An outlook on deployment the storage energy technologies in Iraq

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Abstract. This study aims to analyze and implement methods for storing electrical energy directly or indirectly in the Iraq National Grid to avoid electricity shortage. Renewable energy sources are changing with time and climatology conditions. Therefore, the impact of weather on power generated and demand using renewable energy is considerable. This issue becomes a new motivation for developing new energy storage systems independent of time and weather. Stored energy ensures the smooth and clean transmission of electricity in conditions where the delivery may be interrupted or mismatched. Storage energy technologies are intelligent as they diversify energy sources, develop economic growth and produce more jobs. Technologies like Redox Flow Batteries (RFB), Pumped Hydro Storage (PHS), Compressed Air Energy Storage (CAES) and other forms were analyzed within this study. The PHS mechanical indirect electrical energy storage system is a great way to store large amounts of off-peak energy; however, it faces geographical challenges when siting such a development. The paper has strongly recommended the PHS to be used in Iraq due to the unique characteristics of 20,000 cycles, 33 year lifespan, and 80% round trip efficiency. Although Iraq has two rivers, salinity and water management must take into consideration. The study also suggested that RFB and CAES can be added to the network. The future work will concentrate on employing biomass technology, protection and improving the life span of these technologies. Solar and Wind technologies are excluded, as many research papers are available online.

Keywords: Iraq National Grid, Renewable Energy, Energy Storage, Pumped hydro storage, Batteries.

1. Introduction
Electrical energy is a vital and versatile asset that has been developed and utilized over centuries. However, it is a resource that once generated, is not easily stored. This study has three phases:

1. Studying the source of pollution caused by conventional power stations in the national grid.
2. Choosing suitable energy storage technologies to cover the shortage of power generated instead of using public diesel generators.
3. Estimating the Round-Trip Efficiency (RTE), Lifespan and the initial cost of each technology.

Power stations produce electricity at a level to match the demand of the power grid [1]. The problem escalates if the power supply does not match the demand; the imbalance can cause problems with the power grid quality and stability. Iraq continuously suffers from this problem. The national grid employs conventional power stations that, most of which are Thermal, Natural gas and a few Hydraulic power stations.

The diagram below, figure 1, clearly shows that fossil fuel power stations are the cornerstone of the industry, which converts combustion's heat energy into mechanical energy. Problems with natural gas power stations are steadily escalating. On one hand, they are cheap, less pollution than other thermal power plants, easy to establish, and having high thermodynamic efficiencies [1]. On the other hand, these power plants significantly subsidize climate change by warming up our planet. Natural gas mainly consists of methane, CH4, a potent greenhouse gas that causes lung cancer, asphyxia and other series of diseases. Reducing this gas emission benefits public health [2].
Hydraulic power stations are mostly placed in the north of Baghdad. The northern largest hydraulic power plants are placed in Mosul Dam generates 1,052 MW, which is insufficient to cover the city of Mosul, the second-largest city, and an estimated population of four million inhabitants [3, 4].

Due to the invasion, continuous terrorism and corruption, the Iraqi national grid cannot match the demand. This fact gives the public the right to use diesel generators everywhere in the country. These power stations are releasing Nitrogen Oxide (NOx) as well as Sulphur Oxides (SOx) [5]; therefore, they are unclean. Other disadvantages like eyesore looking and operation costs, maintenance, and lubrication are very high [6]. Clarifies why the energy production in Iraq is unclean and expensive. Advantages are summarized in small size, which translates to faster installation time, quicker start-up, portability and relatively low installation cost [5, 6].

At peak periods, the energy producers are forced to use diesel power stations to meet the high demand. It should be noted that most of these units have closely lied in residential areas and schools, causing massive noise pollution in addition to health harm [7, 8]. Therefore, the Baghdad city estimated nine million, is considered one of the most polluted cities in the world [9]. According to the World Health Organization's guidelines, Iraq is one of the countries contributing to high CO₂ emissions due to power generation and exhausting gas vehicles and industry [10].

Renewable energy generates no greenhouse gas emissions and decreases air contamination [11]. Therefore, it considers green and clean technologies. This kind of energy diversifies the power supply and minimizes the dependence on conventional unclean energy. Besides, it creates economic development, increasing job opportunities, and gain knowledge of design and installation. Therefore, renewable energy is considered intelligent. Renewable energy sources are categorized by their power
availability and climatology conditions [12]. This creates a problem of using part of this knowledge in one place without the other. The new motivation is to understand and develop modern energy storage units that can be used everywhere like batteries [13].

