

Sustainability Innovation

Innovative Approaches To Limiting The Adverse Effects Of Urbanization On The Water Cycle

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Summary

Nowadays, as society steps forward, more cities are built, which leads to terrible urbanization. At the same time, the usable water is getting less because of over-extraction, pollution, and various factors. As human is the one that mainly responsible for the result, we want to investigate the approaches to limit the adverse effects of urbanization on the water cycle. We decide to put our investigation in our community, on our campus in Shanghai, China.

We first discuss several factors that affect the water resources in Shanghai. Each one gives a brief introduction of the main reason for threatening and challenges to the water in different aspects, like environment or daily life.

Then, we further analyze two major causes of water resources in the Shanghai area. We mainly focused on the cause of 'urbanization' and combined this concept with practical Shanghai geological figures, identifying how the city's growth and adjacent environment contribute to the disruption of the water cycle. The minor cause refers to the issue of water deficiency, which is a kind of physical water scarcity in quality and quantity.

Aim at those two causes, we analyze the problem solution from multiple perspectives through the EVS analysis method. This approach effectively allows us to think about solving the problem of sustainable water resources from multiple perspectives, such as technology, policy, and ecology. At the same time, in the presentation of the scheme, we add our thinking and preliminary evaluation of the scheme.

To find the best solution among all others, we adopt the SWOT analysis method, which is very effective and considers the rationality of the scoring standard from the program itself and external factors.

We grade each solution against the SWOT scoring criteria. And, with each assessment, we explain in detail. "Rainwater collection," "Recycle of greywater" and "Drip irrigation" and "Reconstruction of the city" get high marks. Because almost all of these are related to agriculture, and almost all of them are effective solutions. We finally adopt the form of Greenhouse to combine several of our solutions to develop our next action plan.

Before we designing our greenhouse, several examples are being researched online to find out some previous experience in building the greenhouse. Through the examples, we find several common characteristics which we can adapt to our own. While designing the greenhouse, we design up a complete rainwater collection system and added several data which will be most efficient to the whole process. At the same time, other factors, including the material is also considered to meet the requirement for a sustainable greenhouse.

We make a prototype picture based on the action plan and design a series of questions and integrate them as a survey. After receiving the survey' s feedback from the users who see the design, we analyze our weaknesses and strengths and find out some potential risks. From the feedback, we also find out some parts that we can give further improvements to, such as the poor temperature control system. We try to implement our design on our campus and do some changes based on our design. We solve the temperature control problem but hard to achieve rain harvesting. Currently taking a role as an educational tool, we plan to develop further into irrigation system and focus on agriculture in the future.

Choose the Topic

Identify the Challenges

1. Population

The permanent resident population of Shanghai is 27,795,702, with an annual growth rate 2.72%. While some would believe that Shanghai has hit its peak population, this is far from the truth. It is estimated that by 2050, the population of Shanghai and Beijing will exceed 50 million, which is twice the current level due to the rapid urbanization process and strong economic growth in the region [1]. With the growth of Shanghai's population, the contradiction between supply and demand of water resources in China is still very serious, especially the serious phenomenon of water resources waste and pollution, which increases the contradiction: the massive growth of population accelerates and aggravates the emergence of water resources crisis. The water consumption of production and living increased greatly, and the water supply crisis appeared. The source and basin of water are easy to be polluted as well.[2]

2. Eutrophication

Water eutrophication refers to the phenomenon that a large number of nutrients such as nitrogen and phosphorus enter slow flowing water bodies such as lakes, estuaries and bays under the influence of human activities, resulting in the rapid reproduction of algae and other plankton, the decline of water dissolution, the deterioration of water quality and the death of a large number of fish and other organisms.[3]

One of the common indicators of water eutrophication is nutrients, which is also the most important indicator, mainly the concentration of nitrogen and phosphorus (including various states) (mg / L).

The organic pollution of Suzhou River and Huangpu River in Shanghai is becoming more and more serious. In 2020, the organic pollution of Suzhou River is 0.6mg/l, the total nitrogen is 10.06mg/l, the total nitrogen of Huangpu River is 0.23mg/l, and the total nitrogen is 4.03mg/l, which seriously exceeds the standard. Phosphorus in detergent accounts for 6.82% of total phosphorus load.[4] Taking chlorophyll-a, total nitrogen, total phosphorus, permanganate index and ammonia nitrogen as the main water quality indexes and adopting biological indexes such as nutritional status index, the water quality of Shanghai Heping park is inferior to class V (Class V water is mainly applicable to agricultural waters and waters with general landscape requirements. If the water quality of urban river reaches class V water quality standard, it means that the water quality of urban river reaches the standard applicable to agricultural irrigation and general landscape requirements, and if it is inferior to class V here, it means that it is lower than Class V standard).[5]

Eutrophication brings great harm. For example, it will affect water quality and may lead to supersaturation of dissolved oxygen. Because the eutrophic water body contains nitrate and nitrite, people and animals will be poisoned by drinking water with these substances exceeding the standard for a long time.

3. Acid rain

The South China coastal areas represented by Nanjing, Shanghai, Hangzhou, Fuzhou and Xiamen have become the main acid rain areas in China. Shanghai belongs to monsoon climate and is a rainy city, almost one of the three days of the year is raining. [6] Due to the relevant policies and treatment in recent years, the frequency of acid rain has decreased compared with previous years, but it is still one of the factors threatening Shanghai's industry and agriculture.

The chemical characteristics of acid rain in Shanghai are low pH value. The concentrations of sulfate (SO_4^{2-}), ammonium (NH_4^+) and calcium (Ca^{2+}) are much higher than those in Europe and America, while the concentrations of nitrate (NO_3^-) are lower than those in Europe and America. The acid rain in Shanghai is sulfuric acid type, which is mainly caused by man-made emission of SO_2 . Acid rain can cause health problems in people, damages lakes and streams, pollute the water resources thus affect the growth of plants or crops, which lead to more negative effects in Shanghai.[7]

4. Innovative approaches

Lack of water resources management system means. The main reason is that there are no mandatory constraints and measures in water resources management, and the government does not use assessment and approval methods to reflect the management measures of water resources.[8] At the same time, it has been following the management methods in the era of planned economy, without innovative management means, so that the management system is backward, the management is extensive and other problems still exist, affecting the implementation of water resources management.

In addition, the current administrative departments in charge of water resources have redundant institutions and many idle personnel.[9] Meanwhile, sewage treatment involves a lot of content, energy consumption and capital costs are large. At present, the government has less investment in sewage treatment equipment, and the preferential policies given by the government are less, so it is difficult to carry out large-scale sewage treatment. Although China has invested a large number of new urban sewage treatment plants, the investment cost is large, and the later maintenance process also needs to spend a lot of money, resulting in some cities are reluctant to invest more money in sewage treatment work and the water pollution problem cannot be better solved.[9]

5. Infiltration

Soil infiltration is one of the important processes of hydrological cycle. It can affect

groundwater recharge, water conservation and surface runoff, all of which are related to ecological security. In the process of urbanization, concrete pavement or soil compaction often greatly limits soil infiltration and increases soil runoff and flood.[10]

In rainy season, however, sufficient water supply is not allowed, which often leads to water shortage in dry season. Therefore, improving urban soil infiltration rate is particularly important for urban water cycle and ecological security. Compared with herbaceous plants, tree species have a greater impact on soil infiltration.

6. ground water pollution

According to statistics reported by the Chinese media, more than 80% of the underground water in large river basins of mainland China is unfit for drinking or bathing because of contamination from industry and farming. This was first revealed in 2015.[11]

In Shanghai, the underground water is also polluted severely.[12]

The waste water produced by the factory is directly discharged, and the harmful gas and chemical substances enter into the atmosphere, then enters into the groundwater with the rainfall, and the factory waste residue and radioactive substances, heavy metals, organics, petroleum hydrocarbons are buried in the ground, which contact with the groundwater and affect the water quality.

