Perspectives on Published Energy Sources and Smart Energy Supplies

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This article presents a perspective of the several modern alternative energy generation technologies. Moreover, authors facilitate the case study of the application of an emerging energy blockchain (EBC) technology and the Published Energy Sources (PES). A methodical analysis utilizes the EBC input parameters as follows: power generation such as multi-energy complementarity, energy storage, and the smart grid power that has a smart meter and/or control within the EBC system. On the other hand, the EBC technology has several variables as output that includes the following: (1) power consumption focusing on renewable energies; (2) technology enabling financial saving and earning method; (3) peer to peer energy transaction according to the EBC platform.

Introduction

There are significant needs in the world to address pain points in the energy sector shortage that has stable energy supplies; to meet challenges in both environmental carbon footprint and sustainable energy supplies [**1-2**]. Fortunately, breakthrough technology originated from the research community has provided a great selection of promising solutions to address the above needs up to date. For example, the solution to alternative energies includes solar photovoltaic cells, wind power, ocean energies such as ocean thermal energy conversion (OTEC) and tidal wave energy, thermal energies [**3-9**], hydrogen fuel cells, and energy storage technologies, etc. This selection has become available at various commercial stages; and some of this selection is the green energy that has zero carbon footprints. In this article, the authors provide a perspective with methodology and technology to develop sufficient energy availability and to reduce the carbon footprint. Moreover, they provide/ review a simplified published energy source (PES) framework.

The scientific study of many energy technologies is tremendously interesting for scientists and researchers worldwide. The scientists have made numerous advancements in energy technologies in terms of their commercial applications. The criteria of the available energies include that these energies are sustainable and that implementation of the integrated energy technologies can meet the needs in demand and supply of a sustainable community [**1**].

There is an issue in many cases that PES includes some alternative energy that fluctuates significantly in the total power output. For example, solar power is zero at night, and the wind power fluctuates during the day and night but also varies with the season. Nevertheless, the fast-advancing technology has already progressed rapidly and has provided solutions in much alternative energy as demonstrated in Europe, Asia, and North America.

A solution to address the above issue is that the research communities propose an integration of many types of complementary energy sources [**10-12**]; they propose the energy Internet where various types of energy sources function in synchronization that modernizes the supply method of electricity. These types of energies are connected through either intranet or internet so that the energy Internet has good stability in output power and/or has a high quality of merit for the applications.

Finally, the energy Internet has struggled to achieve its claimed "disruption" because it is still just a digital mapping on units of existing centralized energy systems. Its essence is currently that it connects various units in terms of the original energy data; and the Internet is needed for various roles of energy producers, prosumers, and consumers. Among the afore-mentioned roles, prosumers is recognized as the important ones who produce and consume energy and who, at the meantime, trade excess energy through the e-transaction layer, that is the e-commerce of their energy Internet. The rise of the blockchain technology [**11**] has finally brought the vision of the energy Internet closer to realization.

Selected survey of many alternative energies

Solar energy and wind energy are among the fastest developing and most widely used distributed energies. The current market transactions mainly involve distributed photovoltaic and distributed wind power plants, as well as ocean thermal energy conversion power stations that can be implemented near the coast and on the island. Many examples are shown in the **Fig. 1** that illustrates various clean energy sources.

