SYSTEM DYNAMICS MODELING TO DEVELOP INDUSTRIAL WASTEWATER RECYCLE BUSINESS IN INDONESIA

FINAL PROJECT

**In partial fulfilment of the requirements
for the master's degree
from Institut Teknologi Bandung**

By
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(Master of Business Administration Program)

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ABSTRACT

SYSTEM DYNAMICS MODELING
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BUSINESS IN INDONESIA

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Water is an important resource in our life that is used for daily consumption, production and industrial use. Fresh water demand globally increases, and water scarcity issues have become a focus by industry. Indonesia as one of highest country with freshwater withdrawals and wastewater discharge in Southeast Asia have potential to develop wastewater recycle business in industrial sector with growing of industrial estate, increase of freshwater cost and sustainability goals. Water treatment companies need to develop systemic solutions for wastewater recycle business in Indonesia due to complexity of different industry sector, water source and variation of cost in different area.

Data collected using quantitative approaches from literature review, stakeholders' discussion, and internal past project data to identify variables that give significant impact to develop wastewater recycle business. Relationship and feedback from variables analyzed using system dynamics frameworks by build causal loop diagram (CLD) and simulate the variables using stock and flow diagram (SFD).

Scenario simulations are conducted for key variables in wastewater recycle business, wastewater recycle demand, wastewater recycle ratio and wastewater recycle cost. The simulation findings shows that wastewater recycle business have potential to give not only sustainable goals from water saving but also give potential cost saving for customers and become annuity revenue for water treatment companies with reviewing and controlling the key variables. It is clear from simulation using industrial estate case in west java that wastewater recycle have high potential to developed, and this research also could provide customers stakeholders valuable framework to help for decision making to investing in wastewater recycle process.

Keywords: water treatment, water management, wastewater recycle, system dynamics

ABSTRAK

PEMODELAN DINAMIKA SISTEM UNTUK PENGEMBANGAN BISNIS DAUR ULANG AIR LIMBAH INDUSTRI DI INDONESIA

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Air merupakan sumber daya penting dalam kehidupan yang digunakan untuk konsumsi sehari-hari, produksi, dan keperluan industri. Permintaan air bersih secara global terus meningkat, sementara isu kelangkaan air menjadi perhatian bagi industri. Indonesia sebagai salah satu negara dengan tingkat penarikan air baku dan pembuangan air limbah tertinggi di Asia Tenggara memiliki potensi besar untuk mengembangkan bisnis daur ulang air limbah di sektor industri, didukung oleh pertumbuhan kawasan industri, kenaikan biaya air bersih, dan tujuan keberlanjutan. Perusahaan pengolahan air perlu mengembangkan solusi sistemik untuk bisnis daur ulang air limbah di Indonesia mengingat kompleksitas sektor industri yang beragam, sumber air yang berbeda, dan variasi biaya di berbagai wilayah.

Pengumpulan data dilakukan melalui pendekatan kuantitatif dari tinjauan literatur, diskusi dengan pemangku kepentingan, serta data proyek internal sebelumnya untuk mengidentifikasi variabel-variabel yang berdampak signifikan terhadap pengembangan bisnis daur ulang air limbah. Hubungan dan umpan balik antar variabel dianalisis menggunakan kerangka kerja dinamika sistem dengan membangun diagram loop kausal (CLD) dan mensimulasikan variabel-variabel tersebut menggunakan diagram stok dan aliran (SFD).

Simulasi skenario dilakukan pada variabel-variabel kunci seperti permintaan daur ulang air limbah, rasio daur ulang air limbah, dan biaya daur ulang air limbah. Hasil simulasi menunjukkan bahwa bisnis daur ulang air limbah memiliki potensi memberikan penghematan biaya bagi pelanggan selain tujuan keberlanjutan dan menjadi sumber pendapatan tetap bagi perusahaan pengolahan air dengan melakukan evaluasi dan pengendalian pada variabel-variabel kunci. Hasil simulasi pada kasus kawasan industri di Jawa Barat memperlihatkan bahwa bisnis daur ulang air limbah memiliki potensi tinggi untuk dikembangkan. Penelitian ini juga dapat memberikan kerangka kerja yang berharga bagi para pemangku kepentingan pelanggan dalam pengambilan keputusan untuk berinvestasi pada proses daur ulang air limbah.

***Kata Kunci**: pengolahan air, manajemen air, daur ulang air limbah, dinamika sistem*

VALIDATION PAGE

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(Pri Hermawan, S.T., M.T., Dr. Eng)

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LIST OF ABBREVIATIONS AND SYMBOLS

ABREVIATIONS	Name	Page of initial usage
CAGR	Compound Annual Growth Rate	6
CEO	Chief Executive Organization	3
CEW	Circular Economy of Water	2
CLD	Causal Loop diagram	22
DBOOM	Design Build Own Operate and maintenance	11
dmnl	Dimensionless	32
ER	Enviromental Regulation	57
FAO	Food and Agriculture Organization	1
FGD	Focus Group Discussion	27
HKI	Himpunan Kawasan industri	10
KLHK	Kementrian Lingkungan Hidup dan Kehutanan	39
MNC	Multi National company	8
PI	Price Increase	57
SBI	Solusi Bersama Indonesia	3
SDG	Sustainable Development Goals	19
SFD	Stock flow diagram	22
USD	US Dollar	6
VO	Value Optimization	57
WICER	Water in Circular Economy and Resilience	15
WWDR	World Water Development Report	1
WWTP	Wastewater Treatment Plant	8

SYMBOLS	Name	Page of initial usage
[illegible]	Integral (stock over time)	37

Chapter I Introduction

I.1 Background

Water is important resources in our life, water widely used for daily consumption, cleaning, sanitation, agriculture and to Industrial need that could utilize water as main product or to use water in Energy production such as in Coal Power Plant that convert water to steam for producing electricity.

Fresh Water demand globally has been increasing 1% per year over the last 40 years and future trends overall global demand for water sill continue to increase at annual rate 1%, resulting in an increase of between 20 to 30% by 2050, this trend has been driven by a combination of growth of world population, social and economic development. Highest increase of water demand particularly in emerging economies country (WWDR, 2023). Increase in freshwater demand compare to renewable water resource availability increasing water stress and scarcity. Water scarcity is becoming endemic. The local impact of physical water scarcity and freshwater pollution is spreading and accelerating (FAO, 2022).

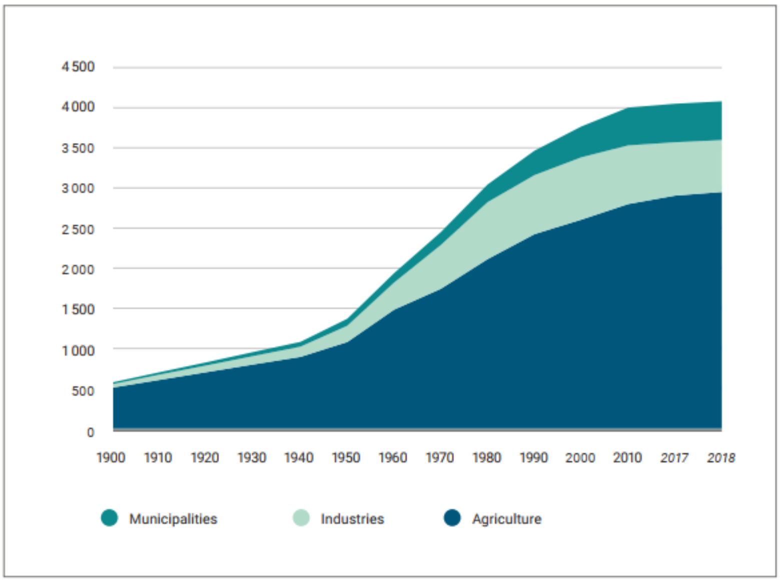

Figure I.1 Evolution of global water withdrawals, 1900–2018 (km³/year) (WWDR, 2023)

Managing source, and sustainable management of water is part of Sustainable Development goal. Water become part item in Circular economy management that seen as resources that need to manage sustainably. Circular Economy of Water CEW is an economic framework for reducing, preserving, and optimizing the use of the water through waste avoidance, efficient utilization and quality retention while ensuring environmental protection and conservation (Morseletto et al., 2022).

Water resilience coalition that involves CEO of world companies put Java Island as area of focus due to include in most stressed water area. This impacted to some of Multinational companies that have plant in Java Islands that need also to sustainably manage their water consumption (UN Global Compact, 2023). Figure I.2 is an area with high water stress basin in the world and Java Island is one area with high stress in Southeast Asia.

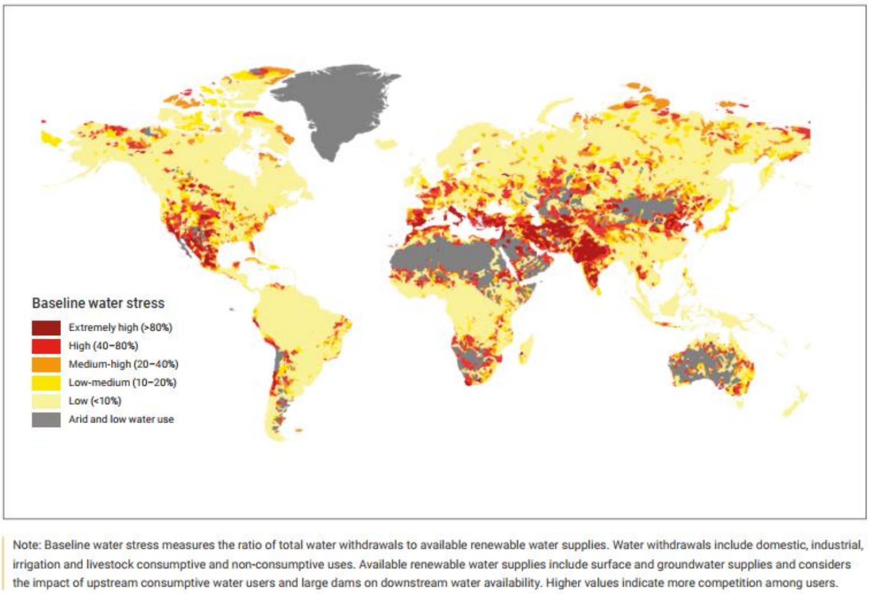

Figure I.2 Water stress basin source WDDR 2023 (WWDR, 2023)

Indonesia is Highest Country with Fresh Water Withdrawals in Southeast Asia up to 222.6 billion cubic meters annually, Trending data from 2015 shows that freshwater withdrawals at South East Asia Country include Indonesia remain stable this could indicate improvement in water resource management from 2015-2020.

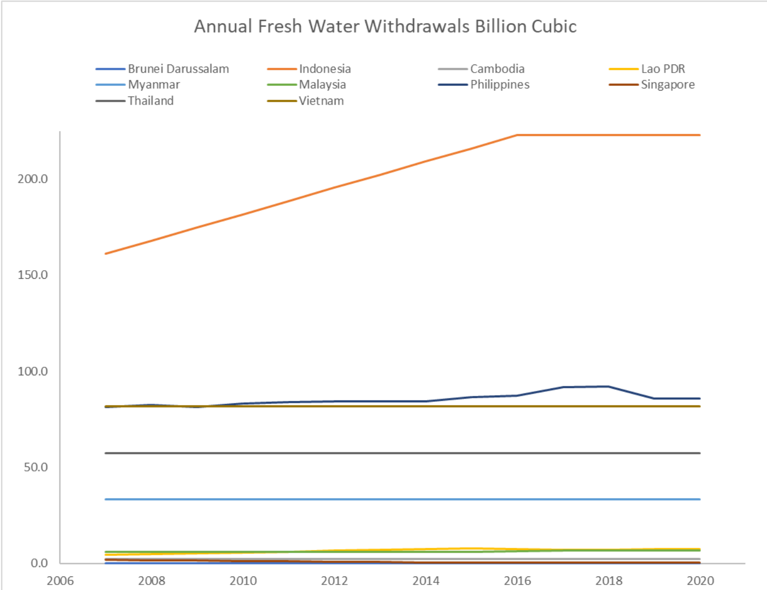

Figure I.3 South East Asia Country Annual Fresh Water withdrawals data processed from data.worldbank.org (Worldbank, 2023).

Java Island as main islands in Indonesia with highest population only have freshwater availability of Indonesian water 4.2%. Based on 2010 data, water needed in Java islands is 2,079 m3/s and has status low critical zone for water availability. Java Island water availability per capita is 1.200 m3 per capita per year below minimum 1.600 m3 per capita per year (Hatmoko et al., 2012). Latest data from Bappenas, Java, Bali and Nusa Tenggara islands estimated water scarcity will increase from 6.0% in the year 2000 to 9.6% at 2045 (National Development Planning Agency (Bappenas), 2020)

Table 1.1 Water demands in Java Islands (Santikayasa & Okhy Wiranta, 2022).

	10^9 m^3/year				
Water Need	**1981-1990**	**1991-2000**	**2001-2010**	**Increase**	**% Increase**
Domestic water	6.26	7.5	8.69	2.43	39%
Industrial water	14.42	18.52	21.43	7.01	49%
Agriculture water	57.49	56.29	54.98	-2.51	-4%
Environmental water	40.19	37.45	39.21	-0.98	-2%
	118.36	119.76	124.31	5.95	5.0%

Table 1.1 shows that water demand in Java Islands increased a total of about 5% from 1981 to 2010, with the highest demand increase for industrial water followed by domestic water. Industrial water demand increases about 49%.

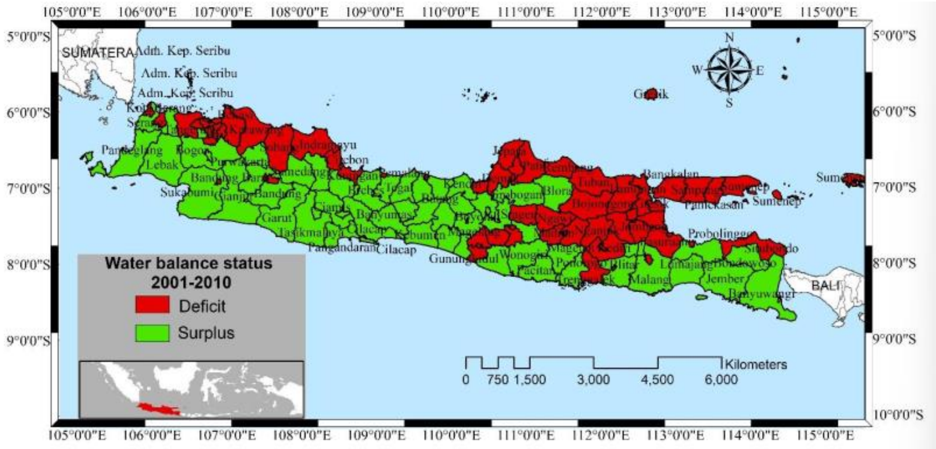

Figure I.4 Water balance status 2001-2010 in Java Islands (Santikayasa & Okhy Wiranta, 2022)

Figure I.4 shows water balance status in Java islands area with green as surplus and red as deficit, it shows that area with most deficit is Jakarta, East Java followed by West Java.

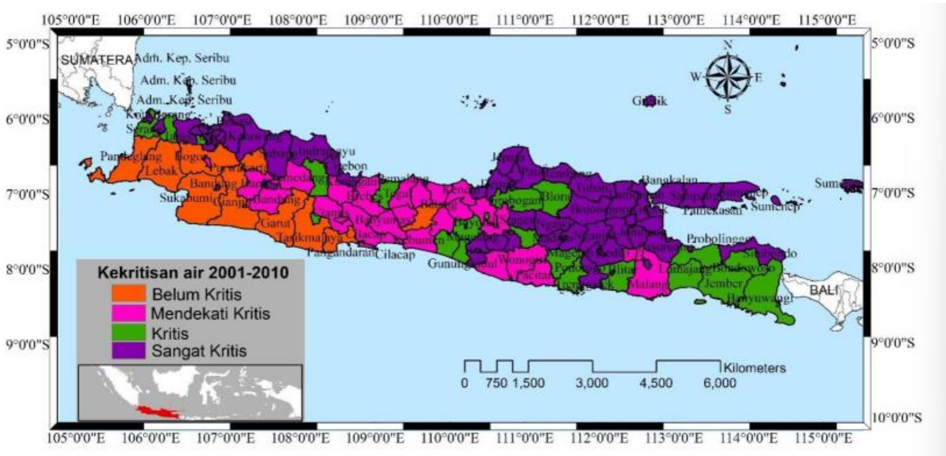

Figure I.5 Water scarcity distribution map 2001-2010 in Java Islands (Santikayasa & Okhy Wiranta, 2022)

Figure I.5 shows the water scarcity index in Java Islands, with very critical area with purple, highest critical area is at Jakarta, east java and west java (north area). With the increasing demand for domestic and industrial water driven by population growth and industrial expansion, it is essential to implement measures to mitigate water scarcity on Java Island.

I.2 Company Profile

PT. Solusi Bersama Indonesia (SBI) is subsidiary of Solution Inc., a global leader in water, hygiene and services, protecting what is vital: clean water, safe food and healthy environments. Solution Inc is a trusted partner working behind the scenes at nearly 3 million customer locations throughout the world and operates in more than 170 countries.

Solution Inc. in 2024 already operated for 101 years, founded at 1923 as chemical companies that provide solutions for hotels to clean carpets without needing to shut down, reflecting its mission to save customers time, labor and money. At 2006 Solution Inc. honored as food safety leader and become global leader in Hygiene technologies and services (Solution, 2020).

At 2011 Solution Inc. acquires Water Inc. global leader of water treatment chemicals and service company and become global leader in water and hygiene technologies and services. Followed by the acquisition at 2014 Local entity of both company merge to become now PT. Solusi Bersama Indonesia that have two manufacturing Plant in Cikarang Bekasi and Citeureup Bogor. Water Inc. became a division of PT SBI that focusing on provide water treatment solution chemical, equipment and services.

PT SBI has 5 Business Units with more than 400 employees, and more than 300 field sales and service, Head office at Jakarta and office Representative at Medan, Palembang, Cilegon, Surabaya, Bali, and Banjarmasin.

I.2.1 Vision and Mission

Vision

Global leader in water, hygiene and antimicrobial technologies and services

Mission

Solution Inc. Vision is Protecting people and the resources vital to life. Make the world cleaner, safer and healthier, helping business succeed while protecting people and vital resources. What is vital: clean water, safe food and healthy environments

<u>Strategy</u>

- **Helping customers succeed**

  From restaurants and hotels to power plant and manufacturing facilities, PT SBI have trained sales and service associates that will help customers solve their cleaning, sanitizing and water and energy management challenges. To help customer ensure operational efficiencies, product integrity and brand reputation
- **Providing personalized service**

  PT Solusi Bersama Indonesia ultimate competitive advantage is to make tailor made solution for every unique customer challenge. With provide innovative solutions, digital technologies and expertise.
- **Developing innovative solution**

  Solution inc. has a long history of innovation and strategy is based on chemistry, digital technology and service to deliver exponential customer value to improve operational

I.2.2 Water Division Business Unit

PT.SBI water division business unit already operated from 1986 in Indonesia that supplied water treatment specialty chemical and service for Industry more than 1000 customer. PT. SBI water division business unit in Indonesia have subdivision as District that serve customer based on Market Industry characteristics and Geographical location. Based on industry market water division divided to two market for Industrial segmentation as below:

Table I.2 PT. SBI Water Industry Market

Light Industry	Heavy and Mining Industry
Data Center	Chemical processing plant
Palm Oil Mill	Power generation Coal Based
Food & Beverages	Primary Metal
Institutional	Coal, alumina, gold and copper mining
Automotive	Fertilizer and Oil Refinery Plant
Textile	Geothermal
Manufacturing	Oil Refinery

Solution Inc. have 2030 Impact goals to working toward a 100% positive future, as a mindset that propels associates, customers and communities forward. First impact goals are related to water division business unit, the 2030 impact goals listed as below (Solution, 2023):

1. **Water Goal:** By 2030, our goal is to help customers conserve 300 billion gallons (~1.1 billion cubic meters) of water annually, equivalent to the annual drinking water needs of 1 billion people.
2. **Climate Goal:** By 2030, our ambition is to help customers become carbon neutral by reducing greenhouse gas emissions by 6 million metric tons annually, preventing nearly 10 million pollution-related illnesses.
3. **Food Goal:** By 2030, we aim to help customers provide high-quality and safe food to 2 billion people for an entire year, preventing 11 million foodborne illnesses.
4. **Health Goal:** By 2030, our goal is to help clean 90 billion hands and provide medical care for 116 million people each year, reducing more than 1.7 million infections.

I.3 Business Issue

I.3.1 Sustainable Growth

As a specialty chemicals Company PT. Solusi Bersama Indonesia (SBI) have target for sustainable growth, sales trend data from 2019 to 2020 is decrease due to Covid19, from 2021 to 2023 Compound Annual Growth Rate is 8% as figure I.6.

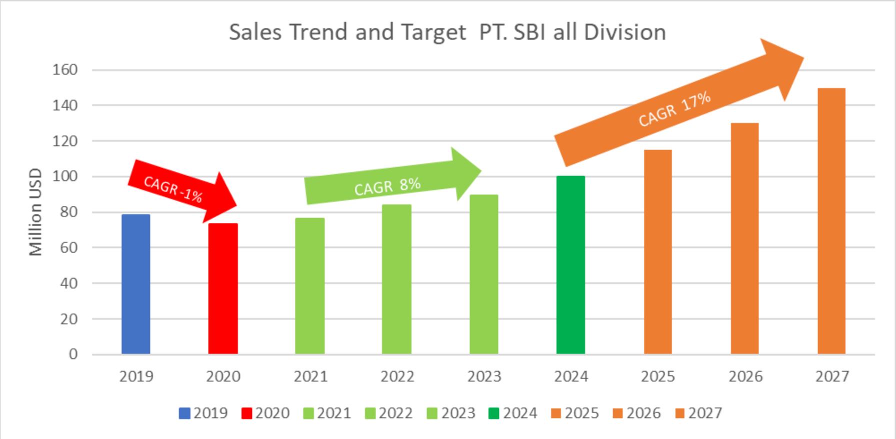

Figure I.6 Sales Trend 2019-2023 and Target PT SBI 2024-2027

PT. Solusi Bersama have target for 2024 to 2027 CAGR is 17% with milestone target at 2024 could close 100 million USD Sales from all division and at 2027 could reach 150 million USD. With this target each division of PT Solusi Bersama needs to develop a new business strategy to achieve this target. Figure below is sales trend and target for PT. SBI water manufacturing division , water business unit manufacturing division have gap target from 2024 to 2027 34.34 billion IDR that need to be fullfilled to achieve growth target

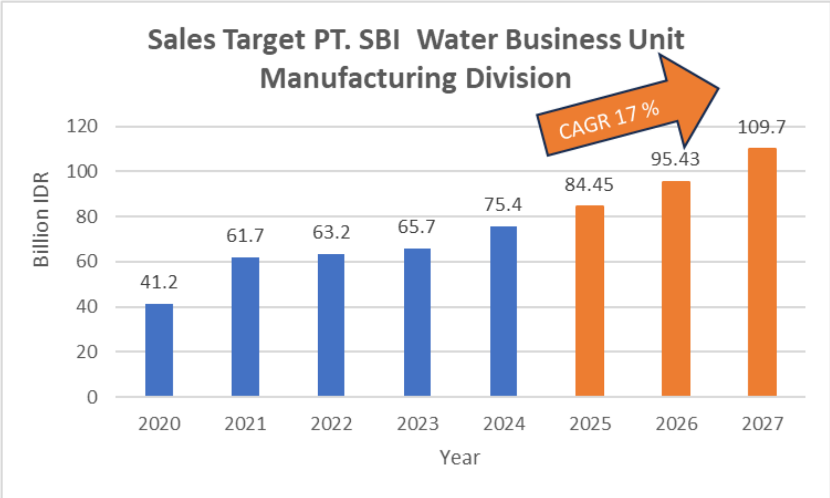

Figure I.7 Sales Target PT SBI Water Business Unit Manufacturing Division.