Third, in order to pursue benefits, farmers use a large number of pesticides and fertilizers, and the unabsorbed substances enter the underground, which makes the nitrogen, phosphorus and other elements in the groundwater exceed the standard. Here is the list of groundwater pollution sites in Shanghai (as of December 31, 2020) *[13], which indicates the underground polluted situation in different districts.

7. Fertilizer

Agricultural soil pollution is on the rise in Shanghai. The heavy metal pollution has been caused by the extensive use of pesticides and organic fertilizers. The characteristics of chemical fertilizer and pesticide pollution in Shanghai are mainly nitrogen loss from chemical fertilizer and organic material loss from pesticide. [14,15]

At the same time, the structural defects of chemical fertilizer and pesticide varieties, the weak ability of technological innovation in the use of chemical fertilizer and pesticide, and the technical obstacles in pollution control are the main reasons for the aggravation of chemical fertilizer and pesticide pollution in this city.

Professionals show that agricultural land is more difficult to repair than industrial land.[14] Many of the former are abandoned land, which is neither used for living nor for production, and there is enough time to harness them. Although the latter can separate heavy metals from soil by replanting plants, these lands bear the heavy responsibility of producing food and vegetables, and it is difficult to make time for "recuperation".[15] When these pesticides and fertilizers enter into the water source, it will lead to serious problems such as the destruction of water quality and the

reduction of water resources.

8. Chemicals

Some industrial areas in Shanghai, such as Jinshan Chemical Plant, have unreasonable management and technology when dealing with industrial waste products.[16] At the same time, due to the large number of industrial areas in Shanghai, their chemical pollutants also have a certain negative impact on the environment of Shanghai. For example, sulfur oxides, carbon oxides, nitrogen oxides, particulate matter, hydrocarbons and other harmful substances brought by chemical pollutants, such as heavy metals, all cause a variety of environmental problems, such as aggravation of acid rain, destruction of the ozone layer, water pollution (industrial sewage), increase of solid waste, biodiversity change, habitat destruction, etc.[17]

The harmful chemicals directly flow into channels, rivers and lakes and pollute the surface water, causing the death of aquatic animals and plants. Industrial wastewater seeps into the ground and pollutes the groundwater, thus polluting the crops.[16] The pollution and scarcity of water resources will endanger the health of residents and cause life safety problems.

9. Climate and landscape

Shanghai enjoys a mild and moist climate, a subtropical maritime monsoon climate with four distinct seasons, with high temperature and rainy in summer and mild and less rain in winter. [18] It is extremely unstable because it is formed by the southeast summer monsoon. Since the terrain of Shanghai is plain, when the summer monsoon is weak, the summer monsoon is easy to invade, which is easy to cause the result of South water-logging. [19] This is a challenge to the uneven seasonal distribution of water resources in Shanghai.

10. Human activities

First of all, Shanghai sewage treatment technology consumes a lot of energy, which not only wastes water resources, but also seriously hinders the efficiency of sewage purification.

Secondly, in the process of urban development, residents will produce a lot of sewage every day. When these sewages cannot be treated timely and properly, it will have adverse effects on urban water resources and environment. [20]

At the same time, due to the limited level of wastewater treatment technology in some cities, it is unable to maintain long-term, stable and up to standard operation. In order to ensure that wastewater treatment meets the specified requirements, some enterprises will increase energy consumption, increase the dosage of chemicals, extend the treatment time to a certain extent, and even continuously treat the same wastewater for many times, which seriously increases the cost of wastewater treatment.[2,8] In the process of urban sewage treatment, in order to obtain more profits, enterprises will reduce the cost of sewage treatment, and the

standard of sewage treatment will be reduced as much as possible, resulting in serious water discharge phenomenon in the process of sewage treatment.[21] In addition, the sewage treatment technology is more complex, and the quality of technical staff is difficult to adapt to the technical requirements, resulting in low efficiency of sewage treatment and difficult to meet the specified standards. The sewage treatment work is mainly carried out by the internal staff of the enterprise, and the supervision and management work are not strict enough. Sometimes, it will even discharge at will regardless of the national sewage standards, causing immeasurable damage to human health. [8,9,22]

11. Contamination and over-extraction of water

With the rapid growth of human population and people's increasing living standard, the demand for water access has been sharply on the rising trend, which causes the over-extraction of water resources. Whether it's from domestic aspect or from industrial and agricultural perspective, it all greatly contributed to the disruption of water cycle. Our team aims to identify this challenge from two dimensions: One is for over-extraction, the other one is for Water Contamination.

11.1 Over-extraction of water

According to The World Counts, we consume almost 4 trillion cubic meters of fresh water annually. The agriculture alone has accounted for more than 75% to 90% of a region's available fresh water. [23] With the over-extraction of water resources, it would harm water cycle greatly. Removing water from groundwater sources through extraction techniques, such as digging wells reduces the amount of water available for surface water, which is a great part in water cycle. This can cause the drying of surface water because less water is left and less water is in the process of evaporation, thus interception, infiltration... When water is extracted from rocks and soil (groundwater), this means that less water is in the process of through-flow and infiltration, it will cause the collapse and collision of rocks, which also leads to the unbalance of water cycle.

11.2 Contamination of water resources

Shanghai is now facing a severe problem with water quality these years. In 2017, Ministry of Ecology and Environment figured out that only 22 percent of water monitoring stations in Shanghai had potable water to consume on. [24] Compared with other provinces and cities in China, Shanghai was ranking the top one when considering polluted water, total wasted water, COD emissions (Chemical Oxygen Demand) according to China Eco-City Tracker's Data. [25] Through industrial usage, the factories will produce much exhaust gases and even poisonous chemicals to the atmosphere, which will contribute to acid rain and eventually land on the surface water resources. Also, the sewage will directly pull into nearby rivers without strict regulation, which not only carry a bunch of water-related diseases, but also decrease the quality of water. Besides, agricultural use matters from the overuse of

fertilizers. Specifically, when misuse of chemical fertilizer happens and when the soil is not fully compacted, it's easy to experience run-off and soil erosion. It's even worse when the fertilizer contains toxic chemicals. What's more, one of the major causes of water contamination derives from human faeces (most serious in African areas). As some of the developing countries don't have sufficient access to public toilet and WC, their mismanagement of faeces will topple and flow into rivers and streams. Since water is cycled, if one cycle is disrupted, the other remaining process will be affected.

12. Tourism

With the rising trend of per capital consumption level, more of the young are into travelling all over the world. Although tourism may bring local job opportunities and income access, this entertainment form does pose threats to the water resources during the process. According to jaunt and excursion, the transporting mode are usually private cars and HSR. It is estimated that 5 quarts of exhaust gases from private cars will pollute a million gallons of drinking water. [26] The constructing transportation path (land use) will decrease the permeability of surface ground, thus increasing water run-off, accelerating the rate of soil erosion and water erosion.

Construction of hotels will require many timbers, which will lead to rising rate of deforestation. Once the forests are cut down, it means that less water sources will be intercepted by leaves and the rate of infiltration will decrease at a fast speed. At the same time, the soil will be less compacted because the roots of trees are already loose, posing threat to the possibility of water erosion, more importantly, the tourism overuses water resources for hotels, swimming pools will lead to water shortages and degradation of water resources, which will generate wasted water at the same time.

