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Household Water and Energy Conservation: A Key to Addressing the Water-Energy Nexus

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ABSTRACT

Water and energy are dependent on each other. All energy production need water to work, similarly water needs energy to treat hydropower's, power plants. Recently many studies are done on water-energy nexus (Vakilifard et al., 2018). The main purpose of this study is to find locals behavior towards water and energy conservation, to teach them and aware them from upcoming challenges (Perrone, Murphy, & Hornberger, 2011). This research uses survey questionnaire methodology for collecting data about water and energy uses, conservation from Rawalpindi, Wah Cantt and Hasan Abdal.10 to 15 samples are collected from each area. By using formula, we estimated total water and energy consumption in these areas. Results shows that there are only 10% people that conserves water and 40% that conserve energy. This is because of unawareness between locals about sustainable use, lack of knowledge, not adopting modern technology (Walsh, Murray, & O'Sullivan, 2015). Findings of the research shows that locals are consuming more water and energy then conserving it. This study also highlight's conservation barrier, future impact of inefficient water and energy use, future benefit of water and energy conservation.

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1. Introduction

The Water-energy nexus means that they are interconnected with each other which shows that action in one domain may have direct consequences for the other and we have to understand what kinds of consequences they are showing in our society and how our society consumes and utilizes it properly. Water energy conservation from previous research shows current existing methods and tools that highlights its importance and its current analysis but their studies also aim to develop new frameworks that assess link between water, energy and other elements but none can provide single framework to performing nexus study (Dai et al., 2018). The research gap that we fill is about if they do not implement their application in society then what will be the future impacts on our society. If we want to conserve one source the other source is automatically conserved. Therefore, water is essential for the production of energy because all energy sources require water for their production. Water in case of energy shows dependency on hydropower, thermoelectric power plants, bioenergy production by following the process of pumping, drilling, flowing and discharging. Water energy is dependent on water transport, water treatment and irrigation practices. The water-energy nexus highlights that managing both resources requires an integrated approach, because in future due to increasing population, climate change and environmental challenges there is high demand of water and energy which may cause pressure on them. The uniqueness about our study is that we have worked on current and future impacts of water-energy nexus system that would benefit us in long-term if we properly worked on it because water-energy nexus system is crucial to managing these resources in an integrated and sustainable manner. Due to their links with each other some interconnected challenges like water scarcity, energy scarcity and climate change can affect our environment;

through conservation, efficiency and innovations we can mitigate these interconnected challenges.

1.1. Objective

The main objective of this study is to assess the current behavior of local communities towards water and energy conservation and how water-energy nexus help our local communities in future especially for those who are the residence of those areas where water scarcity and energy production is a critical issue (Tovar-Facio et al., 2021). These objectives main focuses on improving efficiency and ensuring the long-term availability of water and energy. The measurable outcomes that we see after this system implementation is reduction in water withdrawal, energy use per unit of water that is treated, greenhouse gas emissions and cause increase in improved storage of water and energy consumption, also increased participation of public to support water-energy nexus policies and initiatives. Water-energy nexus promote sustainability by encouraging different practices to conserve water and energy, secure the resources to enable all the reliable access adapting better water and energy system. After that they showed a minimal impact on environment by reducing greenhouse gas emissions and make our environment by reducing greenhouse gas emissions and make our environment resilient for our population.

2. Methodology

2.1.1. Research Approach

Quantitative survey studies are useful for investigating water usage and energy consumption as well as the water-energy conservation efforts of local household communities. This methodological approach is optimal for collecting numerical data that can be subjected to statistical analysis to identify water-energy consumption patterns and conservation efforts.

2.1.1. Research Design

This study employs a survey questionnaire methodology for collecting data. The selected methodology aimed to collect precise information on water and energy consumption, enabling meaningful comparisons among various local communities. In the survey study, we gathered data from three cities regarding water usage habits, energy consumption patterns, and water energy conservation efforts of local household communities. The survey was structured with portions containing questions. The questions were designed to gather data regarding their daily water consumption patterns (such as baths, dishwashing, and laundry), energy usage habits (such as electricity, cooking, lighting, and heating purposes), and water and energy conservation efforts (like energy-efficient appliances usage, switching off needless lights, and rainwater harvesting). The households we selected from the three cities were asked to provide information regarding their practices, to understand their daily water and energy consumption and conservation patterns. This survey study collects data and statistically analyzes water and energy consumption and conservation efforts.