As company in water treatment business PT Solusi Bersama Indonesia already have well-known portfolio in chemical supply and services at below Customer process:

1. Water pre-treatment and wastewater treatment
2. Boiler
3. Cooling Water

The wastewater recycles is extension of wastewater treatment business but need to consider other system due to wastewater that recycled especially in industry to be use need further study where and how much recycled water can be use. Wastewater recycle sector not only once off project but could give potential annuity business from operational chemical that could support 2027 target. Wastewaters recycling also will align with 2030 goal to conserve water. As water sustainability concern growth in the industry, building expertise, value preposition and develop business strategy will help PT. SBI strengthen position in the market and creating value for customer.

I.3.2 Wastewater Recycle Business Opportunity

The private sector Industry as main users of water are increasingly reporting water as a material risk. Water risks like scarcity, floods and drought can cause operational and supplier disruptions, higher operational costs, brand damage and heightened regulatory uncertainty (WWDR, 2023)

Water clearly becomes important resources especially for Industry that need high water consumption whether use as part of Product or high consumption for Utility and Production Process. Some of the world's leaders in sustainable water management endorsed by United Nation form CEO Water Mandate with over 240 companies join to implementing water stewardship. In point 6 of CEO Water Mandate Transparency Company need to Publish and Share Water Strategies (Including targets and results as well as areas for improvement). (CEO water Mandate, 2024). Reduce, Reuse and Recycle of the water have been best practices strategies for private sector. Recycle of wastewater effluent of the industry become the last and peak option due to conduct Recycle process need higher investment compared to Reduction and Reuse Program of Water. According to Liao et al. (2021), wastewater treatment and reuse are advancing in major Asian countries. Their study on the impact of GDP, water resources, water withdrawal, and water stress reveals that nations like Indonesia and the Philippines are experiencing water shortages.

In Indonesia, corporate water disclosure remain limited. However, a study by Adhariani (2020) highlights the importance of water management and water accountability in Indonesia. Circular water management accountability that studied by Meiryani et al.(2022) highlights increase in water accountability reporting with reduce reuse and recycle indicator. Multinational companies are increasingly incorporating water stewardship into their targets and ESG programs. For instance, 376 companies have endorsed the Alliance for Water Stewardship (CEO water Mandate, 2024). Below are examples of strategies employed by multinational companies operating in Indonesia :

1. Kraft Heinz , Reduce water use intensity by 20% in high-risk watershed areas by 2025 (per metric ton of product made) (*The Kraft Heinz Company: Environmental Social Governance*, n.d.).
2. Nestle, Nestle waters business aims to lead the regeneration of the water cycle to help create a positive water impact everywhere it operates by 2025 (*Water Management in Our Operations | Nestlé Global*, n.d.).
3. Unilever , Unilever have goal to implement water stewardship programs in 100 of Unilever most water-stressed areas by 2030 (*Sustainable Solutions to Water Scarcity | Unilever*, n.d.)
4. Microsoft, Microsoft have goal in 2030 will be water positive, meaning Microsoft will replenish more water than Microsoft use. (Microsoft, 2024)
5. Friesland Campina, Friesland Campina with entity in Indonesia as Frisian Flag have target to reduce water consumption at our production facilities by 25% between 2018 and 2030. (*Water and Waste - FrieslandCampina Global - FrieslandCampina*, n.d.)

Wastewater treatment plant (WWTP) function is to remove contaminants and pollutant from wastewater that coming from production activity to meet with standard regulation. High wastewater discharge could indicate high prospect for the Wastewater Recycle Project. From Figure I.8 Indonesia is highest Country in Southeast Asia with Wastewater Discharge that up to 10 million m3 annually compared to all total Other South East Asian Country summed up Indonesia is still bigger.

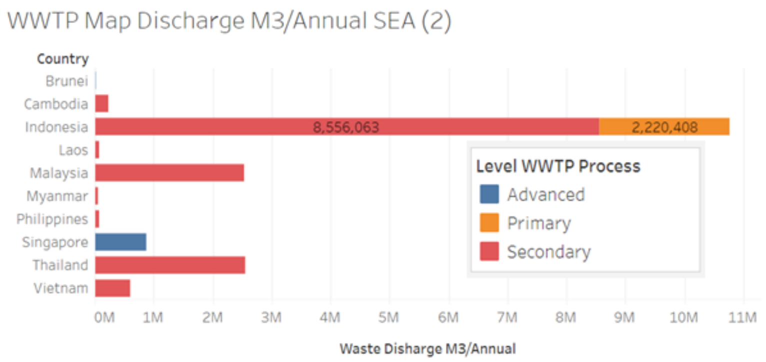

Figure I.8 Waste Water Discharge at South East Asia (Ehalt MacEdo et al., 2022)

Wastewater recycling and reuse applications have grown in popularity because of global water scarcity. The technological advancements in wastewater treatment mean that water treatment process can be tailored for specific water reuse applications. (Kumar et al., 2021). Industrial wastewater become sector that have probability to implemented wastewater recycle in Indonesia especially in west java area because product wastewater that has been processed already have system that could utilize this product water like for Utility application (Boiler, Cooling Tower or flushing). Application of wastewater recycling in Industrial sector also more feasible in investment due to with high capital expenditure, treating wastewater for recycling in Industry could more easily to review the Benefit from Economic, Environmental and Social, compared to Domestic or Agricultural sector in Indonesia.

West java area become province that have high concentrated industrial area operation in Indonesia with 30 industrial estates operated in 2023 (HKI, 2023). Factory in Industrial estate still growing with development of infrastructure. West Java Province also develop new area for economic growth utilize new Patimban Port and Kertajati Air Port, this area cover Subang, Indramayu, Majalengka, Cirebon, Sumedang and Kuningan called Rebana (BAPPEDA JABAR, 2020) from previously concentrated in Bekasi, Karawang and Purwakarta.

Total registered Industrial Estate across Indonesia is 113 with 32 Industrial estates still not operational yet. With industrial growth is increase demand for fresh water will increase and with growing concern of sustainability followed by technology application and increasing commitment of Wastewater quality, Wastewater Recycle could be implemented to recovering water quality to meet Industrial and hygienic standard and use as alternative water resources than fresh water to reduce further water consumption. This potential of Industrial Wastewater Recycle demand also will be increase and become of potential business opportunity for water treatment company. Study from Nyoman et al. (2020) shows that implementation of wastewater resource recovery could be followed by another type of potential study of different industry due to wastewater that discharge could have other potential resouce for other industry such as metal and fiber.

Figure I.9 Data of Location Industrial Estate in Indonesia (HKI, 2023)

I.3.3 Water Treatment Company Business Model

PT SBI as water treatment company conducted Business to Business (B2B) operation with Customers from different industrial sector with different wastewater characteristic. For water treatment company below are business model option that could be taken from wastewater recycle business potential:

1. Consultation Service Offering: Water treatment company could offer consultation service to review wastewater treatment unit process, feasibility of wastewater recycles implementation and basic engineering design.
2. Equipment Project Build Capital Expenditure Offering: Water treatment company offer for manufacturing, building and installation of the equipment.
3. Operational and service (Chemical management services): Water Treatment company could provide chemical for operational of Recycle unit and offer for manpower and maintenance services to operate wastewater recycle
4. Chemical offering: This is the most common model that water treatment company sells chemical and after sales service for chemical application by ship and bill method.

5. Design Build Own Operate and Maintenance (DBOOM) offering: This is business model when Water Treatment Company fully financing, design, build and operate the system and customer will be charge could be by m3/hr wastewater recycled or by fixed billing.

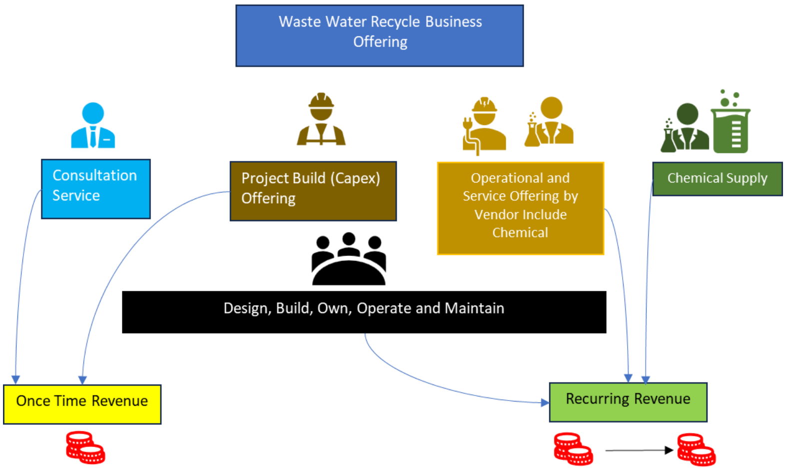

Figure I.10 Wastewater Recycle Business model image by Author

I.3.4 Challenges of implementing Wastewater Recycle

Challenges in Wastewater Recycling is to determine factor that most influent Customer to investing in Recycling Wastewater due to different Industry have different characteristic of wastewater and what Strategy that need to take business potential in this wastewater recycle business. Recycle of the water is put as latest process in 3R method due to water especially effluent before recycled due to Wastewater Recycle process need high Capital Investment and Operating Expense for operating the Recycle unit. Wastewater recycle implementation barriers studied by Morris et al.(2021) that conduct PESTEL analysis for wastewater recycle with important factor is technology application to handle challange from political, legal, social, economical and environmental barriers.

Based on best practice study of water recycling in Greater Jakarta showed that the main driver for the business sector is saving costs on water bills, followed by Company commitment for Global company and Being a Role Model (Priadi et al., 2017), additional study of water reuse planning in Indonesia include of recycle water need to consider in three aspects such as the environment quality, the values of economic, and acceptance in society (Aru Yudhantoro et al., 2020).

Other Problems also related with tariff scheme of Recycle Water Price, Water Price component in Factory usually consist of water price and discharge price. Based on different tariff structures need to be adopted based on Local socioeconomic factors and water authorities’ objectives (Fagundes & Marques, 2023) . The price of Water in West Java Area are variated, water price in Industrial Estate is higher compared to directly taking water from Citarum River, it means from economic review more feasible to get cost saving from water bills in Industrial estate.

Industrial Customer based on water resources and wastewater discharge could be classified as below:

1. Direct watershed user, mostly in Industry that near with rivers, in greater Jakarta Big Factory using direct water from Citarum River Watershed and directly discharge to River
2. Industrial Estate user, water take from Industrial Estate and wastewater to Industrial Estate
3. Deep Well User, water taken from Deep Well and wastewater discharge to River, generally small river that become part of main River watershed.
4. Sea Water User, water taken from sea water and converted to industrial water that meet with Criteria for Industrial use such as Power Plant or Refineries

Water Treatment Company needs to offer tailor-made solutions for Wastewater Recycle for different customers based on their most concern and motivation. There are 11 Buyer motivations by sector for user-driven watershed investments as described at figure I.11

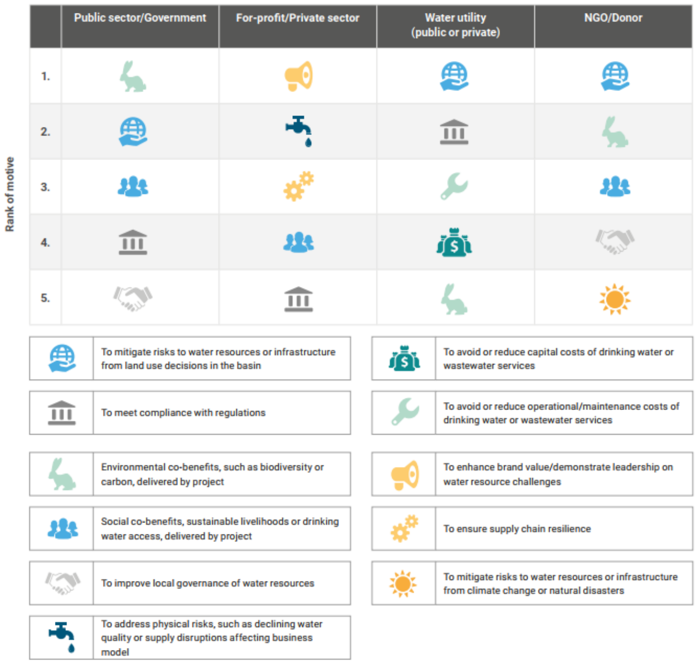

Figure I.11 Wastewater Recycle buyer motivation Source (WWDR, 2023)

Lists in Figure I.11 are rank of motive from Sector that taken water resources from watershed. Globally, avoiding or reducing capital cost of drinking water or wastewater services only occurs 1 and at rank 4. It indicates that most industries at the watershed are already valuing water as resources that have risks and need to be mitigated. By identifying the right motives of customers, PT. SBI, as a water treatment company, could be one step ahead of the competitor and become the right partner as business solution partner for wastewater recycling provider.

PT. SBI need to discover first what factor that affect customer to develop wastewater recycle, customer business strategy in wastewater, and other variable that impacted from customer side. Internally PT. SBI could identify current capabilities, resources, technology, and other variables that are needed for PT. SBI to develop wastewater business capability.

With variable form internal and external scenario that complex and interconnected, need to develop systemic solutions with holistic approaches so PT SBI could identify scenarios and business strategies with give optimum revenue.

I.4 Research Questions

According to the background and business issues the research questions are:

1. What are the variables that need to be considered in the wastewater treatment recycle business.
2. What method that could be used to analyze variable in wastewater treatment recycle business with systemic approach
3. What is scenario that PT Solusi Bersama Indonesia need to be implemented in wastewater recycle business to growth revenue

I.5 Research Objectives

Research Objective of this research are:

1. To identify and analyze the critical variables that influence the operations, performance, and sustainability of the wastewater treatment recycling business.
2. To determine appropriate systemic methods for analyzing variables in the wastewater treatment recycling business to support comprehensive decision-making and strategic planning for PT SBI.
3. To identify scenario and propose implementation plan for PT Solusi Bersama Indonesia in the wastewater recycling business that will drive revenue growth and enhance business performance.

I.6 Research Scope and Limitation

1. Research scope is wastewater recycle for Industrial application and use, wastewater recycle application for urban, domestic, building and agriculture are not included
2. Research limited to PT. Solusi Bersama Indonesia Light Industry Market (Business unit water manufacturing division) as stated at table I.2 and limited geographical area to be evaluated at West Java Province due to current responsibility area of researcher. Wastewaters recycle development for this research also limited to existing customers for this business unit.

3. Research for wastewater recycling business studied conducted with assumptions no competition enters to existing customers during development of wastewater recycling business.
4. Data limitations for research simulations using data from Bekasi (Cikarang) and Karawang as area with concentrated industrial estate

Chapter II Literature Review

II.1 Theoretical Foundation

II.1.1 Developing Circular Economy of Water Sector

Water in earth naturally have recycling process called hydrologic cycle with evaporation to atmosphere and when saturated, water will be back to earth by rain, water collected by earth in natural basin, forest or other fresh water source that available. Due to water overuse, uneven distribution, surface and groundwater contamination, population increase and climate change, many places in the world are experiencing water scarcity. Artificial water recycling like waste water recycle could works simultaneously with the natural water cycle helps to mitigate water scarcity (Kumar et al., 2021)

Circular Economy of Water sector embrace water usage with circular economy model compared with linear economy model that mostly use as current application in domestic, agriculture or industrial use (Figure II.1). Generally, the water extracted from the natural environment, processed as needed, use in domestic, industry or agriculture and discharge back to environment with or without treatment.

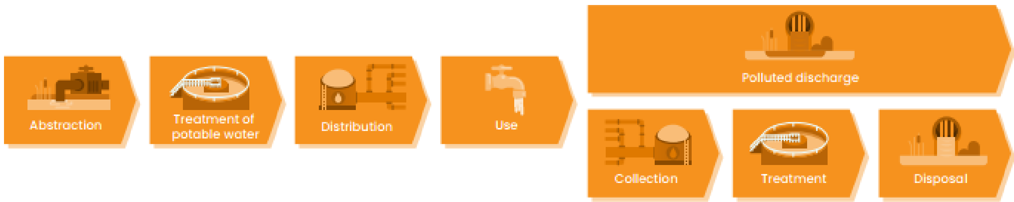

Figure II.1 The linear approach: Freshwater abstraction, treatment, use and disposal (Delgado et al., 2021)

Delgado et. Al at Water in Circular Economy and Resilience (WICER) report, propose framework to change from linear approach to Circular Approach, in this approach full value of water is recognized and captured, water recognizes as the finite resources, and in this further approach water sector also mitigates its emissions of greenhouse gases. Communities, business and institutions in circular economy in water sector also need to applied Resilience principle with persistence, adaptability and transformability.

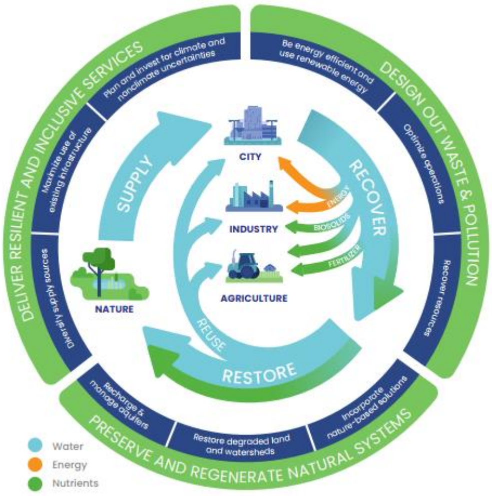

Figure II.2 The WICER Framework (Delgado et al., 2021)

WICER framework provide approach of Circular Water management that consist of City, Industry and Agriculture, this system could be implemented in developing Industrial Estate that integrated with Cities especially for new industrial area like Subang at West Java.

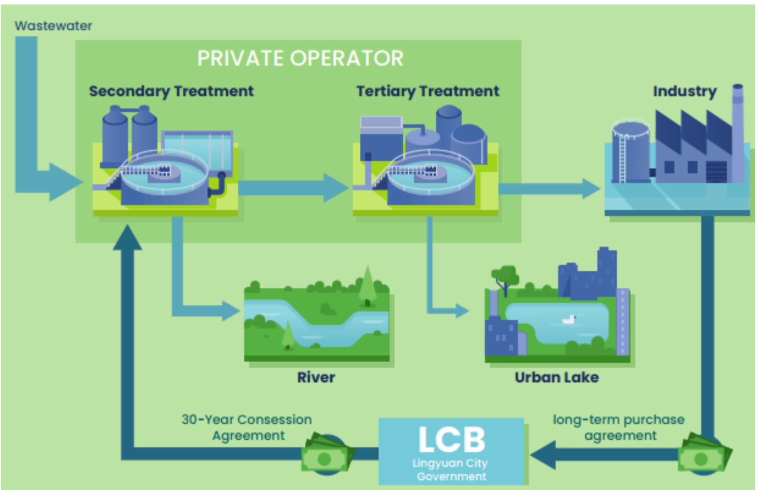

Figure II.3 Application of WICER Framework (Delgado et al., 2021)

Figure II.3 shows Circular approach of water usage with Private Operator that have system to Recycling wastewater and utilize as Industry water source, that collecting waste water from domestic (City) and Industry.

II.1.2 Water recycles (Industrial reuse practices)

Industrial reuse and recycling differ from other types of reuses, as it involves the private sector. In general, it is common to set recycle projects in industries, when water is reused, before any economic benefits are realized, investments need to be made, proper treatment methods and monitoring programs need to be put in place, and negotiations need to be undertaken by the concerned parties. Table II.1 is advantages and disadvantages of Industrial Recycling and Reuse, before implementing industrial reuse need proper study to eliminate or control potential problem (Cisneros, 2014).

Table II.1 Advantages and Disadvantages of Reusing Water

Advantages	Disadvantages
• It allows recovering energy (as heat) from used effluents. • It reduces the production costs, as it saves water. • It allows recovery of prime matter. • It reduces the cost of treating and disposing wastewater (discharging fees).	• if no proper water quality criteria are set, the quality of the product might be decreased and the industrial processes may be affected or their efficiency reduced. • There are some health concerns because of the exposure to organic volatile compounds or microorganisms (such as Legionella) that might be disseminated through aerosols.

Managing disadvantage of recycle process also could conducted using Value Creating and Sharing between user and supplier with contract model as figure II.4

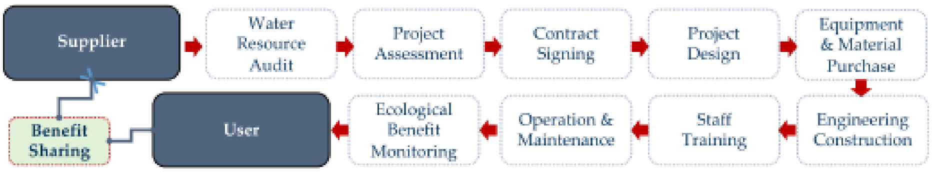

Figure II.4 Value-sharing contract between user and supplier (Liu & Jia, 2021)

Industrial recycle and reuse options are as varied as industrial processes and water source location. Table II.2 is option of available technology treatment for specific concern for Industrial water reuse (Cisneros, 2014).

Table II.2 Concerns for Industrial Water Reuse and Treatment Options

Concern	**Cause**	**Treatment Options**
Scaling	Inorganic compounds Salts	Scaling inhibitor Adsorption into activated carbon Filtration Ionic exchange Regulation of flow
Corrosion	Dissolved and suspended solids pH imbalance	Corrosion inhibitors Reverse osmosis Nanofiltration
Biological Growth	Organic residues Ammoniacal nitrogen Phosphorus	Biocides Biological treatment Filtration
Clogging and biofilm formation	Phosphates Dissolved and suspended solids Organic residues	Corrosion control Biological growth control Filtration Physical and chemical treatment

Figure II.5 is example of wastewater recycle simplified flow diagram that already applied at PT Frisian Flag Indonesia for that already save fresh water up to 4,446 m3/month but in term of cost saving is not much but there's other benefit for company reputation to reduce freshwater usage and reducing water stress.

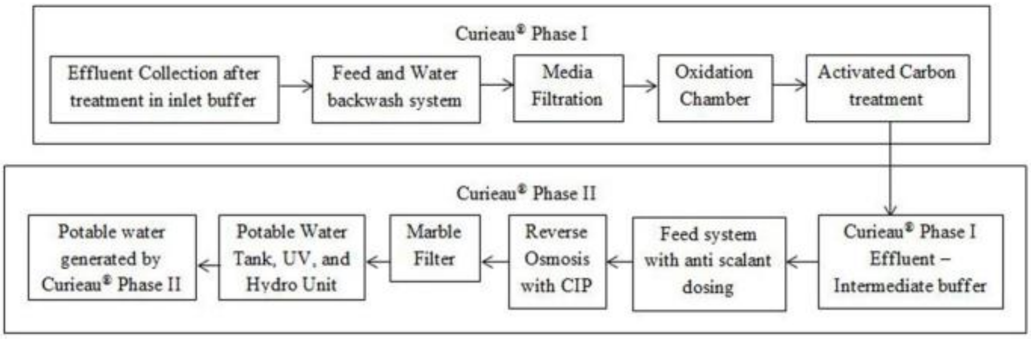

Figure II.5 Simplified flow diagram of water recycling process at Frisian Flag Indonesia (Priadi et al., 2017)

II.1.3 Contributions of Recycle Wastewater to Environment and Sustainability

Wastewater treatment plant (WWTP) as processing unit for Industry that now become obligation and discharge regulated by government currently still viewed do not have economic value and become cost burden to production, with advance in technology of water filtration and process, waste water that discharged could be recycled and have economic value. Figure II.6 show potential environmental benefit for reuse of recycle waste water based on Kumar et al. (2021) that could converted to economic benefit.

