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Integrating Energy Storage Systems Using IoT and AI, with Renewable Energy Sources

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ABSTRACT
As a result of issues like the lack of clean energy usage in the power system and the insufficiency of power supply in agriculture, both the agricultural and power systems have had significant issues during the past few decades. This paper puts forth the notion of combining smart agriculture and clean energy usage, using surplus clean energy to supply agricultural output, and leveraging smart agriculture to assist power systems with clean energy penetration to address and resolve these concerns. First, a thorough analysis of the feasibility and benefits of linking a clean energy system with agriculture has been done. For the development of a combination system consisting of intelligent farm production and clean energy consumption, the most recent technologies and obstacles are compiled and assessed. To examine the synergies between agriculture-clean power systems in the energy and food industries, several case studies are provided.

We begin by outlining the various energy storage technologies and their many uses, such as for transportation, heating, cooling, and utility-based power generating. Second, we provide a brief overview of the states, operational procedures, and energy storage capacity of an energy storage system. Third, a thorough analysis of artificial intelligence applications is done regarding the suitability of various energy storage technologies, system configuration optimization, and energy control strategy. Finally, several topics and insights are covered, providing fresh ideas and concepts for the investigation of integrated energy storage systems in the future.
Keywords: Hybrid energy storage system, Renewable energy, Artificial intelligent, Optimization and state estimation, Control strategy

I. INTRODUCTION

For human, social, and economic growth, food and energy resources are essential. The finite resources of our world, including water, energy, food, land, and ecosystems, have been under intense strain since the dawn of the twenty-first century because of fast population and urban expansion as well as global economic development [1]. The development of the food, energy, and water resources will face new obstacles because of global climate change, extreme weather events, unequal distribution of water resources, and carbon emission requirements. The sustainability of lengthy food and energy systems will also be put to the test by diverse resource availability, restricted resource access, rising resource scarcity, deteriorated resource quality, and reduced ecosystem services.

Renewable energy integration with ESSs, wind-solar hybrid power generating systems, wind-storage access power systems, and optical storage distribution networks have all been examined by researchers [10]. The use of renewable energy, frequency management, and peak regulation of the power grid have all been made more difficult by the advent of new technology, which has further affected the system's functioning. Energy storage technology offers an efficient way to address the issues by applying various energy storage devices to the power grid and promptly and adaptably adjusting the system power. The dependability of wind, solar, storage, or distribution networks has been studied [12]. By 2030, the installed capacity of energy storage will expand globally by 42% to 68%, predicts the International Renewable Energy Agency. India and China will have the quickest rate of growth for energy storage installations by 2025, while Japan and Australia will have the highest percentages of installations [14]. Energy storage technology may be used to spread out energy peaks, control frequency, tame volatility, and provide high-quality electrical energy. Energy storage technology can also deliver a temporary energy source that can be effortlessly shifted off the grid, and the financial advantages are significant [15].

As a result, it is anticipated that renewable energy sources (such wind and solar energy) would progressively displace fossil fuels and steadily grow their share of global energy consumption [5]. The widespread use of intermittent renewable energy sources with multiple time scales, however, has the potential to have a significant negative impact on the power system's forecasting and scheduling accuracy as well as operational safety and power quality issues when power is exchanged with the power grid [14]. Therefore, it is vitally necessary for renewable energy to be employed in operation control and energy management to have a control system that considers both the sufficiency of the power generating capacity and the flexibility of the power generation [13]. It guarantees that the renewable energy generator set can operate across a wider power range, maintains the system's stable and efficient operation both in grid-connected and island modes, and reduces the intermittent renewable energy production that causes power fluctuations [14]. Their application has been increased to further enhance the ESSs' economic and environmental advantages, such as in solar photovoltaic (PV), concentrated solar thermal, and heat energy systems [15].

1.1: AGRICULTURAL TRANSFORMATION PROBLEMS AND CHALLENGES

From the perspective of agricultural output, several variables, such as climate change, freshwater availability, and soil salinity, have an impact on crop productivity [2]. Additionally, the amount of CO_2 and O_2 in the air will have an impact on photosynthesis and the metabolic process that drives plant development.

