	**Risk Seeking** *e.g. Lottery* Hope to large gain Reject favorable settlement	**Risk Averse** *e.g. Insurance* Fear of large loss Accept unfavorable settlement

Figure 1. Fourfold pattern (adapted [11])

To explain the change of choice, an understanding of the values of gains and losses is necessary [11]. According to [11], the prospect value (also called utility) of gains and losses are in a relation of 1:2 and hence the expected responses for gains are weaker than for losses. Thus, people normally exhibit loss aversion and defend their status quo. Secondly, the evaluation of positive or negative alterations requires a reference point distinguishing between the same utility.

On the other axis, the probability of occurrence can be separated in possibility and certainty effects. Normally, a 5% change of probability to win a gamble would be expected equally regardless of whether the probability increases from 0% to 5% or from 95% to 100%, but, as shown by [11], the decision weights are disproportional to the probability of change and hence do not depend solely on quantitative probabilities [11].The prospect of unlikely outcomes influences someone to weight higher the change as it exists in reality. This possibility effect explains lotteries where people pay higher prices for a small chance to win a large prize. Another example is paying insurance for rare events such as fire to cover losses. On the other hand, the certainty effect causes lower decision weights as the probability justifies. This is attributed to the fact that people are risk-averse in the prospect of a certain gain (Bernoulli's expected utility) and accept less risk to avoid disappointment. By contrast, in certain loss situations (deciding between bad options) a risk-seeking behavior occurs in a bid to avoid losses. The negative prospect of a sure loss is less desirable than the gamble. Overall, the diminishing sensitivity under high probability promotes risk aversion for gains and risk-seeking for losses. However, low probability outweighs the sensitivity and produces the pattern of risk-seeking for gains and risk aversion for losses (Fig. 1).

B. The Socio-Technological Environment

The described decision pattern of a simple gamble example allows for understanding individual behavior, but for a more elaborate discussion it is necessary to transfer these patterns into a socio-technological system like the Swiss electrical grid. The electrical grid consists of agents (e.g., suppliers, distributors or consumers), the grid network (e.g., plants, wires, transformers) and ruling (e.g., policy, mindsets, behavior) which are in dynamic mutual interactions (Fig. 2) [4]. Agents adapt dynamically to the new context through a continuous process of combining rules to seek benefits [16]. In certain situations, they act more selfishly than in others. At a given time point a consumer follows a set of successful rules that provide strategic scope. The different strategic patterns allow for moving through the rugged landscape [17].

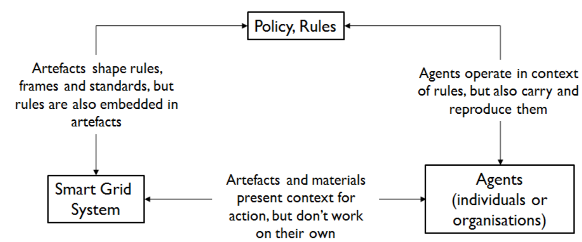

Figure 2. Three interrelated analytic dimensions (adapted [4])

There are different regimes involved that are distinguished by social groups and related rules [4]. For example, traditional suppliers with their artefacts (e.g., plants) operate according to certain policies and mind-sets in a technological regime (covering demand in real-time). The transition to a smart grid entails the entrance of new technology and agents (ICT sector) changing existing rules and enforcing the development of new artefacts and standards. Technological innovation not only creates new artefacts causing alteration of the own regime but also induces reactions in other regimes [4]. For example, the availability of cheaper and more efficient solar panels supports the decentralization of production [18] and permits to establish a consumer regime in the electricity industry following their own mind-set, beliefs and values. A consumer regime is bounded by regulative rules (e.g., laws, sanctions) defining the scope of decision options for individuals. For example, the context for decentralization is supported through policy initiatives by regulating the barriers [19–21]. Furthermore, up to the present defined normative rules specify that the expected consumer's role and actions would be seen as demand for electricity while the supplier's role and actions are to make profit. Nevertheless, both parties require stability of the network, and in a realistic scenario, neither party can conform to these simple rules one hundred percent effectively nor can parties be viewed in isolation. There is a definitive link through supply and demand that postulates the need to cultivate a symbiotic relationship. In the future, the consumer will produce and store electricity spanning both roles (producer and consumer) and provide a closer link among actors in their dedicated role. For example, the adoption of decentralized storage to balance surpluses is an act of the consumer giving up his own benefit for the grid. This is not limitless and an expected equilibrium is reached at 38% [10].