Figure 1

2.2. Data Collection

2.2.1. Survey Development

A questionnaire-based survey was conducted in 3 different cities RWP, Wah Cantt and Hassan Abdal. The main focus of this survey was on how much water and energy consumed and conserved by local household communities. The questions address individual usage habits, efforts to conserve resources, awareness regarding water and energy conservation, and knowledge regarding the overuse of water and energy that will lead to water-energy scarcity on future generation.

2.2.2. Target Population

For our research study, we conducted a survey among local household communities in Rawalpindi, Wah Cantt and Hassan Abdal. This survey was based on their daily water and energy consumption. Water supply in domestic area and their consumption vary from cites to cites in Pakistan and the reason for this is significantly based on the area they are living (location), the climate they face and individuals' total consumption. For our research study, we selected

Rawalpindi, Wah Cantt and Hassan Abdal due to their various population size and urban characteristics giving us a range of household behavior related to water energy Nexus. Rawalpindi, a densely populated megacity was included to investigate how high population density and extensive infrastructure influence water and energy usage, as well as conservation practices in urban areas. Wah Cantt, although smaller remains a primary populated city, making it suitable for examining consumption trends. Hasan Abdal, the least populous of the three, offered into how households in smaller, less urbanized areas manage resource use and conservation with limited infrastructural resources.

2.2.3. Study Area

Three cities were involved in the survey: Hasan Abdal, Rawalpindi, and Wah Cantt. The population density, industrial activity, and urbanization of these urban areas contributed to various patterns of water and energy use that are discussed there. Urbanization is the major reason of Rawalpindi large density population. The Water supplies in those areas of Rawalpindi are extremely stressed and city contains very high-water demand. There aren't many water reservoirs in Rawalpindi, and some of them are contaminated by human activity. Though the total area of Wah Cantt is less than Rawalpindi, it is still a highly populated, more industrialized city. Wah Cantt is a place where industries as well as nearby family settlements consume water. Even still, compared to Rawalpindi, the paucity of water is not as severe. There is a little concept regarding sustainable water resources with few initiatives. In Hasan Abdal, which is smaller and less populous than the other two cities, homes typically use wells or boreholes for their water supply, which is mostly derived from underground sources. Although Hasan Abdal's water use is more consistent than that of Rawalpindi and Wah Cantt, little domestic conservation is done.

2.2.4. Sampling Technique

The sampling technique adopted during collection of samples from local household communities is random sampling. 3 surveys are conducted in three different cities:

From the city Rawalpindi, the sample is collected after a survey of 15 houses. The residents were asked about the daily water and energy consumption in a questionnaire session. Second survey was conducted in Wah Cantt. The sample was collected in a questionnaire session from 10 houses. The residents of these houses were asked about their daily water and energy consumption. Same survey was conducted in Hasan Abdal and it is based on12 houses. This survey-based study selected 10 to 15 houses from the three cities to examine local water and energy consumption patterns and conservation efforts. When we combine this limited sample size with our nature of research, it improves household consumption and conservation behaviors without any broad concept. And after focusing on a select number of households across various urban areas, the study ensures us important variations in practices while ensuring data quality. This study also serves as a primary investigation for future research, providing us a basis for more comprehensive studies on the water-energy nexus.

Table 1

CITIES	TOTAL HOUSES
RAWALPINDI	15
WAH CANTT	10
HASAN ABDAL	12

3. Data Analysis

3.1. Quantitative Analysis

The numerical data collected from surveys made in Rawalpindi, Wah Cantt, and Hasan Abdal shows a relationship between water and energy consumption of local communities consuming that water and energy.

Table 2

Cities	Water Consumption(Liters/Day)	Energy Consumption (Kwh/Day)	Water Conservation	Energy Conservation	Total Houses
RWP	300-600	6-15	13%	40%	15
Wah Cantt	250-500	10-16	10%	50%	10

Hasan Abdal	250-450	8-13	8.3%	30%	12

3.2. Formula

Percentage of conserving water & energy= $\frac{Number\ of\ houses\ conserving}{Total\ Houses} \times 100$

To understand the percentage of households implementing water and energy conservation measures, a percentage calculation is implemented to show the data regarding our survey. These calculations are done by dividing the number of actively houses conserving resources by the total number of surveyed residences, then multiplying the result by 100 to express the result in percentage form. These calculation plays a crucial role in evaluating survey results, and provides us a numerical representation of those households who are adopting conservation practices. By make use of this formula, researchers can easily assess the frequency of water-energy conservation efforts among the sampled population. After a survey conducted that we conducted in 3 different cities of Pakistan; Rawalpindi, Hassan Abdal & Wah Cantt. The overall estimated water consumption among local household communities in Rawalpindi was in a range of 300-600 liters per day and energy consumption was 6-15 kWh per day and 200-450kWh per month. In Rawalpindi only 2 out of 15 houses (2/15×100=13%) were conserving water and 6 out of 15 houses (6/15×100=40%) were conserving energy.