Artificial regulation of the above mentioned influenced variables of plant growth has become important to boost plant yields. The agricultural industry has started to change in favor of intelligent and autonomous characteristics. Information technology is generally used in drip irrigation, greenhouses, animal husbandry, disease prevention, and pest management to achieve smart agriculture [3]. America led the way in pushing the development of smart agriculture. The implementation focuses largely on three areas: highly automated production, cutting-edge agricultural biotechnology, and "precision agriculture"-based information technology [4]. Like this, several nations, like Germany and Denmark, are committed to researching innovative agricultural technology.

The power supply, especially in irrigation, heating, equipment, mechanical, and monitoring systems, is one of the major barriers in the transition to smart agriculture. Additionally, the additional energy needed to clean and transport water might result in energy constraints in agriculture [5]. The primary obstacles to the delivery of agricultural power are:

- Lack of energy supply capacity in rural regions, particularly due to insufficient power output during times of high demand to meet the additional agricultural loads.
- Availability of energy in rural regions, including distribution and micro-grid network dependability and power transmission capacity.
- Smart agricultural practices including automation and electrification of farm operations have changed consumer demand patterns.

In conclusion, rural communities are currently in a crucial phase of their transition from conventional to modern agriculture. Traditional power systems, however, are unable to handle such a change, necessitating the urgent need for workable solutions.

II. LITERATURE REVIEW

Recent research [10] that examined the carbon footprint of developing deep NLP models concluded that costly computational experiments could have significant negative effects on the environment and the economy. Many researchers, particularly those in academia, lack the funding necessary to engage in many high-profile fields since current experiments have such big costs. By placing more emphasis on computationally efficient methodologies, more diverse groups will be able to contribute to research. We stress that the findings of [10] are the outcome of long-term trends and apply to all branches of machine learning, not only NLP.

Although some businesses buy carbon credits to offset their power use, it is unclear if doing so is as efficient as using less energy. Additionally, purchasing carbon credits is optional. While Amazon's AWS22 (the largest cloud computing platform23) covered fifty percent of its power use with renewable energy, Google Cloud20 and Microsoft Azure21 pay carbon credits to offset their wasted energy.

The research community has concentrated its efforts on providing the single best result after conducting several tests for model creation and hyperparameter tweaking to advance state-of-the-art performance. Future researchers cannot comprehend how much work is necessary to replicate or extend a discovery if these trials are not clearly reported [9].

III. TYPES AND FEATURES OF ENERGY STORAGE SYSTEMS

Energy storage technology has been used in a variety of industries because to its ongoing growth and maturity, including those involving electric cars, renewable energy power plants, RESs, distribution networks, and transmission grids [14]. The features of numerous popular kinds of energy storage are shown in Figure No. 1, where various forms of energy storage display various technical properties, particularly about energy characteristics [13]. These shapes particular technological features are listed below.

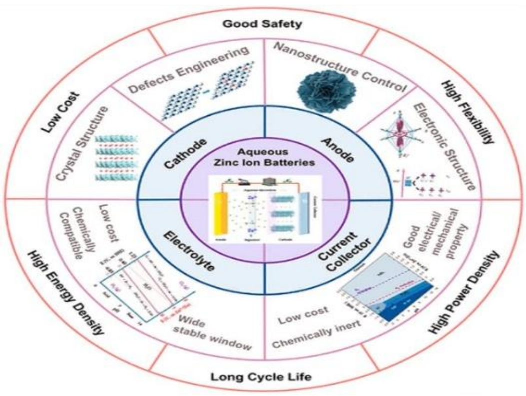

Figure No. 1 - Energy storage systems are classified.

3.1: Mechanical Energy

Through the conversion of mechanical energy into electrical energy, or electrical energy stored in the form of mechanical energy, mechanical energy storage enables energy storage and release. Flywheel energy storage, compressed air energy storage, and pumped energy storage are the three basic forms of energy storage [13].

a) Pumped Storage: With the longest life cycle and the greatest installed capacity, pumped storage is currently the most developed technology. To realize the flexible conversion efficiently actually between both the potential energy of the water and electrical energy, its operating principle is to pump the water from a down - stream reservoir to an upstream reservoir once storing energy, and to use the ocean level difference between the downstream and upstream reservoirs for hydropower generation when releasing energy [14]. It is possible to determine the stored pump energy (Ep) as shown below [13].

