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**FIN4720 Sustainability and Finance**

**Semester 1 AY 2023/2024**

**Final Project**

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| --- | --- |
| Chong Kha Lek | A0223918B |
| Loh Rui Xuan Carine | A0203922N |
| Liu Yunuo | A0220032H |
| Lim Zhi Shin | A0219785M |
| Chan Fung Seng | A0218075E |

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# Executive Summary

In light of Singapore's dedicated commitment to sustainable development and green initiatives, postgraduate students from the College of Design and Engineering have embarked on a ground-breaking project: the redevelopment of the National University of Singapore (NUS) campus. The overarching goal is to re-envision it as a standard-bearer of sustainability, integrating critical systems at both the individual building and broader campus levels. The redesigned systems encompass energy, water, connectivity, public space, and greenery.

Central to this project is the challenge of pinpointing the broader value proposition of such a redesign. It is essential to not only consider the financial costs but also to quantify the combined environmental and social benefits. To achieve this, the theory of change (ToC) model and the social return on investment (SROI) framework have been employed, offering a multi-dimensional view of the potential value of the project, encompassing economic, environmental, and social angles.

Key stakeholders include the entire NUS community—students, management, staff—as well as the wider Singaporean society and regulatory bodies. With projections based on the present day and extending a decade into the future, the financial forecast culminates with an assessment of the project's terminal value.

Our initial analyses indicate a favourable SROI value for the NUS redesign, represented by a value of 2.65. This suggests a substantial positive return on the envisioned changes, implying that for every dollar invested in the project, a social value worth $2.65 is generated. This holistic approach is a departure from traditional capital budgeting models, as it factors in the environmental and social benefits which often go unquantified. We cover a broad range of externalities, varying from traditional ones such as cost savings to less tangible ones such as increased mental and physical health in students and staff.

Additionally, our sensitivity analysis, which identifies potential variables affecting the project's success, has shown a possible fluctuation in SROI values. This analysis resulted in an SROI value of 1.24 in the worst case and 9.37 in the best case. Because of this, we anticipate that the project will have a very large chance of providing a positive net benefit for all its stakeholders despite varying project conditions. We highly recommend undertaking this project.

The proposed redesign of the NUS campus promises not only to elevate the institution's commitment to sustainability but also to set a precedent that could influence higher education institutions on a national and potentially global scale. This project is a testament to the transformative power of integrated, forward-thinking design in the service of a greener, more sustainable future.

# 1. Introduction & Background of Project

Sustainability revolves around the enduring balance between current societal needs and those of future generations, underpinned by infrastructural enhancements and active systems engagement. Embracing this ideology, Singapore has been at the forefront of promoting green initiatives and sustainable development, marking its commitment to global efforts such as the 2015 Paris Agreement. These aspirations are seamlessly aligned with the broader 17 Sustainable Development Goals (SDGs).

The project of redeveloping the NUS campus, serves as a paradigmatic illustration of these aspirations. The project's primary focus is to quantify and elucidate the value created through a combination of financial, environmental, and social costs and benefits inherent to the redevelopment.

## 1.1 Background of Project

The NUS Campus Redevelopment Initiative is the recent undertaking by postgraduate students from the College of Design and Engineering to transform NUS into a model of sustainable design and functionality. The focus is on constructing new sustainable infrastructure to enhance its sustainability, where sustainability means actively involving essential systems at both the building and overall campus levels.

The goal encompasses a wide spectrum of systems, including leveraging renewable energy sources, creating water-efficient landscapes, enhancing connectivity to reduce carbon footprints, and curating public spaces that foster community, collaboration, and innovation.

The imperative to adopt such measures stems from several identified needs:

1. The aspiration to achieve higher energy self-sustainability,
2. The goal to reduce the escalating daily water consumption rates,
3. The pursuit to better connect various parts of the vast campus,
4. The drive to increase lush green zones, and
5. The vision to create more inclusive public spaces for a growing student body.

To meet these challenges, the plan incorporates the setting up of solar energy stations, introducing advanced water conservation systems, optimizing transportation links, expanding verdant areas, and creating more communal spaces for students and staff. The end goal of these enhancements is to make NUS not just environmentally efficient and self-sufficient, but also a more vibrant, inclusive, and holistic place for learning, innovation, and community engagement.

# 2.Theory of change

The National University of Singapore Kent Ridge Campus has 4 key aspirations: Responsible carbon footprint, a climate resilient cool campus, driving positive social norms and responsible procurement practices. Plans to re-design the National University of Singapore Campus to make it more sustainable

It has become increasingly important to clearly define the value proposition for re-development, providing a view of the financial value attached to the environmental and social impact generated as well.

Thus, we first establish the Strategic Plan using Theory of Change to establish the problem and intended impact. Followed by the establishment of the Standards of Performance with the Logic Model in order to pick out weaknesses and barriers to implementation, measure progress and outcome metrics and design an evaluation plan for the impact achieved.