The increase in the demand for 'off-grid' technologies and portable devices with 'cleaner' environmental implications have meant marginal technologies are now used on a large scale in terms of cost and design [13, 14]. Electricity storage can take many forms and sizes from the smallest most basic battery to more sophisticated large-scale hydropower storage systems. The storage solutions for electrical energy can either be in a direct form (Hydrogen, battery, etc.) or an indirect form from mechanical sources (such as from a flywheel or heated rocks, etc.).

Storing electrical energy is challenging by its nature because the flow of the electromagnetic field travels at high speeds and instantaneously dissipates unless it is being used [15]. Many forms of power plants produce electricity in various ways. In more recent years renewable technologies have been developed to combat the environmental pressures from using conventional fossil fuels to produce a 'cleaner' form of electricity; however, the nature of this type of supply can cause reliability complications [15].

Energy storage is defined as converting electrical energy from a power network into a new stored form until converted back to electrical energy. Therefore, energy storage could experience many advantages when stores on a large scale [16, 12]. Some of these advantages are flexibility and versatility role in the electricity supply grid to accomplish resources effectively. The energy storage can profit from savings in operating costs or capital disbursements. Besides, storage systems can improve the operation of existing transmission and distribution equipment and eradicate the necessity for costly transmissions and distribution arrangements. Therefore, energy storage reduces the pressure on overhead power transmission lines by sharing demand [16]. People could argue about the depletion of natural resources, climate change and reliability of renewable energy. A review process shows that 93% of participants did not consider that renewable energy is a reliable energy source [12, 17].

This study explores the possibility of employing renewable storage technologies in the Iraqi national grid. The following approach provides individual analysis of each method. The choice of the site for energy storage installation is another task of this study and estimation of the Round Trip Efficiency (RTE), average life span, and possible annual cost. Solar technology was excluded because these panels are already available, limitedly, and many research papers are available about solar and wind technologies [18, 19, 20].

2. Types of electrical storage energies suggested to Iraq

In the past, the energy was either spent on human needs or wasted. With the gradual development of renewable energy, industrial methods of energy storage are increasingly attracting attention. This has prepared a list of the best ideas on this subject: compressed air, molten salts and ducted redox systems [21].

2.1 Traditional Electrochemical Batteries

Batteries serve a useful purpose for storing chemical energy and converting that energy into electrical energy on demand. There are many types of batteries; however, they all share similar design features. Typically, the lithium-ion cells are more expensive than other batteries producing and transport (up to 40% more than a Nickel-cadmium cell). This can be a significant problem when mass producing them when considering economies of scale [22, 23].

Tesla says: "Each Megapack can store up to 3 megawatt-hours (MWh) of energy at a time, and it is possible to string enough Megapacks together to create a battery with more than 1 GWh of energy storage" [24, 25]. This kind of battery can be used everywhere in the Iraqi grid. Therefore, the load can be fed indirectly through the national grid or by connecting the load directly through a conversion system. Companies are continually generating new and developing battery systems; the current mission to generate a pressure tolerant battery by utilizing new Lithium-Sulfur cell technology generation.
Table 1: Li-ion Batteries - cycles, life in years, and round-trip efficiency.

| Cycles     | Life Years | RTE       | Source |
|------------|------------|-----------|--------|
| 3500       | 10         | 77-85%    | [26]   |
| 400-1200   | 9          | 80-90%    | [27]   |
| 2,000-10,000 | 15-20     | 90-98%    | [28]   |

According to different sources (Li-ion battery prices have reduced massively over the last decade, have assessed the operation and maintenance charge in the range of $6–$14/kW-yr for their 4 MW/16 MWh. The total annualized price based on 2018 is $293.92/kW [26, 28].