In Wah Cantt the overall estimated water consumption among local household communities was in a range of 250-500 liters per day and energy consumption was 10-16 kWh per day and 300-500kWh per month. In this city 1 out of 10 houses (1/10×100=10%) were conserving water and 5 out of 10 houses (5/10 ×100=50%) were conserving energy. However, in Hassan Abdal the overall estimated water consumption among local household communities was in a range of 250-450 liters per day and energy consumption was 8-13kWh per day and 250-400kWh per month. In this city 1 out of 12 houses (1/12 ×100=8.3%) were conserving water and 4 out of 12 houses (4/12×100=33%)

3.3. Key Findings

Figure 2

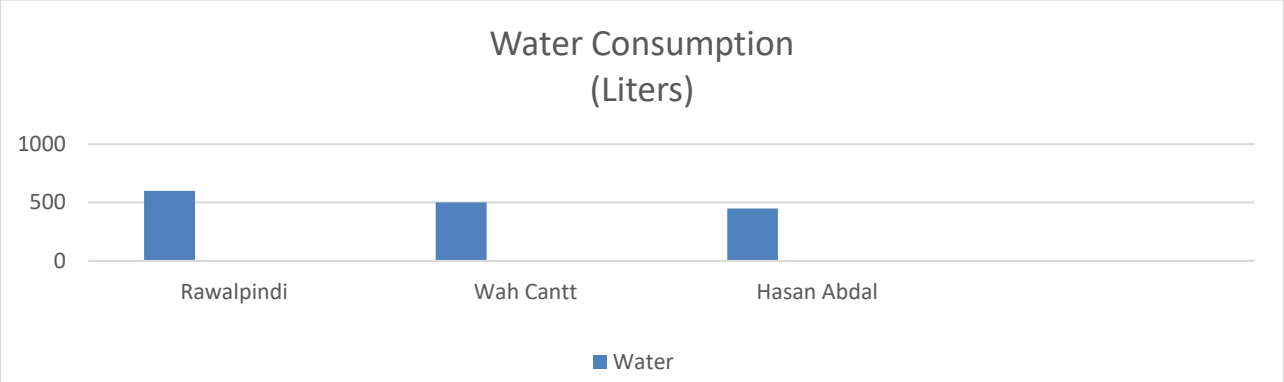
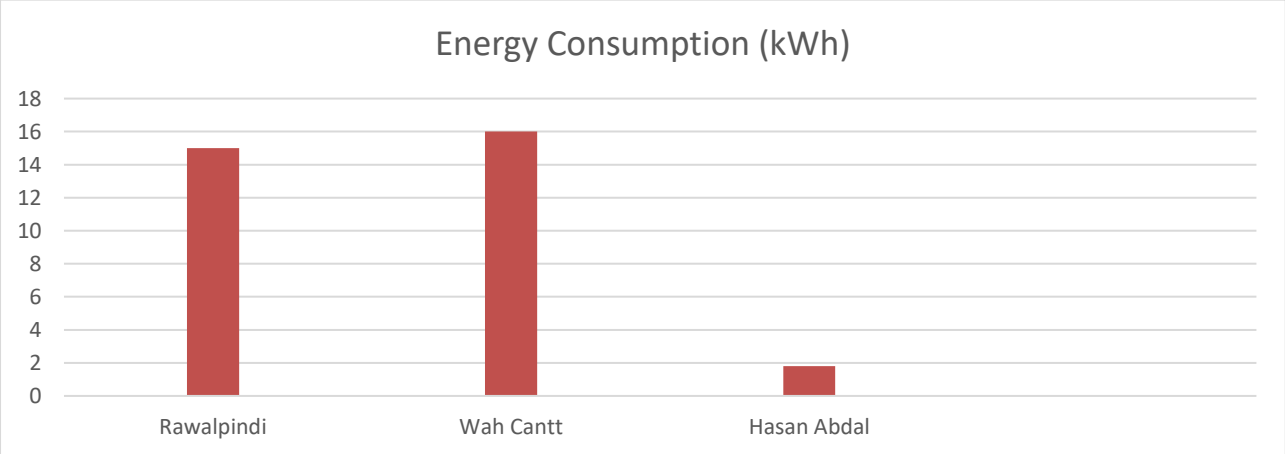


Figure 3



The upper bar chart shows the maximum water-energy consumption are observed in local household communities in 3 different cities of Pakistan.