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| **Organisation:** University Campus Infrastructure  **Intervention:** NUS Campus Masterplan: A Carbon Neutral Campus | | | |
| **Key Element** | **Current State** | **Intervention** | **Desired State** |
| **Energy** | The current campus generates 0.6 mil kWh of energy, which is 0.2% energy self-sufficient.    The main source of energy supply is only from existing solar PV, generating 0.6 mil kWh.  Existing district cooling system reduces 70 mil kWh, 25.3% of the energy demand. | Proposed measures to generate energy and reduce energy demand  1. Additional Rooftop solar PV that generates 197 mil kWh, 143% of energy demand  2. façade solar PV that generates 11 mil kWh, 8% of energy demand  3. wind turbine with rooftop PV, that generates 18 mil kWh, 11% of energy demand  4. district cooling system is proposed to reduce energy demand by 26 mil kWh, 7.4% of energy demand | The campus can generate 226 mil kWh of energy, which is 163% energy self-sufficient. |
| **Water** | Current water demand is 1.66 mil meter cubes per year- 40% potable water demand and 60% non-potable water. | Proposed measures to generate water to meet demand:   1. Rainwater harvesting from building roofs to meet potable water demand (0.67 mil meter cubes a year). 2. Rainwater Harvesting from Ground Surfaces (Roads, pavements, landscape etc) to meet Non-Potable Water Demand (0.29 mil meter cubes a year) 3. Grey Water Recycling to use as Non-Potable Water (1.08 million cubes a year) | The target demand is 2.3 mil meter cubes per year. The target on-campus water generation is 2.04 mil meter cubes per year – 89% self-sufficient. |
| **Greenery** | Lack greenery on the campus and limited green coverage.  Lack of water-centric spaces. | By planting 100,000 new trees on the campus through polyculture of trees, Vertical greenery and Urban farming.  Create experiential landscape, recreational natural space and freshwater habitat. | Increase total number of trees on campus by 100,000.  Increase Total Green Space on Campus by 23.4%.  Reduce Campus Daytime urban heat island intensity by 1.6 Degree Celsius. |
| **Mobility** | Currently takes approximately 30mins to travel from Clementi to Faculty of Science   1. Lack of walkable and cyclable spaces, with congested buses the main form of public transport within the campus. 2. Driverless shuttle buses on a university campus reduce emissions and promote efficient transportation 3. Monorails for fast mobility reduce traffic congestion and carbon emissions, supporting urban sustainability | Proposed measures to increase mobility across campus:   1. Create a Canopy Walk Network and reinforced Yellow Cycling Canopy Network for slow mobility 2. Driverless shuttle bus for medium mobility 3. Monorail for fast mobility | Reduce overall time taken to travel across the campus; decrease time taken to travel from Clementi to Faculty of Science by 63%.    Create a car-free and walkable and cyclable area on campus. |
| **Public Space** | Limited open public spaces available for staff and students to interact and be engaged in community events.    Currently, existing public spaces in NUS cover only 2.6 hectares, which is 1.73% of the total campus area.  For scale, Utown Green takes up approximately half that specified space (appendix) | Creation of 7 new public space areas, strategically positioned across the entire campus area from the faculty of arts to the faculty of science.    Merging of public spaces with natural surroundings as well as green transportation through the construction of a new eco-link coverage. | Increase the total amount of public space available to 51.6 hectares, which is approximately a third of the overall campus area. (150 hectares).    These public spaces will be available for students and staff alike to build more networks, take part in recreational activities, and lead a more fulfilling campus lifestyle. |

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| **Evidence to Substantiate the Need for Intervention** | |
| **Increased need to improve energy self-sufficiency** | 1. Singapore's heavy reliance on imported natural gas, which accounts for 95% of its electricity generation, makes it highly vulnerable to price fluctuations in the global energy market. Any fluctuations in the global energy market will potentially lead to higher domestic electricity prices when fuel prices rise (Energy Market Authority, 2022).   Given the ongoing uncertainties and volatilities in global energy markets, due to the surge in global gas prices and the prolonged conflict in Ukraine, Singapore faces a pressing need to enhance its energy self-sufficiency. The Energy Market Authority of Singapore has also been actively encouraging and implementing measures to enhance the nation's energy security. 2. Nonetheless, Singapore's leading universities have shown minimal to negligible progress in reducing the reliance on oil and gas industry (Hicks, 2023). 3. None of the top universities in Singapore have established a timeline for divestment from fossil fuels (Students for a Fossil Free Future, 2022). This absence of a clear roadmap hinders progress toward reducing dependency on fossil fuels. 4. Extensive ties even exist between Singaporean universities and the fossil fuel industry, as these institutions have yet to pledge the cessation of investments in fossil fuel companies (CNA, 2022). For example, NUS has substantial investments, estimated at a minimum of S$59 million as of 2021, indirectly linked to fossil fuels through its endowment fund. By comparison, NUS's investments in fossil fuels are three times greater than those of National Taiwan University, which successfully completed a divestment of NT$432 million (S$21 million) from six companies characterized as having 'high pollution' and 'high carbon emissions' in 2019 (Wu, 2019). NUS’s continued financial reliance on the fossil fuel industry hence contradicts efforts to achieving energy self-sufficiency. 5. With the adoption of solar energy, Singapore could attain a remarkable 22% and 43% solar power contribution to its electricity demand during mid-day by the year 2030 and 2050 respectively (Solar Energy Research Institute of Singapore, 2020). This progress would also lead to annual CO2 emission reductions of 1.6 and 3.4 million tonnes (Mt) in 2030 and 2050, respectively. The projected level of solar power photovoltaic (PV) penetration signifies a substantial increase from our current 5% (Union Power, 2022). 6. Reducing reliance on fossil fuels and embracing renewable energy initiatives would hence empower NUS to enhance its energy self-sufficiency. |
| **Reasons for intervention in water** | 1. Need to be self-sufficient on a national level 2. Singapore has the goal of becoming fully water self-sufficient as early as possible. The deadline for this is the year 2061, when the second contract for water import with Malaysia will expire (Puttkamer, 2023). NUS as a leading university in Singapore need to lead the change and spearhead initiatives to achieve this goal. 3. Increasing water demand 4. NUS graduate student enrolment has increased steadily across the years – from 11,300 in 2020 to 16,200 in 2022. The increase in student population drives demand for both potable and non-potable water. 5. Well positioned for water recycling   a. Annual rainfall in Singapore is 2,400 mm, more than double the global average of 1,050 mm (Puttkamer, 2023). This gives NUS the advantage to utilize rainwater harvesting for self-sustaining its water demand. |
| **Increased need for green spaces** | 1. Societal benefits:    1. The lack of Green spaces in urban cities can lead to a lower life expectancy.    2. An increased amount of time spent surrounded by greenery can benefit mental wellness. (Chowdhury, 2023)    3. Parks and Green spaces also provide an environment for people to partake in physical activity, benefitting their health (Fransen, 2023).    4. Singapore residents have stated that Green spaces have made Singapore a better place to live in, increasing their quality of life (Fransen, 2023). 2. Environmental benefits: (Ng, 2021A)    1. Green spaces in cities mitigate the urban heat island effect, reducing the need for cooling and burning of fossil fuels which contributes to air pollution (Mair, n.d.).    2. This urban heat island effect can also result in hotter pavements that can damage the aquatic ecosystem, as the heat transfers to the rainwater which is then drained out into surrounding water bodies (Mair, n.d.).    3. Green spaces can increase biodiversity, allowing ecosystems to flourish. |
| **Increased need for more walkable and cyclable infrastructures.** | 1. More mobility options and a development plan with the stakeholders in mind is essential to encourage a more active lifestyle among students and staff on campus and ensure their safety (*Building a better environment for cycling and walking* 2016). 2. The promotion of walking and cycling reduces traffic congestion, increases accessibility to those without cars and ensures a high degree of liveability, contributing to a more vibrant campus (Shah, 2014). 3. The campus also has limited space, thus encouraging walking and cycling and reducing our reliance on cars can ensure a more sustainable future (*Walkable bikeable cities – CLC, n.d.*). |
| **Demand for more public spaces** | 1. Public spaces provide an avenue for chance meetings, informal discussions, and networks to form among students and staff.    1. These kinds of interactions are especially valuable when students / staff from diverse academic / cultural backgrounds can interact via shared interests and form networks which enhances the university experience (*The benefits of public spaces in cities,* 2022).    2. Innovation hubs in developed nations such as Silicon Valley and various other science parks leverage public spaces for experts, entrepreneurs and various stakeholders to communicate and build networks which enhance innovation (Wagner, 2023). 2. Public spaces provide residents with a sense of belonging, as well as promote better mental and physical health    1. Increased social interaction in public spaces can help foster connections which increase mental wellbeing among students and staff (*The benefits of public spaces in cities,* 2022.    2. Public spaces allow for recreational activities to take place, which help people from diverse backgrounds interact with one another and form connections (*The benefits of public spaces in cities,* 2022. 3. As the percentage of students living in campus is projected to increase from 30% to 50%, it is paramount that the university has an adequate number of communal spaces to give its students the best possible university experience. |