2.2 Redox Flow Batteries (RFB),

Oxidative and restorative flow batteries comprise massive tanks with electrolytes, which pass through the membranes and create an electric charge. Vanadium is commonly utilized as an electrolyte, besides solutions of salt water and zinc. They have a long span life of operation; besides, they are reliable. The world's most massive running battery is going to be built in the caves of Germany. The flow battery energy is stored via a process of transferring energy into liquid electrolytes. Electrolytes are saved in tanks and sent through an electromechanical cell; this then converts chemical energy into electrical energy [28, 29]. The electromechanical cell is designed to produce a required power output; however, the energy stored is dependent on the size of the tanks. There are two categories of flow batteries redox or hybrid flow batteries. Flow batteries benefit from having compensations in terms of the design and installation, the environment and operation. Flow batteries also have flexible arrangements due to segregation of the energy and power mechanisms, long cycle life, short response periods, no necessity for "equalization" they can be charged with no emissions. Although these types of batteries offer flexibility in design, they are very complicated to install, as they require a different use of sensors, control units and pumps, etc. Overall, the battery's energy density are lower than other portable batteries available [29]. This kind of technology can be used all over Iraq, where the demand is severely variable concerning the density population. It should be noted that this battery is stable between (−25 to −30) °C.

Table 2: Redox Flow Batteries - cycles, life in years, and round-trip efficiency.

| Cycles     | Life Years | RTE       | Source |
|------------|------------|-----------|--------|
| 5,000      | 14         | 65-78%    | [26]   |
| 10,000     | 15         | 70%       | [25]   |
| >12,000    | 10-20      | 70-75%    | [30]   |

The value of RFB is between $730/kWh and $1,200/kWh when involving power conversion system cost. The total annualized price based on 2018 is 464.37$/kw [28].

2.3 Pumped Hydro Storage (PHS)

The basic principle of a pumped hydro system (PHS) is to use surplus electrical energy (off-peak energy) to transfer water to a higher reservoir and store it as potential energy. During higher demand periods the water is then fed via gravity down to a turbine, which is used to transfer the kinetic energy back into electrical energy for use through a generator. This process is one of the best ways to store and deliver electrical energy on a large scale. They are quite commonplace all over the world, with four being found in the UK. "The total efficiency of the process is directly affected by the efficiencies of the pump, motor, turbine and generator in addition to evaporation rates. The expected efficiency is between 70 – 85% [15, 31].

This type of electrical energy storage has a huge advantage as it can be a very efficient, environmentally friendly way to store electrical energy. Pumped Hydro Storage is considered the only
operated technique of large-scale energy storage networks. It benefits from storing and delivering vast amounts of electrical energy and once put into place can expect to last for as long as fifty years. PHS can be considered a standby reserve provision; it provides considerable assistance to the energy scheme, including frequency control, load leveling and peak shaving, and load-following [30, 31]. This technology has obvious advantages associated with it; however, this all comes at a price. The outlay in terms of cost for this technology is expensive; it also requires the correct geography in site selection. This project is recommended to Diala Weir, Hemrin dam, Mosul Dam, Ramadi barrage, Samarra Barrage, Adhim, Dukan and Kut and Darbandikhan dams [4]. The chosen areas are well-known due to the dams are already established, which reduces the capital cost. According to different sources, e.g. [32, 33], the salinity of the waters of the Euphrates, Tigris and Shatt Al-Arab River amplified in the last years. Therefore, precautions must be taken, and further discussion with the ministry of water resources must be opened. Another issue that may stop this project is water management. Different dam projects have been established over the last decades in Turkey, Iran, and Iraq, which have reduced the Tigris and Euphrates rivers' annual flows, resulting in a significant reduction of the wealth ecology.

PHS units are sought for their capability to provide bulk power to the grid at a reduced $/kW rate. PHS has an overall estimated cost of $165/KW for 16 hours of daily working [28]. It consists of 98% of worldwide energy storage and has an enormous deployed megawatt of about 170, 000 MW. However, PHS has also some disadvantages, including high capital cost. The ecological and environmental impacts of the site and future deterioration. The electrical power which feeds the PHS could come from conventional sources like thermal power stations. However, these power stations are uncontrolled to load fluctuations. This fact might affect the reliability of the whole system. The total annualized price based on 2018 is $308.24 [34].