13. Invasive species

It's quite common that there are a certain number of animals moving into a new area through different ways and cause impacts to the local ecosystem. These animals and plants enter a new habitat by different natural events or natural hazards, such as flooding, storming, tropical cyclones and so on. Also, their migration matters at the same way, the existence of new invasive species will compete for the same resources with the local species and affect the original water cycle especially when these species are live nearby the water access. For example, invasive plants will increase the speed of evaporation, decrease the water currents, and change the nutrient cycle as well. Also, some animals like cattle will consume much water, which will decrease the water available for humans in this aspect. Another situation happens when some species are toxic, which will add more toxins into the river resources and then reduce the water quality, which will make it again unavailable to drink and consume up, Therefore, with the introducing of new species into a local area, both the ecosystem and water quality will be affected in

this way. According to IAS published by CAS (China Academy Sciences), species originating from Americas made up of 51% of the total. 52% of the plant' s species were introduced intentionally and 82% of the animal species were introduced unintendedly. 93% of the species are distributed in highly disturbed habitats. [27]

14. Aquaculture

There is a rising trend that aquaculture gradually dominated the fish production for human consumption instead of fishing, which accounts for about 87% of the total production in 2014. However, fish farming does cause lots of water pollution variably. Our group aims to analyze the water pollution from different aspects. For the use of chemical fertilizers feeding on fish, these chemicals may although be beneficial for growth of fish, but however damage the water quality. The reason is that fish farming needs the water to be current at any time in order to produce enough oxygen for fish species they are cultivating. Therefore, sometimes when the fertilizers are pushed into the water, these chemicals are not fully absorbed by the fish and then being pushed into the rivers locally. In this way, harmful and toxic chemicals will enter the water table and spread out very quickly. Toxicity chemicals in aquaculture usually involves the harmful effects of elevated concentrations of metabolites (carbon dioxide, ammonia, nitrite, and hydrogen sulfide), algal toxins, heavy metals, and agricultural and industrial chemicals. For example, the waste produced through the process of aquaculture may contain antibiotics, pesticides and dish feces which pollutes the open water and make it unavailable for human drinking, recreational use and so on.

Since the space is limited with a decade number of fish species, it' s easy for disease and pathogens to live in the water table. As soon as one disease is emerging, it would spread out very quickly inside the water. Despite from the sewage and toxic water pulling into local rivers, our groups think that the dead body of fish will also be a matter. When the fish are suffered from illness and diseases, they may die very quickly, and the farmers need to deal with these dead fish. The most frequent solution is to treat them as a wasted rubbish. If these wastes are not treated correctly, the chemicals dead bodies of fish produced will again cause the death of many other species and pollute the local water table at the same time, which will lead to the fact that: aquaculture has high possibility to be a serious case of disruption for local water cycle and water availability.

15. Overfishing

The waste produced by human consumptions will be the first case. It' s recorded that more than 35 million tons of food were lost or wasted in China annually, enough to feed 30 to 50 million people. [28] With the increasing world population and urbanization, people' s living standard has sharply increased these decades, which leads to the overfishing in the ocean. However, when people cannot consume all the fish they bought from the fisheries, the waste they produce will be a huge matter. Since food waste is already a serious problem in local areas, the addition of

wasting fish will add more severity to the issue. As the waste is not fully well-treated, they will be thrown into somewhere else or pull into rivers. Besides, since more fishermen are deciding to catch fish in the ocean, the creation and construction of fishing boats will be another case. Also, the effluents made by ships will flush into oceans, which is not only harmful for local marine ecosystems, but also greatly cause damage to the water quality. For example, a study shows that 'bottom trawling' can disrupt the ability of microbes in sediment to remove excess nutrients in coastal water, potentially increasing that pollution. [29]

 [The classification of lake eutrophication](#)

 [List of groundwater pollution sites in Shanghai](#)

 [Work cited page](#)

Identify a Root Cause

Part1. Urbanization

Nowadays, with people's increasing population and increasing up-warding standards, the urbanization is at sharply rising tendency together with industrialization. Through analyzing the challenges water cycle might face in the contemporary society in defined areas, our group draws into a conclusion that: Urbanization will be the mandatory root cause for the disruption of water cycle in Shanghai.

Urbanization can be defined in terms of the concentration of population in larger urban settlements of a given territory. Since urbanization has played an essential role in the development of each country, it's estimated that more than half of the world's population now live-in urban areas-increasingly in highly dense cities. Around more than 4 billion people live in urban areas globally. [1] Given to the coastal geology site and China's economic reform, Shanghai has experienced fast urbanization, which is obvious when people compared photographs' of Pudong nowadays and in the past. From the geology of Shanghai graph inserted [2], Shanghai is located on the Yangtze River Delta on China's East coast and its proximity to the Pacific Ocean via the East China Sea. Shanghai contains 53.1 km of rivers and streams and is part of the Lake tai drainage area. Huangpu River is 80 km long and is around 400 meters wide. [3] Nonetheless, regardless of the positive benefits it brings to the city, our group has considered this growth as a main cause for water cycle disruption, which we will discuss in the following paragraphs. It's estimated that around just 3 percent of the water in Shanghai city is portable to drink and use, discovered by one census of water resources.

The influence caused by urbanization is mainly two aspects: precipitation and water quality. The loss of water resources and pollution is mainly driven by the construction of equipment, more advanced transportation system, rising of industrialization, designing of roadways and pipelines and so on, which potentially or directly add pollutants to the water resources. The inserted graph and picture shows the water cycle process in Shanghai area. [4]

To begin with, to talk about the decrease of through-flow, people will cut down many forests and trees, which reduce the rate of interception and transpiration. According to global forest watch, Shanghai has lost 1.4 ha of tree cover, equivalent to 138t of carbon dioxide of emissions. [5] As a consequence, the rate of through-flow will increase, and the number of interceptions will decrease at the same time.

Additionally, according to the data from Freshwater Watch Platform, it's discovered that most of the water resources have the situation of increasing concentration and turbidity of nitrate near Huang Pu River areas. [6] The fact that peak point of nitrate concentration happened during summer in Shanghai means that more of these chemicals are entering into the water table through various routes. To consider where these pollutants come from and where do they finally go, our group determined these aspects. Normally, the pollutants in precipitation (which experiences through-flow later) comes from natural process precipitation, the soil surface itself and the underground water system. It's mainly classified as SS, heavy metal, nutrients from eutrophication (which is caused by misuse of fertilizers), bacteria, virus, acids, different types of pesticides and herbicides, humus and so on. [7] It's worthy to mention that the pollutants will flow from the roof of buildings, effluents of vehicles or other approaches and finally can enter the water table, which is a serious problem we called 'sewage'. People's increasing desire for vehicles and job opportunities, or even rising desire for traveling with friends will let the car factory produce more cars, which produces more poisonous gases to the atmosphere.

During the process, the food waste produced by people is also another huge problem. The urbanization has attracted people from other province to come to Shanghai, seeking for job opportunities and higher lifestyles, which means that more population will be gathered in a tiny city area. According to World Population Review, Shanghai's population has now achieved more than 27 million, which means it has surpassed the entire population of nearby Taiwan. According to the 2010 Census, Shanghai's population was 89.3% (20.6 million) urban and 10.7% (2.5 million) rural. Over 39% of Shanghai's residents are long-term migrants, primarily from Anhui, Jiangsu, Henan and Sichuan, while mostly from rural areas. [8] The food wasted produced by citizens will partly be poured into water resources without legal restriction secretly. Also given to the geology issue, Shanghai's local pollutants will flow into other provinces by the link of Huang Pu River, which will cause a more severe problem for other cities.

In conclusion, the resources are already limited, but young people's desire for seeking higher living standards are unlimited and uncontrolled. Shanghai is a defined area with only 6340.5 square kilometers. [9] If more population is gathered in this international city, it will be undoubted that more pollutants will be poured into water table and more factories are encouraged to produce more products, while in the process do great harm for the water cycle.

Part 2. Water Deficiency.

The fact is that Shanghai was chosen to be one of the cities which are experiencing

water deficiency. 'Water scarcity is the lack of sufficient available water resources to meet the demands of the water usage within a region' ---Sciencedaily It's estimated that over 2 billion people live in countries experiencing high water scarcity today. [10] Water deficiency is correlated with physical resource water scarcity and economic water scarcity. In general, both scarcities will deteriorate the issue of water deficiency. The most mandatory cause for this issue for Shanghai is the severe pollution in upper stream of Huangpu River given by Shanghai's geology feature. It's predicted that by 2030, China will have over 40 billion cubic meters of water in shortage. Nonetheless, according to Shanghai, which is in the estuary of Yangtze River by the East China Sea has been threatened.[11] Shanghai's per capita water availability to consume in daily and industry is 1049 cubic meters, 40 percent of the country's average data. As a matter of fact, the Huangpu River has offered supply of over 80 percent of potable water for citizens from local areas and other provinces. [12] What's more, the pollution in adjacent tail Lake also adds further scarcity for Shanghai water storage.