# 3. Logic Model

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Figure 1: Logic Model

# 4. Impact Valuation

To assess the feasibility and potential of the re-development project at NUS for enhanced sustainability, the team employed the social return on investment (SROI) framework.

Making use of the re-development information offered by the College of Design and Engineering from NUS regarding system deliverables and a range of financial proxies, we measure the economic, environmental, and social benefits and costs of initiating the re-development scheme. We will discuss the assumptions underlying our impact valuation in the following sections.

## General Model Assumptions

In order to forecast the SROI from the green campus project, we built a financial model that incorporated several key assumptions for each key element of the project. We will first discuss the general assumptions of the model – these are assumptions that affect the entire SROI analysis and affect the SROI figure generated from not just one key element but all key elements of the project. Namely, these assumptions are: The model forecasting period, Discount Rate, Inflation Rate, and terminal growth rate.

**Discount Rate:** For SROI analysis, there appears to be no widely agreed upon method for determining the discount rate unlike in typical Discounted Cash Flow Valuations where the discount rate is typically WACC. Many SROI projects use the municipal bond rate or the 30-year treasury rate (Olsen & Lingane, 2003)**.** However, we find that a higher discount rate would be more appropriate to reflect the risk associated with the fact that some of our forecasted social benefits may not accrue as expected. Hence, we use a base discount rate of 7%.

**Inflation Rate:** We assume that the annual inflation rate in the model is a constant, determined by the historical average inflation rate of the past 51 years. Singapore has a good track record of maintaining low and stable inflation rates, hence we find this assumption reasonable.

**Model Forecast Period:** We assume that most of our project elements will continue to exist and accrue social benefits, as well as costs for an indefinite period of time. However, there are a few elements in the SROI analysis that do not follow this assumption – one example is the use of solar panels in our project. Solar panels do not have a plausibly indefinite lifespan, and most usually come with a 25 – 30-year useful life warranty (Glover & Tynan 2023). Hence, we forecast the model for 30 years to allow for the end of the useful life of the solar panels.

**Terminal Growth Rate**: Because we assume that the project will have an indefinite useful life, we will also have to forecast a terminal growth rate. In typical valuation models, the terminal growth rate is somewhere between the historical average inflation rate and the nominal GDP growth rate (Corporate Finance Institute n.d.). Because we do not believe the NUS green campus project is similar in nature to a profit generating project, we find that the terminal growth rate figure should just be the same as the inflation rate constant we use in this analysis.

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| **Model General Assumptions** | |
| Model Forecast Period | 30 years |
| Discount Rate | 7% |
| Inflation Rate | 2.47% |
| Terminal Growth Rate | 2.47% |

## Investment Outlay and Social Cost Assumptions

We now discuss the investment outlay and social cost assumptions in this segment. We provide two tables which break down the investments and costs by project key element –Greenery, Public Space, Water, Energy, and Mobility.

Before we state the key assumptions for calculating investment outlay and costs, we first provide a breakdown of the costs by key element.