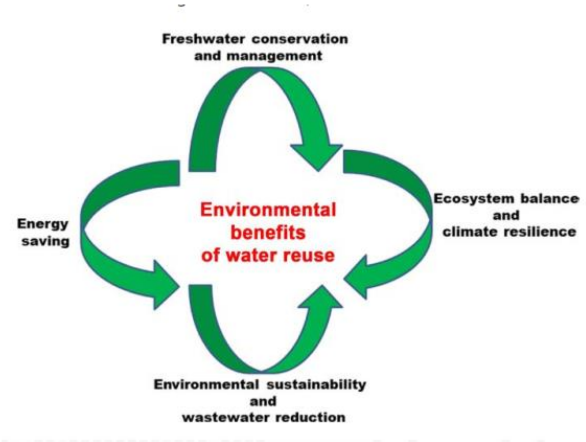

Figure II.6 Environmental benefits of water reuse

Using recycled water will decrease fresh water consumption. Water cost reduction will be vary based on fresh water price and location of the industry. Reduction of the cost of Drainage system more related if the location of waste water discharge area is far from the WWTP, increase recycle volume will be lowering need of big Drainage system and will reducing the investment cost for sewer or piping and energy for waste water discharge.

Singapore is successful case of application of water recycling with NEWater program started in 2003 as part of long-term strategy to diversify water resources and reduce Singapore’s dependence on imported water from Johor Malaysia with a goal of resilience and self-sufficiency by 2060 (Tortajada, 2020). Level of water stress Singapore reduce significant from above 300 to below 100 below 10 years while Indonesia tend to increase and second in region below Singapore for Level of water stress (Worldbank, 2023b).

Currently common use of Industrial wastewater recycle is for utility system, Of the 17 SDGs, the sixth goal is to “ensure availability and sustainable management of water and sanitation for all”, recycle wastewater program could support SDG goal with reduce fresh water usage, reduce wastewater discharge to environment and ensure water quality that discharge not harmful to human health.

II.1.4 System Dynamics

In 1950s Jay Forester introduce system dynamics at MIT in the 1950s, is designed to help us learn about the structure and dynamics of the complex systems in which we are embedded, design high-leverage policies for sustained improvement, and catalyze successful implementation and change (Sterman, 2002).

An important aspect of system dynamics is systems thinking, Sterman (2002) describes systems thinking the ability to see the world as a complex system, to understand how everything is connected to everything else with holistic view. Object called a systems if there's not only elements but also interactions of that elements, in the systems relationship or connections of each element matters.

Sterman (2002) give explanation how systems thinking is a way seeing dynamic complexity of the world. Complexity defined in terms of the number of, or links among, the elements of a system. The elements of dynamic complexity are feedback, time delays and stock and flows.

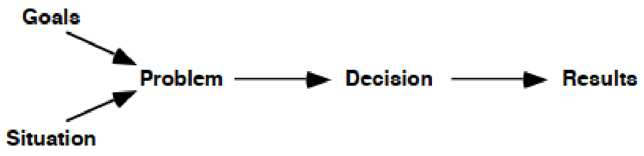

Figure II.7 Event-oriented view of the world (Sterman, 2002)

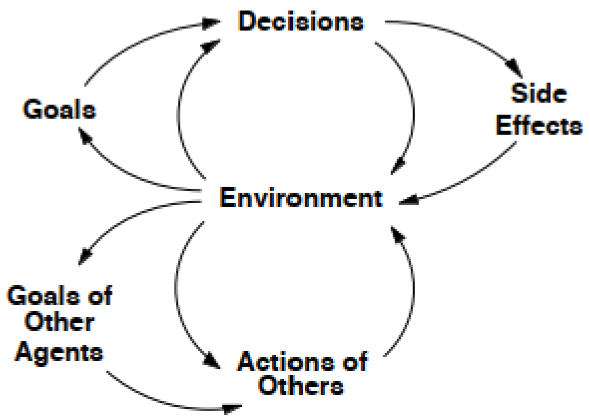

Figure II.8 The Feedback view of the world (Sterman, 2002)

Figure II.7 is common practices that conducted without applying systems thinking, that event or problem solving conducted with linier process, in figure II.8 Sterman (2002) explain decisions that taken could leading to new decisions and triggering side effects, delayed reactions, changes in goals and intervention by others. System dynamics modelling is discovering and representing feedback process. Feedback in system dynamics divided by two:

a. Positive feedback: Positive loops are self-reinforcing, this positive feedback in causal relationship will be indicate by **+** sign
b. Negative feedback: Negative loops are self-correcting, this negative feedback in causal relationship will be indicate by **-** sign

All systems, no matter how complex, will be consists of net positive and negative feedback and the dynamics of the system will be arise with interaction of these loops with one another.

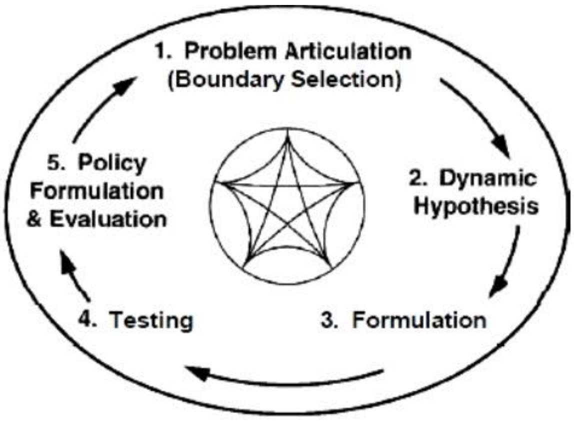

Figure II.9 System Dynamic Modelling (Sterman, 2000)

Process of Modelling method using system dynamics includes with five-steps as explained by Sterman (2000) figure II.9.

1. Problem Articulation (Boundary Selection), purpose of this step is to define the goal, problem and boundary of the modelling
2. Dynamic Hypothesis, purpose of this step is to develop dynamic hypothesis, what is relationship of each variable and model to reach the goal
3. Formulation, purpose of this step is to formulate stock and flow diagram that contain formula and equation.

4. Testing, purpose of this step is to test the model behaviour validity that consist of sensitivity analysis and robustness of the model
5. Policy formulation and evaluation, in this step model could be use for evaluation scenario or policies that will be taken to achieve the goal

II.1.5 System Dynamics Modelling for Water Management

In water resource management System Dynamics captures the collective non-linear interaction effects and dynamics within the hydrologic, social, economic and environmental subsystems. The causal loop diagram (CLD) as qualitative tools and stock flow diagram (SFD) represents the water quantity. (Naeem et al., 2023). Below are previous studies for application of System Dynamic Model in water resources management.

Naeem et al. (2024) develop system dynamics approach to management of water resources in Qatar as decision support system to enhance stakeholder engagement and assist policymakers in determining the tipping points of various water management strategies with formulate strategies that harmonize societal and environmental sustainability while considering increasing socio-economic growth rates.

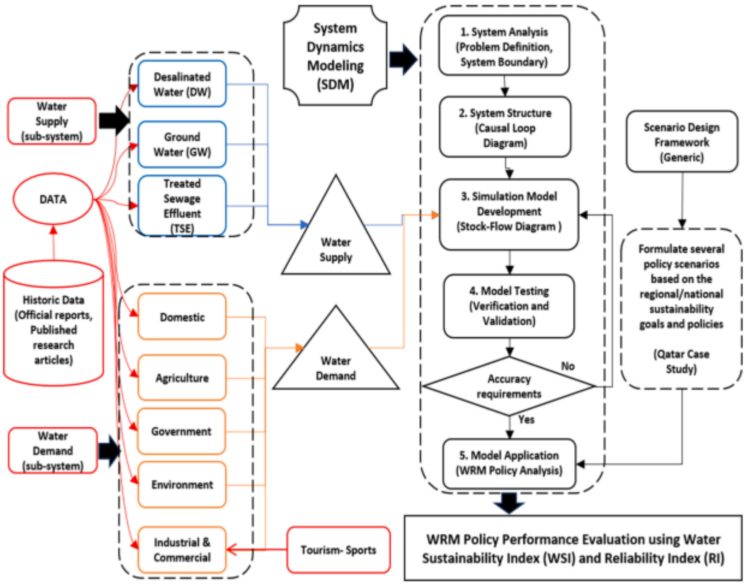

Figure II.10 Schematic diagram framework developed by Naeem et al. (2024)

Figure II.11 is Causal Loop Diagram that develop as qualitative analysis for water resources management after developing process using above schematic diagram frame work.

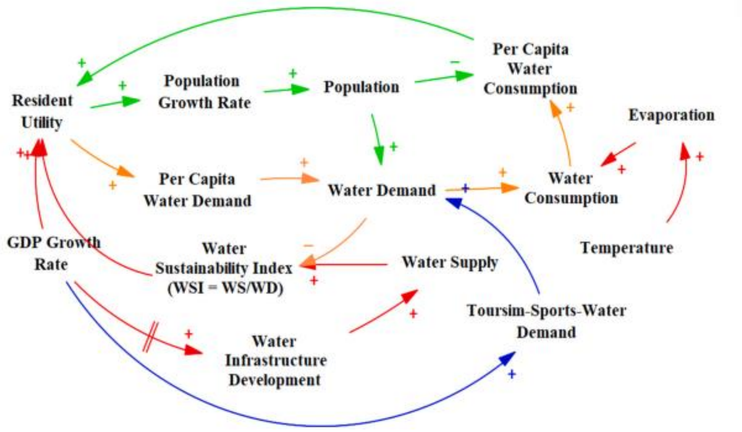

Figure II.11 Causal Loop Diagram developed by Naeem et al. (2024)

Baskoro et al. (2021) develop system dynamic model for sustainable water supply strategy in Sentul City area with objective to predict the water supply and demand in Sentul City urban area and then to predict the impact of water policies in Sentul City urban area with developed CLD at figure II.12 and II.13 below.

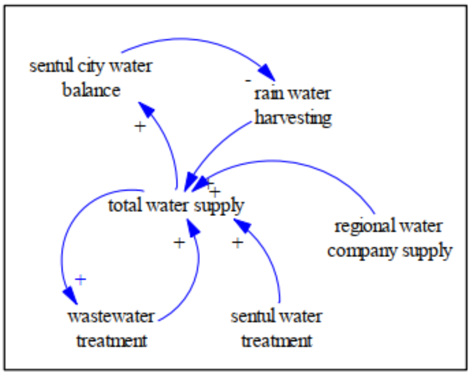

Figure II.12 Causal loop diagram of water supply subsystem at Sentul City

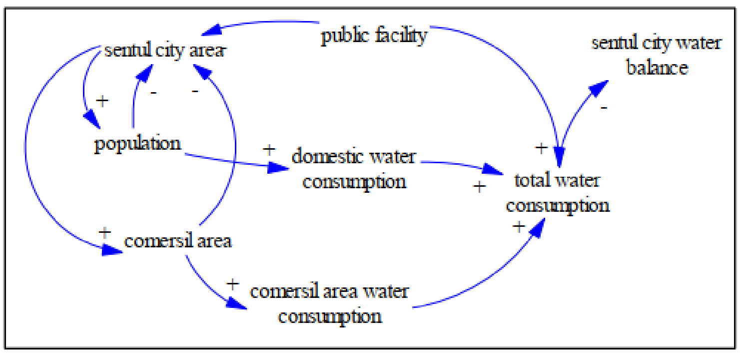

Figure II.13 Causal loop diagram of water demand subsystem at Sentul City

II.1.6 System Dynamics Modelling toward a circular economy

Water is not only resource that could be recycled, a study case for implementing circular economy of recycling also developed for aseptic paper packaging. Kuo et al. (2021) develop Recycling system dynamic model for paper recycling packaging waste in Indonesia.

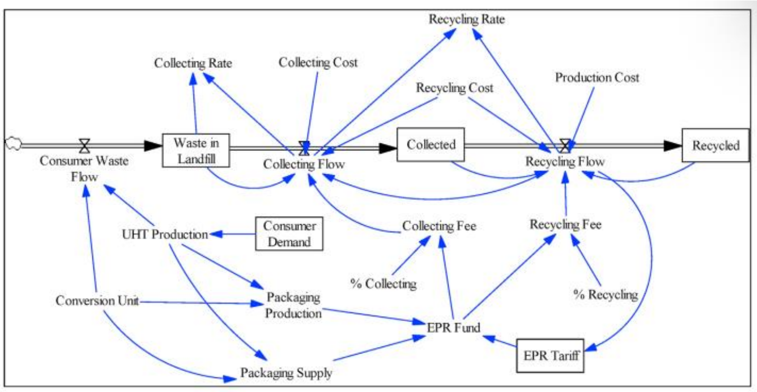

Figure II.14 SFD of Paper Recycling developed by Kuo et al. (2021)

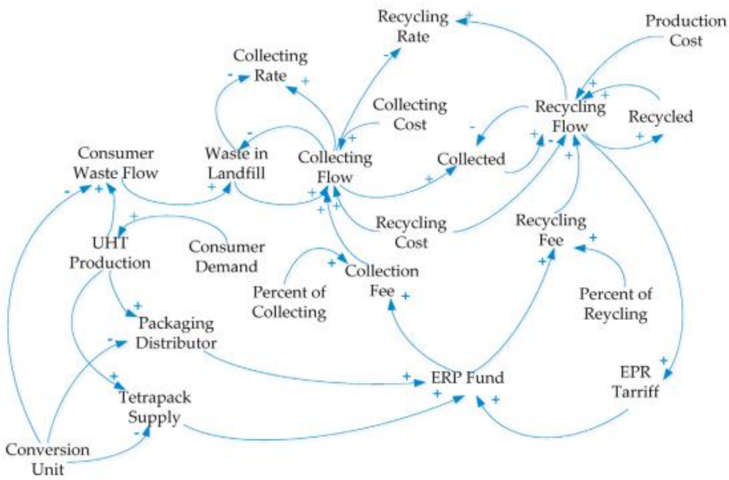

Figure II.15 CLD of Paper Recycling developed by Kuo et al. (2021)

With system dynamic model that developed, producer could simulate which scenario of Extended Producer Responsibility (EPR) fund scheme, subsidies to recycler and subsidies to collecting partner that give optimum impact for each goal of stakeholders.

II.2 Conceptual Framework

Conceptual framework of this research starts from sustainability issue in water scarcity and business opportunities that coming from these issues. Research frame works based on system dynamics approach due to wastewater recycle system business is dynamics, and key variables could be change such as technology implementation and vary for different industries. Concept of Wastewater Recycle start developed when Reverse Osmosis technology introduced that possible for wastewater to be reused and meet with industry specification.

With system dynamics, connections between of customer aspect such as wastewater quality that will be impacted to technology that needs to be deployed and technology will impact to Cost for Investment and Operational cost, could be developed with causal loop diagram of system dynamics.

Outcome of system dynamics Modelling is development of strategies for wastewater Recycle business with output is estimation of potential revenue. With system dynamics analysis PT. SBI also could estimate potential of freshwater consumption to environment could be reduced.

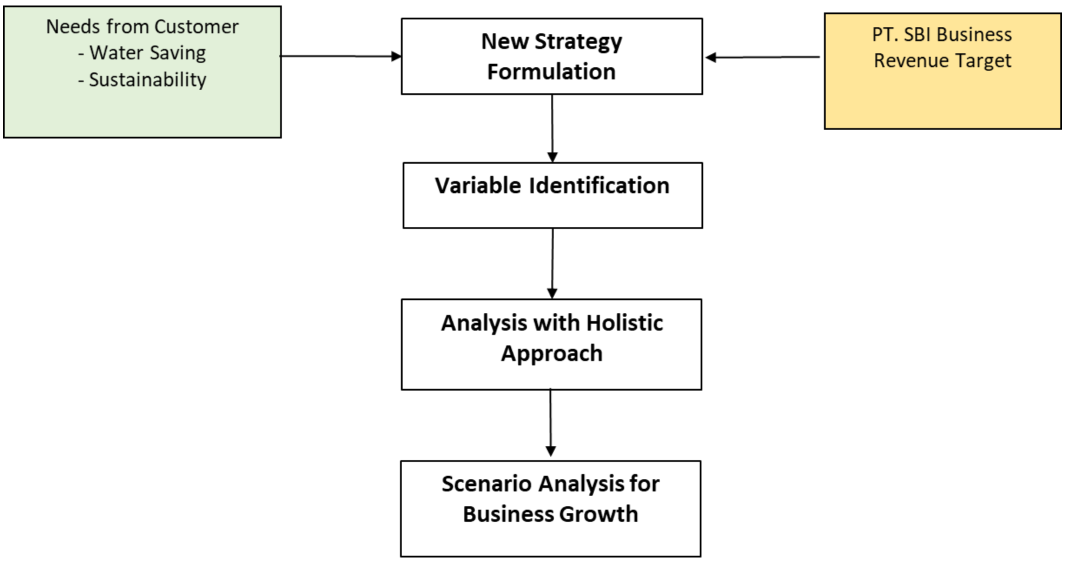

Figure II.16 Conceptual Framework of the research

Chapter III Research Methodology

III.1 Research Design

Following conceptual frameworks to answer research question, system dynamics modelling approach will be used.

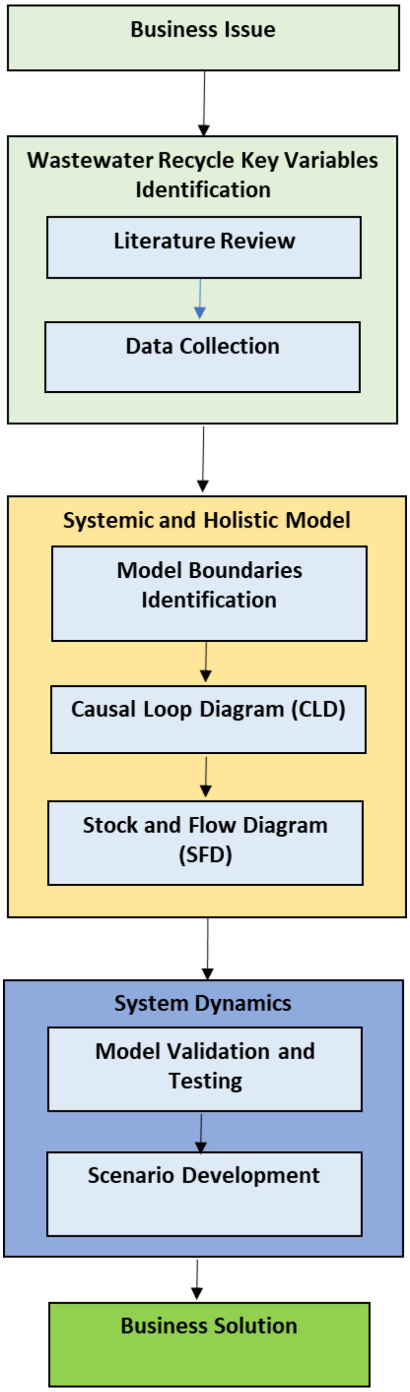

Figure III.1 Research design flowchart

III.2 Data Collection Method

Data collection method to answer research question and research methodology using mixed approach using primary data through Focus Group Discussion (FGD) to evaluate of variable that affected to wastewater recycle and validate the stock and flow diagram model that developed.

Secondary data also collected by literature review from published reports related to wastewater recycle or water sustainability practices that conducted in Industry sector and from internal document from previous project of wastewater recycling. Table below is planned data source for this research.

Table III.1 Data Collection sources

Type	Methode	Source	Objective
Secondary	Literature Review and Report	Scientific articles, or report about wastewater recycle, business model, case that already implemented	Secondary data collection to Identifying Key variables and for baseline data
Secondary	Internal Documents	PT SBI internal documents from historical project data, company. Customer Inquiry for wastewater recycle	Secondary data collection to Identifying Key variables and for baseline data
Secondary	Policy and Regulatory	Policy and Regulatory for wastewater treatment recycle and wastewater discharge	Secondary data collection to Identifying Key variables and for baseline data

III.3 Data Analysis Method

Data analysis was conducted using a system thinking approach and developed into a system dynamics model. Key variables were analyzed, and boundaries were set based on the goals of generating revenue and saving fresh water. The relationships among variables were reviewed to build a Causal Loop Diagram (CLD), and the type of each loop was identified as either a reinforcing or balancing loop. Vensim software was used to simulate the system dynamics model and the associated stock and flow diagrams (SFD) in this research.

The SFD model that developed was validated and tested utilizing Vensim's features for model and unit consistency during the model development phase. Validation of the model involved PT SBI stakeholders, as outlined in Table 3.1, who reviewed and verified the model through focus group discussions or model group discussions.

After validation of the model, scenarios were developed and simulated with the goal of optimizing revenue and water saving. The optimal scenarios were tested using sensitivity analysis, scenarios that have optimal results were identified as strategic recommendations for PT SBI in the wastewater recycling business.

Chapter IV Result and Discussion

This chapter of this research presents analysis of wastewater recycle business strategies using system dynamics approach. The first section analysed key variable in wastewater recycle business first step is schematic of wastewater recycle process and how wastewater recycle process uses in Industrial use, second step is how PT SBI could generate revenue in wastewater recycle business, third step is setting key variables and system boundaries. The third section is to build relationship of each of variables with causal loop diagram (CLD) and identify type of the loop whether reinforced or balancing loop. The fourth section is to develop stock and flow diagram with identifying what variables that as stock and flow and develop basic data, initial value, equation and assumptions for model to be run for analysis.

The fifth section is model verification with model and unit checks using vensim and comparing the model output with actual conditions. The final section is scenario development to review alternative that could be implemented as strategy for wastewater recycle business development.

IV.1 Business Analysis

IV.1.1 Wastewater Recycle Process System Industrial Sector Key Factor

To identifying key variables in wastewater recycle we need to understand overall process of water use in the customer and Boundaries. The goal in customer side for industrial wastewater applications is to reduce freshwater consumption.

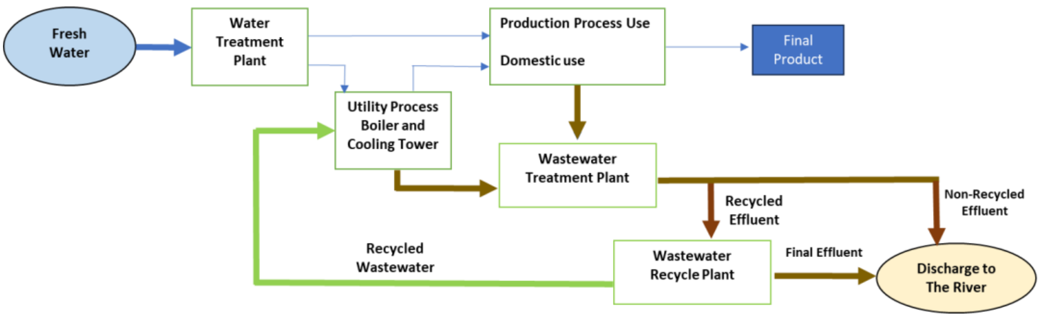

Figure IV.1 Wastewater recycling in Industrial sector (Image by author)

With reducing freshwater consumption industrial sector have potential to get economic benefit from cost reductions if operational cost of Recycle water per m^3 is lower compared to freshwater cost. Economic benefits not only factor that affected wastewater recycle implementation other factors that affecting customer to applied wastewater recycle in greater Jakarta area : Urge to become a role model for other companies, and company commitment to improve environmental performance (Priadi et al., 2017)

Factor that will impact economic benefit from wastewater recycle is investment and operational cost, investment and operational cost will be dependent to what equipment and technology that will be installed, and technology that installed will depend to wastewater treatment plant effluent quality and specification of where's recycled wastewater will be used. Wastewaters recycling process that will be used for utilities need at industrial customers will have different technologies application. If recycled wastewater will be used for domestic use, need to add additional disinfection and Ultraviolet technology displayed at figure IV.2 as in application at NEWater Singapore

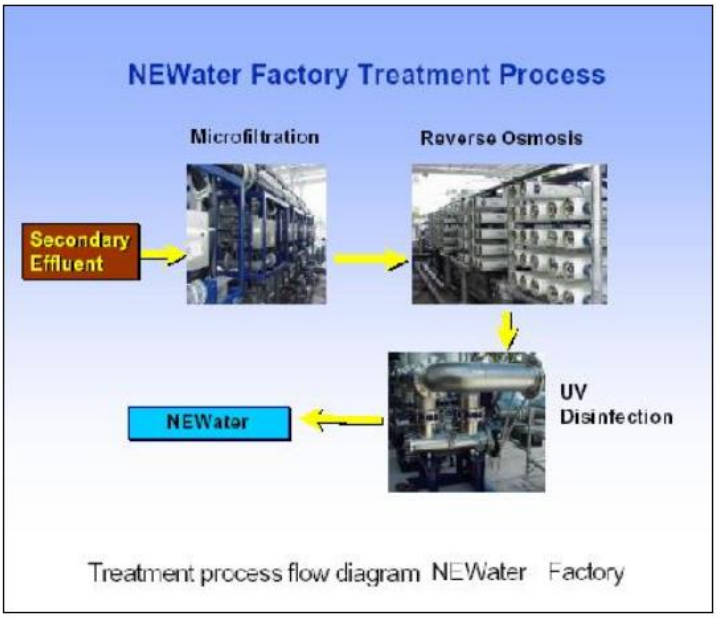

Figure IV.2 NEWater Factory Treatment Process (Teknologi Lingkungan & Pengkajian dan Penerapan Teknologi, 2006)

Common process in Industrial application of wastewater recycle as below, area with box (Section for alternative technology application) will be impacted to the overall cost for the customer, and for PT SBI or other water treatment companies will be section for value added or solution offering in terms of technology that could affected to how much water could be recycled and operating cost of recycle system.