 [Work cited page](#)

 [The geology of Shanghai](#)

 [The water cycle in Shanghai area](#)

Generate Solutions

1. Technocentric

1.1 Rainwater collection & treatment

Rainwater harvesting could be applied to collect rain and store it for future use, instead of letting it runoff. Rainwater could be collected from the run-down of rooftops on open areas that are accessible. The water harvested could be treated for domestic, agricultural, and industrial usages. Water treatment is another crucial step to take in the process of ensuring the safety and quality of water and to combat water shortage. A water treatment system could consist of the following steps: removal of large particles through screening, primary treatment to remove human waste, secondary treatment of oxidation to allow bacteria growth which breaks down particles, then the water is filtered before being released. Water treatment should be a necessary infrastructure to ensure the right to have access to clean water for every individual.

1.2 Reuse of rainwater and recycle of greywater

Rainwater collected could be used to serve irrigational and other agricultural purposes, which could reduce the water consumption of agricultural use (which makes up approximately 70% of the water consumption). Being referred to as wastewater that is not contaminated by fecal material, greywater could also be reused in irrigation, for both crops and non-food producing products. As water does not diminish in the water cycle, but would get unusable, the reuse and recycle of potentially usable water could benefit the reduction of water consumption.

1.3 Improve the efficiency of water use in machinery

Machinery with high efficiency of water use could help to alleviate water depletion. Factories could introduce machinery that demands less water supply in manufacturing, such as use less water in making and cooling the products. Toilets could be designed to use less water in flush valves to replace high-flow ones.

1.4 Removal of pollutants in water

Pollutants from agricultural waste, such as excessive fertilizers, insecticides, herbicides, and feces of livestock, could be tackled by water treatment that includes bioremediation or oxidation to reduce BOD. Industrial wastes that contain heavy metal, VOCs, chemical waste, etc. should be banned from discharging into the water bodies. If being released into water, it should be treated via absorption, nanofiltration, ion exchange process, and use of biological compounds, etc.

1.5 Develop better water treatment technologies

In Shanghai, though there are still some deficiencies in water treatment, the more important problem is sludge treatment. Sludge with nutrients is effluent into the watercourses and accumulates at the bottom of the water.

1.5.1 Activated sludge:

It's the most basic and general water treatment process. Sewage first enters several settling tanks and goes through oxidation (break down dissolved organic matter by using aerobic bacteria), and finally anaerobic digestion for disposing of sludge. However, some anaerobic tank is not sealed and many tanks are old and dirty, which means the treatment is not perfect. Thus, the treatment process still needs improvements. This can be commonly used in big treatment plants because this method is cheap and simple to set up. Also, most of the place has this technology.

1.5.2 Coagulants and chlorination:

Raw water firstly mixes with coagulants which makes particles clump together and settle. After filtration, water is disinfected with chlorine that kills bacteria.

1.5.3 Supercritical Water Oxidation (SCWO):

Nowadays, there are more and more food waste and agricultural waste, which are both organic wastes. The critical point of water is 374.3°C and 22.064MPa . If the temperature and pressure of water are raised above the critical point, the water becomes supercritical water. SCWO is the complete oxidation of converting organic matter to clean H_2O , CO_2 , and N_2 by oxidation. It also converts S and P to the highest valence salts for stabilization and oxidizes heavy metals to stabilize the solid phase present in the ash. It is a good way to dispose of sludge, but it takes large areas and requires a lot of money.

1.5.4 Fenton:

The decomposition of H_2O_2 under the catalytic effect of Fe^{2+} generates $\cdot\text{OH}$. H_2O_2 oxidizes and decomposes organic matter into small molecules through electron transfer and other means. At the same time, Fe^{2+} is oxidized to Fe^{3+} to produce coagulation, which removes a large amount of organic matter. Fenton can degrade organic matter in the dark. The chemical method is usually efficient and simple to apply. This method can reduce the organic carbon content in the water from 50 ppm to about 10 ppm at most. It saves money but the utilization rate of H_2O_2 is low.

1.5.5 Reusing wastewater instead of discharging:

Much of the wastewater can actually be used again. There are mainly two ways to prevent leakage: changing the permeability of soil and installation of an impermeable layer. These are relatively physical and chemical methods. The former is to reduce leakage by reducing soil void through compaction, siltation, smearing, etc. People can also achieve this by adding natural fertilizers. For example, growing maize can improve the fraction of compacted soil to 60 to 87%. The latter is to incorporate chemical materials to enhance the impermeability of the soil in the canal bed. The former one is suitable for the small-scale application, while the latter

one is for extensive (commercial) and large-scale agriculture.

1.6 Reduce eutrophication

Eutrophication is a sequence event starting with the enrichment of water by mineral nutrients or organic matter that leads to a reduction in oxygen level in the water and the death of fish and other animals. This always results in the growth of algae. Shanghai reported 3 large-scale eutrophication in 2007 and 5 large-scale eutrophication in 2008.

1.6.1 Biological

[1]Vegetation: Growing aquatic vegetation on the river can reduce the oxygen in the water. However, this method is labor-consuming, because these vegetations are easy to die and people need to clean them up manually.

[2]Living organisms: increase the number of aquatic organisms, such as fish, to let them consume excess oxygen.

1.6.2 Filtration:

Grow more aquatic plants in the water or trees on riverbanks. Plants roots and grass in the water can filtrate nutrient-rich water.

1.6.3 Reduce nutrient releasing:

factories that release their wastewater into the river should reduce BOD (biochemical oxygen demand) before releasing it.

1.7 Sustainable water usage in agriculture

1.7.1 Sprinkler:

Sprinklers are divided into stationary sprinkler systems, semi-fixed sprinkler systems, and mobile sprinkler systems. The basic functions of them are similar. Sprinklers use a special nozzle with a small aperture that forces the water out under huge pressure. This pressure forms water droplets, which will fall on top of the crop rather like rainfall. This method is easy to set up, covers a large area, but water is easy to evaporate.

1.7.2 Drip irrigation:

Specifically, drip irrigation is to uses a series of flat polythene (stable and does not absorb water) hoses laid on the surface of soil between the intervals of rows of crops. When irrigation is needed, farmers opened the control valve attached to the general water tank, then water is transported to these hoses through pipes and finally drip the water directly onto the plant through microtubes (emitters).

According to research, drip irrigation has a precision of 90% directly to reach the plants' roots and sprinkler has 70% precision.

Compared to flood irrigation, drip irrigation is more efficient in water usage. In addition, the drip irrigation system can be controlled by a computer automatically.

In order to apply this method well, researchers should firstly carry out surveys to decide what phase in the growth of crops that need more water than usual, then apply water according to the data. For example, farmers find out that a certain kind

of crop needs more water when it's about to flowering. Then they will have to modify the drip system at the flowering time every year.

1.7.3 Clay pot:

Clay pot systems use porous clay pots that are buried in the soil near the crop roots. Each pot is filled with water that will gradually leak into the soil around the roots. This simple and reliable technology helps farmers easier to check the amount of water provide to the soil. It has little surface evaporation due to its location. However, Clay pots are only suitable for permanent plants. In addition, it needs a lot of labor.

1.7.4 Micro-water irrigation:

The simplest clay pot has been outdated, but the foundation of this method remains and generates similar new technology. Micro-water irrigation is the combination of drip irrigation and a clay pot system. "It is a new type of water feeder consisting of a semi-permeable membrane with a double-layer structure, which makes full use of the characteristics of semi-permeable membranes and introduces membrane technology to the field of irrigation." This membrane imitates the function of a cell membrane that can do osmosis. The size of the holes in the membrane wall allows water molecules to pass, but not larger molecular groups or solid particles. When the tube is filled with water, the water molecules migrate outwards through these micro-pores and further into the soil, wetting crop roots and providing irrigation.

When used, the micro-irrigation pipe is buried under the monopole, usually at a depth of 10-20cm, depending on the depth of different roots locations. The water source can be a tank, a water tower, or a tap water pipe. This method is more 20~30% more water-efficient than drip irrigation.

