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Abstract: Information and communication technology plays an important role in achieving a higher level of energy efficiency. In particular, energy efficiency can be achieved by integrating information technology into electricity networks to enable the interaction between suppliers and customers (smart grids). Power generation by renewable energy sources can also benefit from this integration of technologies. Distributed power generation, which will be the basis of renewable energy production, encourages the production of renewable energy resources and, accordingly, decreases transmission loss, increases energy saving, and enhances energy efficiency. Therefore, integrating distributed, renewable energy sources and smart grids within local marketplaces for trading renewable energy in small units can be a promising combination. In this paper, we propose a structure of a marketplace for renewable energy sources, design a market mechanism for trading in this market, and outline the requirements for such a market to function efficiently. Finally, we conclude and present recommendations to policymakers to provide incentives to generators to increase deployment of renewable energy sources and to end users to save electricity and to consume clean energy.

Keywords: Market design; market mechanism; trading energy; renewable energy; clean energy; energy policy;

JEL Classification: D40; H44; L11; L49; Q13; Q27; Q42;

1. Introduction

Energy efficiency is one of the most important approaches to reducing electricity consumption. Information and communication technology (ICT) play an increasingly important role in achieving higher efficiency targets. In particular, smart grids can achieve energy efficiency by integrating information technology and the interactions between suppliers and customers. Smart grids have been used since 2005, when Amin and Wollenberg (2005) introduced the concept of smart systems in electricity networks. Smart grids help in avoiding the problems of traditional systems, such as transmission loss, inefficiency, unbalanced supply and demand in peak time, and interdependency among the components of the network.

The improved flexibility of the smart grid network helps to develop different kinds of renewable energy sources, such as solar and wind power. The smart grid enables households to have their own devices to produce renewable energy and trade their surpluses of electricity. Furthermore, households can manage their energy consumption by using intelligent control systems. Households that generate electricity using their own resources may enter the surplus electricity into the pooled network and take it back another time in accordance with their needs. However, the power exchange between the Distributed Generation (DG) owner and the network requires appropriate management (Mashhour and Tafreshi, 2009).

Regarding the outlook of the renewable energy market, a marketplace for energy trading in small volumes is required. The world will use DG because of environmental concerns and the limited availability of depletable fossil fuels in the future. By 2030, it is expected that the U.S. Department of Energy (DOE), through the implementation of its Research and Development Plan, will produce 20 percent of U.S. electricity generation, an estimated 200 GW, from distributed and renewable energy sources (DOE, 2010). Due to the predicted high penetration of DG in the future, the power industry should be restructured accordingly. In order to facilitate the use of renewable energy sources, it would be better for power distribution systems at the retail level to change to market-based operations. The market is based on two-way interactions between stakeholders facilitated by internet telecommunication (IT). However, some customers may worry about data privacy issues and the remote monitoring of their devices.

The remainder of this paper is organized as follows. In the second section, we explain the state-of-the art distributed generation networks. In the third section, we consider the components required to build a smart network. We also describe a smart grid market place where energy is traded. In the fourth section, we explain the distributed generation market structure. The smart grid market place requirements are discussed in the fifth section and finally, a model of a renewable energy market and its policy implications and mechanisms to operate efficiently is provided.

2. State-of-the-art market place for electricity

The idea for using a market place and the market mechanism for households' generation and distribution of electricity is not new. It has been employed in wholesale electricity markets and computing resources. In recent years, the idea of distributed resources has spilled over from computer grids to power grids. Therefore, we devote this section to discussing marketplaces for trading electricity, distributed electricity generation, emissions trading, and computing resources.

2.1 Marketplaces for trading electricity

Three fundamental markets are available for trading electricity: the spot market, the physical forward market, and the financial futures market. Nord Pool Spot is considered the largest market for electricity worldwide in terms of the volume traded (TWh) and market share. It provides the leading marketplace for buying and selling power in the Nordic and Baltic regions, as well as in Germany and Great Britain. Nord Pool operates two kinds of markets for trading electricity: Elspot and Eltermin. In the Elspot, buyers and sellers trade in the day-ahead market. The Eltermin market is further divided into two sub-markets: future and forwards (Kristiansen, 2007). The Elbas market[1] bridges the gap between Elspot and the national Nordic real time markets and is a physical market for trading in hourly contracts (Benth et al., 2008). The European Energy Exchange (EEX), based in Leipzig, is a leading trading market for energy and energy-related products. EEX operates as a trading platform for electricity, natural gas and carbon dioxide emission, and coal. The base-load financial contracts traded in this market are similar to the Nord Pool contracts (Benth et al., 2008).