The entire mass of the pump m_p, is shown above together with the gravitational acceleration (g), and height (h). It is possible to compute the pump output power as follows:

Where water density (kg/m^3), Q_w is the turbine's volume flow rate passing it (m^3/s); is the turbine's hydraulic effectiveness (%).

Pumped storage is a popular energy storage system that uses electrical energy to push water resources to store potential energy before converting the potential energy into electrical energy [14]. Its benefits include its enormous capacity, extended life, and low cost. The cycle efficiency, which may reach 75%, is primarily utilized to control the frequency and phase modulations of peak energy and to provide spare capacity. Due to limitations about the geological and topographical circumstances as well as the time of construction, it is not, however, always applicable.

b) Compressed Air: When electricity is needed, compressed air energy storage uses extra electrical energy to compress air in a large storage chamber and then releases the compressed air to power a steam turbine [11]. Compressed air ESSs may be categorized into additional combustion and non-combustion variants [7] based on the various operating principles of the process. Compressed air and a motor power compressed air energy storage, which converts internal energy into electrical energy when the compressed air is released to propel the turbine that produces electricity. The following formula may be used to compute the compressed air energy retained in the storage vessel:

Where P_A and P_B, are constant pressures outside of the vessel; are the compressed gas's volumes (mol) at the beginning and the conclusion of compression, respectively.

3.2: Electrical Energy

Superconductor and supercapacitor storage units, which are now available in a variety of forms, store electrical energy in the form of an electric or magnetic field [50, 51]. Electrical energy storage has a wide range of uses, including those in mobile equipment, transportation, and permanent energy sources.

a) Superconductors: Using superconducting magnets, superconducting energy storage directly stores or releases electromagnetic energy. The following formula [12] can be used to compute the superconductor (Esc) energy stored per coil volume: a precise reference

Where magnetic flux density, permeability

Superconductors have a long useful life, a high energy storage efficiency, and a high energy and power density. They do, however, require more expensive production processes because they are still in the research and development stages of technology. Additional advancements are needed in critical technologies including current leads, large-capacity power conversion systems, low-temperature systems, and superconducting strip technology.

b) Supercapacitors: According to the various electrode materials and charging and discharging operating principles, supercapacitors may be separated into electric double-layer capacitors and faraday capacitors [9]. The gadget stores energy in a double layer produced at the interface between an electrode composed of a specific substance and an electrolyte. It is possible to compute the supercapacitor's energy capacity (Eca) as follows:

Where, is the Voltage Across the Capacitor, c is the capacitance and q is the charge
High charge and discharge efficiency, extended service life, high power density, and a wide temperature range of application are all benefits of supercapacitor energy storage [15]. Although it has several potential uses in situations requiring a lot of power, its fundamental drawback is its poor energy density. Due to the method's low self-discharge energy—about 5% per day—it is challenging to utilize in situations with large energy demands.

3.3: Thermal Energy

Thermal energy storage strategies can be classified as sensible heat storage, latent heat storage, and thermochemical heat storage depending on the properties of the various heat storage materials.
a) Sensible heat storage materials store and release heat because of temperature changes using their unique heat capacity properties. When a heat storage temperature is not necessary, such as in solar air conditioners, liquid sensible heat storage materials like water and solid sensible heat storage materials like crushed stone and soil are frequently utilized [11]. Their enormous heat storage capacity per unit mass or volume, consistent physical and chemical characteristics, and strong thermal conductivity are among their shared characteristics. However, such methods cannot be applied on a broad scale because to the high volume needed. Sensible materials may be made from substances like liquid metals, molten salts, and organic compounds [5]. A common medium- and high-temperature heat transmission and heat storage material, molten salt offers the benefits of a large heat capacity, wide temperature range, and low viscosity.
b) Two phases of a substance must be in an equilibrium and coexist for latent heat storage to exist. Heat is absorbed or emitted as one phase changes into another. Latent heat [12] is the amount of energy absorbed by a substance per mass unit during the phase transition process. Because latent heat storage materials have an energy storage density that is much higher than that of sensible heat storage materials and because they have promising research and development opportunities, latent heat storage is now the most explored heat storage technique. Latent heat storage materials may be categorized into low-temperature phase change material and high-temperature phase change materials based on the phase change temperature of the respective materials. Materials that undergo low-temperature phase transition are mostly employed in solar energy storage and use, heating and cooling systems, and waste heat recovery in industry [10]. The potential for ionic liquids and ionic liquids to be superior medium- and low-temperature latent heat stores materials is quite high. High-temperature molten salts, mixed salts, metals, and alloys are examples of high-temperature phase-change heat storage materials. These materials are mostly employed in aircraft systems, power plants, and other disciplines.