1.8 Replacing combined sewer systems with separated sewer systems

As we mentioned in the challenge, because of the uneven seasonal distribution of water resources in Shanghai, rainwater is often a water resource that we tend to ignore, but it needs to be rationally used. Therefore, we want to improve the utilization of rainwater through rain-pollution diversion. In a two-pipe separated sewer system, stormwater is collected through storm drains. It travels through different pipes than household sewage and other wastewater. The pipes that collect rainwater end up in natural water bodies, irrigating vegetation and replenishing groundwater. The separated sewage is sent to the sewage treatment plant for treatment and then discharged. In the long term, the efficiency and longevity of a separated system will pay for themselves. Further, achieve the maximum utilization of water resources.

1.9 Permeable Reactive Barriers

The groundwater pollution in Shanghai is very serious, which is related to the urbanization of Shanghai. Meanwhile, as a coastal city, Shanghai's water pollution

will directly affect the coastal water quality. Therefore, groundwater management is necessary. According to Cognition Land And Water, "The permeable reaction barrier (PRB) is an area in which an active substance is treated. The pollutants in the plume react with the media within the barrier, either to break down the compounds into harmless products or to immobilize the pollutants by precipitation or adsorption." Therefore, PRB also takes different forms.

Currently, there are Vertical Funnel & Gate, Horizontal Funnel & Gate, and Fully Permeable Reactive Barriers (AquaBlok). The first is to deal with the problem of ebullition in sediment, as the sediment rises and the groundwater moves vertically. The second approach is suitable for cases where the shoreline seepage affects sediments only a short distance from the relevant upland area. When the affected groundwater flows along a lateral path, contaminants are removed by the reactive material before the water is discharged into the water body from below the low-permeable layer. This method can prolong the contact time between water flow and treated material and improve the utilization rate. The third could be built on the Ha 'a line to intercept potential upland contaminant migration. Because this method requires a special design of the reflection layer, it is necessary to simulate groundwater flux, pollutant concentration, and other better information based on the required conditions before construction. The results are targeted but take time to adjust. The three PRB models can be used according to different river conditions, point pollution or non-point pollution, and the number of pollutants. In terms of reactive materials, we hope to use ZVI (Zerovalent Iron Barriers) Wall as reactive materials, because it can safely, efficiently and economically treat sewage and turn toxic substances into non-toxic ones.

2. Anthropocentric

2.1 Government Legislation

The legislation serves as the last mandatory means to restrict and regulate one's behaviors, so it would effectively prohibit illegal activities that will damage water (neither quantitatively nor qualitatively). For example, the discharge of untreated wastewater from factories or sewage from residential areas. Governments could impose a fine for such activities and provide standards of safe disposal of wastewater and water treatment through the establishment of laws. If being implanted properly, legislation could be an effective strategy to tackle the problem of water shortage.

2.2 Reconstruction of the city

2.2.1 Reforestation:

Due to urbanization, area cement ground is increasing. However, cement is not good at permeate rainwater. Therefore, cities should increase the area of exposed soil, which absorbs a lot of rainwater. Reforestation can reduce the risks of runoff

and erosion.

2.2.2 Add on to roof construction:

[1]Rooftop garden: Rooftop gardens, also called green roofs, are designed to harness the moderating forces of natural ecosystems and reduce the building's carbon footprint. In 2016, San Francisco became the first U.S. city to implement green roof management. There have been already some rooftop gardens in my community, but the number is small and some of the plants that grow on that are not suitable for roofs. The soil is not fertile and thick enough for large plants, for example, trees, so shrubs and sedums are preferred. They are also natural rainwater filtration. Rainwater is filtered and drained so that plants can survive. With the installation of rooftop gardens, energy use for cooling drops by 50%.

[2]Rooftop rainwater collection tank: It can be used in agriculture. Tanks can be installed on the rooftop, but they need to be almost sealed because if they are largely opened, bacteria are easy to generate in them. This reduces the cost of irrigation and water use. It is not suitable for households, because although water tanks for households have a self-treatment system, the water is still not healthy enough for drinking.

2.3 Manage and limit aquaculture

As we mentioned in Challenge, aquaculture is gradually replacing fishing as the largest supplier of fish. With the emergence of this phenomenon, a variety of chain reactions brought by aquaculture are gradually affecting the water environment. Therefore, our group proposed the management and restriction policies for the aquaculture industry. First, the management, which is to monitor the indicators of aquaculture. The two most important environmental indicators for monitoring are resource utilization and pollution. Resource use indicators include land, energy, protein, water, and wetland conservation. Pollution indicators include reduced use of chemicals, effluent BOD control, control of ammonia nitrogen, phosphorus, suspended solids, and the use of non-native species in aquaculture. Includes processes for identifying, assessing, and addressing spatial and cumulative aspects of environmental impacts, as well as spatial and cumulative effects of environmental impacts. For example, Location of impacts, e.g., on-site, off site, the scale of impacts, e.g., farm level, watershed level, cumulative impacts, e.g., from different components of the same aquaculture operation; from unrelated aquaculture operations in the same area, restoration of previously damaged habitats. Then, if some aquaculture farms are defined as being "at-risk", in which case action must be taken to reduce the risk, such as fines or closure, that's how we limit aquaculture.

2.4 Limit the use of fertilizer

Because the agricultural pollution in Shanghai increases with the use of fertilizers, which leads to a series of environmental pollution such as soil degradation and water eutrophication, we need to improve or reduce the use of fertilizers. First, measure or sort out the nutrients that different plants need at the different periods

through experiments or existing data. Then, fertilizer was added effectively according to the experimental data to avoid water eutrophication and biodiversity reduction caused by the waste of fertilizer. Or, switching to Slow-Release Fertilizer. In this case, the nutrients are released at a slower rate, allowing the soil to absorb the nutrients, thus preventing excess nutrients from flowing into storm drains and seeping through the soil into groundwater.

3. Ecocentric

Education

Education plays a vital role in any forms of social issues associated with ideal and conceptual changes, including environmental crises. Education frames the mindsets and constructs values and awareness of the young generation via the pedagogy and the teaching content used, thus being one of the primary ways to effectively implant environmental awareness in the youths' intact minds. The responsibility of educating the youth to lead eco-friendly lifestyles voluntarily and love the environment from the bottom of their hearts falls on schools. Schools could prompt ways, such as "4R" of water (refuse, reduce, reuse, recycle), and stress every individual effort could help to make a difference. Beyond the context of school, education to promote changes in personal behaviors and habits could as well be implemented in communities through lectures, podcasts, posters, fliers, TV channels, etc. Citizens should be fully informed of the water shortage we are facing mutually and effective methods an individual can apply to play a part in alleviating the problem. For example, means to cut down domestic use of water could be informed and encouraged.

 [Work-Cited Page](#)

Identify the Criteria

Identify criteria:

Based on SWOT analysis model

1. Strengths (25%)

1.1 Whether the solution is innovative? (Technology, method, etc.) (10%)

1.2 Can the sustainable development concept be well realized? Can be recycled? Renewable? (10%)

1.3 Does the solution solve the problem faster and more efficiently (Time required to solve/mitigate the problem) (5%)

2. Weakness (25%)

2.1 Will it cause other environmental pollution, or cause some side effects? (10%)

2.2 Is the cost reasonable? (5%)

2.3 Availability (e.g. Current technology level) (10%)

3. Opportunity (25%)

3.1 Is it in line with market demand? Such as geographical conditions, climatic conditions, cultural environment, ecosystem condition. (20%)

3.2 If there are existing cases, do they correct the deficiencies of past cases? (optional) (5%)

4. Threats (25%)

4.1 Public acceptance (12.5%)

4.2 Does it fit the current policy? (12.5%)

Evaluate the Solutions

Points will be added and subtracted according to the scoring criteria. Positive points are added to the Strengths and Opportunities sections with a maximum of 10 points for each. The Weakness and Threats sections will be marked down by a maximum of 10 points each. The four points are added up to a maximum of 20 points.

1. Technocentric

1.1 Rainwater collection & treatment $9+9-2-0 = 17$

Renewable; using innovative technology that is environmentally friendly; makes water recyclable in the water cycle; reduces the water consumption.

