RACE for 2030

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Decision Engine to Support the Path to Net Zero
Draft Report 2024

RACE for Network Program

Decision Engine to Support the Path to Net Zero

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What is RACE for 2030?

Reliable, Affordable Clean Energy for 2030 (RACE for 2030) is an innovative collaborative research centre for energy and carbon transition. The centre was funded with $68.5 million of Commonwealth funds and commitments of $280 million of cash and in-kind contributions from our partners. The aim is to deliver $3.8 billion of cumulative energy productivity benefits and 20 megatons of cumulative carbon emissions savings by 2030.

racefor2030.com.au

Executive Summary

The Australian government released its long-term emissions reduction plans in achieving net zero emissions by 2050. By enabling companies to plan their path to net zero, this project has led first steps in helping them to convert promises into action.

The project surveyed current practice in devising and meeting Greenhouse Gas (GHG) reduction targets. The assessment of current GHG footprint in several companies was elicited and analysed. These targets were broken down into the three scopes (i.e., 1, 2, and 3), social and community impacts of their targets and plans, cost, and organisational commitment. Considering three detailed case studies, Sydney Water, AGL Energy, and the Tassal Group, a set of investment alternatives for reducing their GHG emissions were elicited. In the presence of environmental constraints and costs, possible future scenarios were projected.

Complementing these studies, the project analysed both socio-political and technical constraints and the resulting options for companies planning their steps towards net zero. Besides the properties of current energy sources, we investigated future developments in renewable resource options, costs and availability. From the annual reports of selective organisations, Sydney Water, AGL, Salvation Army and Monash net zero, seven socio-political themes were extracted, whose priorities would influence their path to net zero.

On this basis the project evolved the design for a decision support platform in supporting to capture both current GHG footprint, and the development of a plan of any organisation in formulating a schedule of actions to meet its GHG reduction targets. This fast-track project sets a platform towards the next steps. These steps include to transform the platform from a design and proof of concept (currently capturing energy usage, sources, scopes, assets, and time periods), to a full production version that can accelerate path to net zero for Australia.

Contents

1 Decarbonisation and Net Zero Targets: An Introduction

The increase in Greenhouse Gas (GHG) emissions due to the burning of fossil fuels and deforestation, the climate has been unstable in recent decades. This causes unprecedented threatening lives, livelihoods, and overall ecosystems. Governments around the globe have been proactive in implementing policy measures and climate actions in mitigating GHG emissions. Above all, the Paris agreement necessitates accelerated actions to reach net zero emissions by 2050 to stop global warming. As of November 2023, 145 countries had decided a planned net zero targets, which accounts 90% of global emissions.

The decision support platform assists users in methodically identifying, weighing, and ranking different solutions for reaching net zero emissions, adding substantial value to the decision-making process. The system assists them in identifying data gaps and requirements, fostering cross-departmental synergies, and pursuing appropriate cross-sector collaborations. Importantly, it enables users to comprehend the unnecessary costs of a reactive strategy and the dangers mitigated by a coordinated, systemic approach.

Throughout this report, we interchangeably use decision engine and decision support platform to refer to an easily accessible platform designed to assist industry leaders and decision-makers in addressing climate preparedness and sustainability in terms of objectives, policies, and practices.

The largest five sectoral activities covering net zero emissions pledges of businesses include heating and cooling, cement, road vehicles, and power sectors as illustrated in Figure 1-1. Net zero targets of businesses accounts 72% of global heating and cooling, 68% of global cement, 66% of global road vehicles, and 63% of global power.

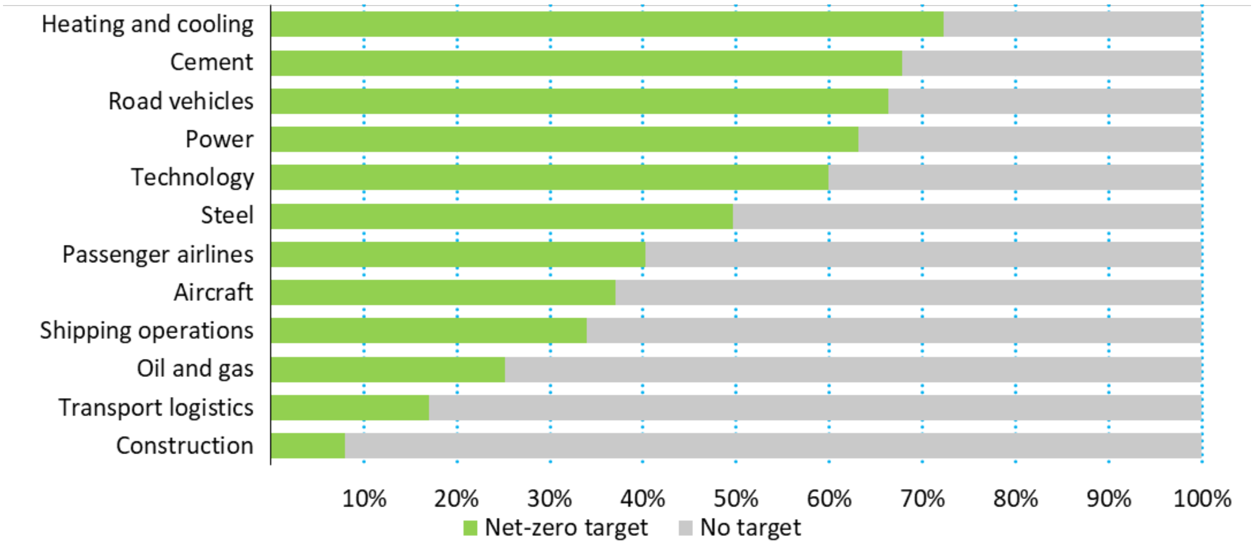

Figure 1-1: Sectoral net-zero emissions targets (modified from IEA report- *Net Zero by 2050—A Roadmap for the Global Energy Sector* 2021)).

1.1 Data-driven targets

The ambition for reducing CO_2-e emissions should reflect high-quality data while setting realistic and practical steps towards pre-set goals. Given carbon jargon, net zero may be totally different with carbon neutrals, positives, and negatives. In addition, Science Based Target Initiatives (SBTIs) are widely used globally to include initiatives followed by companies around the world. Although fairly different, SBTIs and net zero are compatible with each other. Various pledge platforms help participating companies achieve the goals of being carbon neutral, positive or negative, by evaluating their performance as follows:

1.1.1 Race to zero

- Supporting business, investors, and regions by a United Nation (UN) global campaign.
- Currently, Race to Zero include about 1,041 companies, 151 countries, 264 cities and 23 regions are involved[1].
- The general requirements that the industry should satisfy are set out by Race to Zero through accumulating the pledges across the climate action communities.
- All the entities participating in Race to Zero are committed to provide net zero no later than 2050.
- Participants commit themselves to report their progress on a yearly basis.

1.1.2 Building level Advancing Net Zero (ANZ) targets

- As defined by the World Green Building Council (GBC), carbon neutral buildings refer to any structures with efficient energy consumption while being powered by renewable energy generation.
- According to World GBC, business, and organisations as well as cities and states should try to reduce the emissions of the buildings under their control to zero by 2030 and have all buildings net zero carbon by 2050. To date, 75 countries are involved in this program.
- To provide a net zero carbon building, several measures mostly categorised under energy efficiency improvement (e.g., behavioural changes), green power purchasing and equipment retrofitting can be taken. Where necessary, carbon offset can also be a solution. To evaluate the performance of buildings towards above mentioned targets, existing rating tools, for example National Australian Built Environment Rating System (NABERS) in Australia are utilised.

1.1.3 The intersection of the Science-Based Targets initiative (SBTi) and net zero targets

- The designed targets are aimed at limiting carbon emissions so that the global warming increases less than 1.5°C. The targets are realistic as they are consistent with Paris Climate Agreement. Also, the targets do not allow offset in calculations, however, they are required to consider Scope 3 in case emissions is greater than 40 percent of Scope 1 and Scope 2 emissions profile.
- Net zero is more appropriate to individual organisations, while providing them with a flexible framework to set their favourable deadline for reaching their goals and

[1] https://zerotracker.net/.

scheduling their actions. On the other hand, it is crucially important for such organisations to stay informed about any possible changes and variations regarding their pledges.

- The SBTi is an entity whose mission is to set and officially approve the science-based goals. Over 1200 international companies such as Amazon, Facebook and Ford have joined SBTi so far. SBTi provides businesses with independent target validation as well as with technical support and annual progress reports. As stated, according to SBTi, if the Scope 3 emissions are more than 40 percent of the total carbon footprint, the company should set ambitious targets to decrease them. This confluence of net zero and SBTi is a noteworthy development that represents a broader pattern of ESG Framework convergence.