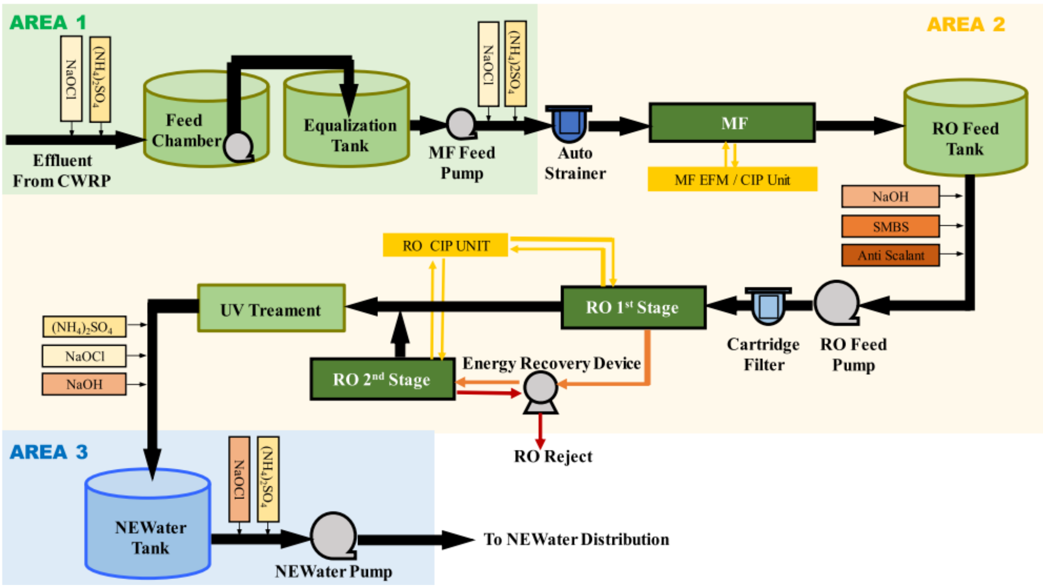

Figure IV.3 Changi airport wastewater recycling project (Bai et al., 2020)

Wastewaters recycle design process is complex and integrated process, even with simplified diagram as figure IV.1, applying wastewater recycling need to see the process as integrated especially for utilizing recycle water results, example of problem that researcher found during discussion is when recycle water product is being used as water source for cooling water system without check water specification of cooling water unit, corrosion happen and impacted with high cost of repair the corrosion damage. Several variables that affecting wastewater recycle business in industrial sector are shown in Table IV.1

Table IV.1 Variable affecting customer Recycle Wastewater

No	Variable Name	Definition	Type	Unit
1	Recycled Wastewater Generated (RWG)	Wastewater that has been processed from wastewater recycle plant, increase by Wastewater Effluent Recycle Rate and reduce freshwater demand (m3/year)	Stock	m^3/year

No	Variable Name	Definition	Type	Unit
2	Fresh Water Demand (FWD)	Demand of fresh water needed for industry production process (m3/year)	Flow	m^3/year
3	Industry Growth Rate (IGR)	Industry yearly growth rate that could affect Industry Production Water Demand (%/year)	Auxiliary	%/year
4	Industry Production water Demand (WD)	Total water that needed for Industry for production process (m3/year)	Flow	m^3/year
5	Wastewater effluent Generated (WEG)	Quantity of wastewater that discharge from wastewater treatment plant (m3/year)	Flow	m^3/year
6	Industrial Wastewater Ratio (IWR)	Ratio of wastewater that produce from freshwater that go to Industrial production	Auxiliary	Dmnl
7	Wastewater Effluent Recycling Rate (RR)	Quantity of wastewater effluent that could be converted as recycled wastewater generated	Auxiliary	Dmnl
8	Wastewater Generated Discharge to environment (WDE)	Wastewater that discharged to environment or Industrial estate, higher Recycling Rate (RR) will decrease wastewater generated discharge to environment	Flow	m^3/year
9	Environmental Regulation (ER)	More strict regulation of wastewater discharge quality will be impact to lower recycling rate.	Auxiliary	Dmnl
10	Wastewater Recycle Demand (WRD)	Wastewater recycle demand is demand of recycled wastewater that affected by fresh water demand and recycle wastewater quality.	Auxiliary	Dmnl
11	Wastewater Recycle Treatment Capacity (WRTC)	Capacity of wastewater recycle treatment that could affect to recycling rate and wastewater recycle investment cost	Auxiliary	m^3/year
12	Recycle Wastewater Quality Specification (RQS)	Recycle wastewater quality specification that required for production and meet with recycle reuse water regulation	Auxiliary	Dmnl
13	Wastewater Recycle equipment Technology (WRT)	Wastewater Recycle equipment technology that affected by effluent quality specification, effluent pollutant quality, and environmental regulation. WRT could affect to investment cost and quality of recycle process discharge to environment	Auxiliary	Dmnl

No	Variable Name	Definition	Type	Unit
14	Wastewater Effluent Pollutant Quality (WEQ)	Wastewater effluent quality that will determine technology needed and recycle demand	Auxiliary	Dmnl
15	Recycle Reuse Water Regulation (RR)	Regulation related recycle and reuse of water in Industry, tighten regulation could increase quality specification of recycle wastewater product	Auxiliary	Dmnl
16	Production Water Specification (PWS)	Specification of water that needed for production or production unit such as Cooling Tower and Boiler	Auxiliary	Dmnl
17	Recycle Wastewater Discharge Quality to Environment (RDQE)	Recycle wastewater quality discharge to environment that affected by wastewater recycle equipment technology and affected by recycling rate, higher recycling rate will decrease quality of recycle process discharge.	Auxiliary	Dmnl
18	Wastewater Recycle Investment Cost (IC)	Wastewater Recycle Capital Investment depend to Technology and Treated Capacity	Auxiliary	Rp/M^3
19	Recycle Consultation Cost (RCC)	Consultation cost for developing wastewater recycle facility	Auxiliary	Rp/M^3
20	Decision in wastewater Recycle investment	Decision in wastewater recycle investment that affected by company sustainability goal, investment cost and potential recycle cost saving.	Auxiliary	Dmnl
21	Company Sustainability Goal (CSG)	Company sustainability related with water reduction and wastewater recycle initiatives	Auxiliary	Dmnl
22	Potential Recycle Cost Saving (PRCS)	Potential cost saving from recycle wastewater that affected from wastewater recycle cost, fresh water cost and wastewater discharge cost.	Auxiliary	Rp/M^3
23	Fresh Water Cost (FWC)	Cost of fresh water that needed for production process	Auxiliary	Rp/M^3
24	Fresh Water Price (FWP)	Fresh water price that ready to use for industrial usage	Auxiliary	Rp/M^3
25	Wastewater Discharge Cost (WDC)	Cost for discharge wastewater	Auxiliary	Rp/M^3
26	Wastewater Discharge Price (WDP)	Price of discharging wastewater effluent to environment	Auxiliary	Rp/M^3
27	Wastewater Recycle Cost (WRC)	Cost of produce wastewater recycle	Auxiliary	Rp/M^3
28	Chemical Cost (CC)	Chemical cost operation for wastewater recycle facility	Auxiliary	Rp/M^3

No	Variable Name	Definition	Type	Unit
29	Equipment Replacement Cost (ERC)	Cost for replacement equipment in wastewater recycle facility	Auxiliary	Rp/Year
30	Electrical Cost (EC)	Electrical Cost for wastewater recycles facility	Auxiliary	Rp/Year
31	Maintenance Cost (MC)	Cost for maintenance for wastewater recycle	Auxiliary	Rp/Year

IV.1.2 Causal Loop Diagram

The complexity of wastewater recycling in this research was analyzed through the relationships and connections between key variables and those associated with PT SBI. This analysis was conducted using a Causal Loop Diagram (CLD) .

In the Causal Loop Diagram, the interrelationships among key variables were built based on system thinking and system dynamics modeling. Using causal loop diagram decision-makers in PT SBI could evaluate relationship of each variable and develop effective strategies in wastewater recycle business.

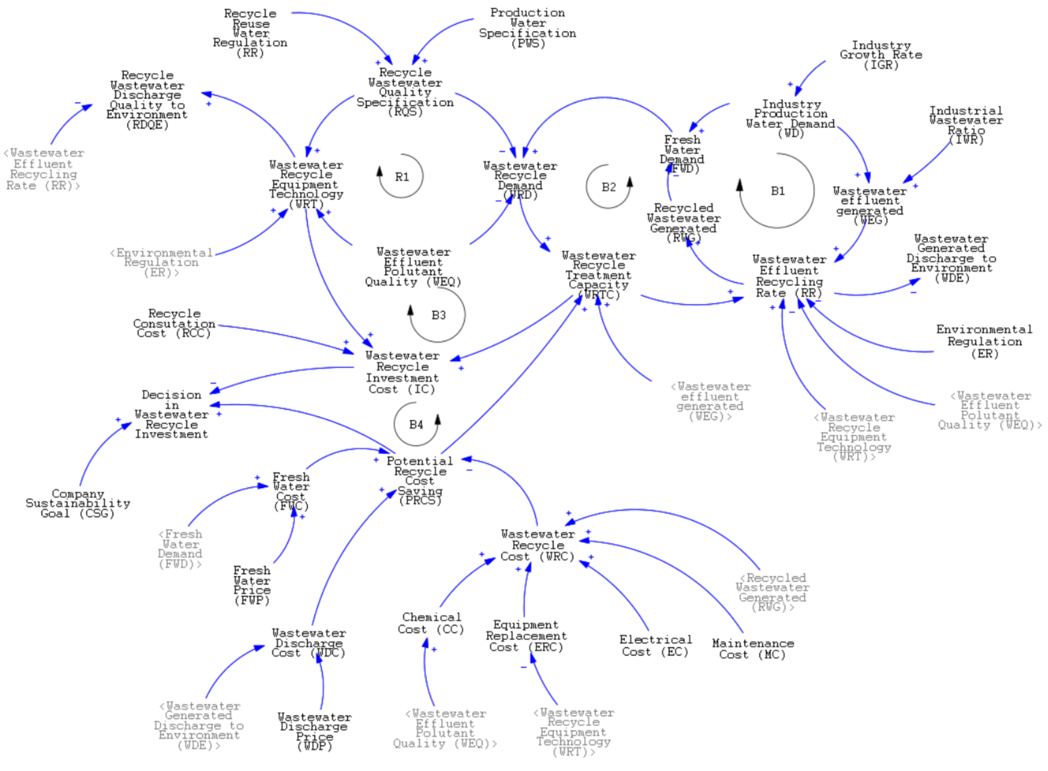

Figure IV.4 Wastewater Recycle Causal Loop Diagram at Industrial Sector

The causal loop diagram consists of two loops identified as Balancing loop and one Lopp as reinforcing loop. 5 loops are identified from the causal loop diagram as below:

a. Balancing Loop 1 (B1) and Balancing Loop 2 (B2)

Balancing loop 1 shows the causal loop diagram of how recycle wastewater conducted in customer site, Industry growth rate increase industry production water demand and will increase fresh water demand, to reduce fresh water demand wastewater effluent recycle process is conducted forming balancing loop. Variable that affects recycled wastewater generated is recycling rate, this recycling rate is affected by other variables in other loop and with higher recycling rate wastewater that discharge to environment will be reduced.

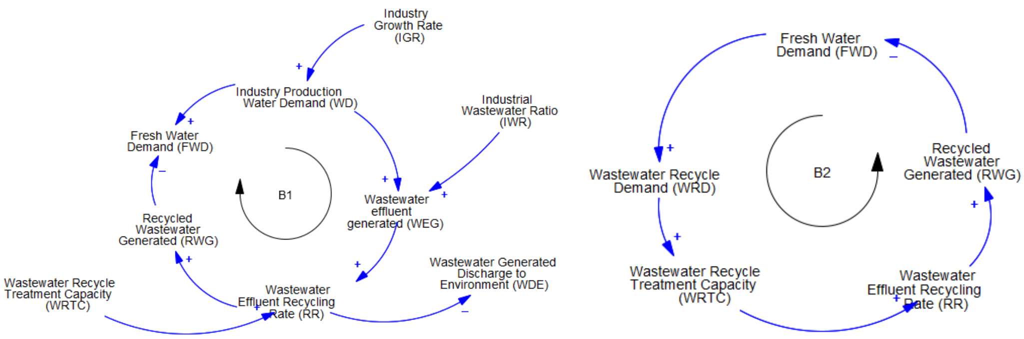

Figure IV.5 Balancing loop 1 (B1) and Balancing Loop 2 (B2)

Balancing Loop 2 illustrate that freshwater demand increase wastewater recycle demand and will increase wastewater recycle treatment capacity. Increase in wastewater recycle treatment capacity will increase wastewater effluent recycling rate. Increase in recycled wastewater generated will reduce freshwater demand and make balancing loop.

b. Balancing Loop 3 (B3) and Balancing Loop 4 (B4)

Balancing Loop 3 is formed by variable of wastewater effluent water pollutant quality could if condition is highly polluted this will reduce wastewater recycle demand and increase implementation of recycle equipment technologies and will increase wastewater recycle investment cost.

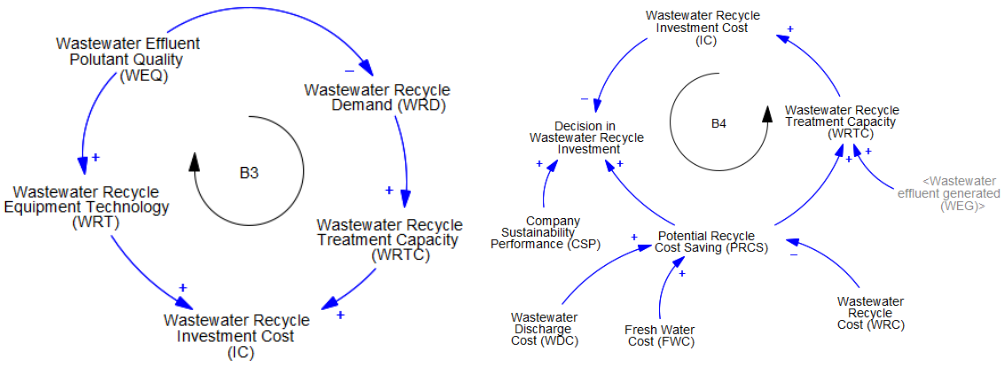

Figure IV.6 Balancing loop 3 (B3) and Balancing Loop 4 (B4)

Balancing Loop 4 is how decision in wastewater recycle investment in industry affected by wastewater recycle treatment capacity and cost component variable. Increase in freshwater cost and wastewater discharge cost could increase potential cost saving and high wastewater recycle cost could decrease potential cost saving. Other variable that could affect to decision in wastewater is company sustainability performance goals due to in some industries wastewater recycling is not give potential cost saving due to high cost of wastewater recycle investment and operation.

c. Reinforced Loop 1 (R1)

Wastewater Recycle demand could affected by recycle wastewater quality demand and wastewater effluent pollutant quality. Higher quality requirement of wastewater recycle will decrease demand and increase implementation need of technology applications such as ultraviolet.

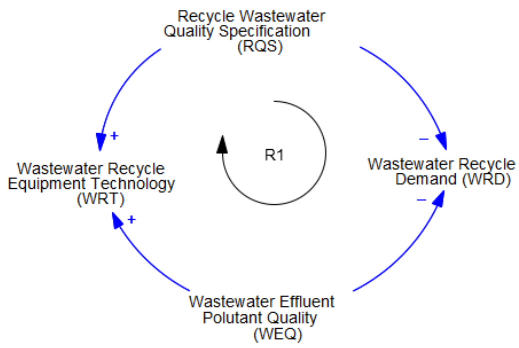

Figure IV.7 Reinforced Loop

IV.1.3 Stock and Flow Diagram

To simulate and model the causal loop diagram of each variable in wastewater recycling, stock and flow diagrams were used. Stocks represented accumulated quantities, while flows represented changes in the quantities of stocks over time. The stocks modelled included water and costs associated with wastewater recycling. In this study, wastewater recycling costs were assumed to represent potential revenue for PT SBI, while potential cost savings for wastewater recycling in the industry or among customers were considered as value delivered to PT SBI.

In this thesis, the stock and flow variables reviewed were the flow of recycled wastewater generated (RWG), measured in m^3/year, and the potential recycling cost saving (PRCS), measured in Rp/year. During process of converting CLD to SFD, model is simplified for this thesis to help for stakeholder's customer and PT. SBI management to evaluate potential of how much water that could be reduce and potential cost saving that could get by Industrial customer.

Three additional stock variables are developed to build modelling process:

$$[illegible]$$

For developing the model author use 10 years with $t_0 = 2025$ as time frame to 2035.

a. Industry water consumption stock

Industry water consumption stock is balance between inflow freshwater demand for water that consumed and not release as wastewater effluent generated. Stock(t_0) for initial stock is industry production water demand during first year of recycle implementation.

[illegible]

$$[illegible]$$

b. Recycle wastewater stock

Recycle wastewater stock is balance between wastewater effluent generated as inlet for wastewater recycle process with outflow wastewater discharge to environment and recycled wastewater generated

[illegible]

[illegible]

c. Accumulated cost saving

Accumulated cost saving is balance between potential water saving that coming from reduction of freshwater with recycled wastewater (water saving cost) as inflow and wastewater recycle cost as outflow

[illegible]

Using accumulated cost savings could help stakeholder for decision process to invest in wastewater recycle process.

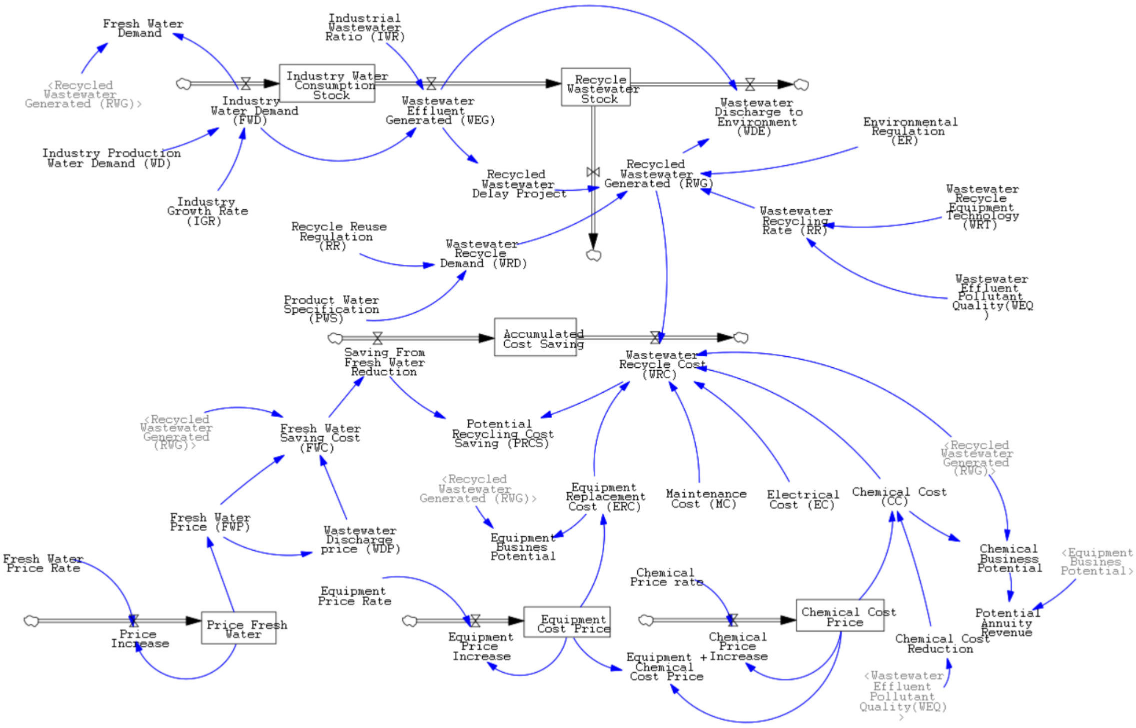

Figure IV.8 Stock and Flow Diagram of Industrial Wastewater Recycle

Figure IV.8 shows the simplified stock and flow diagram from previous causal loop diagram for wastewater recycle process. This stock and flow diagram could us for reviewing business potential of recycle process and for total business potential for recycle water in Indonesia.

IV.1.3.1 Stock and Flow Diagram Mathematical model

Mathematical model and initial value developed in this stock and flow diagram. Auxiliary variables need initial value is provided based on combination of author experience developing wastewater recycle and data from industrial source.

Several variables in this thesis were simplified as ratios. However, in industrial applications, further technical studies are required to determine the appropriate values for these ratios. Initial value and value assumptions in this research provided at table IV.2 below.

Table IV.2 Numerical values for variables at SFD

No	Variable Name	Unit	Initial Value	Note
1	Industrial Wastewater Ratio (IWR)	Dmnl	0.7	Ratio of wastewater that will be produced from freshwater incoming from industrial estate. (Suryacipta Industrial Land, 2024)
2	Industry Production Water Demand (WD)	M3/year	20.692.000.000 (Indonesia) 11,315,000 (SCI) 5,326,000 (GIIC)	Demand of fresh water needed for industry production process (m3/year) using ratio 0.7 and treated wastewater (SISKLHK, 2024), (Suryacipta Industrial Land, 2024), (Deltamas, 2024)
3	Industry Growth Rate (IGR)	Dmnl	4.64%	Industry yearly growth rate that could affect Industry Production Water Demand (%/year) (BPS, 2024)
4	Recycle Reuse Water Regulation (RR)	Dmnl	1	The value will be from 0-1, 1 if recycled wastewater use meet with regulation ratio will be 1, all wastewaters could be recycled
5	Production Water Specification (PWS)	Dmnl	0.5	For industry wastewater recycle could be used for below process - Cooling Tower - Boiler - Domestic Flushing - Production Process For this thesis for assume 25% of wastewater recycle could be reused.