1.2 Reuse of rainwater and recycle of greywater $8+9-2-1=14$

Makes rainwater reusable, thus reducing the water consumption; utilize the water cycle to tackle water shortage; makes use of excessive rainfall locally

1.3 Improve the efficiency of water use in machinery $5+6-5-2=4$

Reduce the water consumption to some extent; requires a large scale of new machinery being used, may not be widely accepted by industry owner for additional costs

1.4 Removal of pollutants in water $7+5-4-3=5$

Protects the water quality, yet maybe technically and financially demanding; some heavily polluted water cannot be treated and reused.

1.5 Develop better water treatment technologies

1.5.1 Activated sludge: $6+5-8-2=1$

It's widely used and has mature technology, but it generates waste sludge that accumulates in the bottom of the water.

1.5.2 Coagulants and chlorination: $5+5-6-3=1$

It's efficient and intensive. However, this process should be carefully used, because if chlorine is in excess, it will be harmful to people and organisms' health.

1.5.3 Supercritical Water Oxidation (SCWO): $7+5-6-2=4$

It is good at disposing of sludge so that sludges won't have to be left in the bottom of the water anymore. However, it requires high technology and a big area to implement. It's also expensive and might generate radioactive waste.

1.5.4 Fenton: $7+5-7-2=3$

It saves huge costs in equipment, but the disadvantage is that the utilization rate of

H₂O₂ is not high, and it cannot fully mineralize organic matter.

1.5.5 Reusing wastewater instead of discharging: $9+8-0-1=16$

Water leakage can be prevented and collected in a huge tank. When additional irrigation is needed, farmers can use it to irrigate crops after being applied by some treatments. However, it's complicated to construct. The use of water is completely sustainable, though it is not very efficient.

1.6 Reduce eutrophication $8+8-1-0=15$

Both biological way and filtration are sustainable ways to control eutrophication. They don't cost a lot but require labor and research about invasive species.

1.7 Sustainable water usage in agriculture

1.7.1 Sprinkler: $5+6-2-0=9$

It covers a large area but water is easy to evaporate.

1.7.2 Drip irrigation: $9+8-0-0=17$

water usage is more direct and the setting is simple and cheap.

1.7.3 Clay pot: $6+6-4-1=7$

Easier to check the amount of water provides to the soil. Also, it has little surface evaporation, because water seeks directly into the soil instead of permeating through the surface. However, Clay pots are only suitable for more permanent plants (larger plants), such as apples and cocoa trees. It costs a lot of the labor force. Farmers need to check the water level in the pot regularly and manually.

1.7.4 Micro-water irrigation: $8+4-5-2=5$

It's innovative and efficient, but it is difficult and expensive to build.

1.8 Replacing combined sewer systems with separated sewer systems $3-1+6-0=8$

This score is given because the rain-pollution diversion technology is also not very innovative. Shanghai plans to implement rain-pollution diversion in residential areas from 2018, so it has a certain coverage rate. At the same time, because acid rain is also an environmental problem in Shanghai, if rainwater was collected for irrigation, it may have side effects.

1.9 Permeable Reactive Barriers $8-5+4-1=6$

This score is given for the following reasons: 1. It is innovative and most environmentally friendly, but it requires a long reaction time. Existing cases are still being implemented, and the final effect and how to recycle the reaction wall are still being studied. 2. The cost of installing treatment walls increases significantly at depths exceeding 80 feet. 3. The installation may require a large amount of work, even if it has no impact on people's lives after the installation. 4. Although the current technology can support the completion of the project, it lacks some experience.

2. Anthropocentric

2.1 Government Legislation $7+4-3-1=7$

Mandatory and national level; however, the outstretched authority may not effectively monitor every industry and individual; not declaring the truth would be easy for business.

2.2 Reconstruction of the city: $9+9-0-1=17$

Reforestation increases the exposed soil areas so that increases the permeability of the ground. Roof construction saves water use. Also, Shanghai has a lot of rainfalls. This method reduces rainwater runoff and control stormwater. This technology can be applied to greenhouse agriculture. The filtered fertile water can be collected and used for irrigation.

2.3 Manage and limit aquaculture $4-0+5-1=8$

This score is given because 1. This method is not very innovative and requires a lot of time to collect and modify data for each aquaculture site. 2. The test of each indicator is a routine test, so there is no great defect in the price and implementation. 3. It conforms to the current situation of aquaculture in Shanghai. 4. Because the reform will harm the original industry to some extent, public acceptance may be reduced.

2.4 Limit the use of fertilizer $2-0+7-0=9$

This score is given because the approach to fertilizer restriction is not very innovative, but it is well in line with market needs and current strategies. At the same time, soil monitoring does not require a lot of costs.

3. Education: $5+6-2-3 = 6$

Education takes a relatively long period of time, and may not absolutely change people' s behaviors and habits, since mindsets and quality are hard to model and restrict.

Make an Action Plan

Energy Use and Savings in Greenhouses and Growth Chambers

The 146 greenhouses and 125 plant growth chambers managed by Cornell AES host 300-400 research projects year-round. Plant growth facilities provide the controlled environments needed for innovative research, but they can also be very energy intensive and expensive to light, heat and cool.

To sustain agriculture, in the face of a changing climate, we must continue to maintain a strong capacity to support agricultural and natural systems teaching and research. We also must focus on maximizing our efficient use of scarce resources. Cornell AES is on a mission to cut energy consumption by improving facilities, upgrading lighting and environmental controls, developing a new generation of energy efficient growth chambers [1], and by working with researchers and educators to maintain optimal growing environments while eliminating unnecessary energy consumption.

As part of this overall effort, we strive to raise awareness by publicizing the cost for heating and lighting of each greenhouse and growth chamber. Check out the energy use signs at each door. We encourage all faculty, staff and students who use the plant growth facilities to join us in our efforts!

Calculating The Energy Use

Energy consumption varies for each greenhouse and growth chamber, depending on size, construction, controls, lighting and more. It also depends on how each facility is used: different crops and project goals naturally require different conditions.

We measured the energy consumption of each plant growth chambers over a 24-hour period, while set to average conditions: the lights were set to the highest setting for 14 hours and off for the remaining time. The daytime temperature was set to 75°F, and to 65°F at night.

To estimate the energy consumption and cost for each greenhouse house as accurately as possible, we made the following assumptions:

Energy consumption data for heating are estimates based on measured heating requirements of several Cornell AES greenhouses over four years, and assume an average indoor temperature of 70°F. Lighting energy consumption data assume the installed growth lights provide a 14-hour photoperiod throughout the year, but are turned off during periods of high sunlight intensity, resulting in an annual average of 11 hours actual operation per day.

Carbon dioxide emission data are specific to Cornell's mix of energy sources, dominated by the central combined heat and power plant. The central plant produces both electricity and steam for heating, which are distributed across the

Ithaca campus, including the Cornell AES greenhouses. The most recent emissions figures are 91 pounds of CO₂ per 1,000 pounds of steam delivered, and 0.90 pounds of CO₂ per kWh of electricity delivered. Because of Cornell's commitment to sustainability and the progress made in producing and obtaining lower-emission energy, these figures are significantly lower than New York State or national averages.

Picture 2: the scientific use and application applied to the greenhouse.

Cornell AES Growth Chamber Prototypes

Cornell's 125 plant growth chambers managed by Cornell AES provide protected environments for smart, innovative research. They offer finely tuned light, temperature, and – in some cases – humidity and carbon dioxide controls. But creating the exacting and reproducible conditions needed for some research can be energy intensive.

Cornell AES has designed a new generation of high-performing and easy-to-maintain growth chambers, with a much smaller carbon footprint.

Two growth chamber prototypes, developed and built by growth chamber staff* at Cornell AES, cut cost and energy consumption significantly compared to traditionally-manufactured chambers of the same size. The outstanding versatility, precision and reliability of the prototypes creates a superior environment to enable valuable research.