One of the goals of the net zero program is to move towards the United Nations Sustainable Development Goals (SDGs). So far, many agreements have been made on the importance of reducing CO_2-e or decarbonisation, but due to the lack of clear details, it has not been possible to use them effectively. In this regard, the use of standards and guidelines such as the SBTi and the Climate Active initiative helps to advance the goals (Roche et al., 2022; VDZ, 2021). The Climate Active Carbon Neutral Standard for Buildings considers operational carbon profile of the buildings. While overlooking carbon emissions from construction processes and materials. Climate active also provides certifications for buildings, events, organization, products, and services. Certificates for buildings are available through the Green Building Council of Australia (GBCA), the Green Star Rating or the National Australian Built Environment Rating System (NABERS) (VDZ, 2021). In addition, the infrastructure Sustainability Council of Australia (ISCA) provides a rating tool for concrete which is officially applied to major construction projects in Australia. According to GBCA, embodied carbon will be much more highlighted in the future policy and there should be positive momentum in the future, however, removing barriers seems necessary to speed up actions and produce low-emission goods (VDZ, 2021).

Australia is committed to achieve net zero by 2050. In 2011, the Australian government established the Emission Reduction Fund (ERF) to significantly reduce emissions in this country through carbon offsets. The capital of ERF is equal to A$2.55 billion, which helps farmers, businesses, and other custodians in the implementation of farming projects and periodic reverse auction. The benchmark in these projects is an Australian Carbon Credit Unit (ACCU) equivalent to one tonne of CO_2-e. About 95% of this budget has been so far spent on carbon offsets by the Australian government. According to the Climate Change Authority, after 2017 no significant reductions have been contracted. Uncertainty in the future of ERF will make it impossible to make decisions for future projects. The sequestration can contribute to reduce carbon emissions from Australian soil and thereby enhance the productivity in agriculture sector. However, the cost of soil sampling has been identified as one of the main barriers.

Another offset emissions reduction program is the Renewable Energy Certificate (REC), which is used to purchase energy and other government mandates. It is known in Australia as large-scale generation certificates (LGCs), each represented 1 MWh. In addition, in Australia, the green power accreditation program is implemented to apply LGCs by retailers and actually on behalf of customers. In addition to government purchases, corporate Power Purchase Agreements (PPAs) are also becoming an important incentive for renewable energy investment throughout the country.

Moreover, some universities in Australia are actively moving towards net zero emissions and each has its own strategies. Among these, we can mention Monash University, which has been active in this direction since 2017. Curtin and University of Technology Sydney (UTS) have not yet officially presented this commitment, but they have started actions in this direction. More specifically, Monash University uses their campuses as living labs for sustainability. In these labs, socio-technical initiatives with the goal of net zero initiative (NZI) are evaluated and developed. NZIs by Australian universities are almost similar to what is done in organisations around the world.

Limited information is available on the scopes of the targets, however, apparently these issues are mostly related to Scopes 1 and 2. In general, the targets of many Australian universities are carbon neutral and 100% use of renewable energy generation before 2030. The commitments of these universities are mainly included water consumption, transportation, waste management and procurement policies, and the emissions of these activities is less considered. In fact, the targeting of these institutes is a percentage of the current level being measured. Also, in order to guide action areas and activities, SDGs are of interest to universities. Some of the universities have stopped investing in fossil fuel-oriented companies; however, its status is not clear at the time being (Roche et al., 2022).

Moreover, AGL as the Australia's largest electricity generator and retailer and the largest private investor in renewable energy sources is actively involved in the decarbonisation process through some climate commitments, including offering carbon neutral price to customers, supporting the voluntary carbon market and investing in green sources of energy (AGL-Energy, 2020b).

Australia currently has the technology required for reducing its emissions by 60% by 2030. By moving in this direction, we will be able to take advantage of tremendous investment opportunities and ensure a smoother transition toward the 2050 net zero targets. The following are the steps that Australia will follow to achieve the net zero objective (O'Brien, 2021).

- Currently, there are 16 coal-fired power plants in Australia, seven scheduled to close by 2035.[2] These power plants supply 60% of electricity demand in the country.
- The gas network will be 15% renewable gas, principally produced from biomethane and supplemented with green hydrogen when not required for industrial activities. There will be clear plans in place for a path to 50% renewable gas and electrification of most home energy demands.
- Through the widespread adoption of battery EVs for commuter traffic and fuel cell EVs fuelled by green hydrogen for heavy transport, including trains, transportation fuels will be more than 60% renewable. This will be supplemented by significant expansion in the biofuels business as

[2] https://www.carbonbrief.org/daily-brief/australias-biggest-coal-fired-power-plant-to-shut-years-ahead-of-schedule/.

a result of the jet biofuels industry. This has increased rural prosperity and allowed the aircraft sector to begin aggressively decarbonizing. Internal combustion engines will see their final sales in niche markets in the early 2030s.

- Agricultural emissions will be reduced significantly as animal supplements become more widely used and agricultural methods change. The expanding offsets market, enabled by advanced satellite tracking, has given a new wave of prosperity to rural areas.
- Emissions-intensive industries have finished all testings and demonstrations and are in the process of rebuilding to bring to market products that meet the same needs in various ways.
- Climate resilience is built into all activities, including predictive, real-time, and digitised insights into current and future disaster risk. This will be supported by significant community investment as well as defined and agreed regional and sectoral adaption paths.

The Corporate Emissions Reduction Transparency (CERT) Report published by Clean Energy CER (2021) provides an opportunity for organisations to highlight their carbon reduction goals, commitments, and progress towards achieving their decarbonisation targets. Organisations can also declare how they reduce their carbon footprints. For each organisation, the CERT report presents a dashboard highlighting its absolute emissions under Scope 1 emissions resulting from burning fossil fuels at its facilities and Scope 2 emissions that result from purchasing electricity. As opposed to the National Greenhouse and Energy Reporting Scheme (NGERS), CERT enables organisations to demonstrate not only their emissions have been reduced through activities such as energy-efficient design, alternating fuels, or enhancements to technology but also through the purchase of renewable energy or a form of emissions offsets.

The GHG Protocol describes the CERT as a 'market-based report' and the NGERS report as 'location-based accounting'. A location-based account shows carbon footprint of any organisation based on its industry, while a market-based account shows the steps the organisation has implimented to reduce carbon emissions. A list of certification systems managed by the Australian Clean Energy Regulator that enable organisations to claim ownership of emissions offsets and renewable energy is summarised as follows (CER, 2021):

- Australian Carbon Credit Units (ACCUs): The Clean Energy Regulator issues an ACCU in 2015 (CER, 2022a) to a person by recording the unit in his or her account in the electronic Australian National Registry of Emissions Units. A single ACCU shows a tonne of carbon dioxide equivalent (tCO_2-e) avoided or stored by a particular project.
- Renewable Energy Certificates (RECs): A renewable energy certificate is a document that describes a unit of renewable electricity energy is generated and distributed to consumers (CER, 2022b) that started prior to 1st of January 2011. A typical certificate traded in Australia is the large-scale generation certificate (LGC), designed to measure renewable energy target achievement. Using these certificates, consumers can ensure that every megawatt of electricity consumed is matched by an equivalent megawatt generated by renewable energy sources.
- Benefits of the CERT system for organisations: Participating organisations probably already provide stakeholders with annual reports on the targets and progress. The value of the CERT is that it allows the Clean Energy Regulator to validate certificate applications

and retirements (CER, 2021). These actions are authenticated by the Government. This is of particular importance in a world where greenwashing is constantly claimed and denied. Some companies that report through NGERS do not report through the CERT. However, it will become apparent over time which companies are reducing emissions.

1.2 Scope of this project

The project addresses the gap between the promise of emissions reduction and the practical steps required to get there. To achieve net zero goals, companies around the globe are committed to upgrade their equipment, enhancing their efficiency, utilizing renewable energy technologies, and re-assess their activities related to producing and supplying in order to cut down their CO_2-e emissions. Moreover, companies can prevent excess pollutant emissions by investing in deforestation and clean energy in order to compensate for the emissions resulting from their activities. However, as net zero can be interpreted in different ways, there is no general consensus on its precise meaning. When it comes to companies, they can decrease or neutralize their emissions by either eliminating their carbon footprint in the atmosphere directly or providing financial supports such as funding CO_2-e reduction initiatives or buying carbon credits, which can both be taken place elsewhere. Therefore, company leaders and industry decision makers are facing a complex problem. Each company can implement a combination of different solutions for reducing CO_2-e emissions where each potential solution incorporates different social effects, financial costs and environmental consequences. The broad steps outlined in the Net Zero pathway[3] are:

- Data collection and opportunity identification.
- Scenario development and modelling.
- Decarbonisation roadmap development.