IV. LINKS BETWEEN CLEAN ENERGY CONSUMPTION AND SMART AGRICULTURE

Finding connections between the two systems is crucial to address problems in both the renewable energy and agricultural sectors. As seen in Fig. 2, agriculture uses electricity to operate farming equipment, provide artificial lighting, regulate temperature, power the water supply and circulation system, among other things. Therefore, a complementary system may be created to meet the need for agriculture with surplus clean energy. By regulating the variables that affect plant development, the clean energy generating system may more specifically directly feed the food and water systems. The relationship between smart agriculture and clean energy usage has unique characteristics when compared to interactions between clean energy and other industries.

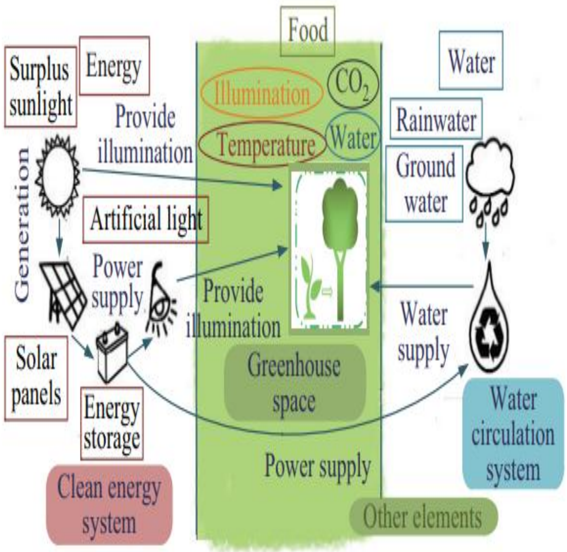

Figure No. 2: combining a clean energy system with intelligent agriculture to fulfil demand for energy.

Seasons, temperature, location, and crop kinds can all have an impact on agricultural burden. For instance, a severe downpour may lessen the agricultural load in dry regions, but the burden will increase in flooded areas owing to the necessity of urgent drainage work. Additionally, various crops require different growth conditions, which will have a big influence on how much power is used.

China is a sizable agricultural nation with a wealth of renewable energy sources, including wind, solar, hydro, and others. Rural locations, where both clean energy production and agricultural activities are primarily concentrated, present excellent potential for the fusion of clean energy and agriculture. The development of clean energy in rural areas can not only improve the ecological environmental quality and support the construction demand of a well-off society, but it can also play a significant role in easing the energy tension and lowering the price of agricultural electricity. This is because as the construction of a wealthy society is deepened overall and as rural energy consumption rises.

The two categories of clean energy consumption are local consumption and remote use. In general, photovoltaic greenhouses are used for local consumption in well-lit locations. This helps to improve local power transmission and supply levels and use local surplus clean energy. Crop yields have also increased in the meanwhile. Additionally, distant clean energy generating may also be employed as a local agricultural power source if there is not enough clean energy available for generation. One advantage of such a strategy is that it would prevent the waste of clean energy generated remotely, which is ideal for addressing the issue of clean energy consumption in the power system. On the other hand, the greenhouse needs an appropriate power supply and information equipment enhancement to achieve multi-period and whole-process modifications, which will result in significant expenditures in agricultural output, particularly in the form of high electricity bills. Smart agricultural output may also result in an anti-peak shaving with the power grid because of intelligent control, which will put more strain on the power supply during the power grid's peak periods. Therefore, by signing the agreements using green certificates and other incentive policies, the electricity price of smart agricultural production in the greenhouses will be significantly reduced for some agricultural greenhouses that already have transmission lines if the remote clean energy supply can be relied upon when it is in surplus.