Figure 4

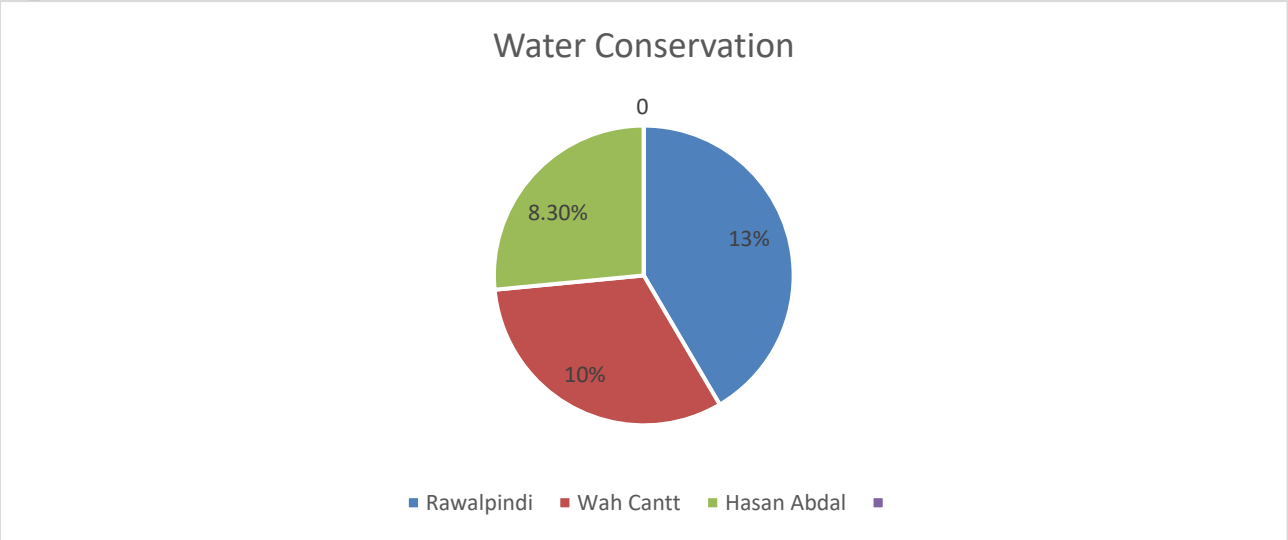
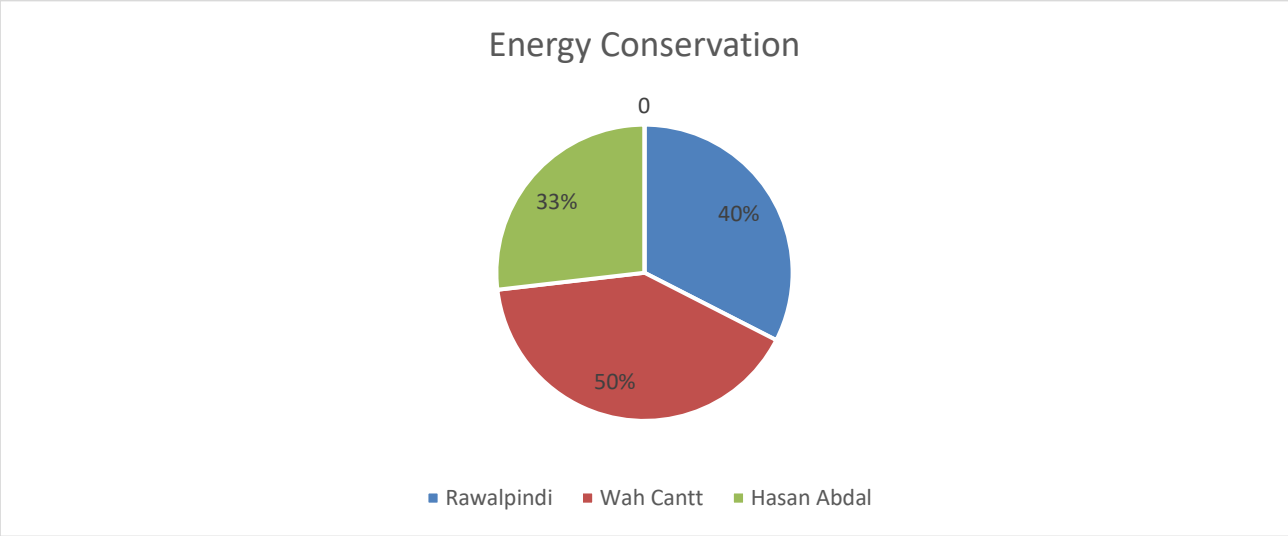