The project explored these steps and applies to three companies. In doing so, we collect data for the current emissions, developing future scenarios and comparing these with the current ones. These studies underpinned the goal of the project which was to understand and design the processes which map emissions reduction promises to actions, and to prototype the design of a decision support engine which can support these processes. To fulfil these objectives, the project pursued three areas of exploration.

1.2.1 Technical basis

An organisation seeking a path to reduced emissions must be informed of all its sources of carbon emissions, the activities that generate them, and their links to its organisational goals. On this basis realistic, significant emissions reduction targets can be developed. The interventions, and changes to these activities, that can achieve these targets depend upon the technologies under development or already available. The volume and complexity of the emissions data, the range of possible future scenarios, the variety of actions that can be implimented, the constraints on budget and risk, and

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[3] "Monash University - developing an actionable decarbonisation roadmap" https://www.monash.edu/__data/assets/pdf_file/0007/2774347/Monash-Clayton-Roadmap-Summary_20211210.pdf

the optimal timing of actions to reduce emissions all render the need for a decision engine necessary to support the path to net zero.

1.2.2 Qualitative forces

The emergence of the social licence to operate (SLO) concept reflects increasing awareness by industries of the need to negotiate with communities and other stakeholders regarding the costs and benefits associated with industry development. Our analysis of the qualitative forces influencing transition has identified shared expectations of increasing stakeholder engagement in net zero commitments, and a view that a social licence to operate may guide this engagement. SLO is a strong driver for industries to invest more in developing tools that may help them in monitoring their CO_2-e emissions as well as exploring different pathways that they may undertake in future in order to reduce their emissions.

We identify challenges that affect the prioritisation of net zero ambitions within these SLO mechanisms. In doing so, we articulate the need for a decision engine to support a pathway to net zero that could input vast quantities of information to elucidate the core elements of the qualitative forces influencing the transition. Indeed, the socio-political risks of climate change can be expressed in quantitative terms so that they can be measured and monitored as an integral feature of our decision engine to support the path to net zero.

1.2.3 Decision engine to support the path to net zero

The main objective is to give businesses control over their carbon data and create tailor-made action plans that enable them to reach their climate goals quickly and easily. We stress the importance of having a decision support platform and explain different desirable features and potential benefits of developing such a decision-making platform. Considering the complexity of the problem, the uncertainty of different parameters, and the large domain of potential solutions for reducing CO_2-e emissions, an interactive decision support software will be a crucial tool for industry leaders to make optimal decisions. The role of the decision support platform is to receive inputs in the form of both qualitative and quantitative information, which it then processes to compute the most effective and cost-efficient steps on the path to net zero.

1.3 Organisation of the report

Chapter 2, explains the framework of the decision support platform and explore different processes that need to be implemented as parts of the decision support software. Key aspects of software implementation is discussed in this In Chapter 3, we discuss the main social and political drivers influencing the path to net zero context. Socio political risks are discussed with case studies. In this chapter, we focus on qualitative information that informs organisational decision making with respect to decarbonisation, information that is generally conceived as the determinants of a social licence to operate.

Chapter 4 discusses technoeconomic drivers in influencing net zero path, with detailed case studies using the AGL Energy, the Tassal Group and Sydney Water. We get here industry-specific perspective and the role of technoeconomic drivers in different sectors.

Finally, the report concludes in Chapter 5 with an indication of the steps to move forward.

2 Decision Support Platform: Framework and Key Considerations

2.1 Introduction

Net zero emissions will impact every product and service provider that uses energy. Energy consumers will have to invest in new technologies that do not produce CO_2-e, either directly or indirectly. The size of this investment has been estimated at about $4Tn by 2050(Deloitte, 2022; McKinsey-&-Company, 2018). Therefore, making even slightly wrong decisions on the options and timing of investment will have a large impact.

Over the past few years, a growing number of organisations are undergoing a phenomenal shift in harnessing the power of computer-based decision support platforms to improve their decision-making process. It is now a common practice, particularly among larger organisations, to actively record an extensive volume of data from their daily operations and utilise it to support various enterprise decisions concerning their resource planning, budgeting, customer relations, and supply chain management. In essence, a decision support platform or decision support system is a computer-based application that processes the data related to various aspects of the business operation and assists in decision-making.

A decision support platform to support the path to net zero emissions needs to receive inputs both on internal organisational data, objectives, and goals as well as on external information sources such as government policies, up-to-date scientific projections concerning climate change impacts, and even market trends pertaining to the business services and products. Subsequently, the platform processes this data to derive solutions that are optimised with respect to multiple constraints. More specifically, the optimisation process encompasses factors like minimising financial costs and environmental impacts while maximising stakeholder approval and adhering to governmental regulations.

Designing and implementing a decision support platform to support the path to net zero emissions is a complex process that can be divided into three distinct phases. These phases encompass identifying the framework of the problem, formulating and grasping the specifications of the decision support platform, and finally, implementing the decision support platform in practice (refer to Figure 2-1).

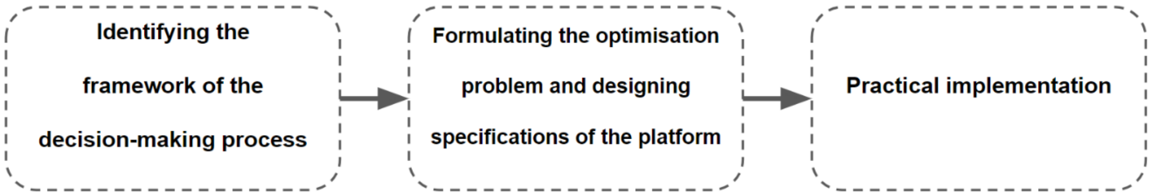

Figure 2-1: The three phases of designing and implementing a decision support platform.

Our focus in this chapter will be on the process of identifying the framework and considering the initial steps toward formulating the optimisation problem. To this end, we present a systemic step-by-step approach for identifying the framework of the decision-making process for reducing CO_2-e emissions and, eventually, achieving net zero emissions targets. Additionally, we provide an initial exploration into formulating the optimisation problem and defining the specifications for the decision support platform. The creation of a comprehensive architectural design and its practical implementation remains for future works. Section 2.2. presents the decision support framework, while section 2.3 includes formulation of the optimisation problem. Section 2.4 discussed input data. Section 2.5 covers key aspects of software implementation. The final section concludes the chapter.

2.2 Decision support platform framework: targets, solutions, and constraints

When it comes in dealing with climate change, local industries usually respond by taking reactive or proactive approaches. Reactive approaches involve uncoordinated or limited responses to climate issues, which can lead to managing problems after they have already happened. This can result in higher costs for damages and unexpected vulnerabilities over time. On the other hand, proactive strategies involve coordinated planning to reduce CO_2-e emissions and ultimately, achieve net zero emissions. This approach enhances the understanding of how adaptation, mitigation, and other community actions work together and improves planning efforts, and helps in maintaining services, managing risks, and reducing expenses over time.

The decision support platform goes beyond the proactive approach and employs a systemic approach, assisting businesses and local governments in devising more comprehensive strategies to address climate change and promote sustainable community development. This method encompasses various aspects, such as risk assessment, vulnerability, emissions reduction, and co-benefits, in every decision. By considering these factors comprehensively, integrated solutions are provided to address the intricate challenges posed by climate change and ensure a sustainable future for the community. Figure 2-2 presents the framework of the decision-making to support the path to net zero emissions that we developed with inputs from industry and academic partners.

In general, the decision support platform may be used in three primary ways:

- **Streamline** climate action planning and key data sets using net zero criteria to prioritise multitasking and organisation-wide implementation methods.
- **Contribute** to the preparation of reports, procurement decisions, and project proposals by offering net zero criteria as an essential component of the decision-making toolkit.
- **Clarify** what may happen under changing circumstances, enabling net zero possibilities to minimise climate risks and emissions in all relevant planning processes, such as an economic development plan.