How this symbiotic relation is defined depends strongly on the evolved social norms in a smart grid. Social norms will influence the decision processes of individuals and organizations. Therefore, the key question is how do we as a society define the social norms for the electricity in the smart grid, in the context of the following question. Is it a fundamental right or can it be treated as a traded market good? The act of conformity to norms is to match attitudes, beliefs, and behaviors to superior norms and thinking [22]. Social response to conformity is a continuum from assimilation (conversion) to neglecting of norms (anti-conformity) [23] and depends strongly on available technology which allows reaching a certain degree of self-sustainability. Besides that the size of majority following specific norms influence private values [23], and is distinctive for regional specified norms rather national-wide ones. Which impact these factors have is object for further research, but the individuality provides groups of conformists and anti-conformists.

III. The Decentralized Smart Grid Scenario

A. *The Consumer's Gains and Losses of Value*

Recent smart grid discussions promote money as the primary value for consumer decisions. The prospect of cheaper electricity and the saving potential of consumption dominate the debates. For an explanation of consumer motivations, these points are arbitrary due to the bounded rationality of consumers to compare prices and since the saving potential only affects the energy price, which is one-third of the electricity bill [20]. Moreover, the feed-in compensation is a driver for diffusion of production, but in the long term, the subvention is insufficient because the consumer regards electricity management a as non-core functionality. Thus, money is more the result of actions rather than the driver, and the quality of the smart grid is a cultural and ethical rather economic and technical question [24].

The purpose of a smart grid is the optimization of electricity, and each player would have to behave according the rules of the game [4] as a derivation jeopardizes the stability and performance. The rules derive from the pursued targets of a consumer and each decision is made to support the goal. So, it becomes an intrinsic motivation. Within a smart grid five targets exist [25]: economic performance, technical performance, environmental friendliness, safety and product quality. Generally, all targets should be achieved, but, agents are more focused on some targets than others. Additionally, some targets are contradistinctive, e.g., environmental friendliness and technical performance. For the consumer, product quality is important; in particular, the security of supply and each gain or loss is evaluated against it. Other targets (e.g., environmental friendliness) might also be important, especially in the Swiss electricity market, which is characterized by stable networks, environmental stewardship, high economic standards, trust in supplier and deep poverty rate; however, the security of electricity originates from the basic instinct of supplying a need [26]. Furthermore, several scenarios claim a higher demand and reliance on electricity due to geographical, electrification and lifestyle trends [27,28]. A shortage of electricity and the subsequent consequences in the areas of industrial production, hospital, or public transport would lead to undesirable benefit loss. For a common private user, there might not be life-threatening reasons; rather, it likely depends on an egocentric, comfortable attitude, e.g., the luxury of devices being available twenty-four hours a day.

B. *The Consumer Regime in a Smart Grid System*

The consumer regime displays different mind-sets, beliefs, and values and competes in the market following other parameters than suppliers do. Decentralized production and storage allow for the manipulation of electricity accessibility (Fig. 3) and support a certain degree of self-sustainability.

The decentralized electricity production offers a direct and close source with tremendous implications for the demand, and it directly influences the security of supply. Associated risk averseness and risk-seeking are linked to performance of production and the inherent limitations[1]. Production and usage distance is tighter, and the advantage is the increasing autonomy of supply and prevention of interferences. The extension of capacity, either through installing new elements or increased efficiency, is regarded as a gain in the security of supply. To determine the capacity, not only is the performance of PV critical, but also the natural load diversity of renewables, especially in adversity periods like winter. Additionally, inherent system limitations like sun irradiation and available surface restrict the capacity [2, 29]. Limitations or other disturbances (e.g., maintenance) foster the losses of value. Additionally, the probability between certainty and possibility changes during the day as well as during the season due to mentioned performance and limitation settings. Thus, it is still necessary to interact with the grid to ensure security. Eventually, the decision pattern is strongly coupled with the characteristic production curve of PV where risk averse behavior is observed when there are surpluses and risk-seeking behavior is observed when there are shortages of electricity.

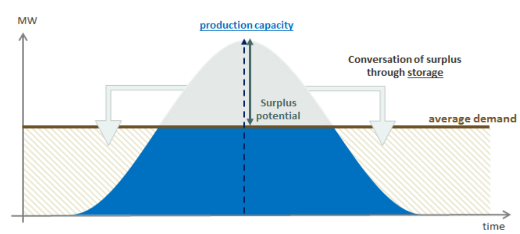

Figure 3. Schemata of decentralized production and storage.