2.2 Marketplaces for distributed electricity generation

Wang et al. (2011) summarized the current state of research on the communication networks of smart grids. Buchholz and Schluecking (2006) showed different experiences with distributed generation and energy management systems in distribution grids in representative European pilot installations. Block et al. (2008) introduced a market mechanism that facilitates the efficient matching of electricity and heating demand and supply in Micro Energy Grid environments.

Molderink et al. (2009) defined and developed a simulator to analyze the impact of different combinations of micro-generators, energy buffers, appliances, and control algorithms on energy efficiency, both within house and on a larger scale. Albadi and El-Saadani (2008) presented a summary of demand responses in deregulated electricity markets. They emphasized the effect of demand response on electricity prices by using a simulated case study. Lund et al. (2012) illustrated the reasons that electricity smart grids should be part of the overall smart energy systems, and they emphasized the inclusion of flexible Combined Heat and Power (CHP) production in electricity balancing and grid stabilization.

Friedman (2002) focused on the technologies required to interconnect distributed energy resources (DER) systems with the grid. Recent increases in electric grid prices, coupled with shortages in electricity generation capacity, have prompted some industrial and commercial customers to evaluate DER solutions for their energy needs. You et al. (2009) proposed a virtual power plant model which provides individual DER units with access to current electricity markets. They applied this model to micro

[1] The Elbas Market is a market for continuous trading of power during trading hours. It is applied to the Nordic market of Sweden and Finland.

Combined Heat and Power (μCHP) systems.

2.3. Marketplace for emission trading

The SO_2 trading system in the US could be considered an early example of an emission trading system created to reduce the effects of emissions from power plants. The US has two major emission trading programs: the SO_2 program began in the early 1990s, and the NO_x program began in the late 1990s (Kruger and Pizer, 2004). The European Union emission trading system (EU ETS), which started in 2005, is the world's largest emission trading market to date, and it covers around 50 percent of Europe's total CO_2 emissions (Hintermann, 2010). As we discussed previously, the Kyoto Protocol introduced three mechanisms to reduce Green House Gases (GHGs) emissions: international emissions trading, joint implementation, and a clean development mechanism. The EU ETS is considered an essential part of EU climate change policy in meeting its obligations under the Kyoto Protocol. Hintermann (2010) examined the drivers of allowance prices in the first phase of the EU ETS and found that it was necessary to set an appropriate price to avoid start-up problems. Soleille (2006) argued that ETS itself does not abate emissions; its efficiency depends on political will, proper design, and implementation. The results obtained by the previous markets in the US and the EU could be employed in the design and operation of a new market like DER in order to take advantage of lessons learned from existing trading programs.

2.4 Marketplace for computing resources

Buyya et al. (2001) made use of economic models of resource allocation and regulating supply and demand in a grid computing environment. They demonstrated the use of economic models in resource brokering for two different optimization strategies on the World Wide Grid test bed, which contains peer-to-peer resources located on five continents: Asia, Australia, Europe, North America, and South America. Preist (1999) described a new agent-based market mechanism for commodity trading via the internet. This institution combines the best properties of the continuous double auction and the call auction approaches. It consists of a marketplace and a set of agents that represent the market participants.

Wolski et al. (2003) described the use of economic principles for grid resource allocation policies and mechanisms. They found that a computational economy, in which users "buy" resources from their owners, is an attractive method of controlling grid resource allocation for several reasons. In another study, Wolski et al. (2001) investigated G-commerce computational economies for controlling resource allocation in a computational grid setting. Their results indicated that commodity markets are a better choice for controlling grid resources than the previously defined auction strategies. Altmann et al. (2008) presented the design and implementation of the GridEcon Market place for trading commoditized computing resources.