*Figure 2: Investment Cost Composition Figure 3: Maintenance Cost Composition per annum*

Our calculations leave us with a base investment cost of 846,406,138.39 SGD. The two largest investment costs by a large margin are Energy and Mobility investment costs respectively. We obtain a base yearly maintenance cost of $94,119,008.54. We observe that the maintenance costs arising from the mobility element far exceed those of any other key element.

### Investment Cost Assumptions

|  |  |  |
| --- | --- | --- |
| **Investment** | **Category** | **Valuation Logic** |
| Investment required for planting additional Trees to reach 100,000 trees | Greenery | Target number of trees to be planted \*  cost per tree |
| Investment required for construction of additional public spaces | Public Space | Cost per m2 of park construction \*  Target increase in public space area |
| Investment Cost of rainwater harvesting tanks | Water | Target Water Supply from rainwater \*  Tank storage to supply ratio (5%) \*  Cost of Tank per m3 of storage needed. |
| Investment cost of water generation set up from rainwater harvesting | Water | Installation Cost per m2 \*  (Target water supply from rainwater harvesting /  Average rainfall estimate in Singapore per year) |
| Investment cost of water generation set up from greywater treatment | Water | Installation Cost per treatment capacity \*  Target water supply from greywater treatment |
| Investment required for construction of Monorail | Mobility | Cost of construction per km of monorail \*  Target length of Monorail |
| Capital Cost of Microgrid required | Energy | Cost per megawatt peak of project \*  Total megawatt peak required for project |
| Cost of retrofitting Green Buildings | Energy | Percentage Increase in number of Green Mark certified buildings on campus by 2030 \* (Office, educational and support facilities GFA on campus \* Cost of retrofitting a Green Mark certified Office, educational and support facility in NUS + Residential GFA on Campus \* Cost of retrofitting a Green Mark certified Residence in NUS) |
| Cost of installing wind turbines and Solar PVs | Energy | Required kilowatt Peak =  Target Electricity Supply /  (Number of Days \*  Number of hours in a day \*  Estimated Capacity Factor)  Required Kilowatt Peak \* Cost per kilowatt Peak |

Table 1: Investment Cost Assumptions across different key elements

### Operating Cost Assumptions

|  |  |  |
| --- | --- | --- |
| **Investment / Cost** | **Category** | **Valuation Logic** |
| Increase in maintenance costs arising from green area increases | Greenery | Greenery Maintenance costs per m2 \*  (Change in green space from vertical green +  Change In green space from rooftop green +  Change in green space from land greenery) |
| Increase in cost of maintenance of Public Spaces | Public Space | Cost per m2 of park maintenance \*  Targeted increase in public space area |
| Maintenance cost for construction of Monorail | Mobility | Maintenance cost per km of monorail path \*  Targeted monorail length |
| Water generation maintenance cost from rainwater harvesting | Water | Electricity Costs of Maintaining Rainwater Catchment =  Target supply of rainwater from Rainwater harvesting \*  kWh needed per m3 of target supply \*  Electricity Tariff per kWh  Other maintenance costs =  Area required for rainwater catchment \*  Maintenance cost per m2 of rainwater  Electricity costs + Other maintenance costs |
| Water generation maintenance cost from greywater treatment | Water | Greywater maintenance cost per m3 of target supply \*  Target supply of water from greywater treatment |
| Cost of operating and maintaining solar and Wind turbine energy | Energy | Target supply of energy \* Maintenance cost per kWh OR  Target kWp required \* Maintenance cost per kWp |
| Operating Cost of Microgrid | Energy | Average Cost of Microgrid maintenance cost per kWh \*  Target Supply of energy from Solar PVs and Wind Turbines |

Table 2:Operating Cost Assumptions across key elements on a per annum basis

## Financial Proxies

Following which, we calculate the social and environmental benefits of the project to gain a comprehensive view of value created by the activities. These benefits can be categorized into 5 categories: Economical, Environmental, Productivity, Mental Wellbeing and Physical Health. These benefits affect our 2 main stakeholders: NUS Student and Staff, University Campus Infrastructure and NUS.

*Figure 4: Benefits per year by Category of Activity (million SGD)*

Due to the comprehensive list of exhaustible Financial Proxies (Appendix A), we will delve into the calculation of key Financial Proxies with a calculated value of over $3 Million accrued per year.

### Cost Savings

|  |  |  |  |
| --- | --- | --- | --- |
| **Outcome** | **Category** | **Valuation Logic** | **Calculation (SGD)** |
| Decrease in electricity bill through in-house rooftop PV | Energy | Electricity supplied by in-house rooftop PV \* SP electricity tariff, GST included | 61,070,000 |
| Decrease in electricity bill through reduced demand due to District cooling system, Retrofitting etc. | Energy | Electricity demand reduction\* SP electricity tariff, GST included | 42,888,405 |
| Decrease in electricity bill through in-house wind turbine | Energy | Electricity supplied by in-house wind turbine\* SP electricity tariff, GST included | 5,580,000 |
| Savings from generation of non-potable water supply | Water | Cost of water \* self-generated non-potable water supply | 4,422,376 |
| Cost avoidance from Reduction in Cars Driven on Campus | Mobility | Number of trips to Campus \* Percentage reduction of cars driven on campus \* Population \* Distance driven | 3,912,431 |
| Decrease in electricity bill through in-house facade PV | Energy | Electricity supplied by in-house facade PV \* SP electricity tariff, GST included | 3,410,000 |

*Table 3: Key Cost avoidance Financial Proxies calculated on a per year basis (SGD)*

From Table 3, we can see that a large proportion of the Cost Avoidance is derived from Solar PV Installation, Wind turbine Installation and Demand reduction from District cooling systems and retrofitting of buildings to attain the Green Mark certification.