X-AIR SUSTAINABLE GREENHOUSE SOLUTION [2]

Designed to optimize plant and crop growth by optimizing the greenhouse and its climate conditions in a sustainable way. This concept takes the natural growth of the plant as the starting point and helps the plant develop optimally, whilst maintaining its balance. The X-AIR Greenhouse is capable of using any ambient physical properties to generate optimal conditions based upon the Data Driven Growing Strategy, restraining the use of natural resources e.g. energy. The plant is central within this strategy and will enable to yield the highest quantity and quality of crop in the shortest time possible.

The new X-AIR Greenhouse includes the X-AIR Ventilation System. This Dalsem invention is an essential part of the energy-efficient climate control system. A solution that combines decentralized forced air ventilation and circulation to resemble natural airflow from above to the crop. By circulating and mixing greenhouse air with outside air or air from above the screens, optimal growing conditions are created inside the greenhouse. A practical and compact ventilation system which is strategically placed to cover the entire greenhouse.

Action plans for the greenhouse.

Introduction:

After the calculation and evaluation of the final result of different solutions, we found that the rainwater collection & treatment and developing new technologies rank the highest. Therefore, we decided to mainly focus on these two aspects when

adding design to the greenhouse.

1. rain water collection and treatment

For the rain water collection and treatment system, we would like to maximize the use of rain water to the agriculture both in and around the greenhouse. It is estimated that the average rain fall in Shanghai is around 1200mm per year. This is a large amount of water resource we sometimes ignore. Also the quality for the required water of agriculture are so high. Therefore, we can directly use the stored rain water in the tank to do the daily agricultural practice.

General design:

For this system, we will incline the greenhouse roof and add pipes around the roof. Finally, the rain water will be collected into the main pipe which connected to the great tank outside the greenhouse. There are several taps connected to the tank which is used for drip irrigation used for agricultural practices.

In the water tank, we will add several layers of substances to help filter the insoluble particles in rainwater from the roof which may cause damage to the tank and block the tapes for irrigation.

There are several factors that need to be considered during the design of the rain water collection system.

rain water collection system:

1) The angle of the roof

In order to control the speed of the rain water flow on the roof and increase the total amount of the water collection. The wise choice of the roof can minimize the water remaining on the roof which further cause the effect to the roof. Since the roof is made of glass, too much water storage remains on roof may leave pressure to it. If so long, the greenhouse may be damaged. Also, if the roof is flat, the rain water is hard to be recycled and used for other purposes. As a result, the angles we choose is 30 degrees. With this range of degree, rain water can flow down in the speed with the balance of considering both the rate for the tank to be filled and the volume of water remaining on the roof. This angle can serve the whole system in the greatest extent.

2) The chosen diameter of the pipes

The speed for the rain water to flow decides how much volume of water can be passed through and the collect finally in the water tank. The normal rain water collection pipe used is 75mm in diameter. With the calculation of the average speed of rain water with the background information of Shanghai' s average rain water volume, the speed can be controlled as 1m/s which is a proper speed for the rain water collection system.

Water storage system (water tank)

1) Choices of layers in the water tank

Since while it is not raining, there must be lots of small particles and leaves remained on the roof. In order to ensure the water quality and prevent it from blocking the tape at the bottom of the tank, we decide to add the basic filter

structure into the top of the water tank in order to get rid of insoluble particles and substances. The top layer is the small cobblestone, the next is the sand, the final layer is the activated carbon. From top to bottom, the large particles will be blocked first, then is the smaller one, the final will absorb smallest, powder-like substances. The reason why we want to get rid of these particles is that through the process of precipitation, it will block the path of water to get out of the tank.

2) Chemicals added

In order to improve the water quality, after physical adsorption, we will add some chemicals to disinfect the water and reduce insoluble substances. First, we're going to add chlorine dioxide. This substance can effectively sterilize water quality. In this way, the toxic substances in the water will be greatly reduced. Secondly, we will survey the plants growing in the soil and find the best pH for them. Based on the pH, we will determine how much acid or base we will put in the soil to achieve the most suitable environment for the plants to grow.

Improved technologies:[3]

1) Materials

A regular greenhouse uses several materials in covering the shade, consolidating soil, and other uses. Most of these materials are plastic or nylon, which are not environmentally friendly. Instead of using these materials to cover the shades and packaging your soil and fertilizers, you can use recycled materials or recyclable components when building or operating your greenhouse. Besides helping you run a sustainable greenhouse, planting pots and trays help you conserve the environment. This situation means you will be preserving the surrounding environment as you enjoy running your greenhouse at lesser costs.

2) Monitoring and Maintaining temperatures

As per their construction and intended use, greenhouses receive the sun's energy and heat the interior or control the inside temperature. The passive solar design used in greenhouses doesn't store or preserve the power for future use. The reason is that they aren't built with mechanical or electrical Powerbank to capture the energy. They use the building structure and materials to collect and use and store the excess energy. How do you maintain the right temperatures? Instead of using fans to control the hot temperatures, thus suffering energy bills, you can allow adequate ventilation to the greenhouses. This situation means you require a greenhouse thermometer that helps monitor the temperatures. You can also incorporate thermal banking, a process that collects and stores solar heat to be used later. The system uses the sunrays to heat water then keeps the water underground to heat the greenhouse during the cold season. You can either construct this system by yourself or have experts help do it.

3) Irrigation

Most greenhouses are made to use a lot of water in their operation. One of the most effective ways of running a sustainable greenhouse gardening is controlling water usage when conducting irrigation. Besides using water from taps and other

water sources, you can tap rainwater through gutters to the storage tanks adjacent to the greenhouse or underground tanks. Ensure water moves from the gutters to the tanks through a gravity way to avoid energy costs. If you have a pond or water well in your house, you can use that to store any running water and use it for irrigation in your greenhouse. Such also ensures you don't affect the environment in your greenhouse gardening operations. You can create boreholes or ponds by yourself or get someone experienced to ensure they hold as much water in a little possible place.

4) Energy Efficiency

Sustainable greenhouse gardening must be energy efficient. Most greenhouses come with installed, improved energy devices, but you can make some changes to regulate their energy consumption. A good example is replacing incandescent lighting, which uses more power, with the energy-efficient, fluorescent fixtures can reduce consumption by half. You can also consider sodium vapor lighting, which is more expensive when purchasing to minimize power consumption, thus reducing the overall running costs. You can also reduce the energy consumption further by providing adequate growing light for all plants simultaneously.

What's more? Besides using artificial lighting, you can opt for the modernized greenhouses that come with solar panels for running the renewable energy in your garden. The solar panels can also pump the water from tanks during irrigation and can provide the necessary heating.

 [Work-Cited Page](#)

 [Cornell AES greenhouse](#)

 [Functions of Cornell AES greenhouse 1](#)

 [Functions of Cornell AES greenhouse 2](#)

 [Functions of Cornell AES greenhouse 3](#)

Prototype and Test

| Prototype Design

Based on the important information about the greenhouse mentioned in the Action Plan section, we present the rough prototype of the greenhouse in the form of a model, which makes it easier for people to understand the basic principles of the greenhouse through concretization and visualization. Here we will look at some of the most vital parts of the greenhouse.

1) Inclined roof with angle 30°

As mentioned earlier in the Action Plan, roofs with a 30-degree angle to the horizon are better for drainage, which helps people collect rainwater more efficiently and conserve resources. Also, because the best angle for installing solar panels is the same as the local latitude, a 30-degree roof tilt means that solar panels maximize their power output since Shanghai is roughly located at 30 degrees north latitude.

2) Pipes with 75mm diameter

The high speed of rainwater passing through the pipes ensures efficient drainage and timely replenishment of water for the water tank. Through calculations, the 75mm diameter rainwater collection pipe can ensure the rapid passage of rain water, thus promoting the high efficiency of the whole system.

3) Water tank with water treatment

In order for collected rainwater to be used in daily life, one of the most essential steps is to remove impurities from it through water treatment. The collected rainwater will be treated twice, first by filtering to remove insoluble particles and then by reacting with chemicals to remove soluble particles. Thus, the impurities and toxic substances in the rainwater can be effectively removed, providing suitable water resources for the irrigation of greenhouse gardening.