3. Stakeholders

First, we need to recognize the components of the smart network for trading renewable energy resources. Our network includes producers, energy providers, energy service providers, consumers, operations, and electricity market participants. Intelligent management is a critical part of the smart network. All components of the network should have the capability of being managed by an automated system. We should keep in mind that new technology for deploying smart control and management is required. It should also be noted that innovative technologies, including advanced power equipment, intelligent home appliances, smart meters, and communication facilities, have not yet sufficiently improved and/or some components are not available commercially.

3.1 Bulk generation companies

Power is produced by using fossil fuels (e.g., coal and natural gas) and non-fossil fuels, such as nuclear fusion, water, wind, and sunlight. This component is connected to the transmission line, and thus to the transmission control center. There should be interactive communication between bulk generation and the control center regarding crucial parameters, such as capacity, production and consumption monitoring, peak-load time, off-load time, and related unit cost. Bulk generation includes nuclear, hydro-electric, or coal power plants. Additionally, some number of DERs with different technologies, such as wind turbines, solar panels, and CHP units, could be combined and connected to the electricity network as a virtual power plant (VPP). All these power sources are connected by smart ICT. (Bühler, 2010)

3.2 Transmission entities

The generated power is transmitted to the distribution network through the transmission line and substations. Large and medium size plants produce power that is transmitted to the network. Due of the importance of the transmission line in the case of possible black outs, our system should be self-healing in order to recover automatically. Furthermore, substations will ideally be controlled remotely and managed by the control center.

3.3 Operators

Operators are responsible for the optimal and efficient operation of the transmission and distribution of power. Information about all activities, including the monitoring, control, and maintenance, is transferred by the smart system. This component has subsidiaries such as energy providers and energy service providers. Energy provider companies supply a bundle of different energy sources (both fossil and non-fossil based) to end users. Energy Service Provider Companies (ESCO) provide investment and operation activity related consultancy services to customers. These companies may be affiliates of the energy provider companies.

Considering that the development of distributed generation (DG) has a wide effect on the network, the role of operators in this system is gaining importance. Technical parameters of the network, such as node voltages, strongly depend on the operation of DG. For example, the high penetration of DG may cause serious problems in the network. Furthermore, some households may inject their surplus power into the network during some hours and compensate their shortages at other times. Therefore, the power flow current in the network may be altered during the day at times of high penetration of DG (Mashhour and Tafreshi, 2009).

3.4 Customers

This domain generates, consumes, and stores electricity power. Customers may be a household, commercial building, or an industrial plant. This domain is one of the most important parts of the network, because they play a key role in the demand response programs. These components should be considered when talking about customers, smart energy efficient devices, smart distributed energy resources, smart control systems, and IT architecture. The customers also participate in the demand response programs to reduce their demand, and thereby the generation during peak loads at a high cost. Heshmati (2014) provides a comprehensive survey of efficient demand responses in electricity markets. In order to have an efficient participation of the customers, an advanced IT infrastructure and a symmetric information system are required. Additionally, there should be methods and incentives that encourage end users to adopt such practices and to overcome various barriers to customers' acceptance and participation.

4. Market structure

The global importance of renewable energy deployment is continuously increasing. It is usually difficult for new players to enter energy markets, but the latter are needed to stimulate the development of the renewable energy market. Without such markets, support policies, and reliable mechanisms, there are no incentives for suppliers or consumers to use electricity generated by renewable energy sources. Renewable energy sources cannot penetrate a market that is not developed or supported. Without market development, there is a limited prospect to cover individual demand. However, if renewable energy usage is connected to a commercial market, its progress is endless (similar to the wholesale electricity market). On the other hand, market development depends on transaction liquidity and the availability of commodities in the market. Therefore, the main challenges to this market are facilitating the transmission of electricity through households and the intermittent characteristics of renewable energy sources. Moreover, another market that is related to this new market would be a strong support policy and associated effective instruments.