No	Variable Name	Unit	Initial Value	Note
6	Environmental Regulation (ER)	Dmnl	1	The value will be from 0-1, 1 if wastewater discharge to environment use meet with regulation ratio will be 1.
7	Wastewater Effluent Pollutant Quality (WEQ)	Dmnl	0.3	Pollutant quality technical details could be referred to Chemical Oxygen Demand and Total Dissolved Solid. Ratio will be assumed 0.3 from 0.0-0.5
8	Wastewater Recycle equipment Technology (WRT)	Dmnl	0.3	Equipment Technology will affect to how much Recycled could generated. In this thesis Recycle factor will be 60% from ratio 0.0-0.5
9	Fresh Water Price (FWP)	Rp/M3	10.850 (SCI) 13.550 (GIIC)	(Suryacipta Industrial Land, 2024) 0.7 USD/M3 (1 USD = Rp. 15.500)
10	Chemical Cost (CC)	Rp/M3	6.500	Chemical cost operation for wastewater recycle facility (Priadi et al., 2017)
11	Equipment Replacement Cost (ERC)	Rp/M3	4500	Cost for replacement equipment in wastewater recycle facility (Priadi et al., 2017)
12	Electrical Cost (EC)	Rp/M3	1.274	Electrical Cost for wastewater recycles facility (Priadi et al., 2017)
13	Maintenance Cost (MC)	Rp/M3	37	Cost for maintenance for wastewater recycle (Priadi et al., 2017)
14	Wastewater Discharge Price	Rp/M3	7.595	0.7 x FWP (Suryacipta Industrial Land, 2024)

Table IV.3 shows mathematical equation to develop Stock and Flow Diagram for wastewater recycle model and assumption correlation between variables

Table IV.3 Stock and Flow Diagram Mathematical Equation

No	Variable Name	Equation	Unit
1	Industry Water Demand (IWD)	Industry Production Water Demand + STEP (Industry Growth Rate, 2026 … 2035)	m^3/year
2	Industry water Consumption Stock	Fresh Water Demand (FWD) - Wastewater effluent Generated (WEG)	m3

No	Variable Name	Equation	Unit
3	Wastewater effluent Generated (WEG)	Fresh Water Demand (FWD) x Industrial Wastewater Ratio (IWR)	m3/year
4	Recycle wastewater stock	Wastewater effluent Generated (WEG) - Wastewater Generated Discharge to environment (WDE)	m3
5	Recycled Wastewater Generated (RWG)	Wastewater Recycling Rate (RR) x Wastewater Effluent Generated (WEG) x Wastewater Recycle Demand (WRD) x Environmental Regulation (ER)	m^3/year
6	Wastewater Recycle Demand (WRD)	Product Water Specification (PWS) x Recycle Reuse Regulation (RR)"	Dmnl
7	Wastewater Effluent Recycling Rate (RR)	Wastewater Effluent Pollutant Quality(WEQ) + Wastewater Recycle Equipment Technology (WRT)"	Dmnl
8	Wastewater Generated Discharge to environment (WDE)	Wastewater Effluent Generated (WEG) - Recycled Wastewater Generated (RWG)	m3/year
9	Wastewater Recycle Cost (WRC)	Equipment Replacement Cost (ERC) + (Electrical Cost (EC) + Chemical Cost (CC) + Maintenance Cost (MC)) x Recycled Wastewater Generated (RWG)	Rp/year
10	Accumulated Cost saving	Water Saving Cost - Wastewater Recycle Cost (WRC)	m^3/year
11	Fresh Water Saving Cost (FWC)	Recycled Wastewater Generated (RWG) x (Fresh Water Price (FWP) + Wastewater Discharge price (WDP))	Rp/year
12	Potential Recycling Cost saving (PRCS)	Water Saving Cost - Wastewater Recycle Cost (WRC)	Rp/year
13	Fresh Water Demand (FWD)	Industry Water Demand (IWD) - Wastewater effluent Generated (WEG)	m3/year
14	Equipment Business Potential	Equipment Replacement Cost x Recycled Wastewater Generated (RWG)	Rp/year
15	Chemical Business Potential	Chemical Cost x Recycled Wastewater Generated (RWG)	Rp/year

No	Variable Name	Equation	Unit
16	Recycled wastewater delay project	Delay for project execution begin assuming 1.5 year for project execution DELAY FIXED("Wastewater Effluent Generated (WEG)", 1.5 , 0)	dmnl

IV.1.4 Model Verification

Stock and Flow Diagram that developed is verified at vensim using model and unit check to ensure the simulation could be conducted. Figure IV.9 shows the model check.

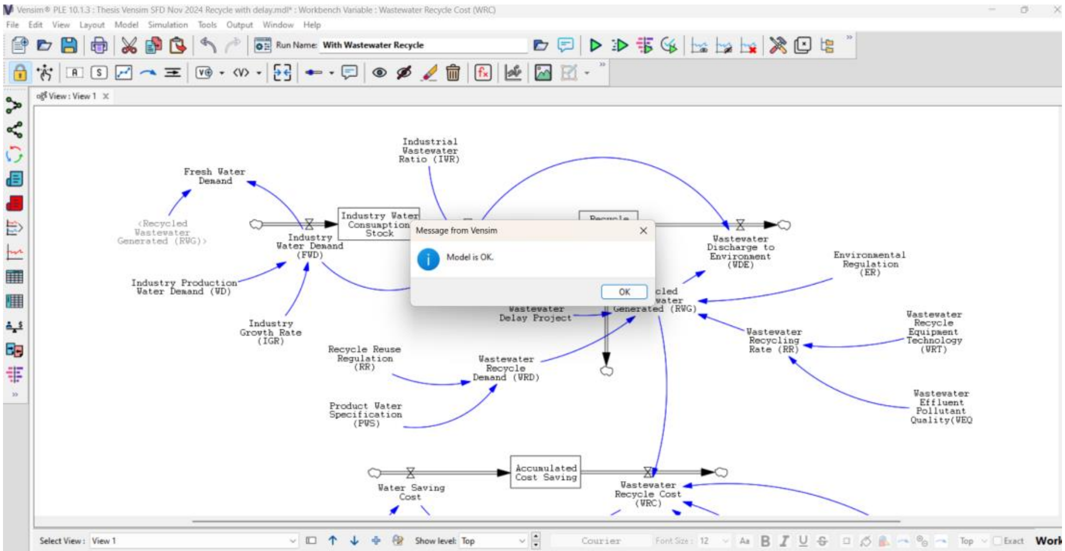

Figure IV.9 SFD Industrial Wastewater Recycle Model Check

Figure IV.10 shows unit check to ensure model were compatible with each other and simulation could be performed.

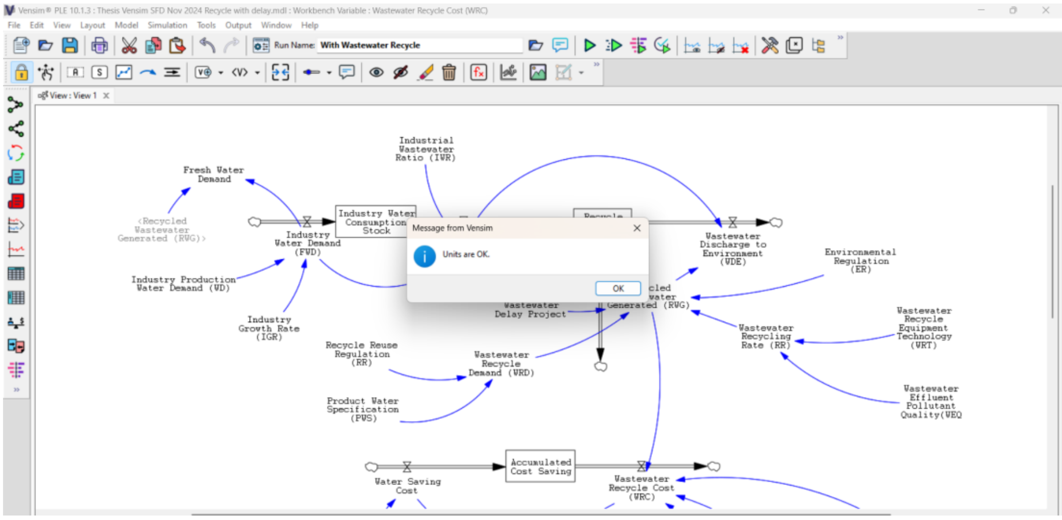

Figure IV.10 SFD Industrial Wastewater Recycle Unit Check

IV.1.5 Model Validation

After SFD model check and verified by vensim, model need to be validated with comparing input and output values with real industry situation to ensure the model could represent dynamic of real world.

IV.1.5.1 Industry water demand and potential cost saving

Based on KLHK 2022 data wastewater debit flow rate per year 14,484,399,523 M^3 and estimated freshwater demand using 0.7 ratio is 20,692,000,000 M3/year-round up. Table IV.4 and Figure IV.11 is water simulation estimated with industrial growth rate 4.6% using vensim

Table IV.4 Vensim generated value (million m3)

Time (Year)	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Fresh Water Demand (FWD)	20,692	21,652	22,612	23,572	24,532	25,493	26,453	27,413	28,373	29,333	30,293
Industry Water Demand (IWD)	20,692	21,652	22,612	23,572	24,532	25,493	26,453	27,413	28,373	29,333	30,293
Wastewater Effluent Generated (WEG)	14,484	15,157	15,829	16,501	17,173	17,845	18,517	19,189	19,861	20,533	21,205
Wastewater Discharge to Environment (WDE)	10,139	10,610	11,080	11,550	12,021	12,491	12,962	13,432	13,903	14,373	14,844

According to Vensim simulations, by 2035, wastewater effluent generated in Indonesia is projected to reach 21 billion m³/year, presenting significant potential for recycling to reduce freshwater consumption. In this thesis, it is assumed that 30% of the wastewater effluent could be recycled as a baseline for industrial use.

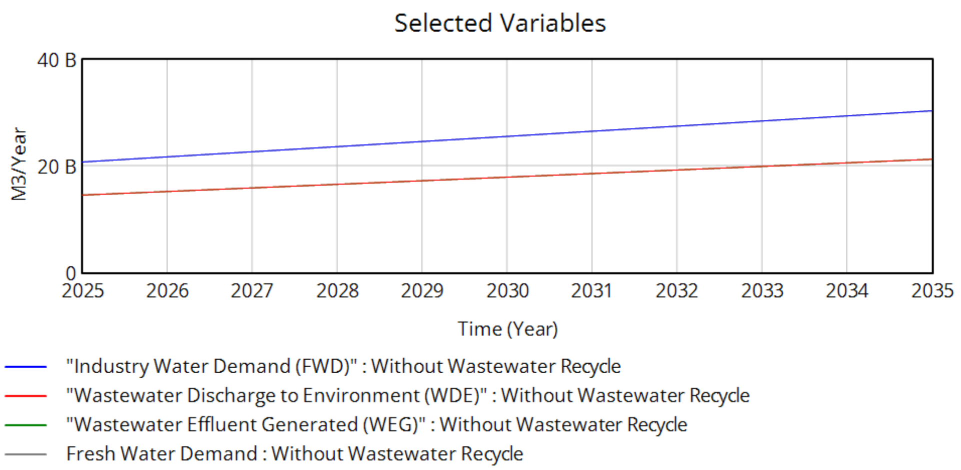

Figure IV.11 Water model simulation without wastewater recycle

Without wastewater recycling, freshwater demand will continue to increase in line with industrial water needs. Additionally, waste discharge into the environment will rise as more wastewater effluent is generated.

Implementation of wastewater recycling illustrated at figures below, with recycling process, fresh water demand and wastewater discharges to environment will decrease. Author add delay variable to represent delay in wastewater recycle application project.

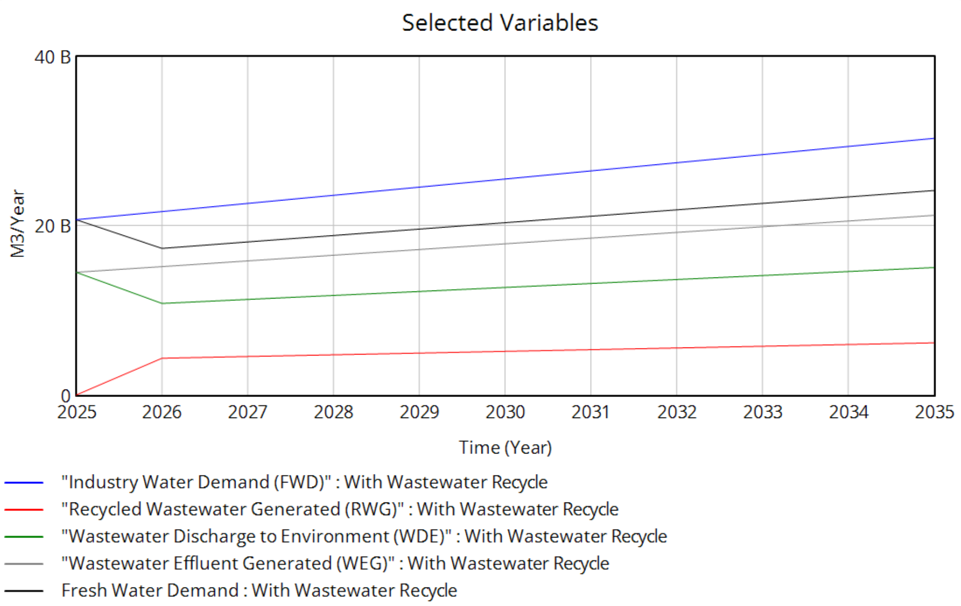

Figure IV.12 Water model simulation with wastewater recycle

Below table is estimated water saving that could conducted yearly basis after application of wastewater recycling project, estimated freshwater demand decrease per yearly basis in 2035 could reach to 6 billion m^3.

Table IV.5 Vensim generated value (million m3)

Time (Year)	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Industry Water Demand (IWD)	20,692	21,652	22,612	23,572	24,532	25,493	26,453	27,413	28,373	29,333	30,293
Fresh Water Demand (FWD)	20,692	17,307	18,065	18,824	19,582	20,341	21,099	21,858	22,616	23,375	24,133
Wastewater Effluent Generated (WEG)	14,484	15,157	15,829	16,501	17,173	17,845	18,517	19,189	19,861	20,533	21,205
Recycled Wastewater Generated (RWG)	-	4,345	4,547	4,749	4,950	5,152	5,353	5,555	5,757	5,958	6,160
Wastewater Discharge to Environment (WDE)	14,484	10,811	11,282	11,752	12,223	12,693	13,163	13,634	14,104	14,575	15,045

IV.1.5.2 Water Saving Potential Cost

Figure IV.12 shows simulation of potential water cost that saved with applying wastewater recycle with cost of fresh water and wastewater recycling referred to table 4.2. If wastewater recycling cost could be managed below water saving cost, potential cost savings will be increased. To close with actual condition due to different price of water in Indonesia, author use Suryacipta Industrial estate (SCI) Karawang and Greenland International Industrial Estate Cikarang (GIIC) water price for cost review and using Suryacipta industrial estate water capacity for this thesis simulation. Time delay of the project is applied with estimated project start is 1.5 year from start of 2025.

Table IV.6 Price Comparison Between Surya Cipta and GIIC

Surya Cipta Industrial Estate Karawang	Greenland Industrial Estate Cikarang
0.7 USD/M3 + (0.7 x Freshwater)/M3	0.85 USD/M3 + (0.8 x Freshwater)/M3
Fresh water price: Rp. 10.850 Wastewater discharge price: Rp. 7.595 Total price: Rp. 18.445/M3	Fresh water price: Rp. 13.550 Wastewater discharge price: Rp. 10.840 Total price: Rp. 24.390/M3

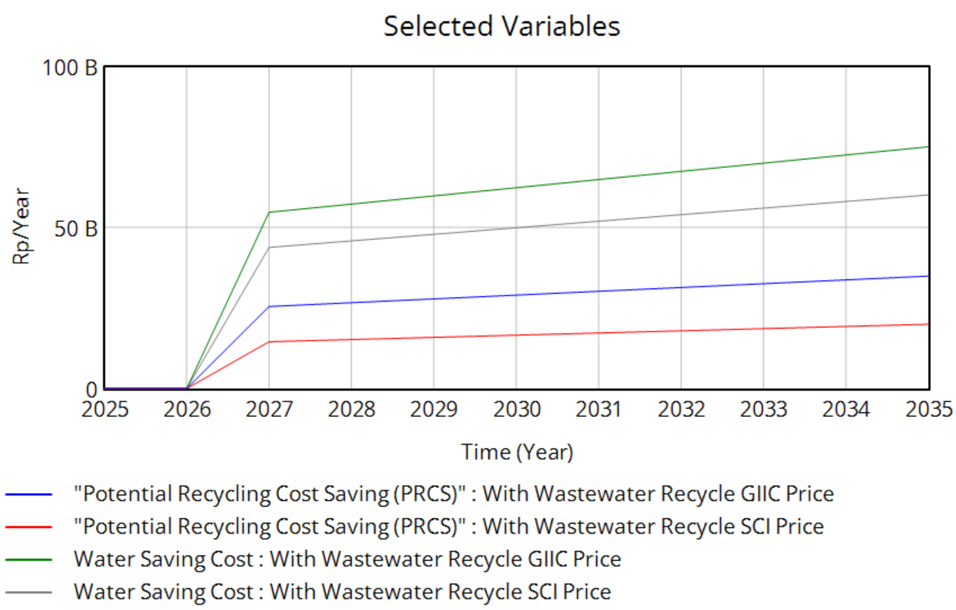

Figure IV.13 Comparison Potential Recycling Cost and Water Saving

With the price of water higher in GIIC potential recycling cost saving is higher than SCI with same wastewater recycling cost. Main contributor to wastewater recycling is chemical and equipment replacement cost. Wastewaters recycling cost variable is at figure IV.14.

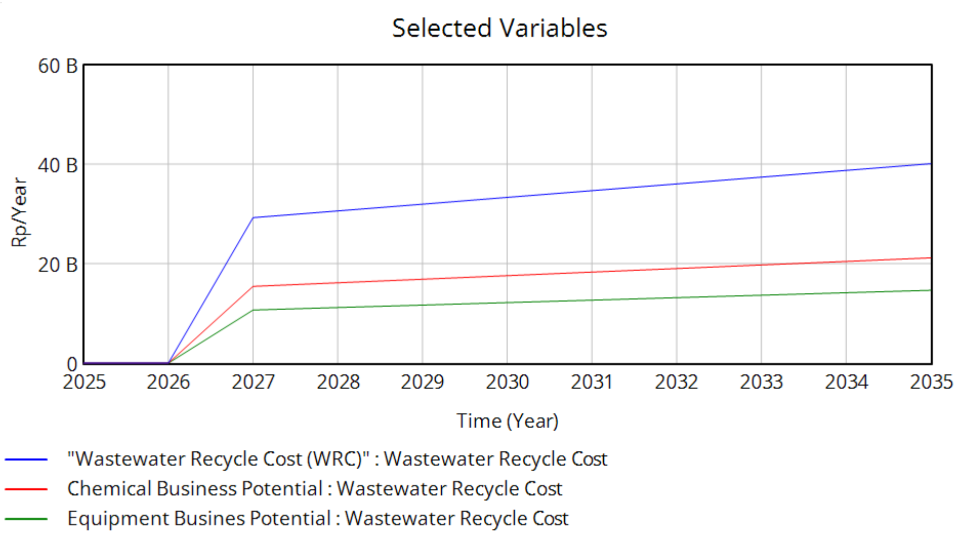

Figure IV.14 Wastewater Recycle Cost and Business Potential

Chemical cost is contributed as highest cost for Wastewater Recycle that align with PT. SBI as water treatment chemical provider. In this case will be use Suryacipta

Industrial area data to evaluate wastewater recycle business potential. In this thesis for simplified for cost in producing wastewater Recycle could become potential revenue generated for PT. SBI.

IV.1.5.3 Accumulated Potential Saving Model for Investment

Accumulated cost savings at vensim could help specific customer to review the investment for wastewater recycling process within 10 years' time frame.

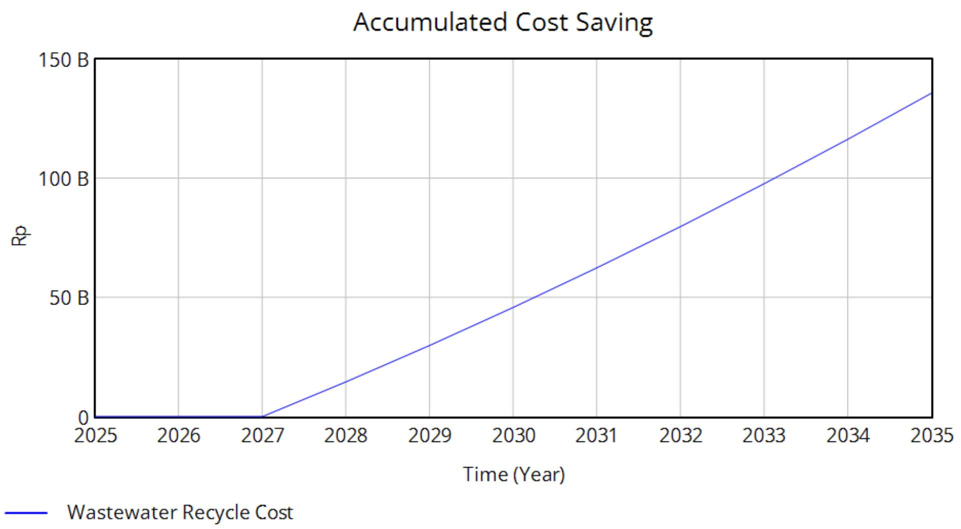

Figure IV.15 Accumulated Cost Saving

Figure IV.15 is example potential of accumulated cost saving that could generated from using wastewater recycle in Indonesia total accumulated cost saving could reach IDR 130 Billion at Suryacipta Industrial Estate. Accumulated cost savings could help for customers to evaluate capital expenditure compared to accumulated potential cost saving.

Figure IV.16 and IV. 17 is simulation for plant with industrial water demand 800 m3/day with assuming no increase in price of fresh water, chemical price, equipment price and fixed water demand in suryacipta industrial estate. Customer could reduce freshwater consumption 21% or recycle generated is 168 m3/day or 7 m3/hr

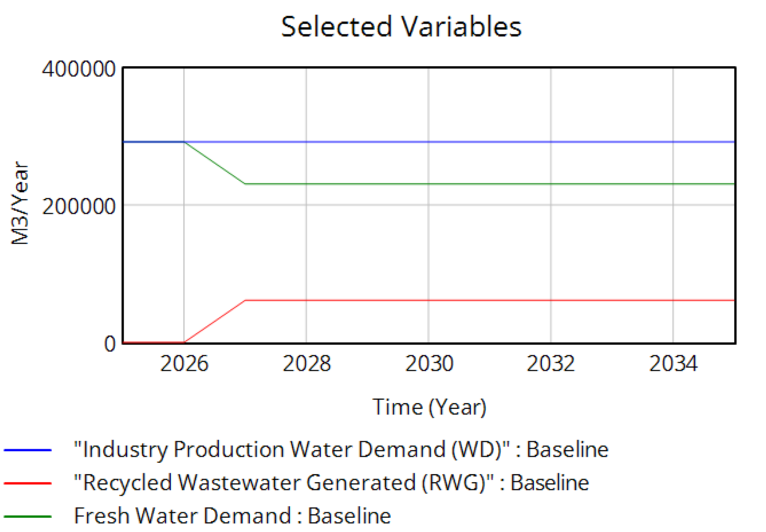

Figure IV.16 Customer simulation RWG

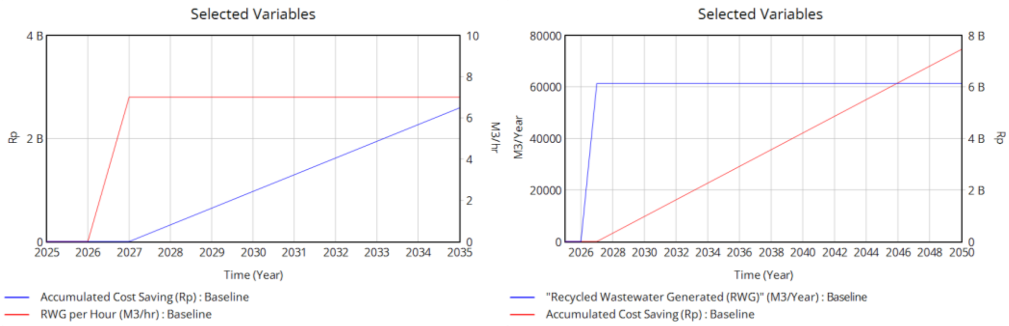

Figure IV.17 Customer simulation accumulated cost savings within 10 vs 25 years

From figure 4.17 with capacity of wastewater recycle generated estimated accumulated cost savings withing 10 years reach to 2.5 billion rupiah, compared to investment from PT. SBI internal data for wastewater recycle capacity 7 m3/hr could reach from 3 to 7 billion rupiah depend on the existing wastewater effluent quality. This simulation shows that with current conditions of freshwater price and wastewater recycle cost wastewater recycling project will give longer return on investment and need company policy and sustainability willingness to investing in wastewater recycling project. To simplifying the thesis, in this thesis will be focusing on variable that affects the annuity revenue or operating expenses with improving variable that affects to the wastewater recycle operating in example reducing wastewater recycling overall cost will give faster turn over for industry that invest to recycling process.