Table 3. PHS- cycles, life in years, and round-trip efficiency.

| Cycles | Life Years | RTE    | Source |
|--------|------------|--------|--------|
| 20,000 | 20         | 82%    | [26]   |
| 20,000 | 50         | 80%    | [25]   |
| 20,000 | >20        | 70-87% | [28]   |

2.4 Hydro-Accumulators

The working principle is modest: there are two water tanks, the first tank is directly above the second. When the electricity demand is light, the surplus energy drives the water up to the second reservoir. However, during the high-demand hours, the water drifts down, spinning the hydro-turbine on the same shaft with a salient pole machine synchronous generator to generate electricity [35]. The classical form of modern energy storage is tied to the power grid. Iraq can update, e.g., Badush Dam, which was established in 1990 by the new Hydro-accumulators project [36]. Authors [37, 38] were successfully compared the cost/power ($/Watt) ratio in the hydraulic accumulator with a set of supercapacitors. It was found 2.9 times smaller in the accumulator than the supercapacitors of equal energy storage capacity. Therefore, the cost per unit of power was 75 USD/kW for the hydraulic accumulator; however, 217 USD/kW for the ultracapacitor. On the other hand, the overall energy efficiency of the supercapacitor was 78.7%. However, the estimated overall energy efficiency was 87.7% in the hydraulic accumulator. The typical life expectancy is 12 years, and the total annualized price based on 2018 is $203.10 [28, 39]. This method also has some disadvantages: the low efficiency due to heat transfer losses, rotation is still slow, a significant number of hoses and slow response.

2.5 Compressed Air Energy Storage (CAES)

This technology has been in theory for several decades, but in practice, because of its high cost, there are only a few working systems and a few more test systems. Canadian company Hydrostor develops a large adiabatic compressor in Ontario and Aruba. This process for storing electrical energy is very similar to that of the pumped hydro system in terms of its application indirectly. However, instead of
using water, ambient air is used by compression, then stored under pressure below ground. When electricity is needed, the air stored in heated expands and uses an expansion turbine, driving a generator to produce electrical energy [22].

Electricity is used via a compressor (during off-peak hours) to store air in underground storage or aboveground systems. This compressed air is called upon (during peak demand) to be mixed with natural gas, it then gets burned and expands in a gas turbine. Once in the high-pressure expander, the exhaust is reheated before entering the expander of low-pressure. It is then sent back through the recuperator that provides an efficient heat source before being discharged into the atmosphere. The high-pressure and low-pressure expanders work to rotate the generator and produce electricity. This process is called adiabatic CAES [40]. As can be inferred, the waste heat, which contains a large amount of energy, is disposed into the atmosphere. This process upsurges the emission of greenhouse gas and may support global warming.

The diabatic technology is also capable of starting without the use of extraneous power. However, the drawbacks to this type of technology have been shown in the unfavorable efficiencies of around 50%. This technology also requires specific geographical needs to be met when locating sites for installation that can be problematic [11, 26].

CAES capital cost breakdown by component: turbine 270 $/KW, compressor $/KW 130, balance of plant $/KW 50, cavern $/KW 50, EPC $/KW 30, and owner’s cost 360. As a summary, the cost of $1,050–$1,400/kW can be provided by Siemens. The total annualized price based on 2018 is $203.10 [28].

| Cycles     | Life Years | RTE  | Source |
|------------|------------|------|--------|
| 10,000     | 25         | 65%  | [25]   |
| 10,000     | >30        | >70% | [40]   |
| 10,000     | >30        | 70%  | [26]   |

2.6 Flywheel Energy Storage (FES)

Essentially, this type of storage works like a battery in that it stores energy in the form of kinetic energy until that energy is needed. It will convert the energy back to an electrical form to meet the demand. This can be used as an ideal solution to help regulate the electrical grid. Energy is stored and transferred to and from the flywheel through an internal combined motor/generator. The speed of the flywheel, together with its inertia, will dictate the amount of stored energy.

Flywheels have many advantages for storing energy in comparison to other technologies; advantages include environmental benefits. Flywheels are not affected by temperature variations, have a less rate of failures compared to chemical rechargeable batteries. Distinct from lithium-ion polymer batteries that work continuously for 36 months, a flywheel may operate indefinitely for as long as its lifespan. Besides, flywheels also have a smaller amount of harmful to the environment because they are made of inert or benign materials. The flywheel's rotation speed represents the amount of energy stored; this is also a good advantage [14, 22, 40].