Our proposed market provides a place to trade the electricity produced by households. In fact, there should be a balance between supply and demand in order to prevent power blockages. Currently, no marketplace exists for trading small amounts of renewable or non-renewable electricity. Furthermore, it is rather difficult to send small amounts of electricity to the transmission network. The proposed marketplace is able to prepare an environment to deal with this type of problem. Due to the increasing penetration of DG, the power industry around the world should be rapidly restructured, and the power system operation at the retail level should be changed to a market-based system that is the same as at the wholesale level. In building the new structure, DG units should be merged according to entity and controlled by an energy management system (EMS) organization, which is a crucial part of the distributed control system

(Mashhour and Tafreshi, 2009).

This section considers the micro-grid concept. A micro-grid consists of a large number of households that are able to connect as micro generators, which then have the capability to reduce energy consumption at peak time periods and justify demand at other times. Therefore, through market development and increasing the number of households in the market, they could reduce the demand for building new power generation capacity to cover electricity consumption. In this view, the costs (i.e., financial and non-financial) required to build power plants could be compared with the cost of our proposed market establishment. We should keep in mind that any type of power plant has a limited capacity, and it is necessary to build a new plant only when demand increases. However, the proposed market is flexible, and it has the capability to develop if the required infrastructure (e.g., IT facilities, intelligent devices, etc.) is available.

By analyzing the incentives of customers to participate in a smart network and by studying the structure of distributed energy resources in order to establish a market, one can identify five major restrictions in widely using renewable energy as follows:

- The risk of accessibility to external resources;
- It is costly to replace old devices for new ones for integrating them into the existing IT infrastructure;
- Different pricing mechanisms cause uncertainty about the actual cost of a resource;
- Reliable models for distributed energy resources that are applicable in the real world do not exist; and
- The penetration and liquidity of energy sources is limited.

The analysis of these objectives show that a solution can be a market for trading renewable energy. This market would also have the capacity to provide support and consultancy services in order to help customers integrate a demand-response program into their existing IT infrastructure. Of course they might change their home appliances to smart devices, but the support services would help take advantage of the current IT network. A number of information-related objectives are important in encouraging customers to use energy efficient devices.

In recent years, concerns about the effects of greenhouse gases have increased. The awareness of this issue and rising energy prices has stimulated end users to improve energy efficiency. This stimulus includes micro-generation, energy storage, and efficient home devices. It will affect electricity infrastructure in the future, and, consequently, the structure of the electricity market will change. Currently, trading in electricity markets is one-sided. In other words, suppliers sell electricity to end users. In line with our argument, in the future, end users will be able to produce electricity in order to use at home or trade it. Since price setting is a crucial part of any market, it is important to provide a mechanism and attractive incentives to customers for trading their energy resources. This trading mechanism will be made possible by using a smart network. Accordingly, these customers need to use new devices in order to take advantage of the smart grid system; however, this procedure is costly because smart meters must be installed. According to the estimates of Faruqui et al. (2010), this cost for the EU would be 51 billion Euros, while the operational savings would be worth between 26 and 41 billion Euros, resulting in a gap of 10-25 billion Euros between the benefits and costs. They argued that smart meters are able to fill this gap, because they enable provisions of dynamic pricing, which reduces electricity consumption at peak times and lowers the demand for building and operating non-base load costly power plants.

In recent years, many market mechanisms have been proposed for trading computing resources, aimed at economically efficient resource allocation (Altman et al., 2008). In a real market, commodities are traded in a certain location. The main index of such a market is that the same goods are offered by different suppliers, whether their identity is known or not. In addition, the price is determined by the unit cost, marginal cost, and the supply and demand of power. All market participants decide the payment amounts for buying or selling commodities. Since the main objective of a smart grid market is to provide end users with electricity regardless of the particular energy provider, we can apply the concept of a natural commodity market to the proposed renewable energy market mechanism.

5. Requirements for establishing market

In this section, the fundamental requirements of designing a marketplace for smart grid and the details of its market mechanism are explained. In general, a market for trading renewable energy will work if the following conditions are achieved:

- Pattern of individual demand for renewable resources is bold;
- Individual storage is possible for owners of renewable energy; and
- Adequate technology for implementing this market is available.