4) Use planting pots

By using recycled planting pots, we can not only operate greenhouse well, but also reduce the use of environmentally unfriendly materials and protect the environment.

5) Control temperature by using thermometer and ventilations

During the operation of greenhouse, it is very likely that a large amount of energy is consumed in order to control the indoor temperature. But this problem can be solved by monitoring room temperatures with thermometers and providing adequate ventilations.

6) Irrigate plants using rain water

Large quantities of water are necessary for greenhouse to operate successfully.

Instead of using water from the water company, we can provide usable water by storing refined rainwater in tanks. This can not only save a lot of unnecessary costs, but also simulate the water cycle to make the whole greenhouse system more perfect.

7) Use fluorescent fixtures

By using fluorescent lamps to illuminate the greenhouse, a lot of energy can be saved, which makes the whole system more energy efficient.

8) Use of solar panels

Using solar panels can provide a lot of energy for a greenhouse to light up or run some equipment, which makes the whole system more sustainable.

 [Prototype design-greenhouse](#)

| Feedbacks learnt from users

Overview:

There are a total of seven questions in the survey and before doing the survey we explain to the users our purpose. After that, we will show them the prototype and explain to them the details if there is confusion. There are 100 valid feedbacks and the users are from all ages and all places around china. The purpose of the survey is to ask the users' attitudes towards the design of the greenhouse.

1. Quantitative feedback from the survey:

1.1 Users' attitudes towards our goal: sustainable

60% of the users think the design can effectively alleviate the water shortage caused by urbanization and form a sustainable development model, 34% of the users disagree with the idea, and 6% of the users think it is possible to be effective but need to depend on the real-life situation and further illustration.

1.2 Users' impression of the most important factor of the greenhouse

60% of the users think the efficiency of the greenhouse is the most important one among all the factors, 37% of the users think the cost of the greenhouse is the most important and 3% of the users think the aesthetics of the greenhouse is the most important.

1.3 Users' attitudes towards the treated rainwater

88% of the users think they will use the treated rainwater from the prototype to water the plants in the garden and for the experiments, 3% of the users think they will not use the water and 9% of the users think they can use it but need to depend on the real-life situation and require further situation.

1.4 Users' attitudes towards the overall design

92% of the users think there are better designs to make greenhouses more sustainable and 8% of the users think there aren't.

1.5 Users' suggestions on the improvements

The sixth question is a multiple choices question, and there are 157 responses. On the base of there are spaces of improvements, 11% of the responses think we can improve rainwater collection system, 25% of the responses think we can improve rainwater treatment and storage system, 27% of the responses think we can install more advanced technologies, and 36% of the responses think we can improve the overall structure of the greenhouse to achieve better temperature control goal.

1.6 Users' concerns on the design

The seventh question is a multiple choices question, and there are 181 responses. Assume the prototype is implemented as planned, 14% of the responses think improper usage and stop using will cause problems, 41% of the responses think follow-up maintenance of facilities may be weak, not in time and insufficient, 9% of the responses think the temperature control in the greenhouse may not be effective enough and cause the death of the plants, 13% of the responses think the ineffective temperature will cause the indoor temperature too high, 14% of the responses think the rainwater may be contaminated which may cause by the contamination of water storage or treatment system, 8% of the responses think the greenhouse's existence and the rainwater usage may cause negative effects towards people.

2. Qualitative feedback from the survey:

From the feedback, it shows that over half of the users think our prototype design will achieve the purpose and the efficiency will be the factor we will put more effort into when implementing the real greenhouse. The rainwater which has been treated and stored is believed to be used widely as most people will agree to use them for watering the plants. Most people think there will be better designs to make our greenhouse improved and among a variety of responses, the indoor temperature and more advanced technologies seem to be the parts that more people are interested in. Users are concerned about many aspects of the greenhouse and the biggest concern is the follow-up maintenance as many of the users think it may be insufficient, weak, or be delayed.

 [Questionnaire, feedback result & diagrams](#)

| Improvement for next iteration

1. For the prototype design:

Although from the users' feedback show that most of the people understand the

information on the prototype design, there are still improvements: first, the picture can be bigger and clearer so that users can view smoothly; second, if there are technical supports, we can make it as a video and show the users from different angles and dynamic; third, the water treatment and storage system can be more detailly show and the functions of using ventilation to control temperature can also be showed by using extra pictures.

2. For the survey:

Many improvements can be taken from the survey: first, we need to contain more questions in our survey to get a more complete idea of what the users are thinking; second, for questions that only need to answer "yes" or "no" , we need to design more follow-up questions to know the reasons of why they make this choice and what can be done to overcome the problems; third, although in multiple-choices questions we have already provided a variety of choices, they are still too limited and can be modified into short-answers questions.

3. For the survey feedback and the prototype design:

From the survey' s feedback, there are still users who think we cannot achieve our goal, and though users think the most important aspect of the greenhouse is the efficiency, we should also put awareness on both the cost and aesthetic. The rainwater treatment system can be improved in order to let more people trust the cleanness of the water and use them for different purposes. We should invent, develop and implement new and advanced technologies in our greenhouse to achieve sustainability, and we can improve the systems which already existed. We should solve the concerns of the users by continuously using the greenhouse' s design, regular and effective maintenance, controlling the room temperature and taking care of plants, always paying attention to the quality of rainwater treatment, and eliminating factors that have negative effects on people.

4. For the implemented greenhouse:

When discussing with school and constructing the greenhouse, there are still some problems and adjustments based on our design. In order to control the indoor temperature, one air conditioner is installed, which increase the carbon footprint. This need to be further improved to overcome the problem. The rain-harvest system is hard to achieve and we find that we can do some further research on irrigation system and the soil capacity need to be determined. We are now using the greenhouse as an educational tool, and we decide to focus on agriculture more in the future which can include crop rotation, decomposing process, drip irrigation and increasing biodiversity.

Team Credits

包乐成 Lecheng is responsible for the action plan. He writes detailly about the overall design of the greenhouse and illustrates clearly the purposes of the design and ways to achieve it.

陈馨儿Xiner is responsible for following up on the progress of every team member, and conducts the survey, and receives feedback from the audience. She analyzes the survey, writes the Improvements for the next iteration, integrates the summary.

陈傲宇 Aoyu collects the resource, analyzes, and writes part of the identifying the challenges and identifying for a root cause, writing part of the summary.

江涵雪 Hanxue is responsible for collecting the resource, analyzes to write for generating solutions, identifies criteria, and evaluates solutions. She also writes part of the summary.

蒯雨檬Yumeng collects the resource, analyzes, and writes part of generating solutions, identifying criteria, and evaluating solutions. She also writes part of the summary.

林卓娃 Zhuowa is responsible to analyze and write: Identify the challenge, Identify a Root Cause.

张晗Han is responsible for designing and drawing the greenhouse and writes the part of prototype and test.

张毓茗 Yuming collects the resource, analyzes, and writes part of generating solutions, identifying criteria, and evaluating solutions. She also writes part of the summary.

朱峻德Junde is responsible for the action plan. He finds the resources of greenhouses design at Cornell University and finds the strengths which can be used in our greenhouse design.

Onsite Conference File

Judge Comments

" It is commendable to see the team explore a challenging urban planning and integrated stormwater management topic.

I appreciate the detailed identification and analysis of the challenges related to water management in the region – it would be helpful to structure these better for future analysis, especially through combining the similar issues together. For instance, contamination, fertilizer use, groundwater pollution etc could be restructured for improved readability. And fishing, while a complex issue, might not be directly connected to the primary issue you are trying to address. It would also be helpful to think about how climate change is likely to affect these issues locally. The SWOT model provides a useful model to analyze this type of questions – I advise the team to also look into the more detailed SWOTLE model which builds in a further legal and environmental angle specifically. It would also be quite helpful with work of this nature.

I also really enjoyed reading about the prototype the team was able to put together. The team has managed to collect useful feedback and reflect that back into their findings in a well-structured manner.

Overall, I think the team did a good job in fleshing out this topic and I wish them the best in taking their learning further.

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