V. CLEAN ENERGY SYSTEM

A pathway is suggested to integrate smart agriculture into clean energy-infiltrated power networks to address the problems in both agricultural productivity and clean energy consumption, as illustrated in Fig. 3. The power system, which is located at the top, is where renewable energy generation is either introduced at the transmission level or integrated into the local distribution and micro-grid systems. The agricultural system is located at the bottom and includes electrically related controls for lighting, temperature, watering, and heating.

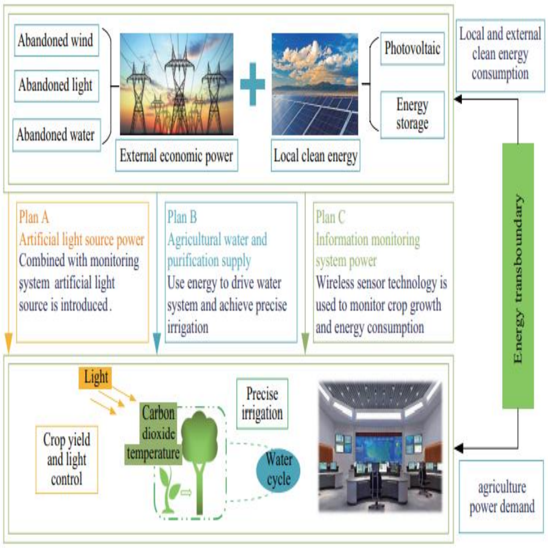

Figure No. 3 - Roadmap for smart agriculture using interactions across clean power systems.

Smart agriculture also makes it possible for the agricultural load to be active and controlled, opening new possibilities for controlling the variations in renewable energy. Three approaches are suggested, including the adoption of solar greenhouses, the development of rural smart micro grids, and agricultural information technology, as indicated in Table I, to break the energy barrier and enable intelligent integration of power and agricultural systems.

Road Map	Typical Projects
Implementation of photovoltaic greenhouse	National golden solar energy photovoltaic greenhouse photovoltaic eco-agricultural demonstration project in China.
Construction of rural Smart micro grid	ReGen community in Netherland
Agriculture Information Technology	Fujitsu Xintian factory farm in technology Japan

Table No. 1: *TYPICAL ENERGY SYSTEM PROJECTS FOR AGRICULTURE*

VI. MECHANISM FOR MULTI-SYSTEM CORRELATION COUPLING

A multi-energy system including subsystems for food, water, and energy is depicted in Fig. 4. Except for the biomass energy system, the crop planting process plays a significant role in the food system. To comprehend the correlation coupling mechanism of the multi-energy system, the bottleneck is to examine the coupling linkages. For smart agriculture to employ clean energy consumption, this is especially helpful.

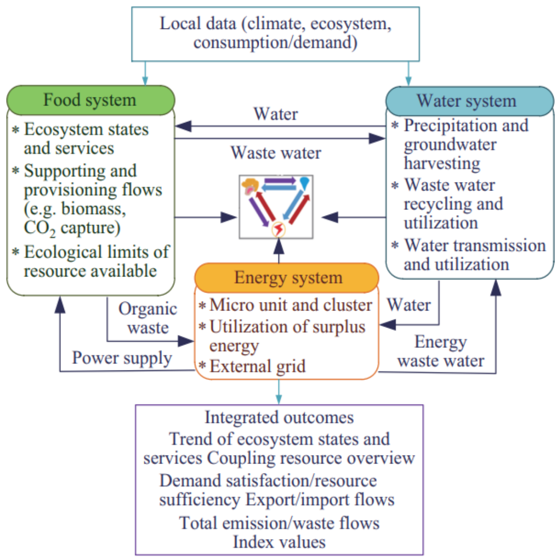

Figure No. 4: The coupling of the crop system and energy system.

The conventional methods rely on local data collection, study of correlation factors between sub-systems, a variety of optimization techniques, and empirical models [3]. Understanding nexus complexity, considering financial factors, and incorporating multitier scales are the primary issues. Such techniques are viewed as inadequate due to the complexity and unpredictability of the food and energy systems.