Limitations to the use of flywheel technology exist in the design. The tensile strength of the material used for the rotor will dictate the speed at which it can be spun. The faster it can be spun, the more energy produced and if exceeded, the flywheel will shatter with disastrous effects. Consequently, flywheel systems require extra safety equipment as precautionary measures. Energy storage time is a limitation to this type of technology as flywheel technology using bearings could lose (20-50) % of their energy in 2 hours, causing efficiency problems. This technology is uncomplicated and can be installed everywhere in Iraq. It should be noted that flywheels are considered of high cost at roughly $3,000/kWh-year. The cycle efficiency of the flywheel is 85%–95%, long life, and is eco-friendly with the total annualized price based on 2018 is $293.0 [28, 41].
2.7 Molten - Salt
This technology is made up of 40% potassium nitrate and 60% sodium nitrate [42]. The technology uses solar energy to warm up the salt to the required temperature at approximately 220°C. The steam may directly be converted into electricity by a turbine-generator unit or stored in an insulating container. During the high demand, the molten salt is pumped into a power turbine-generator unit that boils water, rotates a turbine, and produces electricity. The energy conversion of thermal to electricity can continue by various cycles, for instance, the Air-Brayton, Rankine, and Brayton, cycles [43].

The heat flow equation (Q) from hot to cold is determined as $Q = m C \Delta T$ where $m$ is the mass, $C$ is the specific heat, and $\Delta T$ is the temperature difference. The Australian government has agreed to a 150MW solar thermal scheme project related to 1,100MWh molten salt energy storage [44]. Another such project, the Mohammed bin Rashid Al Maktoum Solar Park, is being implemented in the United Arab Emirates. This project can be used in Iraq as well primarily in Samawa, Najaf and Ramadi. Molten salt storage technology is less efficient than PHS and battery storage. The low energy storage is connected mainly to the low decomposition temperature. It is estimated about 50% [45, 46]. According to different sources, e.g. [45], the annual energy generated changes between 721 GWh to 818 GWh, while the average cost of energy diverges from 10 to 11.2 cents/kWh. Therefore, the reason for the limited use relates to costs; hydro-pumping is still less expensive.

2.8 Electrical – double-layer capacitor storage (EDLCs)
EDLCs accumulate electric field energy of an electrochemical double-layer. The high energy and power concentrations make capacitors choose a brake energy storage in rail vehicles [48]. This type of technology is not used as a replacement for batteries since they are suitable for different purposes. They fit somewhere between a typical capacitor used in electronics and general batteries. They are instrumental as they have substantial power capabilities and have a considerable life cycle compared to an ordinary battery. They also benefit from quick charging times and have cost-effective storage [22].

The disadvantages of this storage technology are that by nature, they have a low energy density, usually holding 1/5 to 1/10 that of a battery's energy. They also suffer from having a high discharge rate when compared to electrochemical batteries. Finally, voltage balancing is needed with EDLCs if they connected in series.

The energy can be estimated by [41]:

$$E = \frac{C V^2}{2}$$

Where: $C =$ Capacitance in Farad; $V =$ Voltage applied.

$$C = \int \frac{\varepsilon_0 \varepsilon_r}{\delta} dS$$

Where: $\varepsilon_0 =$ Vaccum permittivity, $\varepsilon_r =$ relative permittivity; $\delta =$ Double layer thickness; $S =$ Surface area.

According to [38], the cost/power ($$/Watt) ratio is 217 USD/kW for the supercapacitor. On the other hand, the overall energy efficiency of the supercapacitor was 78.7%.

2.9 Superconducting Magnetic Energy Storage (SMES)
The SMES technology has a significant benefit of cultivating power quality for loads and facilitating carryover energy during emergency conditions when instantly voltage sags and power outages. This type of technology utilizes the energy of DC stored in a superconducting coil's magnetic field to induce a state of zero resistance within the superconducting coil. Creating and using a superconducting coil result in a magnetic field being stored within the coil even when the power supply is turned off [49].
The advantage of this type of energy storage is that it has a rapid response time. This is because the energy is available almost instantaneously. It also benefits from having a high overall efficiency (85-90%) with high output power over a short period. However, this technology is crucially very dependent on the costly refrigeration system in place as the energy could theoretically be stored indefinitely so long as the cooling system functions. The total cost of 5 MJ is 1720 k$ during the lifespan of 30 years [50]. This can be estimated in the range of $2000/kWh.