Figure 5



Similarly, this pie chart shows the minimum water-energy conservation are observed in local household communities in 3 different cities of Pakistan. Overall water-energy survey shows that local household communities conserve minimum water-energy and consume maximum water-energy from different sources. In Rawalpindi, Wah Cantt, and Hasan Abdal, water and energy conservation efforts may be hindered by various factors. One significant issue is the limited understanding among residents about the long-term significance of resource conservation and the scarcity of water and energy. Many households might not grasp how their usage patterns affect the environment or their utility expenses. Furthermore, ingrained cultural practices and behaviors contribute to the problem, with some individuals habitually using excessive water for everyday activities or leaving electrical devices on unnecessarily. The situation is exacerbated by subpar infrastructure in certain areas, resulting in water loss through leaks and outdated systems, as well as inefficient energy consumption due to old appliances and poor insulation. These combined factors lead to increased water and energy usage, undermining conservation initiatives in these regions.

3.4. Current Conservation Behavior

Water-energy conservation is essential for building a sustainable environment, especially for climate change, which strains both resources. Energy efficient water management and water saving energy production are key optimizing the relationship between these interconnected sources (Fielding et al., 2012).

3.4.1. Water Conservation

Current data on water conservation that we provided shows that there is misuse of water instead of conserving it for future. The cities which we selected for our research and the data we received regarding conservation of water shows that local household communities of RWP, WAH CANTT and HASSAN ABDAL did not pay much attention for water conservation and their percentages shows that there is very little effort they make to conserve water. RWP contain only 10%, WAH CANTT 10% and HASSAN ABDAL 8.3% which in future may become the biggest reason of water shortage (Hamiche, Stambouli, & Flazi, 2016). This is due to many local household communities did pay much attention to this emerging problem and the reason behind this is lack of awareness and understanding. Many local households might not be aware of water-energy nexus that how wasting water is increasing energy consumption. Without a proper education campaigns people may not be aware of how to conserve water. Those places where water is available all the time, but their local communities might not conserve it because they might not experience the direct water shortage and drought situations. Sometimes inadequate infrastructure may also become the one of reasons in which water start getting wasted. Many people installed old and inefficient systems that waste water. Behavior is the major issue regarding water conservation because they find it difficult to change their long-established habits, sometimes they want to conserve it but then feel that their actions might not bring a change in our society and left it over to government organization.

3.5. Energy Conservation

The energy conservation data that we collected from 3 different cities shows that RWP contain 40%, WAH CANTT 50% and HASSAN ABDAL 30% which indicates that only few people in these 3 cities of local household community conserve energy but rest of them is not conserving it which in future may create problem for them (Shakeel & Salam, 2020). The main reason of those who are not conserving energy is lack of education because they do not understand how conserving energy can impact and their personal finances. Sometimes where energy is inexpensive or having cheap access to local household communities, they can overuse of it like overusing of air conditioner, leaving appliances on standby. In some communities, especially in low-income areas where household may not have enough income to invest in energy efficient appliances, as a result they use old methods of using energy which consume more energy. Housing and infrastructure quality is major reason because those communities where in fracture not support energy efficient technologies might face structural barriers to conserving energy. Addressing these factors through targeted community can help to encourage energy conservation efforts.

3.6. Barriers to Conservation

When we planned to implement some applications regarding water-energy conservation, there are some barriers that we face during their implementation in our society (Fayiah et al., 2020). There are several barriers to conserving water and energy that depend upon social, economic, and geographic contexts.

3.6.1. Inefficient education

School, government and other organization does not provide adequate education regarding conservation of water and energy which in future give benefit to the environment and the human itself.

3.6.2. Incentives Misalignment

Sometimes the cost that we saved from conservation may benefit the third party and for that reason the businessman or investor get demotivated to act.

3.6.3. Aging Infrastructure

Old infrastructure related to water and energy can be inefficient which leads to excess waste of water leaks and energy loss.

3.6.4. Policy Barrier

This is the most important barrier because conserving laws and regulations do exist but due to weak enforcement of laws people may not give proper attention to them.