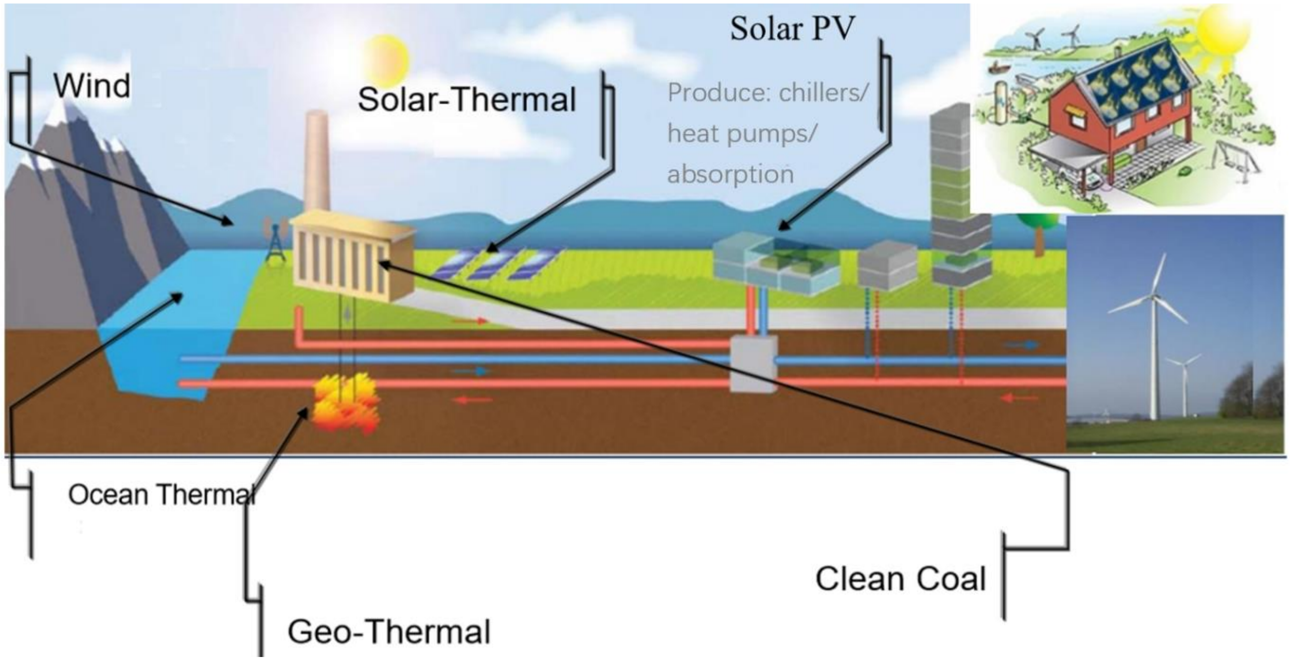

Fig. 1. An overview of many clean energy sources with graphical illustration. The figure has illustrated solar power, wind power, OTEC and energy storage as a whole that function in totality as the distributed energy source for stable power output to consumers.

Solar photovoltaic power generation

Solar PV cells directly convert the solar irradiation into electricity that the conversion is governed by the law of Physics, namely, Photoelectric Effect.

The output characteristics of photovoltaic cells are mainly affected by objective ambient temperature and light intensity. And the steady-state output power of photovoltaic cells in engineering is commonly used as the following simplified model [**13**]:

$$P_{PV} = P_{STC}\frac{G_{AC}[1+k(T_c-T_r)]}{G_{STC}} \quad (1)$$

where, P_{PV} is the output power of photovoltaic cells; G_{AC} is the light intensity; P_{STC} is the maximum output power under standard test conditions (intensity of incident light of 1000W/㎡ and the ambient temperature of 25℃); G_{STC} is the illumination intensity under standard test conditions, taking the value of 1000W/㎡; k is the temperature coefficient of power; T_c is the operating temperature of the panel; T_r is the reference temperature.

The illumination intensity is affected by some random factors, but it is mostly affected by the law of the earth's rotation and revolution. For example, the variation rules of light intensity within 24 hours of one day and the annual seasonal change.

The solar PV is brought into disruptive technology. As the cost of production has come down significantly, the efficiency of some solar cells has improved greatly. The cost is near the grid parity. In practice, to constitute a distributed photovoltaic power station of a certain scale, photovoltaic cells are often required to be connected in series or in parallel in a certain way. Usually, the influence of the performance and environmental differences of a single photovoltaic cell on the output power will be amplified in the photovoltaic power station. Liu *et. al.*, [**14**] have introduced a photovoltaic power generation power prediction modeling method with a four-level structure of cells-components-groups-square-array, and have studied the influence of environmental factors leading to battery performance deviations at any geometric position on the output power of the entire square-array [**13-14**].

Besides the traditional silicon-based solar cells, there are many solar cells such as III-V and II-VI type semiconductor cells. Moreover, the next star solar cells are expected to be Perovskite solar cells in perspective that have achieved higher efficiency and lower cost so far than single crystalline silicon cells.