3. SUMMARY

Table 5 shows a summary of the current. The table has categorized the electrical energy storage systems into three regions: the average life expectancy in years, the round-trip efficiency and the total annual cost. As the paper discussed the most suitable energy storage for Iraq, all data are considered imperative. It can be concluded that these technologies could be executed with greater energy capacity. Noted that, PHS, CAES and Redox have recorded higher life expectancy and total cost benefits among all other energy storage technologies. The PHS is considered the best in this case. However, a further discussion must be disclosed by the ministry of water resources regarding water management. Redox flow batteries have positioned themselves in third place after CAES. However, this kind of battery has comparatively low efficiency, but there is a possibility of improvement. It was noted that FES is the one that is not good enough due to the cost and lifetime. As this technology loses its efficiency by 50% when it works for more than 2 hours, it makes the system's reliability under pressure. Li-ion battery can also utilize; it has a close characteristic of Redox battery except the average life time is less. However, the possibility of improvement may change the overall characteristics. Environmental conditions govern the longevity of the batteries. These batteries are affected by keeping them overcharged at elevated temperatures. Therefore, lower voltages and temperature prolong Li-ion batteries' life span.

| Technology       | Average Life Years | RTE        | Cost / year          |
|------------------|--------------------|------------|----------------------|
| Li-ion Batteries | 10                 | 77-85%     | $293.92/kw           |
| Redox Flow Batteries | 15            | 70%        | $464.37/KWh          |
| PHS              | 50 /16 hr daily = 33 | 80%       | $308.24/KWh          |
| CAES             | 30 /16 hr daily =20 | >70%      | $203.10/KWh          |
| Molten-Salt      | 20                 | 50%        | EUR70/kWh = $85/KWh  |
| FES              | 20 / 2 hours per day = 2 | 90%   | $3,000/kWh          |
| Hydro-accumulators | 12              | 87.7%     | $75/kWh              |
| EDLCs            | 8                  | 78.7%     | $217/KWh             |
| SMES             | 30                 | 90%        | $2000/KWh            |

The future work will concentrate on employing biomass technology, protection and improving the life span of these technologies.

![Comparison of Energy Storage](image)

**Figure. 5** Comparison of different energy storage suggested to the Iraqi national grid.
4. CONCLUSION
This paper aimed to critically evaluate methods for storing electrical energy either directly or indirectly that can be used in the Iraq National Grid to eliminate the electricity shortage. The high RTE in the hydraulic units (≥80%) and the improved power density compared with electrical systems are the main determining factors. The annual cost of PHS energy production per kWh, $308.24, is practicable compared with other technologies. From the mentioned technologies, it can be concluded that each technology has benefits but also faces challenges. For example, using a PHS mechanical indirect electrical energy storage system is a great way to store large amounts of off-peak energy due to the length; nevertheless, it faces geographical challenges when siting such a development. However, the study has recommended this technology to be deployed due to the low initial cost, the existence of two rivers with many establishing dams. RFB and CAES are another good alternative options to be exploited in the Iraq national grid. Both technologies have an RTE of about 70%. However, the annual cost per kWh of RFB, $464, is higher than CAES, $203.10. Besides, the life expectancy of RFB is 15 years, with 20 years for CAES. According to the mentioned data, the CAES can be chosen as a second option. The electrical system can take advantage of the hydraulic system by rapidly charge or discharge to satisfy the load fluctuations or other applications such as regenerative braking. Therefore, in such cases, RFB or Li-ion can be chosen.