In addition to the above three conditions, three principal prerequisites must be fulfilled. First, a friendly user platform should be designed to enable the market participants to communicate and trade. Second, technology for commoditizing energy resources must be easily used by all people, even those who are not highly educated. Many people in urban areas, and especially those in suburban areas, are not familiar with smart technology. Hence, it may be difficult for them to use new devices controlled by smart meters. Third, sufficient information should be available to all customers. In making decisions to buy an intelligent appliance and participate in smart energy market, consumers need to have all available information regarding electricity price, electricity consumption, and initial cost.

5.1 Infrastructure

The main infrastructure components required to establish this proposed renewable energy market are listed as follows:

1. Communication: ICT infrastructure is a key component in this market, including internet based technologies and services, internet protocol based services through broadband availability, virtual private network, wireless technology, etc. (You, 2010).
2. Science-technology infrastructure: The required technology should be available to

control micro grids, coordinate distributed generation, and aggregate resources. Furthermore, smart meters are needed to record data properly, and applied scientific knowledge and skills are needed for knowledge transfer, education, etc.

3. Storage facilities: Due to the intermittent character of wind and solar generators, a storage facility is required. Furthermore, to allow an islanded operation in the micro grid network, which is based mainly on distribution energy sources, storage facilities should be available. Four main tasks addressed by storages include: dispatch ability, interruptibility, efficiency, and regulatory-driven needs (Tester, 2005).
4. Device provisioning: This component connects a newly installed smart meter with the customer's account, and it connects an increasing number of home appliances in each household to the correct smart meter (Sioshansi, 2011).

Market participants need a reliable and complete integrated infrastructure (power grid, IT, etc.) for doing business. The IT communication infrastructure should be provided by the government before the market creation step to enhance an effective operation of the market. Considering that the micro-gird market is internet-based, managing a wide, large-scale communication network is required. Therefore, the IT infrastructure should include both accurate data recording and the integration of diverse applications (i.e., software, micro generators, and home appliances).

As Oliver and Jackson (1999) pointed out, satellites, remote industries, remote communities, solar home systems, remote houses, and consumer products could be considered a niche market for solar photovoltaic (PV). The unit cost of competitors' technologies must be determined in order to select a feasible technology for application in the market. The growth of market sales affects the scale of innovation in the US, Germany, and Japan. In the future, the feasibility of the solar PV system will increase as it expands geographically (Huo et al., 2011). Of course, a reliable political framework is required to ensure both a return on investment and continuous research on cost effective materials, device designing, and improved efficiency (Jäger-Waldau, 2006).

The importance of distributed generation in the electricity network was discussed earlier. An appropriate science-technology infrastructure, such as a virtual power plant (VPP), is required to control and manage the power generated by individual units. It is possible to employ a VPP constituted by a large number of customers with controlled home appliances in order to ameliorate network congestion (Ruiz et al., 2008). Therefore, ICT infrastructure is considered a key component in this market. We cannot apply smart metering if appropriate ICT facilities are absent.

5.2 Regulations

In order to improve energy efficiency and power generation by renewable energy sources, high-level management is required for the development and implementation of policies and programs (Gellings, 2009). There are different kinds of barriers relating to the market (e.g., information transparency, fossil fuel subsidizing, financing), technical issues (e.g., lack of skilled workers, knowledge transfer, intellectual property rights), and public acceptance (e.g., lack of knowledge, lack of interest, avoidance of comfortable decreases), as well as the compatibility between current operating systems and new technology implemented in the renewable energy market (e.g., data recording system). These barriers should be removed in order to facilitate the optimal environment for renewable energy market creation.

It is worth mentioning that no single regulation in the world works well with such comprehensive market mechanisms and requirements. Depending on the conditions and player interest, different complementary policies are required to achieve this goal. According to the argument by Gunningham et al. (1998), a range of policies are available to use for environmental protection: command and control regulation, self-regulation, voluntarism, education and information instruments, economic instruments, and free market environmentalism. Education and information are categorized into education and training, corporate environmental reports, community right-to-know, pollution inventories, product certification, and award schemes. They also categorized economic instruments as property rights, market creation, fiscal instruments, charge systems, financial instruments, liability instruments, performance bonds, deposit refund systems, and the removal of perverse incentives.