The idea of storage is to transfer current electrical capacity through time for future use. The storage symbolizes for the consumer the scarification of demand in favor of postponing the benefit of electricity; similarly to saving money in a banking account. A decoupling of simultaneous production and consumption occurs. Saving electricity can be achieved by consumption reduction or by producing a surplus. The potential for additional available electricity is higher in the production expansion than in the decrease of electricity demand. By absorbing the surplus, storage size strongly correlates with the

[1] For further discussion, we only consider a photovoltaic (PV) solution as a potential application to install in small locations. Therefore, we assume that the production follows the characteristic bell curve shape. The potential for integrated PV production in Swiss buildings is estimated to be 18.410 terawatt hour per year which would cover 34.6% of the total Swiss consumption [18].

maximum capacity of distributed generation. Any increase in production leads to an extension of space as long as empty storage space does not grow proportionally. In the end, an equilibrium state is reached and any short-term alteration will be avoided. Thus, the risk-averse or risk-seeking behavior primarily depends on the factors of storage size and the probability of filling it.

Considering the both factors in interplay, the consumer acts risk-aversely at high production rates when maintaining security and options of wasting electricity or feeding it in to the grid are unfavorable. In other words, selling electricity at low prices during overproduction period is less beneficial as saving it for future references. The certainty to bet on sure thing of electricity availability outweighs the monetary revenues. Any fear of loss during that time caused by unlikely events as malfunctions may be assuaged either through back-up solutions or by covering financial damages. Contrarily, risk-seeking behavior is dominant mostly at low production and low storage capacity – this implies low electricity availability. The consumer is willing to gamble for security due to a high probability of a shortage leading to immense losses. Avoiding sure losses the consumer investigates in different price options. On a lower probability the market offers promising greater prospects to increase security prevail.

Risk behavior differs with the new functionality of short-term buffer memory. The concept is to reserve a certain decentralized storage space exclusively to fill and empty it. For distributors, the extra space provides possibilities to stabilize a network's fluctuations, whereas for producers, it is an additional possibility to transfer cheap produced electricity into expensive periods. Several studies prove the applicability and the potential uses, e.g., hybrid cars [30], electrical batteries [31]. The buffer is a reduction of security from the individual viewpoint and the object is to keep the space at a minimum. Conversely, the short-term buffer is primarily grid-oriented and is subject to social norms that do not consider individualism. Community-related issues are treated with priority. Considering the equilibrium state and that storage cannot extend limitlessly in the short term, the grid shows risk-seeking behavior at prosperity times; e.g., gambling for space is preferred as wasting cheap electricity is a loss in the future security. Conversely, the grid behaves risk-aversely in low production periods and neglects unnecessary supply to sustain security for potentially graver incidents, e.g., shutdowns. How far the consumer incorporates these considerations into decision-making is subject to further research, but there is a conflict between autonomy of consumer and grid requirements. In the end, the consumer becomes a non-profit micro trader extending responsibilities. The industry thus must consider consumers' decision patterns in new pricing strategies.

C. Pricing Strategies Under Decision Patterns

Current pricing debates proclaim that "time of use", "demand bidding" or "auction-based" are adequate techniques for smart grids [13]. Traditionally, these are based on economic mechanisms where the price originates from production costs or trading. So far only suppliers are involved in the price finding process [20], but the consumer's possibilities of production and storage allow participating in this process.

The day-time demand of electricity is high at lunchtime and lower at nighttime (Fig. 4). At prosperity phases, the decentralized production adds to the overall electricity volume and replaces supplier units. Additional generated electricity and decentralized storage bolsters security, and risk aversion is dominant as the stored electricity is a guarantee for adversity times. Temporarily the demand increases and causes no extra marginal costs due to different consumer investment approach. The consumer neglects invested costs and associated return of investment as self-sustainability is egoistic motivated. A "no cost" mentality takes root. Thus, already installed infrastructure is regarded as paid off and decentralized, produced electricity illustrates a zero price being favorable versus paying the real production price.