#### 4.3.1.1 Energy: Solar PV Installation, Wind Turbine Installation, District cooling systems and Retrofitting of Buildings

The cost avoidance from the energy produced and reduction in energy demanded refers to the energy cost savings from the installation of in-house and façade PVs, Wind turbine Installation and Retrofitting of buildings, this value is taken to be NUS’ cost savings for electricity from Electricity Retailers such as SP Group.

Cost Avoidance due to Energy Produced and Demand reduced = [Energy produced by Rooftop & Façade Solar PV + Energy produced by Wind Turbine + (Current Energy Demand - Target Energy Demand)] \* Energy Tariffs

Thus we derived the cost avoidance by multiplying the amount of Energy produced and demand reduced by SP Group’s Electricity Household Tariffs (including GST) (SP Group, 2023) projected over the years of the Project, also adjusting for inflation over time in our SROI calculation below.

#### 4.3.1.2 Water: Rainwater Harvesting and Greywater recycling

The savings from the generation of Non-potable water supply via Rainwater Harvesting and Grey Water Recycling is derived from multiplying the amount of non-potable water generated from the Water recycling initiatives by the Price of water for households.

Cost Avoidance due to generation of Non-potable and potable water supply = Price of water \* Self-generated supply of Non-potable and Potable water

In Singapore, there is not a view on the difference in price between potable and non-potable water thus if we were to incorporate for the lower price of non-potable water, the cost savings should be reduced. However, we do not believe the difference in price to be substantial as Singapore’s tap water is potable. Thus, we calculate the cost avoidance of Rainwater Harvesting and Greywater Recycling by multiplying the Price of Potable Water in Singapore (PUB, 2023) projected for the relevant Project years by the supply of Self-generated Non-potable and Potable water, also adjusting for inflation in our SROI calculation below.

#### 4.3.1.3 Mobility: Multi-modal Transport (YCCN, Driverless Shuttle and Monorail)

The cost avoidance from the reduction of Cars driven on Campus is estimated to be the reduced accident costs, driving costs, time costs and air pollution costs per kilometer.

Cost avoidance due to reduction in cars driven on Campus = [Number of NUS Staff and Students that live off-campus \* Number of trips made to Campus per year (off-campus) + Number of NUS Staff and Students that live on campus \* Number of trips made to Campus per year (on Campus)] \* Percentage that drive to Campus \* Percentage willing to switch to public transport \* Cost savings from reduction in distance driven in a car \* Total distance covered per round trip

A key assumption made was that the current proportion of NUS Staff and Students that travel to Campus in a car do so in a car with fewer than 3 passengers. The second key assumption would be the off-campus population will travel to and fro the Campus 5 times a week all year round and the on-campus population will do so once a week. We assume that such activities will be made all year round instead of only during the Semester Schooling period due to the myriad of activities the NUS Staff and Student population engages in for recreational and academic purposes.

The average distance driven on Campus is taken to be the distance from Clementi MRT to Science S15 and from PGP to Engineering Faculty, due to the improved monorail designed along the 2 routes to facilitate mobility and encourage public transport. The average distance is calculated to be 8.9km for a round trip.

The percentage reduction in cars driven on campus was taken to be the percentage of NUS Staff and students that drive to Campus multiplied by the percentage of those that are willing to take public transport instead. The proportion of NUS Staff and Students that drive to campus is estimated to be the proportion of Singaporeans that drive to work (Kok, 2021). The proportion willing to switch is an estimated 10%, the proportion that normally drive that take public transport at least once in the past 4 weeks in Singapore (Chua, 2020).

### Increased Income

|  |  |  |  |
| --- | --- | --- | --- |
| **Outcome** | **Category** | **Valuation Logic** | **Calculation (SGD)** |
| Increase in productivity due to more Efficient transport system | Mobility | Population \* % Increase in health \* Productivity in dollar terms \* Travel time saved | 39,550,368 |
| Increase in social participation due to increased connectivity | Mobility | Population \* % increase in Connectivity \* increase in happiness due to social participation \* increase in social participation due to connectivity \* increase in productivity \* GDP per capita | 27,374,817 |
| Increase in physical health due to greenery, vertical green and rooftop green | Greenery | Population \* Health cost reduction due to improved air quality \* Target Co2 sequestration | 13,596,419 |
| Increase in health due to more active lifestyles with more public space | Public Space | Population \* increase in vigorous exercise \* decrease in distance from public space \* health cost avoided from better health from exercising regularly | 12,549,365 |
| Increase in health due to more cycling | Public Space | Population \* % willing to cycle \* %increase in health from cycling distance \* cycling trip distance \* cycling frequency \* health costs | 7,966,928 |
| Increase in social participation due to increased public spaces | Public Space | Population \* % increase in public space \* increase in happiness due to social participation \*for the increase in social participation due to public space \* increase in productivity \* GDP per capita | 7,387,408 |
| Increase in mental health due to greenery, vertical green and rooftop green | Greenery | Population \* Proportion with mental health issues \* Costs of mental health treatment \* % Reduction in costs \* Change in % Greenery | 4,695,839 |

*Table 4: Key Increased Income Financial Proxies calculated on a per year basis (SGD)*

Across the various categories, Mobility category project initiatives bring about the highest increase in income, followed by Public Space and Greenery.

#### 4.3.2.1 Mobility: Multi-modal Transport (YCCN, Driverless Shuttle and Monorail)

**The increase in Productivity due to a more efficient transport system** refers to time saved during travel which could be otherwise spent on more productive activities or for relaxation, leading to an increased ability to focus and be more efficient at work or school.