References
[1] Al-hamadani S 2020 Solar energy as a potential contributor to help bridge the gap between electricity supply and growing demand in Iraq: A review, International Journal of Advances in Applied Sciences 9(4):302-12.
[2] Energy Information Administration, The National Academies of Sciences. Engineering, Medicine,* Energy, 2015. [Online]. Available: http://needtoknow.nas.edu/energy/energy-sources/fossil-fuels/natural-gas/. [Accessed 29 12 2020].
[3] Brinkhoff T 2020 City Population. [Online]. Available: https://www.citypopulation.de/en/iraq/cities/. [Accessed 29 12 2020].
[4] Wikipedia, List of power stations in Iraq. [Online]. Available: https://en.wikipedia.org/wiki/List_of_power_stations_in_Iraq. [Accessed 29 12 2020].
[5] Selvam M, et al 2016 Emission Control Diesel Power Plant for Reducing Oxides of Nitrogen through Selective Catalytic Reduction Method using Ammonia, Indian Journal of Science and Technology, 9(1):1-6.
[6] IDC Technologies Operation and Maintenance of Diesel Power Generating Plants, IDC Technologies, Australia.
[7] Alwaeli A et.al. 2014 Evaluation of the spatial distribution of shared electrical generators and their environmental effects: Case Study in Baghdad-Iraq, International Journal of Engineering and Technology, 14 (22):16-23.
[8] Boldo E. et al., 2006 Apheis: Health impact assessment of long-term exposure to PM(2.5) in 23 European cities. European Journal of Epidemiology. 21(6): 49-458.,
[9] The Active Times 15 Dirtiest Cities in the World, The Active Times, 22 February 2016. [Online]. Available: https://www.theactivetimes.com/travel/15-dirtiest-cities-world. [Accessed 2020 12 29].
[10] Ritchie H et al., 2017 Iraq: CO2 Country Profile, Our World In Data, 2017. [Online]. Available: https://ourworldindata.org/co2/country/iraq?country=IRQ. [Accessed 29 12 2020].
[11] Energy storage in the UK, 2016 Retrieved from The association for renewable energy & clean technology, Renewable Energy Association, Autumn 2016. [Online]. Available: https://www.r-e-a.net/wp-content/uploads/2019/10/Energy-Storage-FINAL6.pdf. [Accessed 05 11 2020].
[12] Staffell I, et al., 2018 "The increasing impact of weather on electricity supply and demand. Energy," Renewable and Sustainable Energy Reviews, 145: pp65-78.,
[13] Rufer A, 2018 Energy Storage, Systems and Components, (USA: CRC Press).
[14] Burheim O., 2018 *Engineering Energy Storage*, (London: Academic Press).
[15] Funabashi T 2016 *Resources in Power Systems* 1st Edition, (Japan: Academic Press).
[16] DeMeo E A and Galdo J F 1997 Renewable Energy Technology Characterizations, Topical Report TR-109496.
[17] Ahmed S U, *et al.*, 2018 Renewable Energy's Reliability Issue and Possible Solutions: A Meta-Analytic Review, *Journal of Information and Communication Technology*, 2(3):70-175.
[18] Chichain M T, 2012 Status and future prospects of renewable energy in Iraq, *Renewable and Sustainable Energy Reviews*, vol. 16, pp 6007–12.
[19] Amin A Z, 2018 Global energy transformation - Roadmap to 2050, *International Renewable Energy Agency, Abu Dhabi*.
[20] Al-Kayiem H H *et al.*, Potential of Renewable Energy Resources with an Emphasis on Solar Power in Iraq: An Outlook, *Resouces*, 8(42):2-20.
[21] Hayton J, 2017 Smart Grid Energy Storage, in *The Power Grid Smart, Secure, Green and Reliable*, (London: Academic Press) pp. 93-135.
[22] IEC, Electrical Energy Storage," International Electrotechnical Commission, 2011. [Online]. Available: https://indiasmartgrid.org/Electric-Energy-Storage-(EES).php. [Accessed 06 11 2020].
[23] Pavlov D., 2017 *Lead-Acid Batteries: Science and Technology*, second edition, (Bulgaria: Elsevier).
[24] Sean O’Kane, 2019 Tesla's Megapack battery is big enough to help grids handle peak demand, the verge, 29 July. [Online]. Available: https://www.theverge.com/2019/7/29/20746170/tesla-megapack-battery-pge-storage-announced. [Accessed 06 11 2020].
[25] May G., *et al.*, 2018 Lead batteries for utility energy storage: A review, *Journal of Energy Storage*, vol. 15: 145-57.
[26] Aquino T, *et al.*, 2017 Battery Energy Storage Technology Assessment. Platte River Power authority , Nebraska.
[27] Greenspon A, 2017 The Energy Storage Landscape: Feasibility of Alternatives to Lithium Based Batteries, *Harvard Energy Journal Club, Boston*.
[28] Mongird K, *et al.*, 2019 Energy Storage Technology and Cost Characterization Report, HydroWire, Chicago.
[29] Chen R, *et al.*, 2017 Redox Flow Batteries: Fundamentals and Applications," in Redox - Principles and Advanced Applications, (London:InTech): pp103-15.
[30] ESA (Energy Storage Alliance), Energy Storage Technologies, European Association for Storage of Energy, [Online]. Available: https://ease-storage.eu/energy-storage/technologies/. [Accessed 29 12 2020].
[31] IHA, 2018 Pumped storage hydropower to turbocharge the clean energy transition, International Hydropower Association. [Online]. Available: https://www.hydropower.org/statusreport#. [Accessed 05 11 2020].
[32] Price R A, 2018 Environmental risks in Iraq," K4D Helpdesk Report, Brighton, UK: Institute of Development Studies.
[33] Fawzi M N, *et al.*, 2014 Iraq's inland water quality and their impact on the North-Western Arabian Gulf, *Marsh Bulletin*, 9(1):1-22.
[34] Alternative Energy Tutorial, Pumped Hydro Storage, Alternative Energy Tutorial, [Online]. Available: https://www.alternative-energy-tutorials.com/energy-articles/pumped-hydro-storage.html#:~:text=However%2C%20the%20disadvantages%20of%20pumped%20energy%20sources%2C%20such%20as%20nuclear%2C. [Accessed 25 12 2020].
[35] Rydberg K, 2005 Hydraulic Accumulators as Key Components in Energy Efficient Mobile Systems, in *The Sixth International Conference on Fluid Power Transmission and Control (ICFP’ 2005)*, Hangzhou, China.
[36] Sissakian V K *et al.*, 2018 Badush Dam, NW Iraq: A Geological Study, *Journal of Earth Sciences and Geotechnical Engineering*, 8(2):1-15.
[37] DW, "Hydropower supply dries up with climate change," Made for Mind, 01 03 2018. [Online]. Available: https://www.dw.com/en/hydropower-supply-dries-up-with-climate-change/a-42472070. [Accessed 06 11 2020].