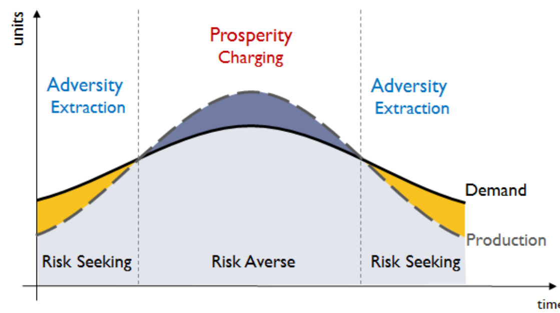

Figure 4. Decoupling of demand and production

The changing situation creates a new competition paradigm. First, suppliers compete on price and capture benefits through strong divergent marginal production costs [2]. Any response from suppliers to cover the request by activating expensive dispatchable units must be compensated by increased prices. This is unacceptable for the consumer except if the occupancy rate of the storage is insufficient. The fear of losses increases the acceptance of paying prices to guarantee security, for example an insurance service to avoid electricity shortage. Those value added services provide a new revenue stream for suppliers and become stronger and diversified in the future. Eventually, preferred sources for storage are either self-produced surplus or very cheap electricity and the consumer is only willing to pay higher external prices due to fear of large losses in the prospect of a failure.

The extraction of cheap electricity from the storage occurs during the offline period of decentralized renewables; hence storage temporarily becomes a "production" unit. Storage extends low electricity prices horizontally through time and prolongs the period into high price segments. At the adversity phase, paying higher premiums with a full storage is not optional. This situation occurs when the storage bridges the renewable offline period when production starts again. Conversely, partial coverage and the prospect of losses in security support risk-seeking leading to a gamble between options. During offline phases, the consumer accepts the market price or value added services that guarantee security. Those services are offered on a higher premium which attracts other suppliers causing a different competition field. Meanwhile, insufficient services or a boost of market prices creates a stimulus to invest in more decentralized units [32] and augments the production-storage capacity. This can lead to consumers investing in more storage as the decentralized generation performs solely to absorb cheap external production. A counter effect on storage capacity is the short-term buffer memory. Any agreement to allocate size for the system purposes expects a reimbursement at least high as the transportation fee.

Eventually, the electricity market will undergo a transformation similar to the telecommunication sector where the basic element (calls) was not profitable and services like data exchange became lucrative. Therefore, the pricing strategy depends strongly on the success of service definitions and the understanding of consumer's requirements for supporting risk-averse and risk-seeking behavior.

IV. Conclusion

Decentralized units represent many challenges for electricity suppliers. A major challenge is the adoption of novel perspectives, skills and capabilities in response to the changing consumer role. The consumer acts like a micro trader and evaluates gains and losses of value outcome. The value is strongly related to security of supply and hence in certain situations the consumer shows risk averseness and can shift to risk-seeking behavior in another moment. By understanding the mechanism of decision-making and a consumer-centric focus, suppliers have the ability to create new tariff structures and value added services, e.g., carefree packages. Such services offer the opportunity to replace the financial losses, as quantity will be decoupled from profit. Another opportunity for business is the integration of numerous small units, and companies can distinguish themselves by the quality of efficient electricity distribution with the grid. Additionally, the management of cooperation among consumers in micro grids, providing the infrastructure for generation and exchange of electricity among the members [9, 33, 34] is another area where opportunities exist.

This article demonstrates that the decision-making patterns of consumers depend on probability and the perceived gains or losses of the outcome. The outcome is contingent on the most important consumer value, security of supply, rather than on economic factors. In conclusion, the consumer behaves in a risk-averse manner in times of electricity prosperity and in a risk-seeking manner in times of electricity scarcity. Such behavior is strongly influenced by the technological diffusion of generation and storage. This article provides a first step to understand consumer decision-making and is a direction to improve smart grid simulation models. However, future research is still necessary to inquire a more detailed approach.

References

[1] Poel, Ibo van de, "The transformation of technological regimes," *Research Policy*, vol. 32, no. 1, pp. 49–68, 2003.

[2] N. E. IEA, *Projected Costs of Generating Electricity*. Paris, 2010.

[3] R. Kemp, J. Schot, and R. Hoogma, "Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management," *Technology Analysis & Strategic Management*, vol. 10, no. 2, pp. 175–198, 1998.

[4] F. W. Geels, "From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory," *Research Policy*, vol. 33, no. 6-7, pp. 897–920, 2004.

[5] T. Moore, D. Rastler, and D. Herman, "Emerging Markets for Distributed Resources," *Cogeneration and Competitive Power Journal*, vol. 13, no. 4, pp. 14–35, 1998.

[6] VSGS, *Weissbuch Smart Grid.*

[7] D. Bohn, "Decentralised energy systems: state of the art and potentials," *IJETP*, vol. 3, no. 1/2, p. 1, 2005.

[8] I. Atzeni, L. G. Ordonez, G. Scutari, D. P. Palomar, and J. R. Fonollosa, "Demand-Side Management via Distributed Energy Generation and Storage Optimization," *Smart Grid, IEEE Transactions on*, vol. 4, no. 2, pp. 866–876, 2013.