IV.1.6 Variable Testing

Before developing business model that offered for customers, variable that impacted to wastewater recycle business in customers side are modelled to find value that could offered to customers and aspects that needed to be focused by PT SBI.

IV.1.6.1 Fresh Water Price Impact

Price of fresh water is become one of major motive for Industry to conduct recycle water. Due to price of fresh water from different industry in Indonesia have high variation from different source. Vensim simulation could help price of fresh water that will give economic benefits to customers. Figure below is simulated price with additional Stock and variable at SFD. With assumptions wastewater recycle cost is same. Initial price start from Rp. 2000/M3.

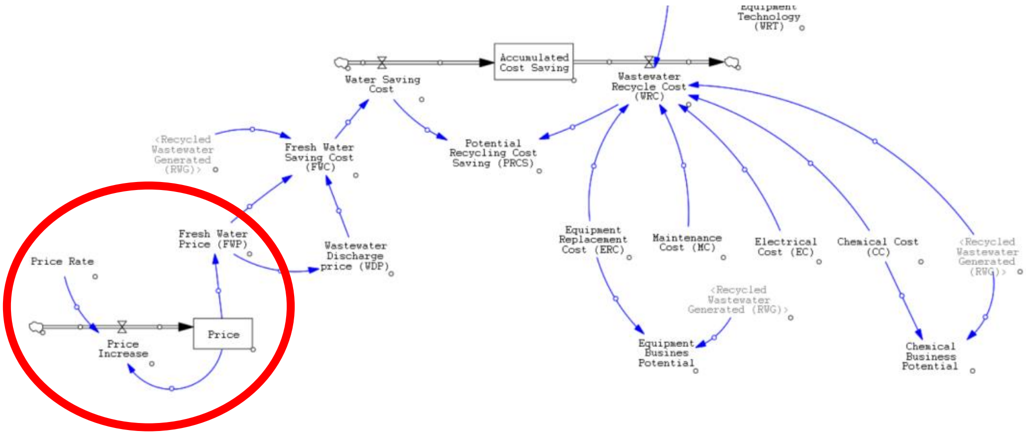

Figure IV.18 SFD with freshwater price simulation

From figure IV.19 we could estimate that economical process for wastewater recycling process, minimum freshwater price is Rp. 10.000/M3 and total Rp. 17.000/M3 with discharge price, if freshwater price below that wastewater recycling process could not give economic benefits for customer but only for sustainable goals to saving freshwater.

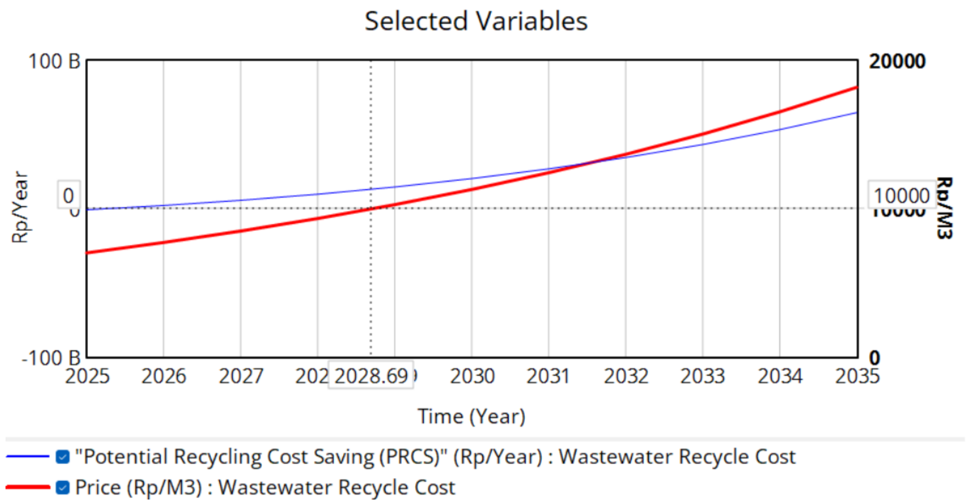

Figure IV.19 Fresh Water Price effect to Potential recycle cost savings

IV.1.6.2 Chemical Cost Impact

Chemical cost as mentioned above is the highest percentage of wastewater recycle cost. Figure below shows impact of chemical price increases to wastewater cost savings, as mentioned in Causal Loop Diagram, chemical cost is impacted by wastewater effluent pollutant quality, more severe the pollutant chemical cost to adjusting the effluent water also will be increase followed by increase in chemical price.

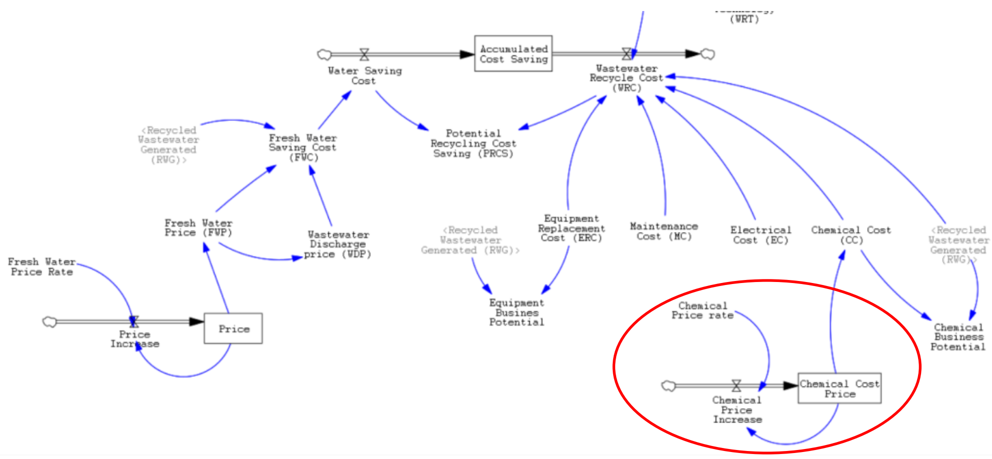

Figure IV.20 SFD with chemical cost price increase simulation

From figure IV.20 vensim model testing shows that chemical cost price increase above Rp. 10.000/M3 will make wastewater recycle not economically beneficial with freshwater price Rp. 10.850/M3

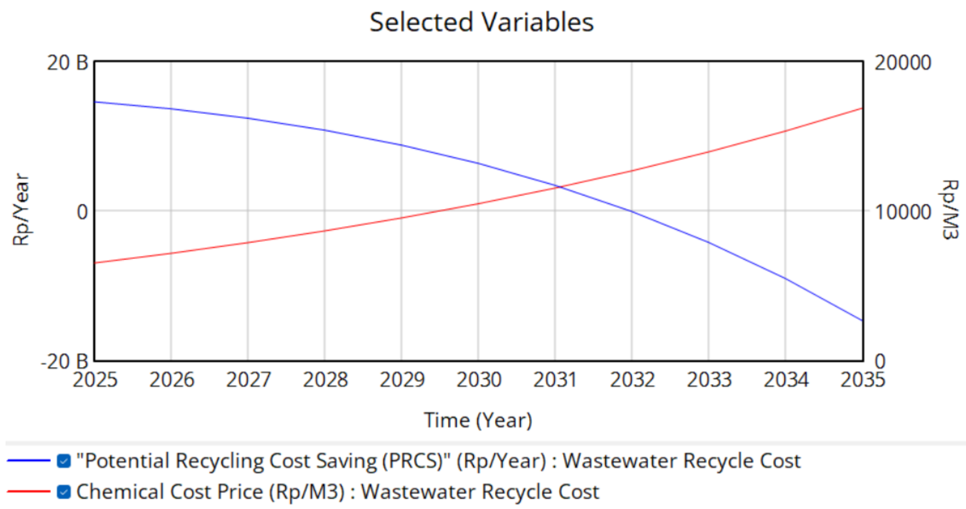

Figure IV.21 Chemical cost price effect to potential recycling cost saving

IV.1.6.3 Equipment Replacement Cost

Wastewaters recycle system equipment as illustrated at figure 4.2, have high consumable cost also for replacement of the equipment. Figure below shows effect of increase in Equipment Replacement cost to wastewater recycle potential cost savings with other parameters fixed.

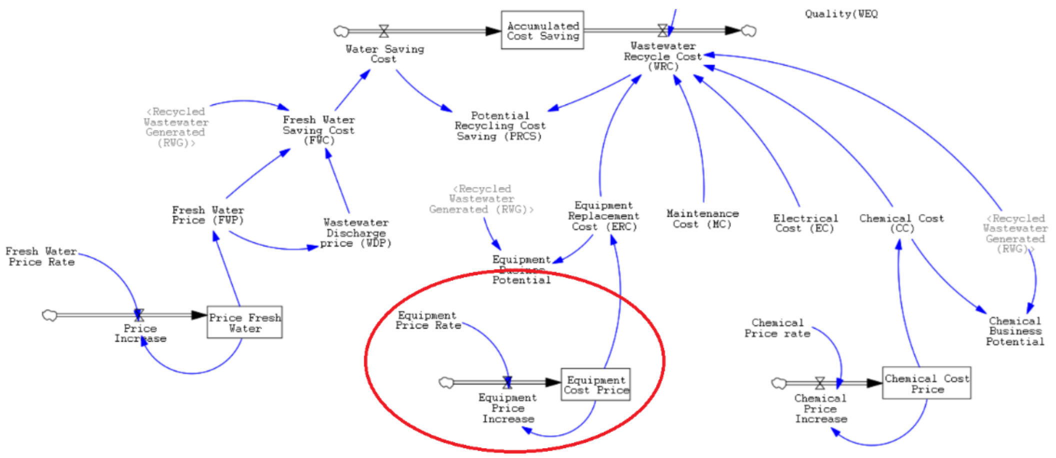

Figure IV.22 SFD with chemical equipment price

From figure IV.22 vensim model testing shows that equipment cost price increase above Rp. 10.600/M3 will make wastewater recycle not economically beneficial with freshwater price Rp. 10.850/M3.

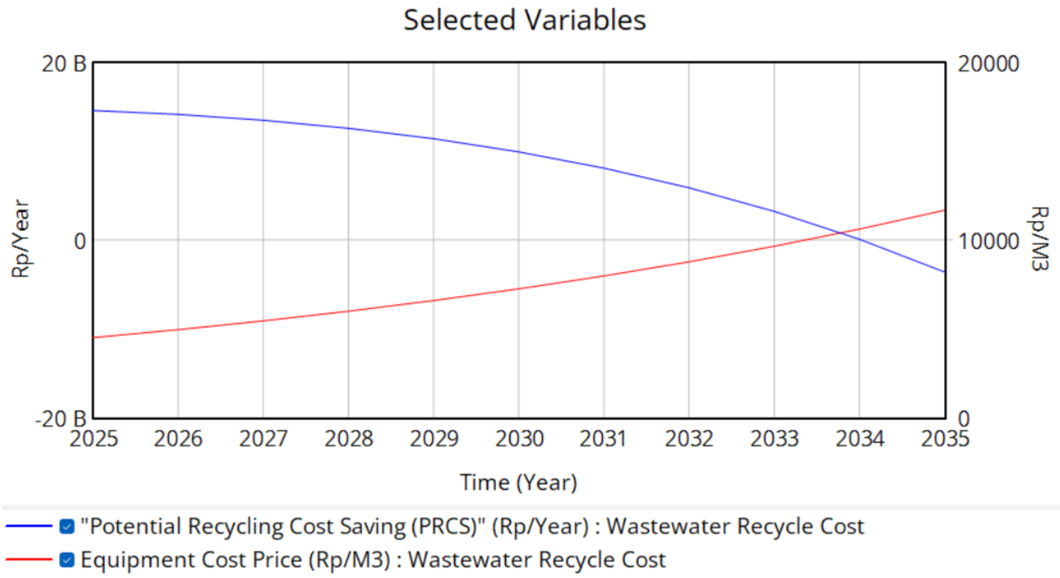

Figure IV.23 SFD with chemical equipment price

IV.1.6.4 Maintenance Cost and Electrical Cost Effect

Maintenance cost is related with manpower and preventive activity that only small portion of wastewater recycle cost component. Electrical cost become component that reach 10% portion (Priadi et al., 2017).

Table IV.7 Wastewater Recycle Cost Component

Wastewater Recycle Cost Component			
Chemical Cost (CC)	Rp/M3	6,500	52.8%
Equipment Replacement Cost (ERC)	Rp/M3	4,500	36.6%
Electrical Cost (EC)	Rp/M3	1,274	10.3%
Maintenance Cost (MC)	Rp/M3	37	0.3%
Total Cost Per M3	Rp/M3	12,311	

Manpower and electrical cost are not main business supply of PT. SBI and can covered by customer, for maintenance cost will not be discovered or varied in this thesis. From above model it shows that increase in wastewater recycle cost component will decrease economic benefit for customer. From PT SBI internal data 2022 cost operation per m3 for wastewater effluent recycle is Rp. 16,208/M3.

IV.1.7 Scenario Development

PT SBI as water treatment company conducted Business to Business (B2B) operation with Customers from different industrial sector with different wastewater characteristic. Within dynamics of variable in customer site, in this thesis scenario developed to optimize value offering for customer within variable that become PT SBI responsibility.

IV.1.7.1 Wastewater Recycle Demand

In SFD wastewater recycle demand simplified by ratio that combining production water specification and recycle reuse regulations. Production water specification is water quality standards that needed to be meet by product water of recycling wastewater. Industrial wastewaters recycle product use mostly for utilities usage. Different industries could give different ratio of recycle demand based on water quality demand. Table 4.5 is the comparison standard for car industry and food and beverages industry.

Table IV.8 Wastewater recycle production water specifications

	Car Industry	F&B Industry
Boiler Water Quality	No need hygiene criteria	Need additional hygiene criteria due to culinary steams
Cooling Tower Quality	Based on Cooling tower material water specification.	Based on Cooling tower material water specification
Production process	Water could be used for cleaning production process for production (car cleaning preparation) as meet with water criteria standard	Water cannot be used for cleaning if not meet with Permenkes (Health Regulation) and need to meet with water production criteria standard

PT. SBI could offer for consultation service for optimization in wastewater recycle utilization for Utility facility Boiler, Cooling Tower and production. In this scenario wastewater recycle demand simulated to increase at 2028 ratio increase to 0.6 and at 2033 ratio increase to 0.7

Table IV.9 Wastewater Recycle Demand Intervention variable

Scenario	Intervention Variable	Baseline (2025)	2028	2033
Increase Wastewater recycle Demand	Production water specification	0.5	0.6	0.7

IV.1.7.2 Wastewater Recycle Equipment Technology

Wastewaters recycle equipment technology in simplified SFD is affecting to wastewater recycling rate, wastewater recycle equipment technology that now available in the market will be affected to Recycling Rate of recycling water, improvement in Recycle equipment technology could be simulated using Vensim as below. Simulation improvements in wastewater Recycle Equipment Technology. Estimated at 2028 and 2033 there's improvements of wastewater recycle equipment technology using STEP function at Vensim.

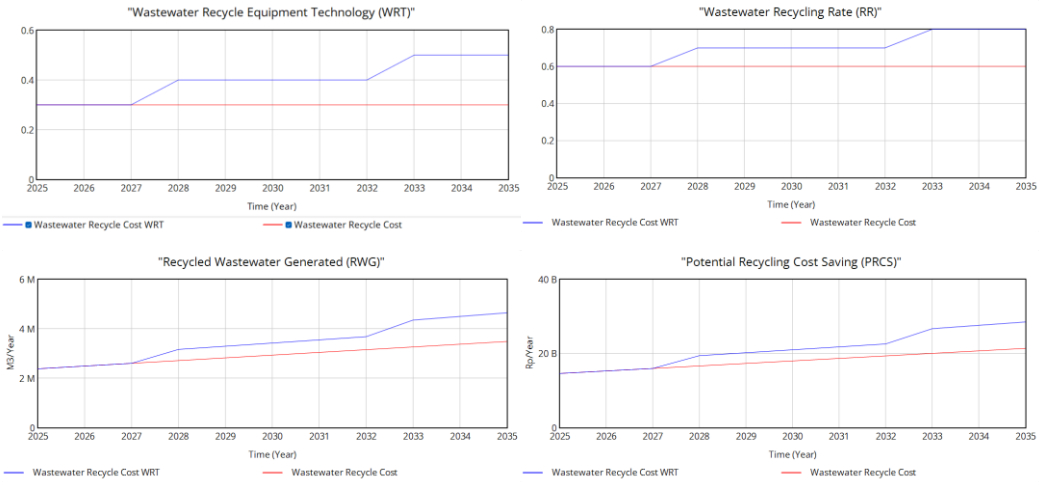

Figure IV.24 Effect of improvement in Recycle Equipment Technology

With technology improvements recycling rate increase and recycled wastewater generated also increase and potential recycling cost saving will be increase also. Wastewaters recycle equipment technology example already illustrates at figure IV.2 and figure IV.3.

PT. SBI as expert in total water management in customer also could evaluate wastewater effluent pollutant quality and improving process before wastewater recycle at production and wastewater treatment plant to improve effluent water quality that could increase wastewater recycling rate. Wastewater recycling rate that currently applied based on author project experience is 50-60% recovery in Indonesia.

Table IV.10 Wastewater Recycle Technology

Scenario	Intervention Variable	Baseline (2025)	2028	2033	2035
Increase Wastewater Recycle Equipment Technology	Wastewater Recycle Equipment Technology	0.3	0.35	0.4	0.45

Wastewaters recycle rate is field that constantly improved within the year. The Changi NEWater project total system recovery rate could increase to 73.5% (Bai et al., 2020). NEWater Singapore have target to increase recovery within research and development to 90% (PUB, 2018).

IV.1.7.3 Wastewaters effluent pollutant quality increase

Wastewater effluent pollutant quality could increase wastewater recycle ration and also have effect to chemical consumptions. With increase quality of effluent quality will decrease of chemical cost consumption.

Table IV.11 Wastewater effluent pollutant quality

Scenario	Intervention Variable	Baseline (2025)	2028	2033
Increase Wastewater Recycle Effluent Pollutant quality	Wastewater Effluent Pollutant quality	0.3	0.35	0.4

With increase 0.05 point of wastewater effluent pollutant. PT. SBI could provide consultancy services to improve wastewater treatment plant performance and increase the quality of wastewater effluent pollutant quality. Chemical cost also assume could be reduced by improving wastewater effluent pollutant quality by 5% per 0.05 point increase

Chemical Cost Reduction as affected by Wastewater effluent quality:	IF THEN ELSE("Wastewater Effluent Pollutant Quality(WEQ)" <= 0.3, 0, IF THEN ELSE("Wastewater Effluent Pollutant Quality(WEQ)" > 0.3 :AND: "Wastewater Effluent Pollutant Quality(WEQ)" <= 0.35, 0.05, IF THEN ELSE("Wastewater Effluent Pollutant Quality(WEQ)" > 0.35 :AND: "Wastewater Effluent Pollutant Quality(WEQ)" <= 0.4, 0.1, 0.15)))

IV.1.7.4 Environmental regulations

Environmental regulations related with limitation of wastewater discharge pollutant to the environment, wastewater recycle process will produce waste that have higher pollutant content due to process of wastewater recycle using reverse osmosis process will produce reject water that higher pollutant content. In this model simulation environmental regulations will set to be tighter and check the effect to wastewater recycle ratio and potential cost saving.

Environment regulation discharge will be related with industrial estate regulation and following government regulation. Tighter Environmental regulations will decrease recycled wastewater generated.

Table IV.12 Environmental regulations

Scenario	Intervention Variable	Baseline (2025)	2030	2035
Tighten of environmental water quality regulations	Environmental Regulation (ER)	1.0	0.9	0.8

IV.1.7.5 Price Scenario

Pricing for equipment and chemical cost will be modelled to evaluate that wastewater recycle project still could give economic benefit value for customers. To simplified simulation price not intervened by yearly price increase rate.

Table IV.13 Price Intervention

Scenario	Intervention Variable	Baseline (2025)	2028	2030	2032	2034
Price increase simulation	Fresh water price %	0	2%	2%	2%	2%
	Chemical cost price %	0	5%	5%	5%	5%
	Equipment cost price %	0	5%	5%	5%	5%

Table IV.14 Scenario Summary

	Scenario	Variable	Baseline (2025)	2028	2030	2032	2033	2034	2035
S1	Increase Wastewater Recycle Demand	Production water specification	0.5	0.6			0.7		
S2	Increase Wastewater Recycle Equipment Technology	Wastewater Recycle Equipment Technology	0.3	0.35			0.4		0.45
S3	Increase Wastewater Recycle Effluent Pollutant quality	Wastewater Effluent Pollutant quality	0.3	0.35			0.4		
S4	Tighten of environmental water quality regulations	Environmental Regulation (ER)	1.0		0.9				0.8
S5	Value Optimization (VO)+ER	S1+S2+S3+S4							
	Price Increase simulation (PI)	Fresh water price %	Fresh water price increases 2% per year						
		Chemical cost price %	Chemical cost price increases 5% per year						
		Equipment cost price %	Equipment cost price increases 5% per year						
S6	VO+ER+PI	S1+S2+S3+S4+S5+S6							
	Price Increase simulation (PI)	Fresh water price %	Fresh water price increases 2% per year						
		Chemical cost price %	Chemical cost price increases 2.5% per year						
		Equipment cost price %	Equipment cost price increases 2.5% per year						
S7	VO+ER+PI	S1+S2+S3+S4+S5+S6							

IV.1.8 Scenario Simulation

Purpose of this simulation is to simulate variable that could intervene by PT SBI as value delivered to customers for water saving as sustainability goals and economic benefits saving for customers. With this simulation PT SBI could evaluate focus in this wastewater recycle business what sector to be focussed on and pricing strategies.

IV.1.8.1 Baseline Simulation

Using baseline data wastewater recycle that applied using baseline data from Suryacipta Industrial Estate. Baseline simulations conducted as below at figure 4.20 for recycled wastewater generated that reduce freshwater demand.