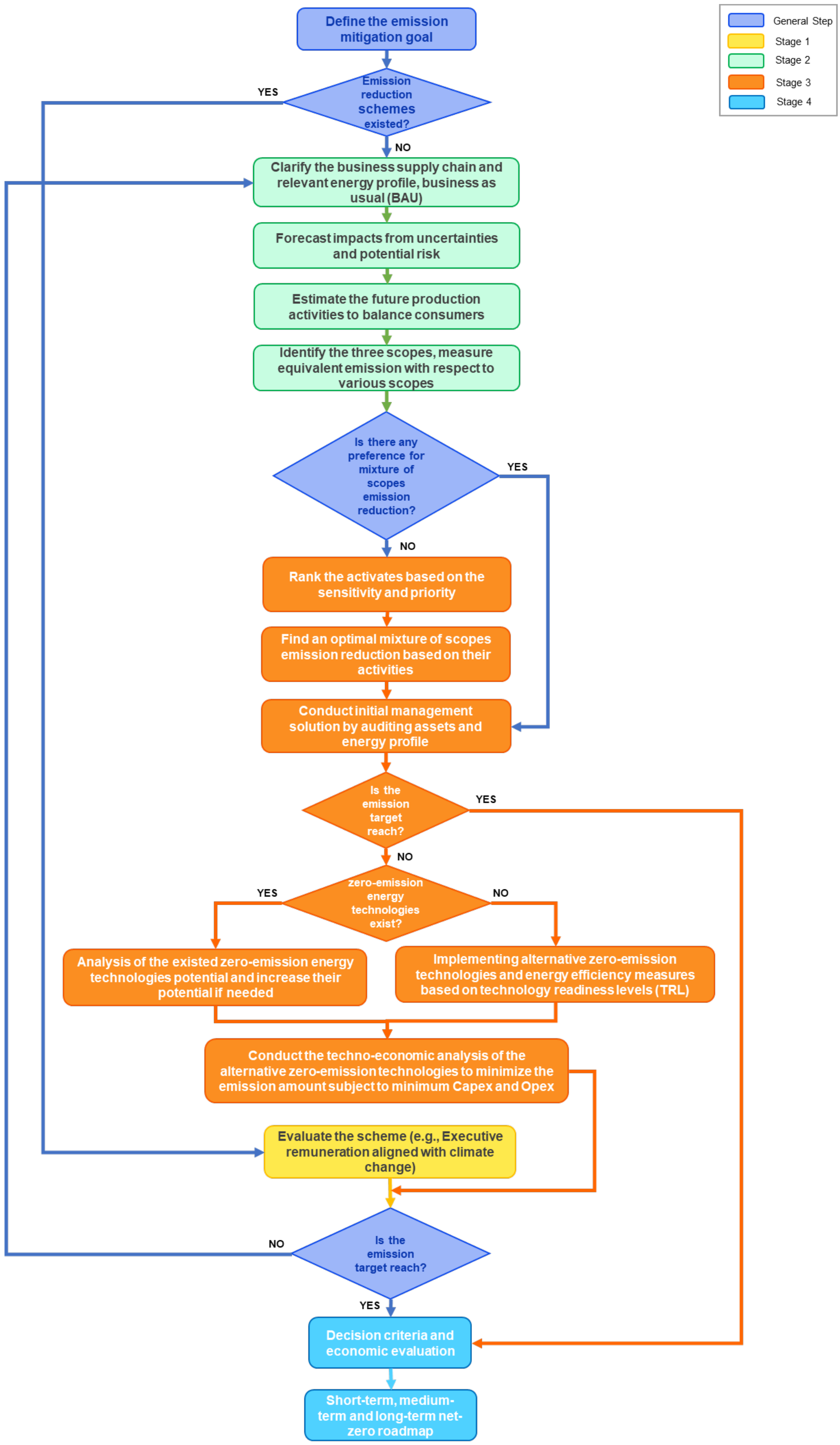

Figure 2-2: The framework of the decision-making to support the path to net zero emissions.

Figure 2-2 presents a systemic approach for decision-making to support the path to net zero emissions. This require businesses to incorporate a range of socio-political and techno-economic variables. The process of identifying the context and the framework of the problem can be divided into several stages, which are outlined below.

Stage 0: Evaluation of the net zero scheme if this exists

Many businesses, particularly large-sized industrial businesses, have an existing net zero scheme in place, which could assist them to achieve the net zero target for all three scopes by 2050. However, some businesses still do not have any clear target and approach to achieve net zero emissions. For those industries that have certain targets, this tool aims to evaluate these schemes to ensure their effectiveness in achieving the defined emissions reduction target. This evaluation aims to analyse the pathway to meet the net zero target for each Scope within the defined timeframe as well as ensure that the proposed solutions are cost-effective without any negative impacts on the future business strategies and plan of seizing the market, especially for a long-term horizon. If there are no existing net zero targets for a certain business, the framework will analyse their different scopes and assists them to identify an achievable target.

Stage 1: Data collection

Capturing and processing the business-as-usual data such as the energy profile for businesses is the key to analyse their carbon-intensive activities and estimating the respective CO_2-e. This data encompasses details such as energy consumption and generation categorised by type, as well as data about material procurement, transportation, and more. Utilising this data, we can calculate the present levels of Scope 1, 2, and 3 emissions and make informed predictions about the future trend. In summary, Stage 0 contains two major steps as follows:

Step 1. Data pre-processing and mapping

- Import business-as-usual data including energy consumption and generation by type.
- Convert the business-as-usual data to estimate the CO_2-e emissions using the emission intensity factors of different activities, energy types, and materials.
- Identify the emissions Scopes (Scope 1, 2, and 3) associated with materials, activities, and energy consumption.

Step 2. Forecast the growth rate of energy demand and CO_2-e emissions

- Forecast the growth of energy demand and material consumptions as a percentage per year (i.e., annual growth factor).
- Forecast the levels of CO_2-e as a percentage per year.

Stage 2: Scenario development and modelling

The emissions reduction goals and targets should be shaped by both the priorities and socio-political factors of business-like community approval and government regulations. These targets can be categorised as short-term (e.g. 5 years), mid-term (e.g. 10 years), and long-term (e.g. 25 years) targets, depending on the timeframe they are expected to be achieved. Accordingly, the CO_2-e emissions reduction solutions can be assessed based on the defined timeframe considering socio-political characteristics into account and includes the priorities of the business in addressing CO_2-e emissions by scope. The main activities associated with Stage 2 can be framed in three steps:

Step 1. Defining scope preferences

The Scopes preferences should be defined based on the business strategy. The emissions scope preferences play a significant role in obtaining the proper solution associated with the pre-defined emissions mitigation target over the timeframe of each term. Accordingly, the following sequence should be followed to define the scopes preference of each Scope:

- The user should define the emissions mitigation target (short-term, medium-term, and long-term) in percentage (e.g., 30% reduction in the short-term, 50% reduction in the medium-term, and 100% reduction in the long-term).
- If the user has a pre-defined preference for the mix of the scopes (e.g., 30% Scope 1, 50% Scope 2, and 20% Scope 3), then the user should input this preference into the decision support platform. Otherwise, the user should rank the activities created in Stage 1 – Step 1 based on the sensitivity (e.g., 1 low-sensitive, 2 medium-sensitive, and 3 high-sensitive). Here, low-sensitive is associated with a short-term target, medium-sensitive is associated with a medium-term target, and high-sensitive is associated with a long-term target.
- Map the scopes with the sensitivity and emissions mitigation target.

Step 2. Energy auditing as an initial solution

An energy audit clarifies the energy use of any organisation and identifies possible cost-cutting opportunities. It may result in decreased energy use, increased productivity, and innovation potential. Accordingly, understanding where and when an organisation consumes energy is essential in determining the most cost-effective strategies to save money.

Energy bills may supply some of this information, statistical analyses can assist the organisation in gaining a deeper knowledge of its energy use. In this context, the energy baseline will explain the relationship between the company's energy use and its operations, establishing a connection between energy expenses and business output.

Energy auditing should be completed to the relevant Australian Standards based on the targeted sector as follows:

- Commercial building: AS/NZS 3598.1:2014
- Industrial and related activities: AS/NZS 3598.2:2014
- Transport-related activities: AS/NZS 3598.3:2014

Step 3. Energy alternative solutions assessment

For most businesses, relevant electricity energy consumptions normally take the largest proportion of CO_2-e emissions. Accordingly, the energy profile and supply chain of the business should also have their priorities clarified. In this context, renewable energy power purchase alternatives should be assessed to ensure energy is provided to the business with high reliability and at a minimum cost. This can be achieved by a techno-economic assessment as follows:

- Import the costs and specifications of renewable energy technologies (e.g., photovoltaic (PV) with storage battery, hydropower, hydrogen-based technology, fuel cells-based technology, etc.).
- Model the potential of the prospective renewable energy technologies, expected energy generation in kWh, and CO_2-e emissions reduction level.
- Build a high-level energy tariff structure model for renewable power purchase, non-renewable energy tariff, and feed-in tariff (FiT).
- Undertake a techno-economic assessment to decrease CO_2-e by increasing renewable energy sources (locally generated or purchased from the grid) subject to minimising the CAPEX and OPEX (i.e., maximising CO_2-e reduction gain or minimising CO_2-e reduction cost).