Therefore, it is necessary to suggest coupling methods that are better suited to the complexity of food, clean energy, and water. The structurally decentralized control algorithm is intended to target multi-coupling systems that have the characteristics of uncertainty, nonlinearity, many variables, and temporal delays [14]. It is also meant to have excellent stability characteristics and antijamming capabilities. In [12], which is intended to address both fast and slow components of coupling systems, the continuous wavelet decomposition and cross-correlation are examined to detect the multi-scale interactions, feedback loops, and regime changes of coupling systems over multiple temporal scales. For examining the coupling of strongly connected systems, a multireference linearized coupled cluster theory is suggested [14]. In [1], input-output analysis tools are used to examine how the energy, water, and food systems interact and how this affects production throughout various supply chains.

6.1: THE POWER SYSTEM FOR SMART AGRICULTURE'S MARKET MECHANISM AND REGULATION

With the need for adaptive management and configuration in the power system for improved collaboration with agricultural output, the amount and quality of power supply has risen in agriculture today. Multi-process collaborative optimization methodologies, creation of regional energy market mechanisms, and precise and autonomous control technologies are commonly employed. As seen in Fig. 5, incentives from the pricing mechanism encourage the high yield by using the extra energy. In consequence, the high yield will further promote the use of renewable energy.

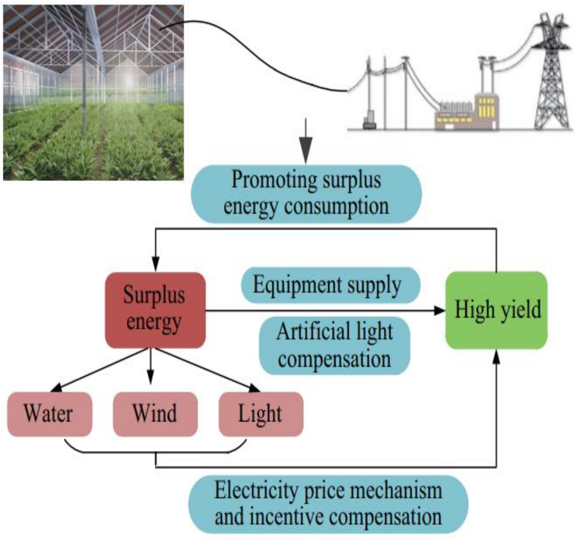

Figure No. 5 - Coordination method for energy transfer across borders.

A multi-objective optimization technique based on small habitat grid evolution for the power system is proposed in [12] with reference to precise and autonomous control technologies. The algorithm determines the variables and variety of parameters, which might increase the accuracy of the automatic control. Fuzzy logic, artificial neural networks (ANN), and hybrid fuzzy neural network techniques are used as intelligent controllers for autonomous generation management because unpredictable load changes in a hydro-thermal linked power system led to power imbalance and frequency deviation [2].

The large region of agricultural consumption cannot be adequately served by the traditional multi-vector energy system's distribution of energy resources. The matching transaction based on the pertinent provisions of the trans-regional and transprovincial energy concentration is therefore taken into consideration while building a market mechanism intended to optimize the optimal allocation in different energy systems in [4]. Additionally, the creation of a market for reserve supplementary services might also be a successful strategy [7]. Examples shown the value of energy storage and demand side response in auxiliary services in lowering overall energy supply costs.

Furthermore, power system inference system and configuration make good use of multi-process collaborative optimization strategies. To remove the inconsistencies and conflicts brought on by many variables, [9] proposes a generalized collaborative optimization (GCO) approach based on linear normalization. A fresh strategy is also put out in [10] with the intention of solving the multi-objective robust collaborative optimization. The optimization challenges were finally resolved by breaking them down into structural layers using a combination of robust collaborative optimization, the worst possible point constraint cuts, and the NSGA-II type genetic algorithm.