Since our proposed market includes different players, such as the major power generators (including fossil fuel and non-fossil fuel generators), distributors, service companies, and consumers (including industries, commercial building and households), the interactions between parties are also equally important. Therefore, we should pay attention to this issue when we discuss regulation. Furthermore, external factors should be considered in order to maintain the stability of our policy and avoid causing uncertainty among the market players regarding policies and regulations.

In order to establish a successful market-based micro-grid, we use a combination of the above-mentioned instruments as a regulatory framework. Governmental regulations described below are set to control and manage the market.

1. Command and control: These regulations apply specific standards to the energy consumption in industries, public sectors, commercial buildings, and households. This regulation could be used in combination with awards and penalty regulations.
2. Self-regulation: The government sets a specific standard for industries, and every industry self-regulates to achieve this standard. This kind of regulation is also seen at the international level. For example, the OECD sets a target for members to reduce carbon emissions, and in turn, each member self-regulates to achieve organizational targets.
3. Education and information: Education and information form a crucial parameter in developing the capacity of renewable energy generation and usage in an industry and the community. Public acceptance is one of the most important components of market development. Environmental information and training programs presented by the government could be considered a supplementary instrument to other forms of regulation (Gunningham et al., 1998).
4. Economic instruments: A wide range of economic instruments exist to encourage private companies and consumers to use renewable energy sources. These include feed-in tariffs, the reduction of fossil fuel subsidies, CO_2 emission trading, renewable fuel standards or targets, green certificate trading, emission and energy taxes, residential and commercial tax credits for renewable energy usage, the Kyoto Protocol, etc. (Hofman and Huisman, 2012). In order to stimulate market creation

and rely on market mechanisms instead of governmental decision making, it is recommended to use feed-in-tariffs that support the movement towards green certificates. Feed-in-tariff policy is related to governmental budget, and it may be not stable in cases of some economic difficulties, like a financial crisis. Decreasing or cutting financial support by feed-in-tariffs has a negative effect on the market, while continuity and sustainability in a policy are the most important factors for success.

The planned target plays a crucial role in the selection of market instruments. For example, as previously discussed, using a harmonized feed-in-tariff (FIT) is almost impossible at the European level because of the intention to promote green certificates instead of FITs to meet the upcoming market demand for emission certificates (Ringel, 2006). However, when no target has been set for creating market oriented renewable energy sources, the FIT policy is able to compensate the negative impacts of low electricity prices on the feasibility of solar PV. These costs could decrease rapidly over time with innovation and technology development (Rigter and Vidican, 2010).

Stability is an important issue that should be seriously considered regarding policy making. Any regulation set by policy makers should be stable. It should be mentioned that, in addition to grid modernization efforts to enhance energy efficiency and adapting current policy, a regulatory framework and market environment are crucial in supporting new technology investment. Suppliers and consumer will not be attracted if they cannot trust the policies due to uncertainty. For example, the financial crisis has forced some European governments to use feed-in tariffs in order to cut their subsidies (Hofman and Huisman, 2012). Public views and investor decision making are affected by this type of issue. Environmental policies and all related supportive instruments, especially economic ones, should be selected properly and considered high priority in government planning. Foxon et al. (2008) provided three areas of concern regarding the sustainability of current policy-making procedures: a low priority compared to the immediate policy pressure, the interaction between problems in addition to uncertainties about future costs, and every plan to achieve stated targets is inevitably contested.

6. An optimal model of a renewable energy market

In order for customers and suppliers to accept a market, it is crucial that the market place be able to meet the following objectives:

- In order to prevent power outages, the supply and demand must be balanced all times. Energy resource offers should be monitored. Therefore, it is assumed that there is no fluctuation in the power network for the market place;
- In order to guarantee customer’s security, energy providers are not allowed to give the customer’s information to third parties;
- In order to gain acceptance of the market place by customers, the marketplace should provide access to energy resources in a transparent and simple way. Furthermore, incentives should encourage customers to use market place services;
- There should be no barriers to entering or exiting the market. The number of participants in the market should be sufficiently large; and

- The information system connecting market participants should be symmetrical.

Offers to sell excess energy resources are matched with orders that have already been placed. The task of the marketplace is allocating time and facilitating financial transactions of private resources.