Stage 3: The decarbonisation roadmap

Technically, several solutions can secure a high reliability level with zero CO_2-e emissions. These solutions could be either to purchase the energy from green sources within a specific PPA, to deploy standalone renewable energy technology, or to use a mix of renewable energy technologies or a mix of renewable energy technologies and PPA. The decision criteria to select the best scenario is subject to minimising the CAPEX and OPEX of any alternative. The decision criteria can underpin an optimisation process, which may also need human input to select the best-fit alternative based on the business strategy.

2.3 Formulation of the optimisation problem

Once the framework of decision-making process is developed, we can begin formulating the optimisation problem to determine the best solutions based on the input data and constraints. Generally, the optimisation problems consist of three pillars:

- Degrees of freedom (what we can do in terms of choices and sizes of equipment)
- Constraints (physical limits, stakeholder approval, rules, regulations, and policies)
- Objective function (what we want to maximise or minimise)

The degrees of freedom and constraints are essentially defined as inputs to the model. The objective function often translates into a forecasted ownership cost, accounting for current monetary values, expected interest rates (reflecting borrowing costs), and inflation. This encompasses diverse components including capital outlay, cumulative net fuel expenses, net maintenance costs, depreciation, and carbon credits or taxes. Here, the term ‘net’ captures change relative to the existing state.

The optimisation problem involves making decisions within an environment of uncertainty. Within the context of decision-making to support the path to net zero emissions the major sources of uncertainty can be summarised into:

- Economic and financial uncertainties: interest rates, inflation, and the future price of goods, services, and technologies, e.g., electricity price, and cost of installation of renewable technologies.
- Technological uncertainties: feasibility, efficiency, and price of technologies in the future, e.g., hydrogen fuel cells, carbon capture and storage solutions, and grid-scale lithium-ion batteries.

- Socio-political uncertainties: level of social and political support for net zero ambitions, stakeholder approval, and future governmental regulations concerning CO_2-e emissions.
- Environmental uncertainties: Future scientific assessments and scenario analysis on the severity of the climate change impacts and the possibility of mitigation.

Energy costs are particularly significant and future estimates can be input directly. For other costs, such as equipment and installation, an annual index is probably significant. It would also make sense to work in nominal monetary values and use a depreciation rate based on the combination of inflation and interest rates. To allow for uncertainty we could use a range of costs (or cost indices) such as the lowest decile, average, and highest decile that are amenable to Monte Carlo simulation and optimisation that creates a distribution of decisions and future costs.

An important consideration is lead time and irreversibility. If we decide in year X to invest, then that decision is made, and the decarbonisation benefits will flow at X + L where L is the lead time. We should probably make a simplified assumption that the result is complete decarbonisation, in which case no further decisions are required relating to that equipment. Otherwise, we will have to model secondary decisions that will make the problem more difficult. In addition, there is no point in reversing a decision. Therefore, once made, that decision disappears from the problem, resulting in the optimisation somewhat simpler.

Uncertainty with availability is more difficult to handle. We may consider a 'what-if' approach where we ascertain how the availability (or not) of certain renewable technologies or fuel types in any future will impact our decisions or costs. Therefore, what we expect is:

- Monte Carlo simulation of the price of goods, services, and technologies such as fuel, renewable equipment, and installation based on costs and indices
- An integer optimisation problem of potential investment options to achieve an annual or eventual carbon reduction target. The nature of the optimisation suggests that direct search or constraint satisfaction algorithms are likely to give the best results
- A probability distribution of decisions and costs
- A what-if overlay on potential technologies and solutions that may become feasible in the future
- A matrix of costs and decisions driven by the assumptions

2.4 Input data

Once the framework of the decision is identified, we can formulate and implement the optimisation problem into the decision support platform. At this stage, the platform is ready for the user to input relevant operational information about the organisation (e.g., energy profile and carbon accounting data), and determine emissions reduction objectives as well as socio-political constraints and priorities. Subsequently, the decision support platform leverages this information to derive optimal strategies. The decision support platform extends the provision for users to dynamically update parameters and execute model recalculations, thereby fostering an iterative decision-making process.

As illustrated in Figure 2-3, we can generally categorise the input data into four groups: data required for estimating carbon footprint by Scope, emissions reduction targets and net zero goals, list of potential strategies and technical solutions, their efficiencies, and their financial costs, and socio-political constraints and priorities.

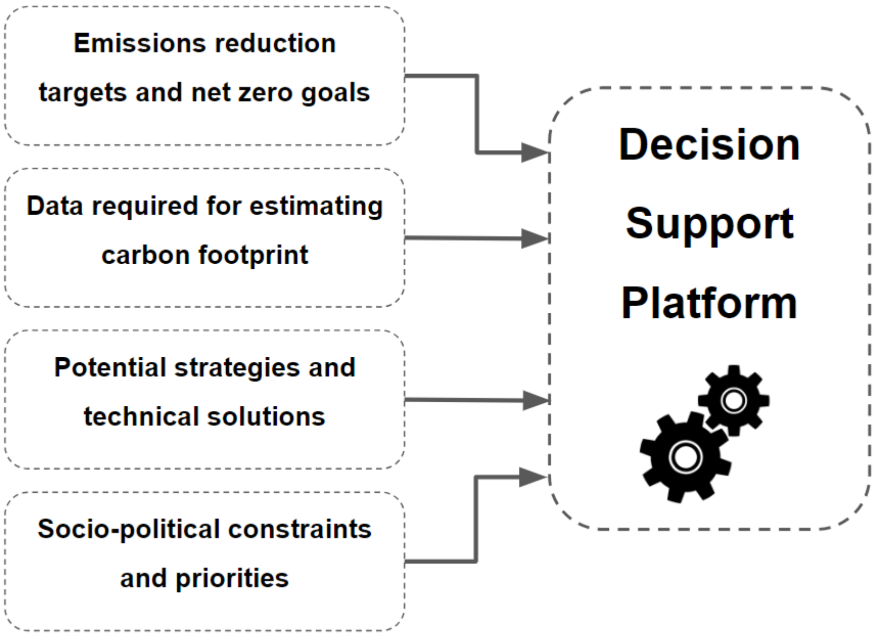

Figure 2-3: Various types of data that is required as input to the decision support platform.

To report the total CO_2-e emissions of any organisation, businesses will need to collect and aggregate data from several facilities, which may be located in various business divisions. It is essential to organise properly this procedure to minimise the reporting load, limit the chance of data compilation mistakes, and guarantee that all facilities gather information in an authorised, uniform manner. In an ideal scenario, firms would integrate CO_2-e reporting with their current reporting tools and procedures and use any relevant data already gathered and reported by facilities to divisions, corporate headquarters, regulators, or other stakeholders.

To simplify this process, we have developed an extensive survey that captures all the information required by the decision support platform. By integrating this survey into the decision support platform, users can import the required information directly into the software application in a systematic manner. Provided in Appendix A, the survey is organised into five sections, Management, Transportation, Utilities, Buildings, and Production Chain, and covers a comprehensive list of information required for the execution of the decision support platform. By categorising the questions under these five sections, companies will be able to assign the completion of each section to the most appropriate expert within their team.

Once completed, the decision support platform then takes all the imported values, priorities, and restrictions into account to propose and assess different strategies for reducing CO_2-e emissions. It is worth mentioning that the decision support software should also provide options for companies that have the required information recorded in other formats to import them directly.

2.5 Key aspects of software implementation

We propose to use an architecture that has demonstrated its efficacy in addressing analogous long-term and strategic optimization challenges, such as those encountered in capital investment, facility location, and strategic sourcing. Following, we briefly discuss the conceptual system architecture of the decision support platform, its user interface, privacy and security features.

2.5.1 System architecture

The optimisation problem will be encapsulated in an EXCEL file. This will facilitate seamless editing and data population from various sources. Furthermore, they conform to established industry standards. The EXCEL file is uploaded to a web Graphical User Interface (GUI) that controls the optimisation process running on the Amazon Web Services (AWS) cloud. With the Web GUI, the user can edit any of the inputs and perform what-if optimisation runs. The results are viewed in the same interface. When a satisfactory result is obtained the output can be downloaded into an EXCEL file containing both the inputs and the results. This ensures complete auditability, and replication, if necessary, of inputs and results.