Increase in Productivity = (Number of NUS Staff and Students off-campus \* Number of trips taken to Campus in a year (off-campus) + Number of NUS Staff and Students on campus \* Number of trips taken to Campus in a year (on campus)) \* Reduction in time taken to travel per round trip on Campus \* Value of Productivity per minute on public transport \* Scaling factor

The Value of productivity per minute spent on Public Transport is taken to be the Value of Time for Seated bus and train passengers in New Zealand (New Zealand Transport Agency, 2002), adjusted for inflation of 72% from the time the study was conducted (Reserve Bank of New Zealand, n.d.). This value of time was the amount passengers were willing to pay for each minute of shorter commute.

The **increase in Social participation due to increased connectivity** refers to the increase in Social support as the increased in connectivity allows more people to navigate to common areas to participate in communal activities, therefore increasing their level of happiness. The value of the increase in happiness to society is estimated to be the increase in productivity.

Increase in Social participation = Number of NUS Staff and Students \* Percentage Increase of social participation due to increased connectivity (via public transport and bicycle) \* Percentage Increase in Happiness due to increased social participation (in common areas) \* Increase in connectivity \* Percentage Increase in productivity due to increased happiness \* Productivity per person

The increase in social participation due to increased connectivity is taken to be 37.8% (Giles-Corti et al., 2005). The percentage of NUS Staff and students that will benefit from increased convenience to Communal areas due to the YCCN bicycle tracks, the Monorail and driverless shuttle, is taken to be the percentage that will travel to nearby Communal areas due to increased accessibility and partake in social activities.

The increase in Happiness due to increased social participation is taken to be 23.1%, the average increase in happiness due to increased recreational activity in common areas (White, 2023).

The increase in connectivity is measured as the percentage decrease in time taken to travel the 2 main routes on Campus. The percentage increase in productivity due to increased happiness is taken to be 12% (White, 2023). The productivity per person is taken to be Singapore’s GDP per capita in 2022 (Singstat, 2023).

#### 4.3.2.2 Public Space: Creation of Common Areas

The **increase in health due to more active lifestyles in the public areas** refers to the increased physical activity engaged in when residents live closer to public areas, therefore increasing their health in the long run. The value of health improvement is estimated using the increase in productivity.

Increase in health = Number of NUS Staff and students \* Increase in exercise conducted per metre distance reduction between the common area and residential estate \* Reduction in distance away from Public Space \* Singapore GDP per capita \* Decrease in mortality rate due to increased exercise

The increase in exercise per metre distance reduction between the common area and residential estate is taken to be the increase in exercise done at least 5 times a week at the nearby common area, 0.00017%/m (Cohen et al., 2007).

The reduction in distance away from public space is taken to be the maximum difference in radius of the Campus compound and the radius of the Public space area before and after the increase in Public space area.

Decrease in mortality rate due to increased exercise is taken to be 26% (Onque, 2022). The increase in productivity due to increased physical activity is taken to be 30.5%, an average increase in productivity given that everyone in the adult population increases their physical activity level regardless of their current level of physical activity (Hafner et al., 2019).

The **increase in health due to cycling** refers to the increase of cycling for travel on Campus with the creation of the YCCN, therefore increasing their health in the long run and reducing the costs paid for potential ailments.

Increase in health = Number of NUS Students and Staff \* Health benefits due to cycling \* Number of trips made to Campus in a year \* Distance of each cycling round trip on campus \* Percentage willing to cycle to school

The health benefits due to cycling are taken to be the saved medical costs and added value at work, taken to be 0.93 SGD/km (Garrett, 2022). The distance of each cycling round trip on campus is taken to be 6.5km, the average distance of the 2 proposed main traffic routes in the project multiplied by 2. The percentage willing to cycle to campus is taken to be the percentage of Singaporeans willing to cycle to work (Chua, 2022). We also assume that no NUS Staff and Students currently cycle to and on Campus.

The **increase in social participation due to increased public spaces** refers to the increase in NUS Staff and Students that will engage in communal activities in public areas, resulting in increased happiness. The value of happiness is estimated to be the increased productivity and GDP per capita generated due to higher levels of relaxation.

Increase in social participation = Number of NUS Students and Staff \* Percentage increase in social participation in common spaces due to increased public spaces \* Percentage Increase in happiness due to more participation in social activities \* Increase in Public Space on Campus \* Percentage Increase in Productivity due to higher level of happiness \* Singapore’s GDP per capita

The Percentage increase in social participation in common spaces due to increased public spaces is taken to be 9.7%, the change in activity levels before there were common areas for activities and after the creation of public spaces for social events (Yilmaz, 2022). The increase in happiness due to more participation in social activities is taken to be 23.1%, (Yilmaz, 2022). The Percentage Increase in Productivity due to higher level of happiness is taken to be 12% (White, 2023).

#### 4.3.2.3 Greenery: Greenery, Vertical Green and Rooftop Green and Planting of 100,000 Trees

The **increase in health due to Greenery** refers to the better air quality resulting from more Greenery, therefore improving the health of residents and NUS Staff and Students that frequent the area. This increase in health is taken to be the reduction in costs paid for potential ailments.

Increase in health = Number of NUS Staff and students \* Participation Rate \* Percentage improvement in PM 2.5 due to CO2 sequestration \* Amount of CO2 sequestrated

The participation rate is a scaling factor as not all NUS Students and Staff will be beneficiaries. The percentage improvement in health due to CO2 sequestration is taken to be the healthcare savings from pm 2.5 reductions, calculated to be 0.01 Trillion SGD per kg of PM 2.5 (Yang et al., 2019).