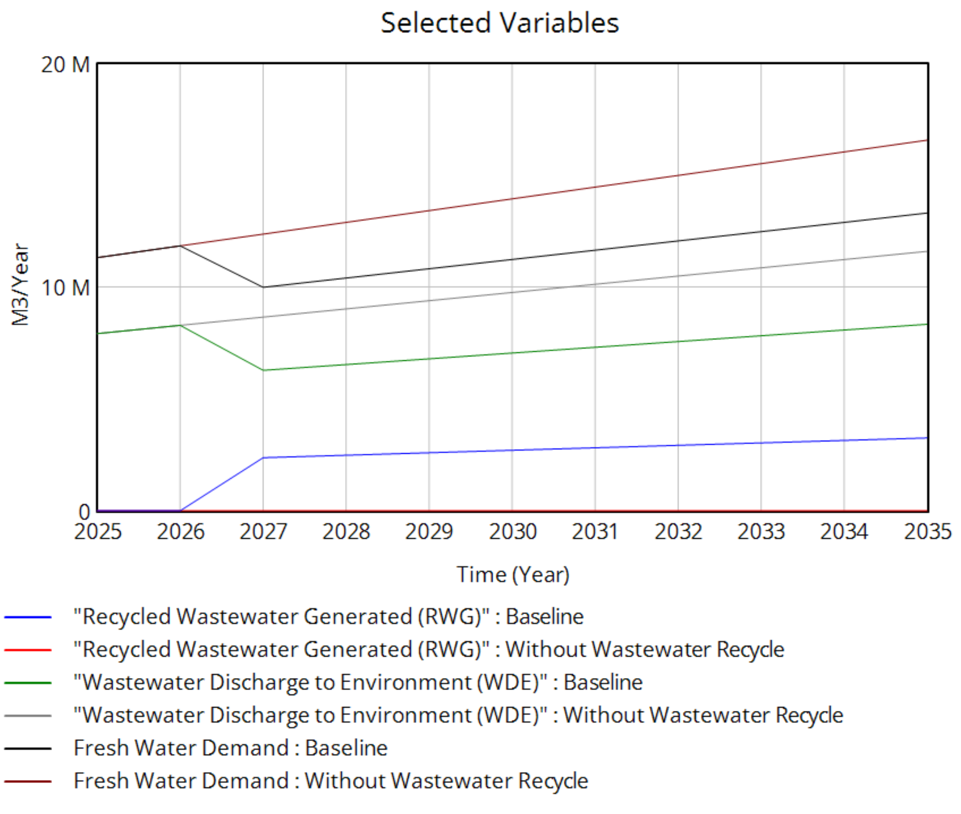

Figure IV.25 Simulation results of wastewater recycle baseline data

With current baseline data potential for water saving or reduction from recycled wastewater generated is reach to 3.26 million m3/year. Potential wastewater recycling water saving in 2027 after project started could reach to 14.5 billion rupiah with potential wastewater recycle cost 40 billion rupiah.

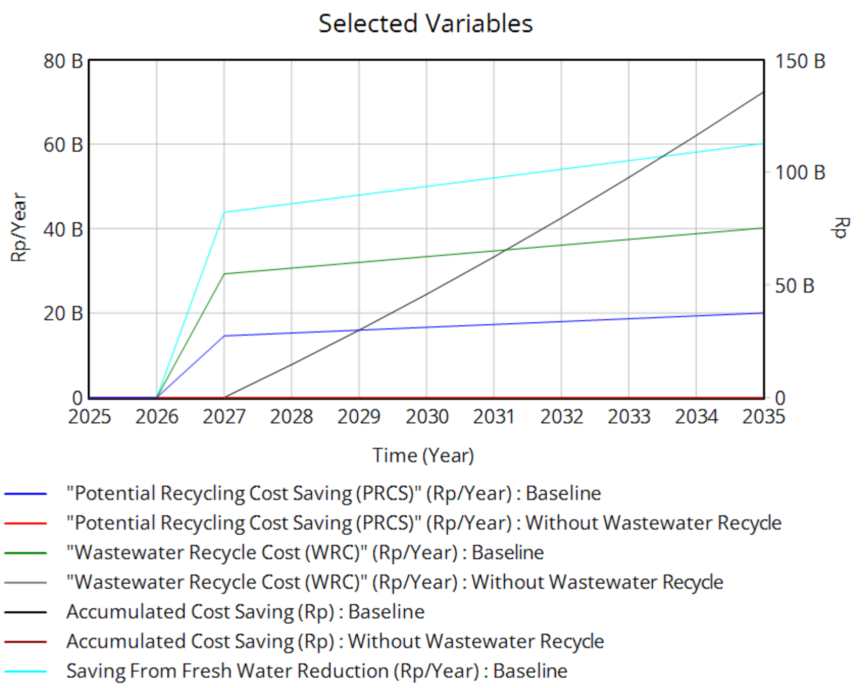

Figure IV.26 Potential economical saving from wastewater recycling process

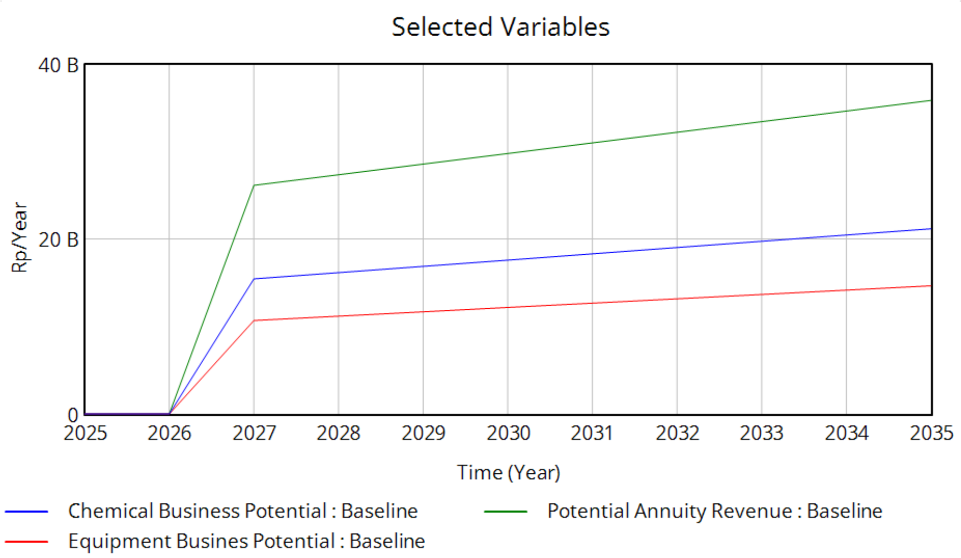

Figure IV.27 Potential water treatment business revenue

Potential annuity revenue from wastewater recycle at Suryacipta Industrial estate from chemical business start at 2027 could reach to 15.45 billion rupiah and from equipment replacement 10.6 billion rupiah. If PT SBI applying contract service with Operation and Maintenance Potential total annuity revenue at 2027 at 26 billion rupiah and estimated at 2035 could reach 35.8 billion

IV.1.8.2 Scenario Variable Simulation

a. Recycled wastewater generated simulation

Table IV.15 Below is comparison from single scenario interventions and multi variable interventions to review what scenario that give higher impact to wastewater recycle business based on table 4.11.

Table IV.15 Recycle Wastewater Generated 1000.000 M3/year

Scenario	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Baseline	0.00	0.00	2.38	2.49	2.60	2.71	2.82	2.93	3.04	3.15	3.26
Scenario-1 PWS	0.00	0.00	2.38	2.98	3.12	3.25	3.38	3.51	4.25	4.41	4.56
Scenario-2 WRT	0.00	0.00	2.38	2.69	2.81	2.93	3.05	3.17	3.54	3.67	4.07
Scenario-3 WEQ	0.00	0.00	2.38	2.69	2.81	2.93	3.05	3.17	3.54	3.67	3.80
Scenario-4 ER	0.00	0.00	2.38	2.49	2.60	2.44	2.54	2.63	2.73	2.83	2.61
Scenario-5 VO	0.00	0.00	2.38	3.48	3.64	3.41	3.55	3.69	5.10	5.29	5.17

From table IV.15 for single scenario intervention the most significant variable is production water specification to increase wastewater recycle demand. Followed by wastewater recycle technology and wastewater effluent quality.

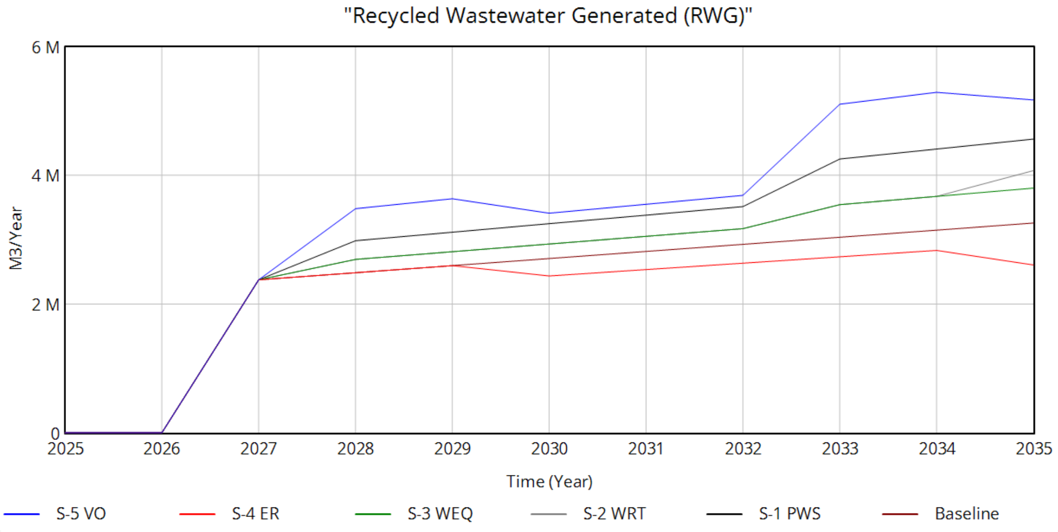

Figure IV.28 Scenario simulation recycled wastewater generated

Scenario-5 value optimization is scenario when PT. SBI could tailored improvements for customer in all variables as simulated using vensim. Using scenario 5 optimized value potential wastewater recycle that could generated could increase 58% from baseline in 2035.

b. Potential recycling cost saving and revenue potential simulation

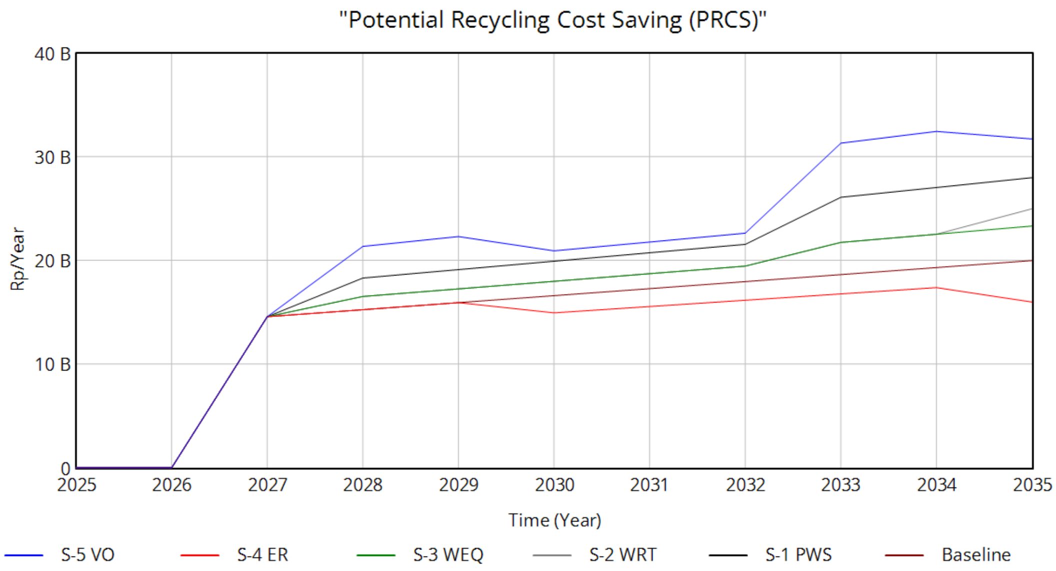

Figure IV.29 Scenario simulation potential recycling cost savings

Following trend of capacity wastewater that recycled with all price or cost remain same potential recycle cost saving also increase. Author simulated potential annuity revenue from wastewater recycling project using 5 scenarios

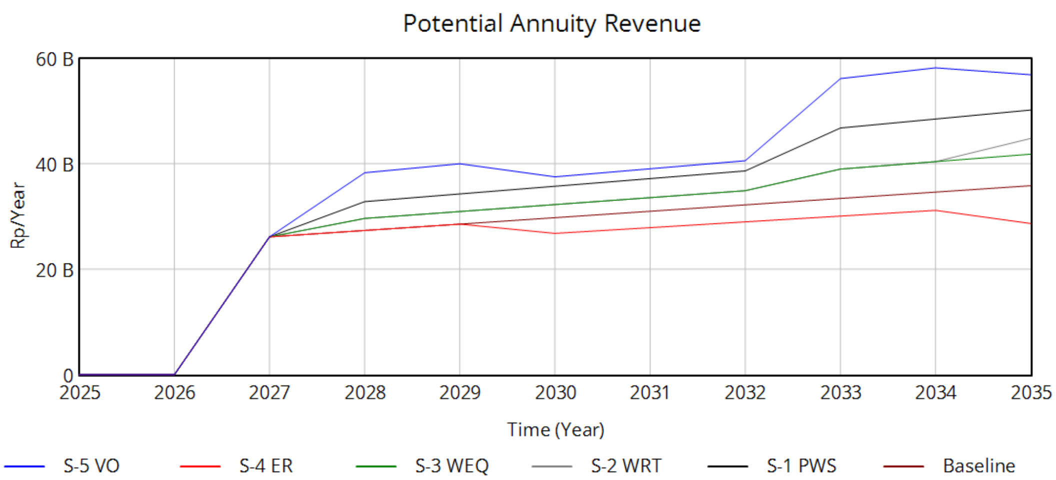

Figure IV.30 Potential annuity revenue from chemical and equipment cost

Potential annuity revenue before margin could reach to 56.7 billion rupiah per year in 2035 with assuming no change in price of fresh water, chemical and equipment replacement cost.

c. Price variable scenario simulation

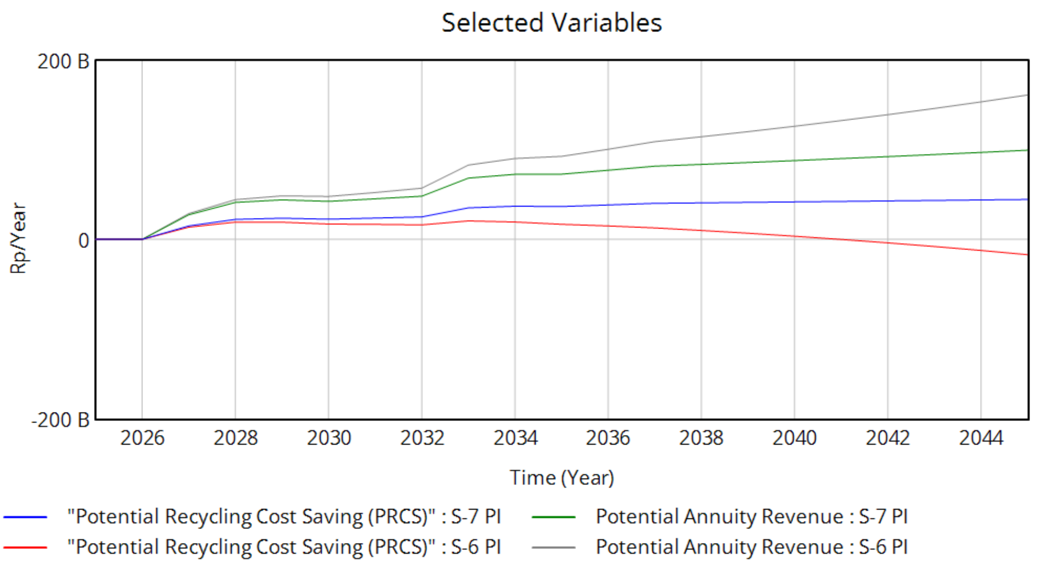

Figure IV.31 Potential annuity revenue from chemical and equipment cost

To sustaining wastewater, recycle business to maintain potential recycling cost saving positive, if wastewater recycle cost increase potential annuity revenue will increase but potential recycling cost saving will become negative and not give economic benefit to customer. Fresh water cost variable correlation with cost saving potential is positive that will increase potential costing saving. From scenario 6 and scenario 7, price of fresh water simulated increase 2% per year this increase of 2% per year based on increase in conversion rate of USD to IDR due to price of water for industrial estate based on USD price. and for scenario 6 both for equipment and chemical cost is increase 5% per year and for scenario 7 increase 2.5% per year.

Scenario 6 shows that PT. SBI need to manage cost of chemicals and cost of equipment replacement, if price of equipment and chemical increase 5% per year before 10 years wastewater recycling economic benefit will negative. Scenario 7 shows that with maintain equipment and chemical price below 2.5% per year economic benefit potential recycling cost saving still positive up to 20 years. The key is to maintain wastewater recycling cost still below cost from fresh water saving.

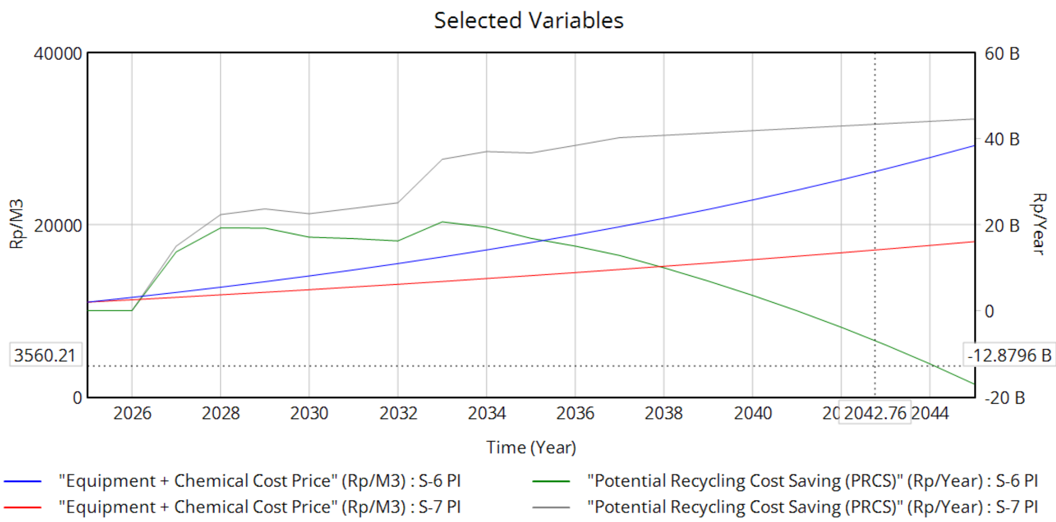

Figure IV.32 Equipment and chemical price simulation scenario

Scenario S-7 shows that potential annuity business for chemical and equipment for wastewater recycle could give potential cost savings reach to 45 B in 2045 from reduction of fresh water and business potential from Equipment and chemical reach to 28 B in 2045 using suryacipta industrial estate at Karawang.

IV.2 Business Solutions

To address the challenges outlined in the business issue of converting wastewater recycling opportunities in the industrial sector into a revenue source for PT. SBI's growth, a business solution was developed using a system dynamics approach. This method facilitates the development of systemic solutions with a holistic perspective. By modeling the complex relationships between internal and external variables identified through literature reviews, analysis of internal documents from past projects, and findings from focus group discussions (FGDs), the approach enables researchers to simulate various scenarios and evaluate the impact of these variables to design business solutions.

IV.2.1 Key Variables and Methode

After conducting research and literature review, key variables were identified as significant for the wastewater recycling business in Indonesia. These variables, outlined in Table IV.16.

Table IV.16 Variables affecting wastewater treatment recycle business

Variable Intervention	Impact on Wastewater Recycle Business
Production water specification (PWS)	Impact on wastewater recycle generated is high due to this parameter impact to wastewater recycle demand that higher the wastewater recycle demand will increase need of recycle process
Wastewater Recycle Equipment Technology (WRT)	Improvement in wastewater recycle technology will increase wastewater recycling ratio that increase wastewater recycle generated and reduce discharge to environment
Wastewater Effluent Pollutant quality (WEQ)	Wastewater effluent pollutant quality will have high impact if effluent pollutant quality cannot meet with specified requirement of Wastewater Recycle Process, improving wastewater effluent pollutant quality could increase recycling ratio and reducing chemical cost consumption to conditioning the incoming pollutant to wastewater recycle process
Environmental Regulation (ER)	Environmental regulation that stricter will limited recycling ratio of wastewater due to current technology that applied will discharge more concentrated pollutant but designed to follow environmental regulation
Fresh water price, chemical cost and equipment cost simulation	Fresh water price highly impacted to economic benefit of wastewater recycle. Chemical cost as highest cost followed by equipment cost need to deep studied before executing the project to ensure sustainability of wastewater recycle project.

The system dynamics modeling approach was selected as the most suitable method for analyzing variables in the wastewater recycling business due to its ability to provide a systemic perspective. This approach allows for the illustration of relationships and feedback loops between variables through the use of causal loop diagrams, effectively capturing the dynamic and interconnected nature of the system. By leveraging system dynamics modeling, researchers can assess the sustainability of the wastewater recycling business and identify strategies to ensure it remains valuable to both customers in the industrial sector and PT. SBI as a water treatment company. This method supports informed decision-making by offering a comprehensive understanding of the system's behavior under different conditions.

IV.2.2 Scenario Evaluation Results

To determine the scenarios PT. Solusi Bersama Indonesia that should be implement for revenue growth in the wastewater recycling business, a system dynamics simulation was conducted using the example of the Suryacipta Industrial Estate with 7 scenario table IV.14. Below are some key business solution from scenario simulation.

1. Baseline simulation at section IV.1.8.1 show that potential fresh water that could be saved reach to 2.38 million m3/year, with potential business revenue from chemical and equipment business could reach to 26 billion rupiah in 2027 and increase as industrial growth. Indicates that wastewater recycle in industry sector have a big potential as revenue source.
2. Baseline simulation for accumulated cost savings simulation from wastewater recycle at section IV.1.5.3 shows that return of investment of customer in wastewater recycle is long time withing 10 to 24 years.
3. To overcome challenge above, scenario simulation is conducted at section IV.1.8.2. PT. SBI need to apply scenario 7, applying optimization of potential value delivered at scenario 1,2,3 while anticipating change in regulation scenario and controlling wastewater recycling cost from chemical and equipment price increase for wastewater recycle business to be sustain and give optimum value for customer and continuous revenue for PT SBI as in Figure IV.31 and Figure IV.32.

IV.2.3 Revenue Simulation

Simulation conducted using Suryacipta industrial estate water and using Greenland industrial estate for potential revenue simulation for wastewater recycle business. Versus revenue gap target for PT. SBI water business unit manufacturing.