[9] A.-H. Mohsenian-Rad, V. W. S. Wong, J. Jatskevich, R. Schober, and A. Leon-Garcia, "Autonomous Demand-Side Management Based on Game-Theoretic Energy Consumption Scheduling for the Future Smart Grid," *IEEE Trans. Smart Grid*, vol. 1, no. 3, pp. 320–331, 2010.

[10] P. Vytelingum, T. D. Voice, S. D. Ramchurn, A. Rogers, and N. R. Jennings, Eds, *Agent-Based Micro-Storage Management for the Smart Grid*: AAMAS, 2010.

[11] D. Kahneman, *Thinking, fast and slow*. London: Penguin, 2012.

[12] M. Roozbehani, M. Dahleh, and S. Mitter, Eds, *Dynamic Pricing and Stabilization of Supply and Demand in Modern Electric Power Grids*. Smart Grid Communications (SmartGridComm), 2010 First IEEE International Conference on, 2010.

[13] G. Strbac, "Demand side management: Benefits and challenges," *Energy Policy*, pp. 4419–4426, 2008.

[14] A. Bruns, *Blogs, Wikipedia, Second life, and Beyond: From production to produsage*. New York: Peter Lang, 2008.

[15] S. Teufel and B. Teufel, *The Crowd Energy Concept*. Fribourg, Switzerland: iimt University Press, 2014.

[16] J. H. Holland, "Studying Complex Adaptive Systems," *Jrl Syst Sci & Complex*, vol. 19, no. 1, pp. 1–8, 2006.

[17] D. A. Levinthal, "Adaptation on Rugged Landscapes," *Management Science*, vol. 43, no. 7, pp. 934–950, http://www.jstor.org/stable/2634336, 1997.

[18] IEA, *Potential for Building Integrated Photovoltaics*, 2002.

[19] Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK, *Aktionsplan „Erneuerbare Energien"*. Faktenblatt 6. Bern, 2008.

[20] BFE, *Strompreisentwicklung in der Schweiz*. Bern, 2011.

[21] B. Woodman and P. Baker, "Regulatory frameworks for decentralised energy," *Energy Policy*, vol. 36, no. 12, pp. 4527–4531, 2008.

[22] R. B. Cialdini and N. J. Goldstein, "Social Influence: Compliance and Conformity," *Annu. Rev. Psychol*, vol. 55, no. 1, 2004.

[23] D. R. Forsyth, *Group dynamics*, 6th ed. Belmont, CA: Wadsworth Cengage Learning, 2014.

[24] H. Herring, "Energy efficiency—a critical view," *Energy*, vol. 31, no. 1, pp. 10–20, 2006.

[25] H. Rui, M. Arnold, and W. H. Wellssow, "Synthetic Medium Voltage Grids for the Assessment of Smart Grid Techniques," in *2012 3rd IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe)*, Berlin: IEEE PES, 2012, pp. 1–8.

[26] A. H. Maslow and R. Frager, *Motivation and personality*, 3rd ed. New York: Harper and Row, 1987.

[27] EIA, *International Energy Outlook 2013*. Washington, 2013.

[28] P. Capros, L. Mantzos, N. Tasios, A. d. Vita, and N. Kouvaritakis, *EU energy trends to 2030: Update 2009*, 4th ed. Luxembourg: Publ. Office of the European Union, 2010.

[29] M. Šúri, T. A. Huld, E. D. Dunlop, and H. A. Ossenbrink, "Potential of solar electricity generation in the European Union member states and candidate countries," *Solar Energy*, vol. 81, no. 10, pp. 1295–1305, 2007.

[30] M. D. Galus, S. Koch, and G. Andersson, "Provision of Load Frequency Control by PHEVs, Controllable Loads, and a Cogeneration Unit," *IEEE Trans. Ind. Electron*, vol. 58, no. 10, pp. 4568–4582, 2011.

[31] J. Schneider, *VARTA Microbattery wins Innovation of the Year*. Germany, 2011.

[32] B. Simmons-Süer, E. Atukeren, and C. Busch, *Elastizitäten und Substitutionsmöglichkeiten.*

[33] S. Hungerbühler, *Regio Energie Solothurn macht vorwärts bei der Energiewende*. Solothurn, Switzerland.

[34] ABB Schweiz and Elektrizitätswerk Zürich, EKZ und ABB nehmen grösste Batterie der Schweiz in Betrieb. Zürich, Switzerland, March 21st 2012.