Wind power generation

The wind power is always present on our planet due to uneven heating of the earth's surface by the sun and the so-called Coriolis effect of the earth spinning which relates to the wind being dragged by the constant rotation of the earth on its axis. The wind turbine manufacturing is cleaner than the volume production of solar PV cells.

The conversion of wind to electrical power is generated by a wind turbine. Incentivized by governmental and private partnership. When planning and designing the installed capacity of wind turbines, the wind resources is generally considered in the region in details. The modern wind power technology (such as the wind turbine) has been perfected over the last two decades.

The output power of the wind turbine is determined by the installation height and wind speed of the fan [**15-16**]. A wind turbine power plant typically generates the electricity in much the same way (through electromagnetic induction) as the alternator in a car. A wind power station is usually positioned such that its rotor always faces the wind. The power engine produces the wind power that depends on three variables: wind velocity, the radius of the generator, and temperature, which determines air density. The following is a simplified summary of this relationship to the operational state of the wind turbine [**16**]:

1. The power increases with the cube of the velocity.
2. The power increases with the square of the radius.
3. The power increases with decreasing temperature (with about 3.3% of power for the change of every 10°C in air temperature).

OTEC system

OTEC has high development and utilization value due to its renewable, stable, clean, and pollution-free characteristics. The system uses the difference in temperature between the surface and deep seawater to convert heat into electricity. The power generation of OTEC is mainly affected by the temperature difference between deep and surface seawater. As seawater temperature changes quite small during the day, OTEC is a relatively stable energy source and it can accept the dispatching of microgrid or power grid. It can effectively make up for the uncertainty or fluctuation of other energy when it is used complementarily with other energy.

The idea of using ocean thermal energy to generate electricity was first proposed by French scientist J. D. Arsonval in 1881 [**17**], but it was not until the 1973 oil crisis that substantial progress was made. In 1964, American scientist J. H. Anderson *et. al.*, designed a new type of closed-cycle OTEC power station. Since 2008, significant progress has been made in the research of some key technologies; and the small-scale demonstration of thermoelectric generation has come a long way. In order to improve the efficiency of OTEC system, the solar auxiliary heat [**18-19**] has been introduced by Ding's and Aydin's teams who have significantly increased the gas temperature at turbine inlet, and who have increased the energy output by 20%~22%. Wang *et. al.*, [**20**] integrated various new energy generation methods such as solar energy, wind energy, and ocean current energy into the ocean thermal energy system, and improved the efficiency of the thermal energy generation system to 5.11%. Based on studies in computer-aided design and simulation, Li. *et. al.*, have achieved higher efficiency, at 13%. [**19, 21**].

$$\eta = \frac{P_j}{Q_e} = \frac{P - P_g - P_{wm} - P_{cm}}{Q_{we} + Q_{te}} \quad (2)$$

where, P_j is the net output power of the turbine. P_g is the actual power consumed by the pump. P_{wm} is the power of the motor with the warm sea water pump. P_{cm} is the power of the motor with the cold sea water pump. Q_e is the heat absorbed by the working fluid. Q_{we} is the heat of absorbing warm sea water for the working fluid. Q_{te} is the heat of absorbing solar energy for the working fluid.

Finally, the **Table 1** has listed a variety of renewable energy technologies that includes efficiency of each technology and its status, and related literature(s):

Table 1. A tabulation illustrates the conversion efficiency for various clean energy technologies.

Renewable Energy Technology	Efficiency	Status and Reference
Solar Energy	25 ~ 30%	Lab for Perovskite, othe PVs refers to NREL [**3, 22-24**]
Wind generators	up to 70%	Lab [**25**]
Ocean Thermal Energy Conversion (OTEC)	1% ~ 5%	Lab and Production [**26-27**]
Solar OTEC (SOTEC)	7% ~ 13.12%	Lab, Simulation [28-29]
Clean Coal	48% ~ 60%	Production, RnD [**30-31**]

Energy storage, and demand response

Energy storage

Various sources in renewable energies have the characteristics of intermittency, volatility and uncertainty. With the increasing energy sources of renewable energies that are fed into the power grid, it brings great challenges that power needs the safe and reliable operation through the power grid. The energy storage system can effectively overcome the uncertainty of renewable energy systems with its operation characteristics of charging and discharging [**9**]. One of the energy storage studies is shown in the **Fig. 2** as follows. In a system that has wind-solar complementary power generation, energy storage and controllable load, the energy management system centralized manages energy storage system, electric vehicle load and controllable load for demand-side response, the energy management system (EMS) conducts dispatching of generator sets. This microgrid provides peak cutting and valley filling assistance services, it reduces the cost of electricity for users and the volatility of renewable energy when connected to the outside grid; furthermore, it increases the stability and reliability of the outside one.