The **increase in mental health due to Greenery** refers to the improved quality of life and relaxation benefits, therefore improving their mental health. The value of increased mental health is taken to be cost savings on trips to mental Healthcare professionals.

Increase in mental health = Number of NUS Staff and students \* Change in Green Space Area \* Percentage decrease in unhappiness due to increase in Greenery \* Cost savings due to improved mental health yearly

The Percentage decrease in unhappiness due to increase in Greenery is taken to be 0.07% (Maas, 2006). The Cost savings due to improved mental health yearly is taken to be SGD 2834.9, this cost includes visits to mental health professionals and productivity losses (Abdin, 2021).

## SROI analysis

Using our estimates of social benefits, operating costs, and investments required, we reach a base case total SROI of 2.65.

|  |  |
| --- | --- |
| **Total PV of Social Benefit** | $3,513,239,621.79 |
| **Total PV of Social Cost** | $1,273,062,260.87 |
| **Total investment Required** | $846,406,138.39 |
| **SROI (= Net Social Benefit / Total Investment Cost)** | **2.65** |

*Figure 5: Overall benefits, costs and SROI of the project*

**Energy:** Energy produces the most social benefit due to the significant savings in electricity costs. However, the SROI from energy is only 1.22, the 2nd lowest SROI among all the project key elements. This is due to the large construction costs required to meet the project goals ($589,610,771.47).

**Public Spaces and Greenery:** Public Spaces and Greenery are significant contributors to the project SROI of 2.65. Together, they contribute 41% of the project’s net benefit, but both obtain very large SROI of 5.56 and 8.58 respectively. From our analysis, public spaces and greenery contribute greatly to the mental and physical health of the NUS population, and these benefits greatly outweigh the low investment and maintenance costs required.

Figure 6: Net Benefit by Key Element

**Water:** While the SROI of water investments is high at 2.43, the percentage contribution to net benefits from water is still rather low. This is despite our team forecasting a higher average cost of per liter of water due to water scarcity in Singapore as well as announcements from PUB stating that water prices will be subject to increases in the near future. (MSE, 2023)

Mobility: Despite forecasting numerous social benefits obtained from increases in connectivity from the construction of the monorail, we find that it is not high enough to offset the maintenance costs from operating the monorail. In our breakdown of maintenance costs, we observed that the costs attributed to the monorail far exceed any other cost. Despite this fact, the SROI is only at -0.5. Furthermore, the net benefit reduction is less than 10%. It is not an exceedingly large loss that would warrant recommending its exclusion from the project.

Figure 7: SROI by Key Element

# 5. Sensitivity and Scenario Analysis

To ensure the robustness of the SROI analysis, sensitivity analysis and scenario analysis were performed.

## 5.1 Sensitivity Analysis

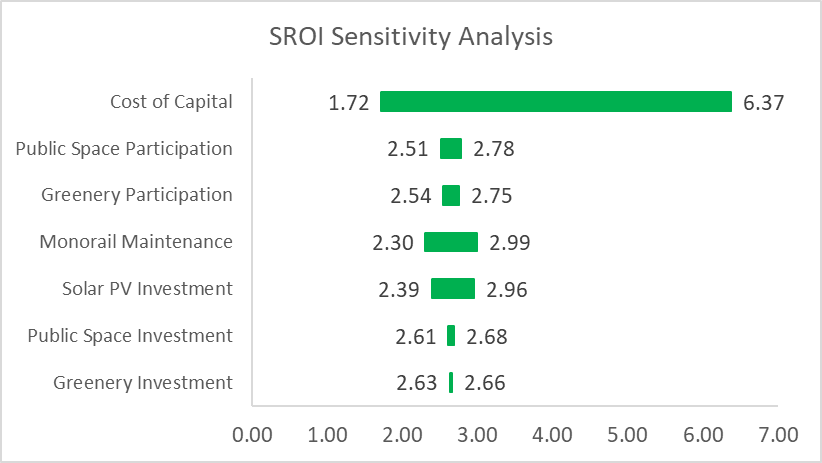
In order to identify the key factors influencing the projected outcomes for the NUS Campus Masterplan, several separate sensitivity analyses were carried out for global project assumptions and category specific assumptions, ceteris paribus. We elaborate on the choice of variables for our analysis below.

**Cost of Capital:** As mentioned earlier, the cost of capital in SROI analysis typically takes on a wide range and could drastically change the results of the SROI analysis (Olsen & Lingane, 2003)**.** Hence, we have decided to vary the cost of capital by 3%.

**Public Space and Greenery Participation:** in our analysis of social benefits accrued from the construction of public spaces and green areas, we estimate that only a certain percentage of the total population of NUS will accrue the benefits. This is because not all students and staff will enter campus five times a week or even frequently. Furthermore, the existence of abundant public space does not necessarily imply that students or staff will fully utilize the areas to participate in social and recreational activities. With these considerations in mind, we decide to vary the participation rate from public spaces and greenery by 20%.

**Solar PV, Public Space, Greenery investments:** The costs of these investments are significant in our analysis – taking up $422,785,388.13, $54,048,920.29, and $24,293,849,86 worth of financial resources in our base case. Furthermore, these costs were estimated using online information which may or may not be reliable. For example, we estimate that the cost of planting a single tree in NUS is $250 – which is a figure benchmarked off what Nparks will charge to assist in planting a tree (Simon 2022). Yet another example of an estimate of our costs is the solar PV capacity factors, which significantly affect the Kilowatt peak estimates used in our calculation.

**Monorail Maintenance:** Our monorail maintenance cost per kilometer is estimated using an overseas study of monorail costs from another country. Different monorail projects have different cost profiles due to varying monorail specifications (Yildizhan & Karacasu, 2022). Hence, we decide to vary the cost of monorail maintenance by 25%



*Figure 8: Football Field Diagram*

Based on the football field diagram, we find that the 3 most critical variables in our analysis are as follows, in order of importance: Cost of Capital, Monorail Maintenance cost, and Solar PV investment cost.