VII. CONCLUSION

To control clean energy usage in agricultural output, this article offers a pathway for integrating smart agriculture with clean energy power systems. Based on a review of recent developments in distributed photovoltaic systems, smart rural micro grids, and agricultural information technologies, bottlenecks and related technologies for coupling agriculture and clean energy systems are presented. These technologies include multi-time scale coupling, measurement and monitoring system configuration, multi-system correlation coupling mechanisms, economic evaluation of clean energy consumption, modelling of smart agricultural load, and an analysis of the coupling between agriculture and clean energy systems. The main advantages of combining agricultural and clean energy systems are to open opportunities for smart agriculture, which can be used to consume excessive amounts of clean energy output, and to use the clean energy system to boost agricultural production yields. This might have positive effects on both the energy and food systems' energy efficiency and utilization rates, helping to reduce environmental pollution.

REFERENCES

[1]. V. Jalali, S. A. Kapourchal, and M. Homaee, “Evaluating performance of macroscopic water uptake models at productive growth stages of durum wheat under salineconditions,” Agricultural Water Management, vol. 180, pp. 13–21, Jan. 2017.

[2]. Y. Yang and J. Tang, “Design of monitoring system for solar energy agricultural machinery engine based on intelligent agriculture information collection,” Journal of Agricultural Mechanization Research, vol. 5, pp. 259–263, May 2018.

[3]. T. T. D. Tran and A. D. Smith, “Evaluation of renewable energy technologies and their potential for technical integration and cost-effective use within the U.S. energy sector,” Renewable & Sustainable Energy Reviews, vol. 80, pp. 1372–1388, Dec. 2017.

[4]. eniat and Ludovic Denoyer. Learning time/memory-efficient deep architectures

with budgeted super networks. In Proc. of CVPR, 2018.

[5]. Aaron Walsman, Yonatan Bisk, Saadia Gabriel, Dipendra Misra, Yoav Artzi, Yejin Choi, and Dieter Fox. Early fusion for goal directed robotic vision. In Proc. of IROS, 2019.

[6]. Alex Wang, Yada Pruksachatkun, Nikita Nangia, Amanpreet Singh, Julian Michael, Felix Hill, Omer Levy, and Samuel R. Bowman. SuperGLUE: A stickier benchmark for general-purpose language understanding systems, 2019. arXiv:1905.00537.

[7]. David Silver, Aja Huang, Chris J Maddison, Arthur Guez, Laurent Sifre, George Van Den Driessche, Julian Schrittwieser, Ioannis Antonoglou, Veda Panneershelvam, Marc Lanctot, Sander Dieleman, Dominik Grewe, John Nham, Nal Kalchbrenner, Ilya Sutskever, Timothy Lillicrap, Madeleine Leach, Koray Kavukcuoglu, Thore Graepel, and Demis Hassabis. Mastering the game of Go with deep neural networks and tree search. Nature, 529(7587):484, 2016.

[8]. Roy Schwartz, Sam Thomson, and Noah A. Smith. SoPa: Bridging CNNs, RNNs, and weighted finite-state machines. In Proc. of ACL, 2018.

[9]. eters, Mark Neumann, Mohit Iyyer, Matt Gardner, Christopher Clark, Kenton Lee, and Luke Zettlemoyer. Deep contextualized word representations. In Proc. of NAACL, 2018.

[10]. W. Fan, N. Liu, and J. Zhang, “Multi-objective optimization model for energy management of household micro-grids participating in demand response,” in Proceedings Innovative Smart Grid Technologies - Asia. IEEE, Nov 2015, pp. 1–6.

[11]. E. Casagrande, B. Mueller, and D. Miralles, “Wavelet correlation and multi-scale coupling in geophysical systems. EGU general assembly conference,” in Proceedings EGU General Assembly Conference Abstracts, vol. 17, 2015.

[12]. Pavlo Molchanov, Stephen Tyree, Tero Karras, Timo Aila, and Jan Kautz. Pruning convolutional neural networks for resource efficient inference. In Proc. of ICLR, 2017.

[13]. Gabor Melis, Chris Dyer, and Phil Blunsom. On the state of the art of evaluation in neural language models. In Proc. of EMNLP, 2018.

[14]. Yunpeng Chen, Jianan Li, Huaxin Xiao, Xiaojie Jin, Shuicheng Yan, and Jiashi Feng. Dual path networks. In Proc. of NeurIPS, 2017.

[15]. Kaiming He, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. Deep residual learning for image recognition. In Proc. of CVPR, 2016.