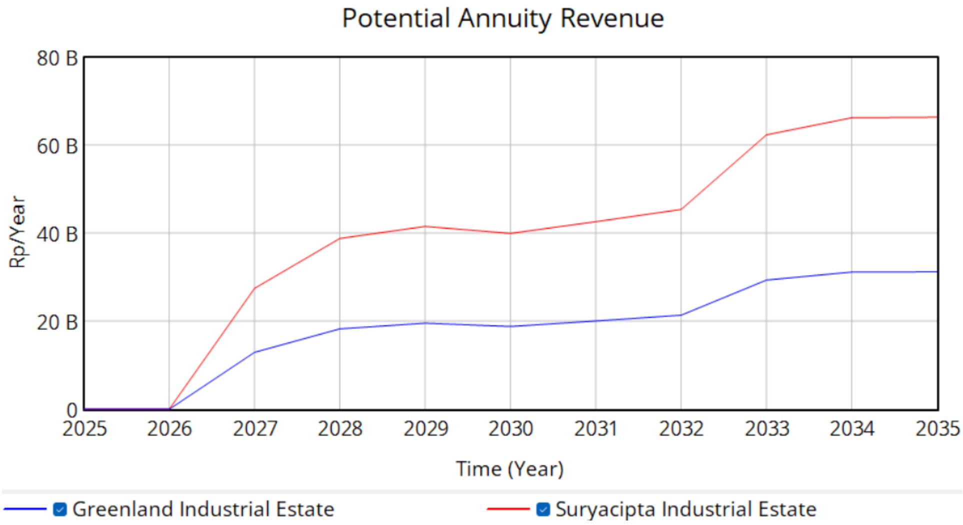

Figure IV.33 Potential annuity revenue simulation

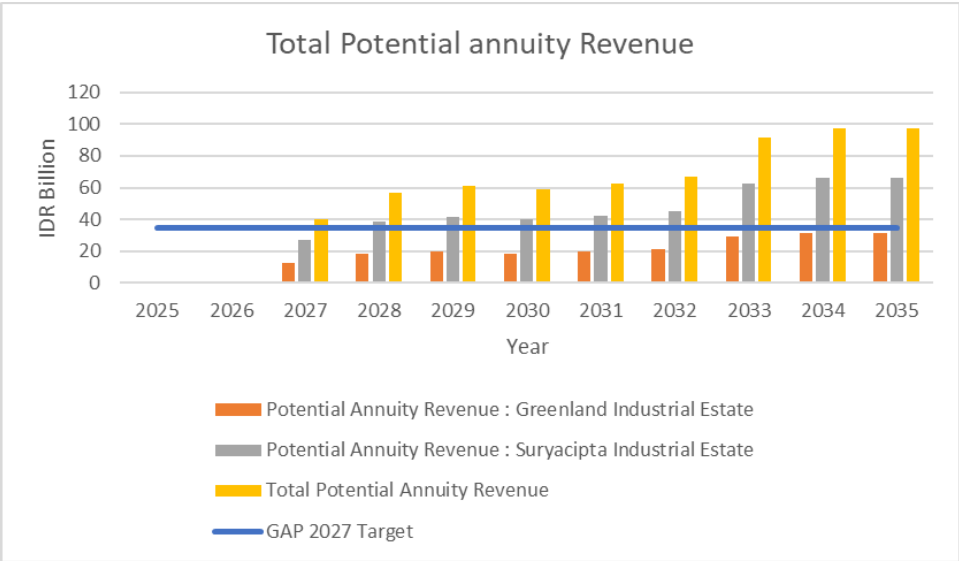

Figure IV.34 Total potential annuity revenue vs GAP

Revenue simulation that conducted using scenario 7 shows that with assumption and limitation as stated for potential business revenue evaluation using data from Greenland Cikarang and Suryacipta Karawang potential revenue at 2027 could reach to 40 billion rupiah that could close GAP of target revenue 34.34 billion rupiah.

IV.3 Implementation Plan

Based on the proposed business solutions, the following activities are recommended for implementation to develop PT. SBI's wastewater recycling business. The table outlines the purpose and sub-plans discussed during focus group discussions (FGDs) with PT. SBI's Greater Jakarta area district members. This proposed plan should also be communicated across other districts and departments within the company. The objective is to achieve measurable impact within two years, contributing to PT. SBI's 2027 Indonesia sales target.

Table IV.17 Timeline implementation

No	**Purpose**	**Plan**	**2025**				**2026**			
			Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
1	Identify and increase wastewater recycle demand.	Identify cluster industry based on production water specification for what industry that have high wastewater recycle demand and environmental regulation								
		Build sales pipeline and quarterly evaluation for wastewater recycle potential customer by PT. SBI sales team								
		Develop industry best practices to optimize utilization of wastewater recycle product for utility application to increase utilization of wastewater recycle.								
		Identify existing PT. SBI customer that have category with high wastewater recycle demand, high freshwater price and review the company sustainability policy in 3R.								
		Discussion with existing PT. SBI customer especially for corporate								

No	Purpose	Plan	2025				2026			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		account to build portfolio in wastewater recycle.								
		Wastewater technical and sales training for internal PT SBI.								
2	Increase capability to optimized wastewater recycling ratio	Partnering with equipment provider for wastewater recycle equipment such as membrane, ultraviolet and other advanced process, to improve wastewater recycle ratio								
		Develop specialty chemicals conditioning to increase wastewater recycle ratio								
		FGD with PT. SBI external teams from SBI Southeast Asia HQ technical team that widely applying recycling process for update in recycle technology								
3	Increase capability to improve wastewater effluent pollutant quality (WEQ)	Develop technical and laboratory capability to assess wastewater treatment performance and improve effluent pollutant quality as input for recycle process								
4	Chemical price control	Securing resources for commodity chemicals that widely used in wastewater recycle								
		Applying PT. SBI specialty chemicals to maintain margin and improve chemical price competitiveness per m3								
		Securing chemical annuity application by long term contract scheme and operation maintenance.								

No	Purpose	Plan	2025				2026			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
5	Equipment Price Control	Securing long term contract with equipment manufacturer for membrane, carbon and UV								
		Partnering with mechanical and installation contractor								

Chapter V Conclusion and Recommendation

V.1 Conclusion

With water scarcity and sustainability concern and rising of freshwater price have open business potential for water treatment company to develop wastewater recycle business and add wastewater recycling as portfolio for increasing revenue and company growth. Due to dynamics of the wastewater recycle especially in Indonesia that every region has different variable that could affect to profitability of this business not only to reach sustainability goals. The system dynamics approach conducted in this study examined variables that influence the wastewater recycle business.

Findings of this study shows that wastewater recycling business in Indonesia have potential as sustainable business revenue for PT. SBI with focusing on below variable:

1. Wastewaters recycling demand, wastewater recycling demand high followed by freshwater price especially in Industrial estate and company regulations for sustainability and willingness to invest in wastewater recycle capital expenditure.
2. Wastewaters recycling ratio, wastewater recycling rate is impacted by effluent pollutant quality, equipment technology and environmental regulations
3. Potential recycling cost, impacted by operational expenditure variable with three main variable that impacted freshwater price, chemical and equipment cost.

Stock and flow diagram and vensim could be implemented in various industrial sector that want to improve water management practices, sustainability goals and managing sustainability project to give profitability for the industry. Cost of recovery as studied by Cagno et al.(2022) still important factor that need policy interventions also from government to increase adoption of water reuse especially for non-industrial area but have water scarcity.

V.2 Recommendation

The recommendations are based on simulation of variables in the system dynamics model, which identified as significant variables for water treatment companies to develop wastewater recycle business and for future researcher and from internal discussions with this model with PT SBI internal teams that what needed to be discovered more.

1. Building partnerships with industry and exploring sustainability issues and wastewater recycling potential within the industry sector so the recycling process could be planned from greenfield project to maximize utilization of wastewater recycle demand.
2. As cost play important factor in wastewater recycling process PT. SBI need to securing long-term partnerships with equipment manufacturers and raw chemicals suppliers to ensure cost of wastewater recycling could be maintained below fresh water saving cost especially if PT SBI applying design build operation and maintenance business model.
3. PT SBI also need to develop expertise in wastewater treatment technologies both for equipment or chemicals that could maximize recycling ratio and prolong equipment lifetime, with reducing replacement time of equipment, cost for equipment replacement will decrease.

For future researcher in wastewater recycling using system dynamics also could develop for non-industrial sector such as in buildings and commercial area. At section 2 author mention WICER (Water in Circular Economy and Resilience) framework provide approach of Circular Water management that consist of City, Industry and Agriculture. System dynamics approach could also develop to combine water, food and energy nexus in Indonesia as study that conducted in Iran by Keyhanpour et al. (2021) especially for area that water is scarce, and wastewater recycle product have potential to be use in agriculture and use as water sources for power plant to produce energy.

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APPENDICES

Appendix A Internal document for wastewater recycle

OPEX BUDGETARY EFFLUENT RECYCLE PROJECT

A. ELECTRICAL LOAD LIST

		ELECTRICAL LOAD LIST					REV. No. : 1	Date : 07/06/22
No	Description	Quantity (unit)			Voltage	Rated Power (kW)	Working Hour (h)	Power Consumption (kWh / day)
		Install	Working	Standby	(V)			
	WTP System							
1	Filter Feed Pump	2	1	1	380	4.00	24	96.00
2	Oxidizer Dosing	1	1	0	380	0.02	24	0.48
3	pH Adjustment Dosing Pump	1	1	0	380	0.02	24	0.48
4	UF Feed Pump	2	1	1	380	4.00	24	96.00
5	Backwash - NaOCl Dosing Pump	1	1	1	380	0.02	24	0.48
6	CEB - NaOH Dosing pump	1	1	0	380	0.02	24	0.48
7	CEB - Acid Dosing Pump	1	1	0	380	0.02	24	0.48
8	CEB - NaOCl Dosing Pump	1	1	0	380	0.20	24	4.80
9	UF Backwash Pump	1	1	0	380	5.50	1.00	5.51
10	Blower for Air mixing	1	1	0	380	11.00	1.00	11.02
11	BWRO Feed Pump	2	1	1	380	3.00	24	72.00
12	Dosing for BWRO	4	4	0	380	0.02	24	1.92
13	BWRO High Pressure Pump	1	1	0	380	11.00	24	264.00
14	UV Lamp	1	1	0	380	1.65	24	39.60
15	CIP Pump	1	1	0	380	5.50	0.02	0.12
16	Utility Outlet (Aux)	1	1	0	220	0.50	10	5.00
TOTAL						46.47		598.38
TOTAL PER MONTH (kWh/month)								17,951.30

B. CHEMICAL AND SPARE CONSUMABLE

B.1 Basic Calculation

1. UF Treatment Plant

UF Capacity	16.0	m3/hr
No. UF	1	
Total Feed UF	16.00	m3/hr
Operation	24	hr/day
	30	days/month
Total UFCapacity flow	384.000	m3/day
	11520.000	m3/Month
UF Recovery	**88.00%**	
Feed Flow	18.18	m3/h
	436	m3/day
	13090.9	m3/month

2. RO RECYCLE TREATMENT

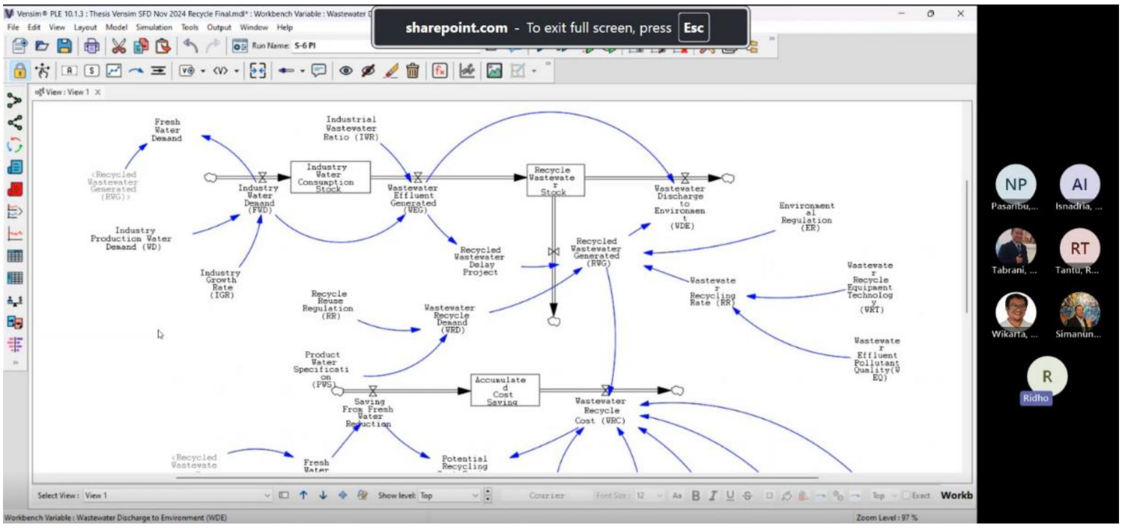
Permeate RO Capacity	8	m3/hr
No of train	1	
Total Peremate flow	8	m3/h
	192	m3/day
	5760	m3/month
BWRO Recovery	**50.00%**	
Feed Flow	16.00	m3/h
	384	m3/day
	11520	m3/month

		SPARE PART				REV. No. : 1	Date : 07/06/22
No	**Product/Chemicals**	**Function**	**Unit**	**Quantity**	**Consumption (Kg/year)**	**Price IDR/Kg**	**Cost/IDR Year**
	Filter Replacement						
1	Sand Filter Media	Filtration	Kg	2400	800.00	6,000	4,800,000
2	Active Carbon Filter Media	Active Carbon	Kg	1000.00	333	120,000	40,000,000
	UF & RO Membrane		**Unit**	**Quantity**	**Qty/Year**		
1	Membrane UF	Ultrafiltration Per 5 Years	Pcs	18	3.6	39,150,000	140,940,000
2	UV Lamp Spare part	UV Lamp Per 1 year	Pcs	2	2	8,500,000	17,000,000
3	Membrane RO Forilife CR100	RO Membrane Per 5 Years	Pcs	12	2.4	17,000,000	40,800,000
	Spare Part for One Year Operations						
1	Spare Part for Pump						20,000,000
2	Dosing Pump Spare Kits						10,000,000
3	Contactor, Push Button, Fuse, Electrical Component, Etc.						5,000,000
4	Pipe Fitting						1,000,000
5	Packing						600,000
6	Hose Compressed Air						1,000,000
7	Hose Chemical						600,000
8	Floating valve						1,600,000
9	Grease						1,000,000
10	Contact Cleaner						600,000
11	Rug						400,000
12	Corrosion Protection						1,000,000
	TOTAL Per Year IDR/Year						**286,340,000.00**
	Total Per Month IDR/Month						**23,861,666.67**

C. OPEX BUDGETARY SUMMARY

			SUMMARY COST			REV. No. : 1	Date : 07/06/22
	System Capacity as Permeate	8	m3/hr	192	m3/day	1 USD to IDR	14500
	Running Day Per Year	345	days	66,240	m3/year		
No	**ITEMS**	**Total Load Per Year**	**Working Cost IDR/Year**	**Working Cost USD/Year**		**Working Cost IDR/M3 Permeate**	**Working Cost USD/M3 Permeate**
1	**ELECTRICAL COST, Estimated KWH per Year, IDR 1100 per KWH**	**218,407**	**Rp 240,248,204**	**$ 16,568.84**		**Rp 3,626.94**	**$ 0.25**
2	**Man Power Cost, Estimated IDR 50.000 per Man Hour**	**2,528**	**Rp 126,400,000**	**$ 8,717.24**		**Rp 1,908.21**	**$ 0.13**
3	**Chemical and Consumable**		**Rp 420,665,148**	**$ 29,011.39**		**Rp 6,350.62**	**$ 0.44**
4	**Spare Part (Include Media and Membrane Replacement Spare part)**		**Rp 286,340,000**	**$ 19,747.59**		**Rp 4,322.77**	**$ 0.30**
	Total per M3 Permeate					**Rp 16,208.53**	**$ 1.12**

Appendix B Focus Group Discussion of System Dynamics Modeling



A. FGD Participants

No	Name (Initial)	Function/Role	Length Of Experience (Years)	Area Responsibility
1	RT	District Manager	23	Banten, West Java, Greater Jakarta and Kalimantan
2	DS	Area Manager	21	Banten, West Java, Greater Jakarta
3	AI	Account Manager	20	Jakarta and Bekasi
4	RW	Account Manager	14	Kab. Bekasi, Karawang, Purwakarta, Subang, Majalengka
5	NEP	District Representative	20	Bogor, Sukabumi, Cianjur, Bandung
6	HT	District Representative	15	Banten and West Jakarta

B. FGD Participant Criteria

No	Criteria	Description
1	Technical Expertise	Ensure participants have technical knowledge in watertreatment with have experience in wastewater treatment (Chemical application and operational)
2	Management Representation	Focus Group Discussion need to have Indonesia Leadership team (District Manager level) to align with PT. SBI goals
3	Geographical Representation	Ensure participants represent PT. SBI water business unit manufacturing division at west java.
4	Customer variety representation	Representatives from variety industries or businesses that could potentially benefit from using recycled wastewater.

C. Question Example used during FGD

No	Question Example
1	Sustainability and water saving. • How customer currently address water sustainability • How customer concern to reduce fresh water • How current regulation affecting customer need for wastewater recycle
2	Wastewater Recycle demand • How customer concern for wastewater recycles, do customer already know for wastewater recycle • What is main concern for customer to applying wastewater recycle project • What is challenge that face in customer site to offer wastewater recycle process.
3	Wastewater Recycle Equipment and Chemical technology • What current technology in wastewater recycle and effect to wastewater recycle cost and recovery • How chemical application could improve wastewater recycle application

FGD Meeting Summary with PT SBI

Meeting transcript notes FGD generated by Microsoft Teams Automated summary:

- **Sustainability and Water Consumption:** FGD Participant and Researcher discussed the importance of sustainability and reducing water consumption. They explored the benefits of implementing sustainable practices and the potential impact on customer savings.
  - **Sustainability:** FGD Participant and Researcher discussed the importance of sustainability in the recycling project. They emphasized the need to adopt environmentally friendly practices to reduce the project's ecological footprint.
  - **Water Consumption:** The reduction of water consumption was a key focus. FGD Participant and Researcher explored strategies to minimize water usage in the recycling process, highlighting the benefits for both the environment and customer savings.
- **Recycling Project:** Researcher and FGD Participant extensively discussed the recycling project, focusing on potential savings for customers, equipment costs, and chemical costs. They explored the feasibility of achieving 100% recycling and the associated cost implications.
  - **Customer Savings:** Researcher and FGD Participant discussed the potential savings for customers through the recycling project. They emphasized the importance of demonstrating tangible benefits to customers to encourage participation and investment in recycling initiatives.
  - **Equipment Costs:** The discussion covered the costs associated with recycling equipment, including initial investment and maintenance expenses. Researcher and FGD Participant explored ways to optimize these costs to make the project financially viable.
  - **Chemical Costs:** Researcher and FGD Participant examined the costs of chemicals required for the recycling process. They discussed strategies to reduce these costs, such as bulk purchasing and negotiating better terms with suppliers.
  - **100% Recycling Feasibility:** Researcher and FGD Participant explored the feasibility of achieving 100% recycling within the project. They discussed the technical and logistical challenges involved and the steps needed to overcome these obstacles to reach full recycling capability.
  - **Cost Implications:** The cost implications of the recycling project were analyzed, including the impact on overall project budget and customer pricing. Researcher and FGD Participant emphasized the need to balance cost savings with the quality and effectiveness of the recycling process.
- **System Dynamics and Predictive Design:** Researcher discussed the completion of the system dynamics and emphasized the need for a predictive design approach. They mentioned the importance of recycling the process model and addressing cost concerns related to equipment and chemicals.
  - **System Dynamics Completion:** Researcher confirmed the completion of the system dynamics, indicating that the foundational work on the system's behavior over time has

been finalized. This sets the stage for further enhancements and predictive design implementations.

  - **Predictive Design Approach:** Researcher emphasized the need for a predictive design approach, which involves using historical data and modeling to forecast future system behavior. This approach aims to improve decision-making and optimize system performance.
  - **Recycling Process Model:** Researcher highlighted the importance of recycling the process model, ensuring that the system can adapt and reuse existing resources efficiently. This involves continuous improvement and iteration of the model to enhance sustainability and reduce waste.
  - **Cost Concerns:** Researcher addressed cost concerns related to equipment and chemicals, emphasizing the need to manage expenses effectively. This includes evaluating the cost-benefit ratio of different components and optimizing resource allocation to minimize costs while maintaining system efficiency.
- **Customer Savings and Equipment Costs:** Researcher and FGD Participant analyzed the potential savings for customers by recycling equipment and chemicals. They discussed the need to set up costs and the importance of accurate data to estimate potential savings.
  - **Potential Savings:** Researcher and FGD Participant analyzed the potential savings for customers by recycling equipment and chemicals. They highlighted the importance of demonstrating these savings to customers to justify the investment in recycling initiatives.
  - **Setup Costs:** The discussion included the need to accurately set up costs for the recycling project. Researcher and FGD Participant emphasized the importance of detailed cost analysis and planning to ensure the project remains within budget and delivers expected savings.
  - **Accurate Data:** Researcher and FGD Participant stressed the importance of accurate data in estimating potential savings. They discussed the need for reliable data collection and analysis to make informed decisions and optimize the recycling process.
- **Technology Improvement and Retention:** Researcher highlighted the need for technology improvement and retention in the recycling process. They emphasized the importance of active customer engagement and potential savings.
  - **Technology Improvement:** Researcher highlighted the need for continuous technology improvement in the recycling process. This includes adopting new technologies and upgrading existing systems to enhance efficiency and effectiveness.
  - **Customer Engagement:** Researcher emphasized the importance of active customer engagement in the recycling process. Engaging customers effectively can lead to better adoption of recycling practices and increased satisfaction with the project outcomes.
- **Payback Period and Cost Analysis:** FGD Participant and Researcher discussed the payback period for customers and the cost analysis of equipment and chemicals. They explored the feasibility of achieving a payback period within two years and the associated cost implications.

  - **Payback Period:** FGD Participant and Researcher discussed the feasibility of achieving a payback period within two years for the recycling project. They analyzed the financial projections and cost savings required to meet this target.
  - **Cost Analysis:** The cost analysis of equipment and chemicals was a key focus. FGD Participant and Researcher examined the initial investment, ongoing maintenance costs, and potential savings to determine the overall financial viability of the project.
  - **Feasibility:** FGD Participant and Researcher explored the feasibility of the proposed payback period and cost analysis. They discussed the assumptions and variables that could impact the project's financial outcomes and the steps needed to mitigate risks.
- **Chemical and Equipment Costs:** Researcher and FGD Participant examined the costs of chemicals and equipment, focusing on potential savings and the impact on customer margins. They discussed the need for accurate data and the importance of setting up costs effectively.
  - **Chemical Costs:** Researcher and FGD Participant examined the costs of chemicals used in the recycling process. They discussed strategies to reduce these costs, such as bulk purchasing and negotiating better terms with suppliers.
  - **Equipment Costs:** The costs associated with recycling equipment were analyzed, including initial investment and maintenance expenses. Researcher and FGD Participant explored ways to optimize these costs to make the project financially viable.
  - **Customer Margins:** Researcher and FGD Participant discussed the impact of chemical and equipment costs on customer margins. They emphasized the need to balance cost savings with the quality and effectiveness of the recycling process to ensure customer satisfaction.
  - **Accurate Data:** The importance of accurate data in estimating chemical and equipment costs was highlighted. Researcher and FGD Participant stressed the need for reliable data collection and analysis to make informed decisions and optimize the recycling process.
- **Project Implementation and Customer Engagement:** Researcher and FGD Participant discussed the implementation of the recycling project and the importance of customer engagement. They emphasized the need for accurate data and effective communication with customers to ensure successful project execution.
  - **Project Implementation:** Researcher and FGD Participant discussed the steps involved in implementing the recycling project. They emphasized the need for careful planning, resource allocation, and monitoring to ensure successful execution.
  - **Customer Engagement:** The importance of customer engagement was highlighted. Researcher and FGD Participant stressed the need for effective communication and collaboration with customers to ensure their participation and satisfaction with the project outcomes.
- **Cost Savings and Profitability:** Researcher and FGD Participant analyzed the potential cost savings and profitability of the recycling project. They discussed the importance of accurate data and effective cost management to achieve the desired outcomes.

- **Cost Savings:** Researcher and FGD Participant analyzed the potential cost savings of the recycling project. They discussed various strategies to reduce expenses and maximize savings for both the project and the customers.
- **Profitability:** The profitability of the recycling project was a key focus. Researcher and FGD Participant examined the financial projections and discussed ways to enhance the project's profitability through effective cost management and optimization.
- **Accurate Data:** The importance of accurate data in achieving cost savings and profitability was emphasized. Researcher and FGD Participant highlighted the need for reliable data collection and analysis to make informed decisions and optimize the recycling process.

- **Chemical and Equipment Pricing:** Researcher and FGD Participant examined the pricing of chemicals and equipment, focusing on potential savings and the impact on customer margins. They discussed the need for accurate data and the importance of setting up costs effectively.
- **Customer Engagement and Project Execution:** Researcher and FGD Participant emphasized the importance of customer engagement and effective project execution. They discussed the need for accurate data and effective communication with customers to ensure successful project outcomes.
- **Recycling and Cost Management:** Researcher and FGD Participant discussed the recycling process and the importance of cost management. They emphasized the need for accurate data and effective cost management to achieve the desired outcomes.