## 5.2 Scenario Analysis

A scenario analysis was also performed using a worst, base, and best case. To formulate our worst and best cases, we simply assumed that all the variables scrutinized in our sensitivity analysis will be at their respective worst and best end ranges respectively.

The interpretation of the worst and best cases is intuitive: In the worst case, our costs are higher than expected and the social benefits that accrue are likewise lower than expected due to a lack of participation from students and staff.

In the best-case scenario, investments are less costly than expected and positive externalities realized are larger due to exceptionally strong engagement and participation from staff and students alike.

Our worst-case scenario gives us an SROI of 1.24 while our best-case scenario gives us an SROI of 9.37. This indicates that even in the worst case, we estimate that the total net social benefits accrued for all stakeholders will still be larger than the initial investments required to make this project work. In the best case, the project will deliver significant outsized social returns to all stakeholders in NUS. This means that despite the risks inherent in this project, it will still develop strong social returns for its stakeholders.

|  |  |  |  |
| --- | --- | --- | --- |
| **Scenario Analysis** | | | |
|  | **Worst Case** | **Base Case** | **Best Case** |
| Total Social Benefit | 2,019,334,729.61 | 3,513,239,621.79 | 10,246,467,609.14 |
| Total Social Cost | 857,843,842.43 | 1,273,062,260.87 | 3,151,541,132.34 |
| Total Investment | 936,330,326.32 | 846,406,138.39 | 757,280,063.65 |
| SROI | 1.24 | 2.65 | 9.37 |

Table 5: Scenario analysis results

# 6. Other Considerations

## 6.1 Campus-Wide Engagement and Customization

The National University of Singapore, being a diverse ecosystem with a myriad of disciplines, facilities, and student cultures, demands a unique approach to sustainability that is sensitive to its specificities. While broad-stroke measures can be applied across the campus, certain faculties or zones might have particular needs and preferences that could diverge from the general model. For instance, certain departments might prioritize energy conservation more than greenery due to their specific research needs or building constraints. Therefore, comprehensive engagement with each faculty, research unit, and even student bodies will ensure that the redesign addresses nuanced needs and ensures widespread buy-in.

Furthermore, these customized solutions might offer innovative models that could be replicated in other universities or large institutions, both locally and globally. Tailored solutions that resonate with the end-users often ensure better maintenance, adherence, and overall success in the long run.

## 6.2 Policy Implications and Stakeholder Engagement

Given the shift towards valuing both tangible and intangible benefits (like social and environmental impact) alongside traditional financial metrics, policymakers have an instrumental role to play in setting the groundwork for such projects. The NUS re-development project, for instance, might challenge traditional funding and valuation models, thus necessitating innovative policy measures.

Additionally, the collaboration between multiple stakeholders - from students and faculty to administrative staff and external partners - is paramount. Engaging these groups from the inception of the project ensures that the re-design aligns with their needs and expectations and can foster a sense of collective ownership and pride in the project's outcomes.

## 6.3 Scaling Effect

There will be significant additional Social and Environmental Benefits from scaling the re-development project given Singapore’s characteristics as a densely populated urban city which is in need of more green spaces and has a focus on self-sufficiency due to their lack of resources. As in Section 4.4, the SROI calculated for the construction of Mobility Initiatives has a negative SROI of 0.51 in our base scenario due to the large initial capital outlay and costs relative to the benefits. With Economies of scale, the beneficiaries of the project will increase and be extended to Singapore residents, reaping greater benefits and gaining a higher SREOI on the Mobility component of the project.

With respect to scaling the Energy component of the project, Singapore as a tropical country on the equator has an even distribution of rainfall throughout the island, receiving high levels of irradiation throughout the year. Thus, the re-development plan can feasibly be scaled to other parts of Singapore.

# 7. Conclusion and Takeaway for the Team

It is beneficial to undertake the NUS campus master plan as the base case SROI is 2.65 - the benefits more than double the costs of the project. A closer look at the key elements reveals that the top 3 contributors to the net social benefits are energy (51%), public space (21%) and greenery (15%). However, the energy element had a low SROI (1.22) on its own due to the high investments needed at the start; greenery and public space had higher SROI and contributed most to the overall SROI of 2.65. even in the worst-case scenario, the SROI is 1.24. 24% return on social investment is sizeable and unambiguously beats the public market. Therefore, we recommend pursuing the NUS campus master plan.

In the process of modelling the future benefits of the projects, there are a few takeaways for the group. Firstly, the financial proxies used were merely estimates based on reasonable assumptions. Therefore, the modelling result can only be used as a reference for decision making. For example, when deciding on the financial proxies for the energy element, there is a lack of data on windmills in Singapore, and data from other countries were used as a proxy for the energy generating capacity of windmills in Singapore. The choice of estimates affects the result.

Another key takeaway for the group is the importance of breaking down the total benefit, total cost and SROI by contributing elements. For example, a breakdown of SROI shows that greenery and public are the major contributors of SROI despite energy element contributing 51% to the total benefits. This provides important insights for the management, and they may be able to better prioritise the projects given constraints like time or budget constraints, to achieve an optimal social return on investment.

Lastly, the group also recognises the importance of sensitivity and scenario analysis when performing financial modelling as they test the robustness of the modelling result and highlight parameters that affect the result most. For example, in this model, sensitivity analysis shows that changes in cost of capital have a large impact on the SROI. This could prompt decision makers to relook at the cost of capital assumptions to make sure they are realistic and reliable.

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