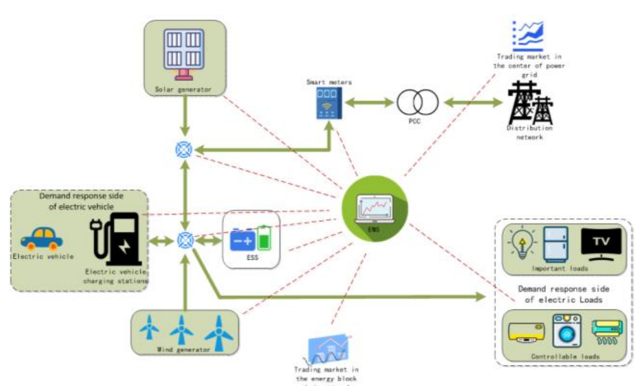

Fig. 2. Wind-solar complementary microgrid is based on demand Response. In this system with wind-solar complementary power generation, energy storage and controllable load, the energy management system centralized manages energy storage system, electric vehicle load and controllable load for demand-side response, and conducts dispatching of generator sets. This microgrid provides peak cutting and valley filling assistance services, reduces the cost of electricity for users and the volatility of renewable energy when connected to the grid, and increases the stability and reliability of the grid.

Currently, the energy storage in the power system has main functions as follows. Firstly, for unstable energy systems such as solar power generation and wind power generation, the energy storage system can stabilize the output and provide a certain range of energy and power support; and eventually achieving the purpose of smooth fluctuations and stable output power. Second, the energy storage system can improve the power quality of the distributed generation system as a whole by maintaining the stability of the distributed power network, balancing power demand, and reducing system disturbance.

When the energy storage system has enough capacity, ES can provide several hours or days or longer energy support. It can realize energy dispatch and management of power grids. ES has usually the effect of peak levelling, emergency mitigation; and it can at the same time reduce costs, improve economic efficiency. The power producer can use some electricity during day to supplement the night demand, thereby reducing the capacity of power generation system as a whole and reducing the construction cost.

One of the most exciting topics in research and development is the hydrogen fuel cell, particularly the solid oxide fuel cell (SOFC). Without discussing details of traditional energy storage and Li-ion battery, the SOFC study as one of the hydrogen fuel cells is discussed as follows. Even though it is typically the case in the fuel cells that the positively charged hydrogen ions travelling from the anode to the cathode, in contrast, SOFC operates differently with oxygen ions traveling [**32**]. In contrast to the usual motion that H+ ion moves through in fuel cell, the SOFC system can be expressed as follows:

Anode reaction: $2H_2 + 2O^{2-} \rightarrow 2H_2O + 4e^-$

Cathode reaction: $O_2 + 4e^- \rightarrow 2O^{2-}$

Overall cell reaction: $2H_2 + O_2 \rightarrow 2H_2O$

Finally, the above formulae complete the whole reaction. SOFCs are unique since that in these, negatively charged oxygen ions travel from the cathode (positive side of the fuel cell) to the anode (negative side of the fuel cell). To date, the SOFC system can run on fuels other than pure hydrogen gas and it may unfortunately run at a high temperature. Despite its unfortunate disadvantage of a high operating temperature, it is advantageous by cost saving without a need of precious metal catalyst like platinum.