3.6.5. Overconsumption

When resources are inefficient and cheap, people tend to over consume it which lead to wasteful of water energy resources.

3.6.6. Technological Barriers

Though technology has improved day by day in energy efficient system and water conserving technologies but further research is needed to make these technologies more affordable on large scale.

3.7. Future Impacts of Inefficient use of Water and Energy

The cities of Rawalpindi, Wah Cantt, and Hasan Abdal face potential dire consequences due to their ineffective management of water and energy resources. As water supplies dwindle from wasteful usage, water shortages will become a pressing concern, affecting both residential and commercial sectors. This scarcity will result in higher water prices, particularly burdening disadvantaged groups. Simultaneously, the excessive dependence on energy for water extraction and purification processes will escalate energy consumption, leading to increased utility expenses and potential power shortages.

3.8. Future Impacts of Inefficient Water use

Inefficient water utilization has significant long-term consequences, particularly in regions experiencing water stress. Due to population growth, urbanization, and agricultural demands, water consumption has increased. The following are some critical future impacts (Pérez, 2016).

3.8.1. Water Scarcity and Depletion of Aquifers

The inefficient utilization of water in residential and agricultural sectors results in the depletion of freshwater resources, particularly groundwater. Excessive extraction from aquifers leads to water scarcity. Inefficient water usage may result in adverse consequences in the future. Anthropogenic and industrial activities are contributing to the pollution of water resources, while the availability of fresh water resources remains limited. Excessive extraction for agricultural or industrial purposes is leading to water scarcity.

3.8.2. Ecosystem Degradation

Inefficient water use results in ecosystem degradation; for instance, excessive irrigation exploits freshwater ecosystems such as rivers and lakes, leading to habitat loss. Suboptimal irrigation practices contribute to soil degradation, resulting in the loss of plant life and habitat. Furthermore, inefficient water use can disrupt the water cycle, thereby affecting ecosystems.

3.8.3. Increase Costs and Social Inequity

As water resources become increasingly scarce, the costs associated with securing water resources will increase. This scarcity will disproportionately affect low-income communities, resulting in social inequity. Regions with limited infrastructure to manage water resources will face challenges in providing safe water. The inefficient use and waste of water lead to increased costs for managing, treating, and distributing water, which may become unaffordable for low-income regions. When water scarcity occurs due to inefficient usage, regions will compete for available resources, potentially exacerbating social inequality.

3.8.4. Climate Change Exacerbation

Climate change is exacerbated by inefficient water use. Ecosystems are impacted and lose some of their capacity to store carbon when rivers and aquifers are over extracted. Natural carbon sinks include wetlands, forests, and other ecosystems; excessive water use degrades these natural resources.

3.9. Future Impacts of Inefficient Energy use

The ecology and society are greatly impacted by inefficient energy consumption, especially when it comes to fossil fuels (Larsen & Drews, 2019). Overuse of energy continues to be a hindrance to sustainability. Several upcoming effects include the following:

3.9.1. Negative Feedback on Water Resources

Water management, treatment, and distribution all require energy. Inefficient energy consumption stressed already scarce water supplies by requiring more water for its production,

which leads to excessive water extraction from natural resources including rivers, lakes, and aquifers.

3.9.2. Health and Environmental Degradation

Pollution of the air and water will result from the continuous inefficient use of energy, especially that which is generated by fossil fuels. Respiratory disorders and heart problems may arise from this. Long-term ecological harm is caused by environmental effects such habitat degradation and air and water pollution.