The optimisation is stateless and requires no other data that the input file and once the session is finished no data is retained. Figure 2-4 illustrates the system architecture of the decision support software.

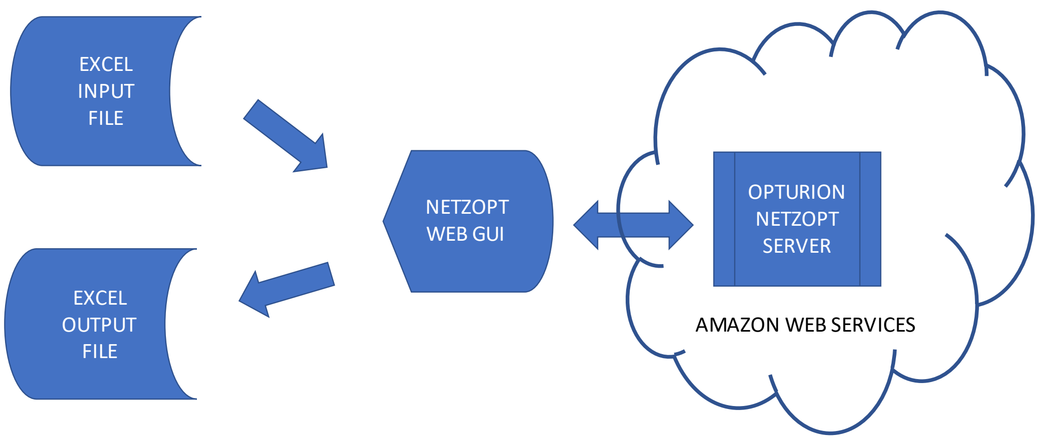

Figure 2-4: The system architecture of the decision support software.

2.5.2 User interface features

As identified above, the user can interact at several levels:

- Prepare the input file in an EXCEL environment by editing input field or merging data from external sources.
- View the inputs using the Web-based graphical user interface (GUI) in tabular or graphical form[4].

[4]The Web GUI is a web-based application which can process data from various sources for network events and presents the event data to users in various graphical formats in a web browser.

- Modify inputs directly in the Web GUI.
- Initiate optimisation runs.
- View the results in several forms:
- Tabular.
- Continuous against time, such as operating costs and carbon emissions, with a trend graph.
- Discrete against time, such as capital investment an availability of green energy with a chronology or GANNT chart.
- Decisions, with a chronology or GANNT chart.
- An overview or summary with KPI's.
- Download the inputs and outputs as an EXCEL file.

2.5.3 Privacy and security properties

The user will log on to the web service using two-factor authentications. The data that defines the optimisation problem is uploaded to the browser as EXCEL. This is converted to JSON for editing and viewing prior to optimisation. The Web GUI communicates with the optimiser (in the AWS cloud) via encrypted JSON files using hypertext transfer protocol secure (HTTPS). The solution is a JSON file that is again encrypted via HTTPS and sent back to the browser. At the end of optimisation run, data in the cloud is deleted.

Privacy and security are assured due to:

- Access to the optimiser web service supports two-factor authentication (2FA).
- Access to the optimiser web service is via HTTPS/TLS using 128-bit.
- encryption as a minimum.
- The optimiser web service is stateless. User data is only present, in-memory, on Opturion servers while the optimisation is running. After the optimisation is complete, no user data is retained on Opturion servers.
- The optimiser web service is securely hosted in the Amazon Web Services (AWS) cloud infrastructure. All processing occurs in the Asia Pacific (Sydney) region. AWS is compliant with all leading security, assurance, and quality standards (e.g., SOC 2, ISO 27001) (See: https://aws.amazon.com/compliance/).
- All Opturion servers are protected by a firewall. They are regularly scanned using antivirus (AV) and intrusion detection software. Software installed on Opturion servers is regularly updated to include the latest operating service (OS) and security. Access to Opturion servers that process customer data is restricted to authorised personnel. The optimiser web service is protected by a web application firewall (WAF).
- Opturion incorporates the open web application security project (OWASP) application security verification standard (ASVS) into its software development lifecycle (SDLC). Applications are regularly audited using web application scanners to ensure compliance with the controls defined in the automatic vulnerability scanning and verification (AVSV) software.

In summary, we discuss the framework of the decision platform and implementation of optimisation problem in this chapter. With the support of the overall system and availability of data, the Opturion is able to use this platform in achieving net zero targets for companies.

3 Socio-Political Drivers Influencing the Path to Net Zero Emissions

3.1 Introduction

The main aim of this chapter is to illuminate the complexities and requirements of incorporating socio-political drivers into the net zero decision support platform and how to effectively address them during the modelling process. Therefore, the chapter explores the role of socio-political drivers and related Social License to Operate (SLO) in decision-making to support the path to net zero emissions. We identify key qualitative socio-political variables influencing decision-making and explain how these variables could be integrated into the decision support platform to enhance outcomes.

A dilemma is raised from the need for urgent changes to business-as-usual practice to accommodate the desired net zero emissions goals while at the same time enhancing social acceptance by local communities. A triple challenge of integrating the effects of climate change, lowering emissions, and the role of Social License to Operate (SLO) are at the centre of such a dilemma. Even though a low-carbon or ultimately a net zero emissions development pattern is conceivable, the acceptance of social license to encourage, implement, and even accelerate necessary changes remains a key to successfully achieving climate goals and limiting global warming. The socio-political drivers of a SLO that influence net zero ambitions are diverse.

We explore how the qualitative information can be fed into the decision support platform to influence organisational strategies to attain/maintain their social license by implementing net zero practices. We identified challenges that affect the prioritisation of net zero ambitions within these SLO mechanisms. In doing so, we articulate the need for a decision engine to support a pathway to net zero that could input vast quantities of information to elucidate the core elements of the qualitative forces influencing the transition.

Our major findings are summarised here:

- SLO is a strong driver for organisations to invest more in developing tools in monitoring their CO_2-e emissions. This helps in exploring different pathways that they may undertake in future in order to reduce their emissions.
- The socio-political risks of climate change can be measured and monitored as an integral feature of the decision support platform.

The rest of this chapter is organised as follows. In Section 3.2, we provide an introductory discussion on the SLO and how they drive internal decision-making processes within organizations. Section 3.3. covers a discussion on social licence while, section 3.3, discusses socio-political risks relating with climate change. Section 3.4 presents our case studies where we conduct a meta-analysis of annual reports from a sample of member organizations within RACE for 2030, analysing SLO actions considering diverse organisations. Section 3.5 integrates the drivers into the decision support platform. Section 3.6 concludes the chapter.

We identify and profile emerging SLO themes, shedding light on the societal pressures on organisations to transition towards net zero operations. Finally, we explore solutions for converting the often-qualitative socio-political variables to qualitative variables and integrating them into the decision support platform.

3.2 Social Licence to Operate: An Overview

The concept of a SLO dates back to the 1990s (Cooney, 2017) and gained popularity to incorporate the social considerations can be addressed in industry development decision-making. The organisational embrace of public perceptions to inform decision-making can be seen in the growing desire for social accountability by industry (Thomson & Boutilier, 2011). A desire which has traditionally been deployed reactively (Owen & Kemp, 2013) and was initially designed to manage social risks (Prno & Slocombe, 2012), minimise operational disruptions (Owen, 2016), and avoid costs (Davis & Franks, 2014). Ultimately, the aim of any SLO measures is to ensure their business activity remains viable (Michell & McManus, 2013). Yet, while the attainment and maintenance of social accountability have increasingly become matters of strategic importance to industry (Overduin & Moore, 2017), organisational strategies remain an exchange of intangible and conceptual ambiguities. This has led to a growth in an array of definitional challenges in determining whether a SLO has been achieved.

In the following sub-sections, we provide essential background information on the concept of social license and elaborate on its significance. Additionally, we employ systems theory to conceptualise organisations as systems. Building upon this conceptual framework, we leverage the concept of social license throughout the chapter to model the influential socio-political drivers that shape the decision-making process within the context of climate change.

3.2.1 Social licence to operate

Social license refers to how a project, organization, or industry is perceived and accepted by society in a particular location or region. It involves the collective attitudes of the public towards environmental conservation, social diversity, and community development. Organizations strive to position themselves favourably in response to societal pressures, aiming to be seen as responsible social actors. Misinterpreting social license implications in the ambiguous and dynamic socio-political context can have tangible consequences for an organization. Public support for an organisation or a project is not static but rather can grow or fall over time, where SLO refers to the ongoing community and stakeholder acceptance of a particular organisation (Prno, 2013). In modern times, the SLO has arguably become as important as any regulatory licence, and it has the potential to become a critical impasse if not managed appropriately.