Demand response and a distributed energy trading approach

Distributed energy has the advantages of small scale, convenient installation, and flexibility. In recent years, more and more distributed equipment has been installed that gradually becomes an important source of power generation. However, distributed energy which is often unstable in power generation is difficult to regulate, which also makes it more difficult to trade freely in the market. The traditional trading between market players mostly adopts a centralized model: the data of power generators and users are uploaded to the central processing system, and the power generators and users are matched through centralized matching or optimization. As the distributed energy resources increase in various types and output number and scale, the data and various information of transactions increased. Centralized decision-making method will make the operation cost of transaction centers become higher and time cost increase. If the trading center is attacked by external hackers, the security of the transaction, and the privacy of participating subjects cannot be guaranteed. Under this backdrop, the distributed trading pattern with many participants and small transaction volume has gradually become a trend [**33-35**]. In the process of distributed transaction decision-making, there is a lack of central supervision mechanism.

Blockchain [**36**] is a distributed transaction technology, which has the favorable data tracking characteristics of intelligence, marketization, decentralization, and non-tampering. The application of blockchain technology to distributed energy can give full play to its advantages of security, reliability, and transparency of transactions. At the same time, it is consistent with the decentralized network structure of distributed energy. The blockchain technology is applied in the distributed energy system, where power transactions are conducted directly between users, and transactions are managed by distributed and cost-effective rather than third-party centers. In a decentralized energy system, energy supply contracts can be communicated between producers and consumers. The emergence of distributed energy makes energy consumers change their identity to producers and consumers. The addition of blockchain will make a large number of transaction demands directly generated between producers and consumers, which can realize transactions with low marginal cost. Based on blockchain technology that will allow local energy producers' and consumers' deal to trade local energy that is direct deal without the involvement of a third-party monitoring platform centered on the grid company. Thanks to encryption processes and distributed storage, transactions almost eliminate the possibility of tampering with data. By combining blockchain technology with micro grid, users have the right to return surplus photovoltaic power generation to the power grid.

Integration and Published Energy Sources (PES)

One of the significant applications of the energy Internet is the technology in the distributed energy sources system that leads to the energy blockchain (EBC). It is the distributed energy that is often owned by the prosumer who produces and consumes the energy locally; it has the advantages of small scale and convenient installation which is becoming growing sources of power generation. However, it has a challenging issue to trade freely in the market. The EBC is a platform in order to overcome this challenge. This platform is powered by the technologies of both energy blockchain and smart power management system. It takes inputs from power generation such as multi-energy complementarity, energy storage, and the smart grid power shown at the left side. It produces output including these variables: renewable energies consumption; transaction technology and method; peer-to-peer energy transaction according to this platform. The outcome is energy saving, residential smart energy management, and mathematical models of return on investment.

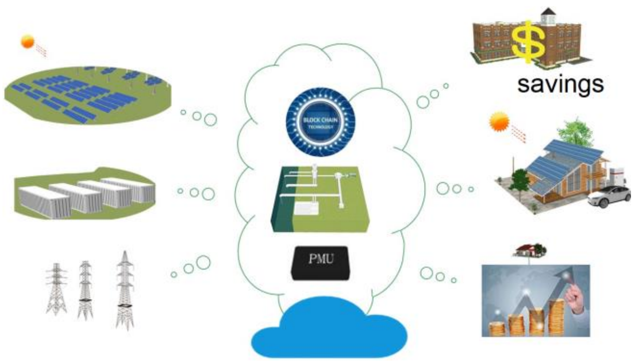

Fig. 3. The Energy blockchain network takes input from power generation such as multi-energy complementarity, energy storage, and the smart grid power shown at the left side of the figure. It produces output including these variables: renewable energies consumption; transaction technology and method; peer-to-peer energy transaction according to this platform. The outcome is energy saving, residential smart energy management, and mathematical models of return on investment.

The PES approach is tremendously useful to govern a prosumer's value dependency law and to work out with an application below [**12**]. Specific input parameters include the following: the rate of power generation feeds into grid power (GP). Moreover, the energy storage is included in the application. Among several output variables, the one solution to solve for is the financial saving and earning (SE), the benefits of energy ES, and peer-to-peer transaction.