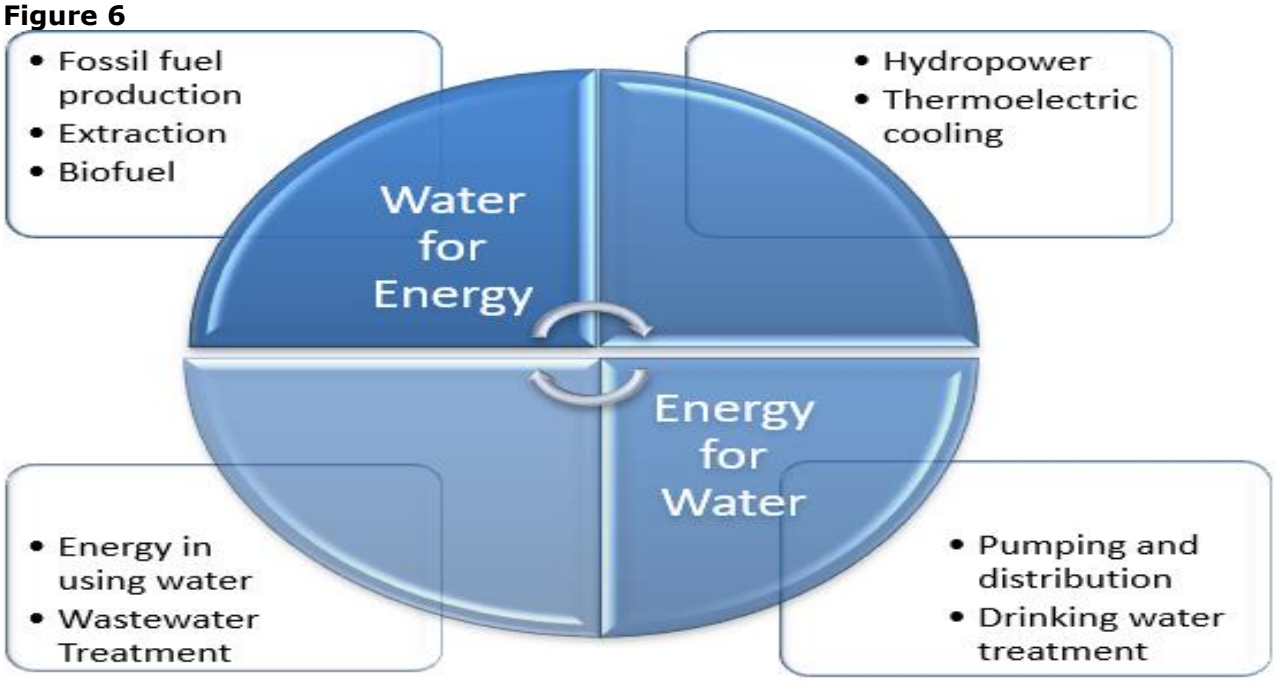
3.9.3. Resource Depletion and Increased Costs

Using more resources than necessary, such as burning fossil fuels to generate electricity, is a common sign of inefficient energy use. This adds to the depletion of resources. Costs may also increase as a result. This covers both the direct expenses of more energy use as well as indirect costs like harm to the environment and health problems. Additionally, it raises greenhouse gas emissions, which exacerbate climate change.

3.10. Water Energy Nexus

The interdependence between water and energy is known as the "water-energy nexus." Water is necessary in vast quantities for the production of energy.Fontenelle et al. (2022) For example, hydropower utilizes water for the production of energy, whereas for cooling purposes thermoelectric plants utilize water. However, energy is utilized for heating, treatment, and distribution of water. This includes the extraction of water for urban and agricultural purposes as well as for treatment, in which energy is utilized to purify water. Because water and energy are interlinked conserving both will reduce stress on them (Nakhaei et al., 2022). Undertaking the difficulties of the water-energy nexus stresses an inclusive strategy that combines policy measures, technological advancements, and community engagement. Through education and public awareness, we can make local communities understand the interconnectedness of water and energy and that conserving both resources reduces stress on them and we can save these resources for future generations. For this purpose government and local communities have to work together for the management of these resources. This will ensure sustainability and mitigate stress on the ecosystem.

Figure 6



4. Future Benefits of Water Conservation

Water is essential requirement for the survival of very human being on earth. Therefore, conservation for water should be a primary concern (Kahe et al., 2023). However, some people assume that earth is mostly made up of water, then water conservation is not necessary. Many people also unaware that excess water usage is a major factor that contributes to worsening environment conditions.

4.1. Impact of Water Conservation on Energy Usage

As all the water that is used by human require treatment & special processing that consume a lot of energy & after all processing done to make water drinkable by humans, the transportation of the processed water also require considerable amount of energy. Hence by conserving water, the use of energy can be minimized.

4.2. Need of Conservation of Water

Freshwater is becoming more of a sparse resource with each passing year, population increase is also a major factor that contribute to extreme water usage. On the other hand, severe droughts have limited its supply. Water is the major resource that is used by all the human beings to perform essential day to day activities. So, we need to save water to keep our daily activities going, to grow the food that we eat & to preserve natural habitats. By conserving water, we can also reduce the burden on water treatment facilities. Thus, saving money & energy.

4.3. Conserving Water Saves Energy

- Saving water can save energy. They both are interacted with each other. Energy is required to filter, heat & pump water to our houses, hence reducing water use also reduces the energy needed to pump & filter the water.
- Saving water helps to reduce energy consumption because the demand for water production reduces, as a result this saves energy which reduce carbon footprints that can damage the water supply & reservoirs.