The level of SLO granted to an organisation is inversely proportionate to the level of socio-political risk that the organisation faces (Boutilier & Thomson, 2011) . A low SLO indicates a higher socio-political risk; the lowest level of SLO leads to having the social license withheld or withdrawn. Low SLO has been revealed as the failure in establishing relationships with stakeholders, communicating impacts of operations with local communities, and addressing sustainability concerns (Prno, 2013).

Approaches which have been shown to prevent the implementation of net zero initiatives in 'top-down' or 'place-blind' ways, can provoke public opposition and failure to achieve a SLO (Burke & Stephens, 2018; Goldthau, 2018). The decision support platform has provided an opportunity to investigate these core elements of the SLO: whereby public attitudes and preferences could be inputted into net zero transition scenarios, and spatially resolved environmental and social outputs can be used to inform decision-making process for any organisation.

Identifying determinants of social license and integrating qualitative inputs into decision-making processes pose challenges. This research aims to address these challenges and expand the range of qualitative inputs that can be interfaced with the decision support platform. A social license exists when either an organisation or a specific project is seen as having the broad, ongoing approval and acceptance of society to conduct its activities (Boutilier & Thomson, 2011; Joyce & Thomson, 2000). Local communities play a significant role in the social licensing process due to their proximity to projects and ability to influence outcomes. Obtaining a social license is often intangible, as it heavily depends on context and dynamic variables. There is general agreement in the literature that the actions an organisation could take to foster SLO broadly speaks to the nature of the relationship a company has with its stakeholders. On the one hand, social license is described in terms of an ongoing acceptance by society of a company carrying out its activities (Joyce & Thomson, 2000; Nelsen & Scoble, 2006; Parker, Van Alstine, Gitsham, & Dakin, 2008; Prno & Slocombe, 2012; Thomson & Boutilier, 2011). On the other hand, some writers define responses to social licence to operate as meeting stakeholder demands and expectations on how a business will operate (Gunningham, Kagan, & Thornton, 2004). There are also those that only see social licence to operate as a company showing concern for social and environmental issues (Aguilera, Rupp, Williams, & Ganapathi, 2007). Responses to social licence to be operational by organisations are also being defined in terms of conforming to prevailing social norms (Harvey, 2011), building ongoing industry-community relations (Hall, Lacey, Carr-Cornish, & Dowd, 2015) or creating industry-community partnerships (Warhurst, 2001).

Evaluating social license determinants and outcomes requires considering context, change, uncertainty, emergence, and feedback. No one-size-fits-all approach exists, as each organization's context is unique (Thomson & Boutilier, 2011). Understanding the social, cultural, and political dynamics of communities neighbouring project sites is crucial to adapt tools and guidelines accordingly. Social accountability has become as important as regulatory compliance, and organizations must navigate urgent societal pressures for environmental action and climate change (Wiseman, Edwards, & Luckins, 2013). Also, recent research suggests civil society commands action by organisations if it is most likely to yield favourable outcomes, actions that are proactive rather than reactive (Lucas, 2016). This presents challenges for organisations to navigate and determine actions to maintain accountability that go beyond their obligations to regulation and compliance (Parsons, Lacey, & Moffat, 2014).

3.2.2 Conceptualising organisations as activity systems

Organizations are entities with a specific purpose, comprising one or more people. They evolve into complex systems where each part affects the whole. Urgently transitioning to net zero operations requires adapting to regulatory and societal pressures. Systems theory offers insights into navigating this change. It explains how an organization's components interact and influence goal setting and change processes. `Equifinality' highlights the need for a decision platform to support the path to net zero. Complex adaptive systems have agents that differ from one another, making decisions and interacting, leading to emergence. Viewing an organization as a complex adaptive system helps investigate interactions among its parts. Every organisational system has permeable boundaries, influenced by its context, defined by its structure, function and role, and expressed through its relations with other systems. Whilst the process for how the organisational systems operate is complex, their outcomes are rudimentarily simple: either total success or failure. There are three interacting components for any organisation (Lai & Huili Lin, 2017): the environment (external), activity (internal), and resources (traverse the internal and external).

The environment is the socio-political context, how governance and society interact and influence one another. This has implications for influencing how activity is conducted by the organisation towards some end (i.e., product or service). Underpinning activities are the resources and information which form the necessary flows or throughput of the organisation. Organisations are open to the surrounding environment; they have permeable boundaries where information and resources flow both in and out. There is also an exchange with the environment, which is not just passive but is active, where socio-political forces directly relate to the throughput (or productivity) of the organisation.

The external environment surrounding an organization is unpredictable and dynamic, influencing internal activity and decision-making. While organizations have autonomy over their activities, they must actively respond to the external environment. Resources and information serve as inputs for the organizational system, leading to outputs like products, services, and profit. Changing public interest and perceptions, along with evolving political landscapes on issues like climate change and emissions regulations, require environmental scanning for navigating change. Boundary spanners gather information on external forces acting on the organization.

Organizational systems are sensitive to internal changes, with parts influencing each other through feedback processes. Negative feedback corrects deviations, while positive feedback amplifies desired changes. These challenges highlight the complexity of information management in responding to and navigating change.

Complex adaptive systems describe organizations as the total interaction of individual parts, influenced by both the operating environment and internal decision-making. Organizational development and technological interventions are complex tasks. Environmental scanning, including assessing socio-political forces, helps organizations navigate change. Customized decision support platforms can assist with information processing for organizational decision-making, especially in the face of technological advancements.

3.3 Socio-political risks and climate change

An energy transition is underway in Australia. In response to the urgency of climate change, the supply of fuel for electricity is decarbonising; fossil fuels are being replaced with renewable sources alongside efforts to reduce demand and increase efficiency. As a result of this transition, civil society generally supports reduced use of fossil fuels in Australia and supports the shift to clean energy. Though the fossil fuel industry has resisted, both in terms of volatile pricing and political pressure to this climate change-induced (Johnsson, Kjärstad, & Rootzén, 2019; Morgunova & Shaton, 2022). Any social and systems change—in particular, any planned social and systems change—is inherently political, as it concerns issues of power and distribution of resources, and this is certainly the case for the Australian energy transition. These changes which form part of the energy transition are necessitating, and prompting, major social and systems change; a process that is most likely to reduce risks to organisations if it is intentional rather than reactive.

Even fully compliant organisations risk negative public perceptions, which can cause problems through consumer boycotts, low staff morale, difficulty recruiting new staff, and uncertainty concerning the renewal of legal licences. The concept of SLO is based on the premise that, especially in the current information age, that organisations cannot rely solely on legal licences obtained from governments. This has become acutely relevant for the establishment of net zero targets.

Organisations are incorporating ambitious net zero targets into decision-making, reducing their socio-political risk by preferencing expected long-term returns through strategic asset allocation. It is widely recognised that climate change has anthropogenic causes; it is a phenomenon produced by civil society associated with carbon emissions. It has also been pointed out that the effects of climate change will impact the actors shown in Figure 3-1, within civil society: community, government and organisations. To prevent upheaval, urgent implementation of climate adaptation and mitigation action must be coordinated amongst actors within civil society.

Figure 3-1: Actors in socio-political risk and their relationship.

Climate change remains the most difficult, and intractable political issue in our time. To a lesser extent society itself remains divided on the issue and large, important parts of government have been indifferent. In many cases, organisations are pulling ahead of government setting their own net zero targets, going beyond compliance and allocating additional resources towards urgent climate action. Organisations are pre-empting shifting community perspectives (and associated future socio-political risk) on net zero operations; repositioning to be valued by its full range of stakeholders, whilst delivering long-term value for its shareholders.

The same social forces that motivate organisations to set even greater emissions reduction targets, also decide the outcome of elections, and the appointment of Government. Collective expressions of public interest are increasingly supportive for increased climate action. In Australia, social drivers are also placing an upward pressure on regulatory emissions targets. Figure 3-2 shows the emissions reduction targets by the Australian political arena before the last Federal Election in 2022. This reveals an increasing shift within collective expressions of public interest in support of increased action on emission reduction and therefore climate change. Whilst the second lowest emission reduction target (43% less by 2030 based on 2005 levels) was enshrined into legislation, the bill also ensured the target would only be increased from this point onwards – setting a new floor. This sudden change – post election, has meant that the organisations which initiated proactive approach to net zero find themselves in a comfortable position where socio- political risk was low, whereas those who have not, now face the consequences of high socio-political risk.