The input parameters are measured data having time variance. These parameters are monitored daily and have a weighted average to influence the output. The output variables, e.g., Fin, deliver results to a prosumer on CP who can make decisions based on the following equation and the data from the input parameters.

$$Fin(t) = \int dt\{[PG * \alpha_1(t) - CP * \alpha_2(t)] \times p(t) + ES \times \alpha_3(t) \times \Delta p - GP * \alpha_4(t) \times p(t)\} \quad (3)$$

Various input parameters are the measured data that have time dependency, and that is integrated over time as shown in eq. (3).

The PG is an input parameter, e.g., of the total solar PV generation (from specification); with a1 being an ambient power coefficient that has a range of (0, 1) and varies with time during the day. p (t) is a scheduled price from the utility provider.

CP is an input parameter dictated by a prosumer who decides how many in total household power to use for what time in which day. In eq. (3), CP is multiplied by a2 where a2 is a parameter that ranges (0, 1) for the distributed power deployment or that may be a customer's specification.

Normally the ES charges energy at night and discharges in the day. The energy level of ES ranges by the manufacturer's spec, e.g., between 10% to 95% during a charge-discharge cycle. The coefficient a3 in ES is the effective charge-discharge rated coefficient that ranges (-1, 1). Its actual range may depend on the manufacturer's specifications. GP represents the grid power input that is a parameter for prosumer to decide. In the equation, the term GP is as a4 * GP, max; where a4 is an ambient power coefficient that ranges from 0 to 1. A smart meter connects EBC to the external grid. p (t) is the price-schedule of electricity.

There are separate studies; Lu *et. al.*, [**38**] have previously found that each of the photovoltaic capacity and the energy storage capacity in deliverable power should be higher than the peak power of the family use.

A typical hardware structure delivers the important input parameters of the system. Inside a local access network (LAN) in particular, the Energy LAN framework, the power supply side can be made of wind turbines, solar photovoltaic (PV) unit, OTEC, energy storage framework, and the external power matrix. The power demand side is made of the traditional load, power transaction, and published available energy storage. Under the activity of the automated demand reaction mode, the demand-side energy storage coordinates its various variables and operation algorithm. Under the condition that the inventory of renewable energy is equal to or higher than the traditional load demand, the energy storage framework may decide and react to the framework by charging or discharging the ES.

As indicated by its charge condition, the energy storage framework can alter its charging and discharging mode to compensate for the change in renewable energy output, ES is designed with its end goal that provides stable power. Moreover, ES can realize the need to demand and electricity transaction cost; it improves the use effectiveness of renewable energy and the grid load leveling. Under the condition of obtaining power from the power grid; the published capacity of PES is dependent upon the present energy storage condition. The power control system is a bidirectional energy transference mechanism that causes energy transaction between the energy storage framework and the power grid. It is equipped with all universal communication interface to acknowledge charge and discharge mode switching, and power control function by accepting the control strategy issued by an upstream controller. What's more, it can execute the digital command by a battery management system in the downstream. Smart electric meters acknowledge two-way metering, recording both energy storage consumption and power output.

Conclusions

There is a great significance to move forward with the currently available research and development including the distributed energy sources and to further develop the solution of energy blockchain as well as published energy sources. To explore a thorough energy solution, authors have investigated the recent exciting development in the areas of theoretical, methodological, and/or a technological framework of the alternative energy. There is a great opportunity for prosumers to select the winning solution on energy supplies. In order to win over the market promotion in EBC areas, more RnD and more community support will propel the alternative energy market greatly. For renewable energy application, the energy storage is a necessarily added unit. For example, stabilizing sources such as hydrogen fuel cells, energy storage, or OTEC are very much needed as integrated energy supplies for general distributed energy system like the solar and wind renewable energies. As the published energy sources is a huge opportunity for advances in the areas of advanced materials, the distributed energy can offer viable solutions for sustainable communities in terms of energy applications. The government incentive and private investment in the frontiers of renewable energy development offer huge opportunities and can certainly pay off the investment in the afore-mentioned areas.

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Abbreviation

- PES: Published Energy Sources
- EBC: energy blockchain
- OTEC: ocean thermal energy conversion
- SOFC: solid oxide fuel cell
- NREL: National Renewable Energy Laboratory
- PV: photovoltaics

Keywords

Energy blockchain, published energy source, renewable energies, energy storage, ocean thermal energy conversion OTEC, peer to peer.

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