4.4. Advantages of Water & Energy Conservation

4.4.1. Water Conservation Sustainability

Water conservation sustainability refers to the conservation of water resources which ensures its availability, affordable access, quality for improving the health, welfare & productivity of populations (Ding et al., 2020).

4.5. Strategies for Water Conservation Sustainability

4.5.1. Water Harvesting & Storage

Many water reservoirs are used to store water on the surface of earth & underground. There also exist some natural reservoirs such as oceans, glaciers, lakes, soil moisture, rivers, atmosphere & groundwater. Another example of water is rainwater harvesting. The rainwater is collected & stored in a suitable container rather than allowing it to runoff (Helmbrecht, Pastor, & Moya, 2017).

4.5.2. Flood Management

It is the method of implementing procedures that helps to protect, restore & reduce the risk of flooding which can be done by planting trees, by preserving or by increasing the riverbeds & canals, by increasing the number of water reservoirs such as dams. This stored water can be useful for the future use.

4.5.3. Resue of Water

Water can be recycled for reuse instead of wasting it. Waste water can be reused after recycling. The wastewater undergoes many treatment processes including physical & biological removal of pollutants, then under go to filtration. This is the reuse of disinfection. This water reuse after recycling can conserve water, fulfill present need of water without comprising the future need of water (Helerea, Calin, & Musuroi, 2023).

4.5.4. Benefits of Water Conservation Sustainability

The benefits of water conservation sustainability is important for future in many ways (Ramos et al., 2021).

- Ensure water availability
- Promote human health by fulfilling its need of water
- Promotes food security
- Support energy production
- Tolerate climate change

4.6. Energy Conservation Benefits in Future

As water-energy interconnected with each other. The uniform use of one will ensure the availability of other. By conserving water, we will automatically conserve energy. Energy generation requires water, decrease in water availability does not generate energy and thus the energy requires to pump the water into our houses get reduced. There will exist the shortage of water in household (Ahmad et al., 2020).

4.6.1. Conservation of Natural Resources

By conserving energy, the load on natural resources will reduce. Hence, they remain conserve and can be used for various other purposes such as in agriculture, manufacturing, industrial processes.

4.6.2. Energy Cost Saving

Conserving energy reduces energy cost in many ways one of which include decreased fuel consumption by conserving energy we can reduce the fuel consumption, save the cost expenditures on fuel.

4.6.3. Protection of Ecosystem

Conserving energy can also protect ecosystem in many ways such as:

a) Water conservation

Water conservation protect aquatic habitats, support biodiversity and maintain water cycles.

b) Decreased air pollution

By consuming energy the harmful pollutants discharged, air will reduce which improves air quality, decrease SO2 emissions. By reducing energy usage reduces the demand of fossil fuels and ultimately lower the level of pollutants likes CO2, SO2 to be discharged in air.

4.7. Future Impacts of Water-Energy Conservation According to Survey

- In a survey which is conducted in RWP, WAH CANTT and HASSAN ABDAL, the ratio of water conservation by people of local household communities was very low as compare to ratio of water use. Only few out of many people according to our survey were conserving water in their household and prevent over use.
- This survey was conducted on a small scale in few houses but still ratio of water conservation was very low.
- Small scale water conservation put a drastic impact on large scale water usage. If the water is not conserving in household than how can we expect its conservation on large scale?
- The environment in which we are living belongs to us, instead of keeping our surroundings clean, safe & hygienic we are making it worse to live.

The purpose of this survey was to estimate how many people are contributing to conserve water but unfortunately the results were not delightful. The reason of today's water deficiency is its overuse in houses by people either intentionally or unintentionally, which directly affect our environment, we are not facing only droughts but also, we are facing energy shortage. The most important step should be taken by every individual is to conserve water because being a human being we are completely dependent on water and energy, by maintaining a balance use of it we can safe both human health and environment.

5. Conclusion

To conclude we can say that water energy nexus is interconnected and interlinked; by conserving one we can reduce stress on both. Current behavior of locals towards water and energy consumption is negligent. Now a days there is usually high consumption and very less conservation of water and energy resources, if this behavior continuous then in future we have to face water and energy scarcity. Limited water resources will automatically generate high expenses for the treatment of water. Local communities cannot afford this high cost of water, energy and their treatment. This is right time to give attention to these issues and this can be done by aware locals, adopt new technologies, and by changing our consumption behavior of water and energy resources. Further that both water and energy are basic need, we have to

consume them carefully so that we can conserve them for our further generations (Marmer, 2018).

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