6.1 Market mechanism

Different market mechanisms are used for trading commodities. A continuous double auction (CDA) is the main market institution and is used widely in the existing related markets, including stock exchanges and commodity markets. The CDA mechanism matches buyers and sellers of a particular good, and it determines the prices at which trades are executed. The specifications of electricity differ from other commodities, due to the small unit of trade and extra cost of using batteries to store electricity. As such, we use future contracts to trade electricity in our designed marketplace. This type of contract is designed for use in the wholesale electricity market, but it can also be used in the retail market and smart grid network.

Since power companies use blocks for end users, future contracts can adopt this system. Of course, these contracts could also be used in dynamic pricing. Electricity prices are volatile because demand changes continuously, depending on the time of day and weather conditions. The unit of trade and bid-ask procedure can optimally be defined as follows:

Unit of trade

The most important factor in this market is the unit of trade because it is small and is not available in any other markets. Therefore, we should organize our market based on this unique capability. The format of the specification of the unit of trade is defined by the following three parameters:

- Start time: It is the time at which the resource is available for the buyer or the time that the resource is required by the buyer.
- Unit duration: This is the standard length of time that the resource will be available to the buyer or the shortest period that the resource will be required by the buyer. The unit duration is set according to the acceptance of users within the marketplace. The unit of trade is one hour in the traditional power market. However, because of the size of the proposed market, we can use a smaller division, such as five minutes of unit duration.
- Unit volume: This is calculated based on kWh, but the total volume should be defined in the contract.

Bids and Asks

Based on the unit of trade, we define bids and asks. An ask is submitted by a customer who owns extra electricity and wants to supply it to the market. The bid is submitted by a customer who needs extra electricity at a low price. These customers may be households, commercial buildings, or industrial sectors. The unit of trade, bids, and asks comprise the following parameters:

- Price: This parameter defines the minimum price that a seller is willing to accept or the maximum price a buyer is willing to pay for a unit of trade. We should consider additional items that are usually added to the unit price. There are additional charges regarding option contracts or settlement operations (in some cases) which should be included in the requested price.

- Volume of resources: This parameter defines the number of units of trade. Due to the small size of the unit of trade, each buyer may purchase the required electricity from the pull of several sellers.
- Duration: This is based on the dynamic pricing period, which is used by power companies to set the price of electricity consumption. The minimum duration is one hour because the kilowatt hour is used as a billing unit for energy delivered to consumers by power companies.

In what follows, we explain an example of renewable electricity pricing for a typical customer in order to show the abovementioned conditions and procedures. Table 1 shows the electricity price which is printed on a utility bill in Seoul:

Table 1: Electricity Price – December 2012

Electricity Consumption (kWh)	Price Rate (won/kWh)
1-100	57.90
101-200	120.20
201-300	179.40
301-400	267.80
401-500	398.70
Excess of 500	677.30

Ref: KEPCO

There is a positive relationship between the unit price rate and the quantity consumed. For instance, for a customer who is in the range of 301-400 kWh, the electricity price is 267.80 won/kWh for excess electricity consumption exceeding 300 kWh and 179.40 won/kWh for excess electricity consumption to 200 kWh. Therefore, it is economical for the former customer to pay any amount lower than the mentioned heterogeneous price.

For example, a customer who consumes more than 300 kWh could use a renewable energy generator, like solar PV, to reduce their consumption and keep itself in a lower category or buy a contract from the customer who generated electricity by renewable energy sources. The price should be sufficient for covering the unit cost and provide a reasonable excess return to the renewable energy supplied. The result will be economical for the buyer if it is lower than 267.80 won. Obviously, electricity generated by renewable energy sources is not compatible with a subsidized system. A prerequisite for taking advantage of this type of transaction is market liberalization with an aim to enhance the effective operation of the market to lower prices.

The excess electricity, which may be offered by a contract, in this mechanism is not too high. Therefore, the buyer may buy several contracts at different prices. Since the contracts have different ranges of electricity consumption, accordingly, the optimal price is not the same for all ranges and quantities. Due to price fluctuations in the electricity market by the time of the day, week, or season and location, the participants can use option contracts as derivatives to cover possible market supply risks.