[38] Leon-Quiroga J, et al., 2020 Energy Efficiency Comparison of Hydraulic Accumulators and Ultracapacitors, Energies, 13(7).

[39] Casey B., 2009 Advice For Maintaining Hydraulic Accumulators, Machinery Lubrication., [Online]. Available: https://www.machinerylubrication.com/Read/2305/hydraulic-accumulators#:~:text=The%20typical%20design%20life%20for,inspection%20and%20recertification%20is%20required.. [Accessed 26 12 2020].

[40] ESA, Mechanical Energy Storage," Energy Storage Association, 2020. [Online]. Available: https://energystorage.org/why-energy-storage/technologies/mechanical-energy-storage/. [Accessed 06 11 2020].

[41] Salameh Z, 2014 Renewable Energy System Design, Massachusetts-Lowell: Academic Press.

[42] Bindra H, et al., 2019 Storage and Hybridization of Nuclear Energy, (New York : Elsevier).

[43] Orosz M, et al., 2017 Organic Rankine Cycle (ORC) Power Systems, (Cambridge: Woodhead Publishing).

[44] Breidenbach N, et al., 2016 Thermal Energy Storage in Molten Salts: Overview of Novel Concepts and the DLR Test Facility TESIS, Energy Procedia, 99: pp120-9.

[45] Bielecki A, et al, 2019 Concentrated Solar Power Plants with Molten Salt Storage: Economic Aspects and Perspectives in the European Union, International Journal of Photoenergy.

[46] Bullis K., 2014 Molten Salts Might Provide Half-Price Grid Energy Storage, MIT Technology Review, 27 February 2014. [Online]. Available: https://www.technologyreview.com/2014/02/27/173828/molten-salts-might-provide-half-price-grid-energy-storage/#:~:text=Molten%20salt%20storage%20is%20less,be%20over%2090%20percent%20efficient.. [Accessed 25 12 2020].

[47] Baerbel Epp, 2018 Molten salt storage 33 times cheaper than lithium-ion batteries," Solar Thermal World Organisation, 12 March 2018. [Online]. Available: https://www.solarthermalworld.org/news/molten-salt-storage-33-times-cheaper-lithium-ion-batteries. [Accessed 27 12 2020].

[48] Shiraishi S, 2003 Electric Double Layer Capacitor, in Carbon Alloys, (Japan:Elsevier Science) pp447-57.

[49] Tixador P, 2013 Superconducting magnetic energy storage (SMES) systems," in Electricity Transmission, Distribution and Storage Systems, Cambridge , Woodhead Publishing Series in Energy, pp442-77.

[50] Zhu J, et al, 2018 Techno-economic analysis of MJ class high temperature Superconducting Magnetic Energy Storage (SMES) systems applied to renewable power grids, Global Energy Interconnection, 1(2):172-178.

[51] Nomura S, et al., 2010 Technical and Cost Evaluation on SMES for Electric Power Compensation, IEEE, 12, pp:1373-8.