6.2 Market performance evaluation

Performance evaluation is a crucial part of market creation. An essential goal in establishing this market is energy efficiency. Although the investments in many projects involving energy-efficient technology show good economic results, the percentage of their successful implementation is less than expected, resulting from barriers that discourage decision makers, such as households and firms (IEA, 2012). The lack of a measurement of energy efficiency has led to the effect that opportunities are not fully visible. Hence, no decisions are made to take advantage of them. We have to define some indices to show households, firms, and policy-makers the economic and environmental benefits of the micro-grid market.

A different type of index could be calculated to evaluate market performance some of which are used in current markets. For example, Energy Exchange Austria (EXAA) is a European energy exchange headquartered in Vienna that covers energy trading in Austria and Germany. Table 2 shows some selected indices in EXAA, which are applicable to the proposed micro-grid market.

Table 2: Key Performance Ratios for EXAA

Key Performance ratios	**2010**	**2011**
Sales revenues (in Euro)	2,030,159	2,324,493
Spot market electric power:		
Trading volume in GWh	6,410	7,558
Clearing volume in Euro	292,146,570	390,236,567
Number of trading members	90	71
Spot market CO2 allowance:		
Trading volume in t	88,401	19,179
Trading volume in Euro	1,260,481	269,072
In % of Austrian consumption:		
Market share	10.7	13.1

Source: Annual Report 2011, EXAA

In addition to the numbers used for the energy exchange center, other indices, such as storage capacity, storage inflow, storage outflow, generation capacity, installed generators, and load shift numbers, could be calculated to analyze market performance.

Of course, because of the small amount of electricity traded in the micro-grid market, the unit volume is in MWh instead of GWh. In addition, the CO_2 savings number could be calculated as an index, and could represent the share of market participants contributing to CO_2 savings.

Another approach to evaluating market performance is the decomposition method. By calculating the renewable energy intensity and performing a cross-national analysis, we can compare market performance in countries that have planned to mitigate the effects of energy consumption and carbon emission on climate change. For example, this kind of analysis could be used by the OECD in order to compare members' achievements. In addition, the economic side effects of funding the micro-grid market could be evaluated by economic indices. For example, producing companies will be affected by market development and this effect could be measured according to the rate of production, employment, payroll, number of patents, R&D investment, number of skilled laborers, or education investment, all of which are considered economic effects of the market creation.

7. Summary and Conclusion

Energy efficiency is one of the most important approaches to reducing electricity consumption in current times, as well as in the future. Information and communication technology play important roles to achieving this target. In particular, a smart grid can achieve a higher rate of energy efficiency by integrating information technology and establishing interactions between suppliers and customers. The concept of a grid market is already created for computing resources. For instance, some scholars have expressed views about the potentials of virtual power plant and micro sources already.

In this paper, we tried to design a similar market for renewable energy resources. At first, we need to recognize the components of a smart network. All components should have this capability to be managed by an automated system. We should keep in mind that new technology to deploy smart control and management is required. Also, it should be compatible with the current system. Next, we analyzed the regulatory framework and introduced some instruments for the efficient operation of the proposed market.

By analyzing the incentives of customers to participate in a smart network and by studying the structure of distributed energy resources in order to establish a market, we have identified the existence of 5 potential major restrictions to the wide use of renewable energy. The analysis of these restrictions has indicated that a solution can be a market for trading renewable energy generated by micro sources. This market has the capacity to provide support and consultancy services in order to help customers to integrate demand response programs into their existing IT infrastructures.

Considering that the market mechanism is the core of a marketplace, we defined different parameters, such as the start time, unit of duration, and unit of trade, for the optimal functioning of the proposed renewable marketplace. We explained our proposals for the smooth function of the market mechanism. We the suggested some indices to evaluate the market's performance. These indices include: sales revenue, trading volume, storage capacity, installed generators, CO_2 reduction, etc. Finally, we proposed a combination of a few complementary policies for building the necessary infrastructure, removing barriers, and the financial support for market creation and its development and effective operation. Furthermore, we emphasized that the stability and sustainability for any effective policy and regulation is one of the most important factors to enabling the successfulness in the new market operation.

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