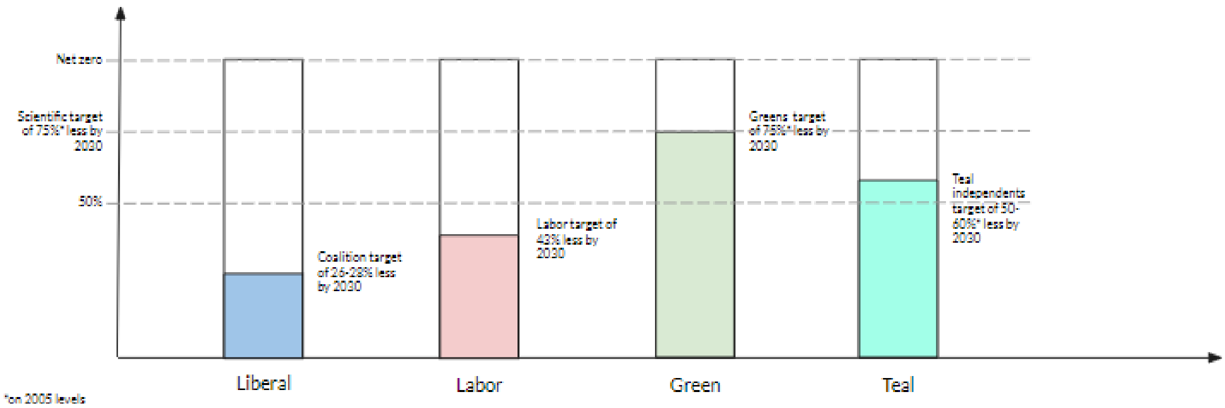

Figure 3-2: New emissions reduction targets initiated before the Australian 2022 Federal Election

The gap between the values of collective public expression and existing regulation and compliance sets the magnitude for socio-political risk. In the current information age, organisations cannot rely solely on legal licences obtained from governments but must also rely on a more intangible social license. This has become acutely relevant for action on climate change and the establishment of net zero targets. To prevent societal upheaval, urgent implementation of climate adaptation and mitigation action must be coordinated amongst actors within civil society. Organisations are pre-empting shifting community perspectives (and reducing future socio-political risk) on the adoption net zero targets. Repositioning their activities to be valued by its full range of stakeholders, whilst delivering long-term value for its shareholders. Increasingly organisations who take a proactive approach to net zero commitments find themselves exposed to less socio-political risk. Whereas organisations who focus on reactive approaches are at much greater risk in sudden and steep changes in emissions regulation.

3.4 Case Studies

In this section, we conduct a thematic meta-analysis to identify and profile public attitudes and preferences that relate to net zero transition scenarios, in addition, suggesting spatially resolved actions that can be deployed to foster SLO and reduces socio-political risk profile of any organisation. In the current information age, organisations face overwhelming complexity in data-driven decision-making. Both qualitative and quantitative information must be used to compute evidence-based advice. In this chapter, we have shown how qualitative forces that inform organisational decision-making can influence net zero goals (i.e., decarbonisation). We now categorise these qualitative forces into themes to reveal the determinants of a SLO as they relate to net zero. Specifically, we have examined the collective socio-political perspectives and values which influence organisational strategy and decision-making using case studies on annual reports and profiled their relationship to the transition to net zero operations. In doing so, we articulate the need for a decision support platform, demonstrating how it could support a pathway to net zero. Vast quantities of information from a population of individuals must be input, then aggregated to elucidate their collective expressions and how they relate to net zero commitments.

3.4.1 Method

The meta-analysis has been conducted using four case studies targeting our Race for 2030 industry partners: AGL, Sydney Water, Salvation Army, and Monash University. This research is perhaps one of the first known cross-industry examinations of social licence to operate, comparing the use of this concept in four Australian industry contexts: not-for-profit, university, electricity generator and retailer, and water utility service. An analysis of publicly available reports and feedback sessions with industry representatives was conducted to provide a comparison of views on the understanding and application of social licence to operate in these industries. Results from the data collection were then grouped into themes, where each was profiled. Finally, actions and information-sharing activities associated with each theme have been used to develop a SLO framework to guide decision-makers.

All of the participating industry partners used in the case study have net zero targets in place:

- Sydney Water (Scope 1 & 2 by 2030, Scope 3 by 2040).
- AGL net zero by 2050.
- Salvation Army net zero by 2030.
- Monash net zero by 2030.

3.4.2 Findings

The meta-analysis of all four annual reports identified seven key themes associated with SLO. Over the course of conducting the keyword search, it was revealed that some themes which were mentioned in some reports as directly related to SLO, were still collected from other reports who did not explicitly link them to SLO. As shown in Figure 3-3 the seven key themes identified are: customers, communities, relationships, people, environment, infrastructure, and transparency. Each of these themes are defined in Figure 3-4. An interesting finding was that each of these themes were linked to one of two discrete actions: ‘engagement and partnerships’ and ‘communication and information'. These two discrete actions were then used to develop a framework that describes the relationship between an organisation's actions and the perceived granting of a social license.

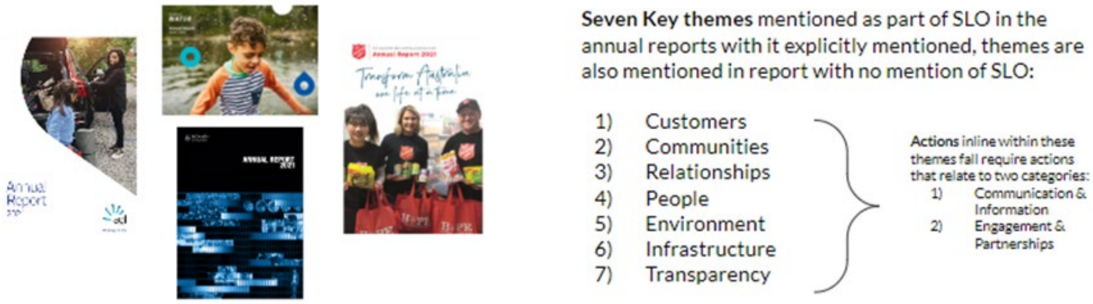

Figure 3-3: Seven key themes identified.

Themes	Definition
Customers	Effective and trusted relationships with all customers.
Communities	Targeted development/strengthening of trust with key communities and interest groups.
Relationships	Broad development/strengthening of working relationships (Government, society and other organisations).
People	Fostering the competencies, experience, behaviours, engagement and wellbeing of the organisations' people.
Environment	Conservation, stewardship, preservation and development of biodiversity and atmosphere.
Infrastructure	Maintaining effective, efficient and responsible use of assets and advancements in technology.
Transparency	External clarity of business practices and decision-making.

Figure 3-4: Key themes defined.

The SLO framework developed here categorises and explains the relationship between the types of actions organisations in the case study have used to develop a social license to navigate pathways to net zero. It may the case that the approach presented in Figure 3-5 could help other organisations overcome many of the challenges associated with decision-making to achieve net zero. It could equally inform micro or site-specific project-based strategies in addition to broader strategies for macro (i.e. national) social license campaigns. Basically, there are two key elements common all to successful social licence interventions by an organisation: 1) engagement and partnerships; and 2) communication and information. Engagement and partnerships refer to the active formation of working groups and roundtables with communities and other interest groups, which may involve investment in community infrastructure and local amenities. Communication and information refer to the transparency of an organisation's activities, in addition to meeting commitments. For example, disclosure of current CO_2-e emissions and a public commitment to net zero by the year 2030. The most successful interventions revealed that both 'engagement and partnerships' and 'communication and information' were deployed at the same time, in fact, this combination was most likely to lead to meaningful change and development of a social license.

Figure 3-5: Social license framework

3.5 Integrating socio-political drivers into the decision support platform

We now outline how the qualitative socio-political information may be integrated into the decision support platform to enhance the outcomes. From the analysis of the case studies, we have compiled a comprehensive list of qualitative themes and corresponding actions. These form a robust framework designed to provide guidance in decision-making processes when considering the qualitative forces. This framework forms the basis for the qualitative component of the decision support platform. Each of the seven themes identified will be ranked in order of importance using surveys of people both within the organisation and external to it. Figure 3-6 shows a choice of the seven themes where respondents will be asked to rank the themes in order of importance to them. In other words, in achieving net zero what themes have the most personal importance to them? For example, are the lowest costs to customers the most important? Or is it greater utilisation of infrastructure, by using the most efficient modern technologies? Or is it the empowerment of communities that live close to a mine that extracts the minerals to create clean technologies? etc. The collective expression of public interest gathered in these surveys is then aggregated and compared to the total activity and resource allocation relevant to these themes as listed in the latest annual report.

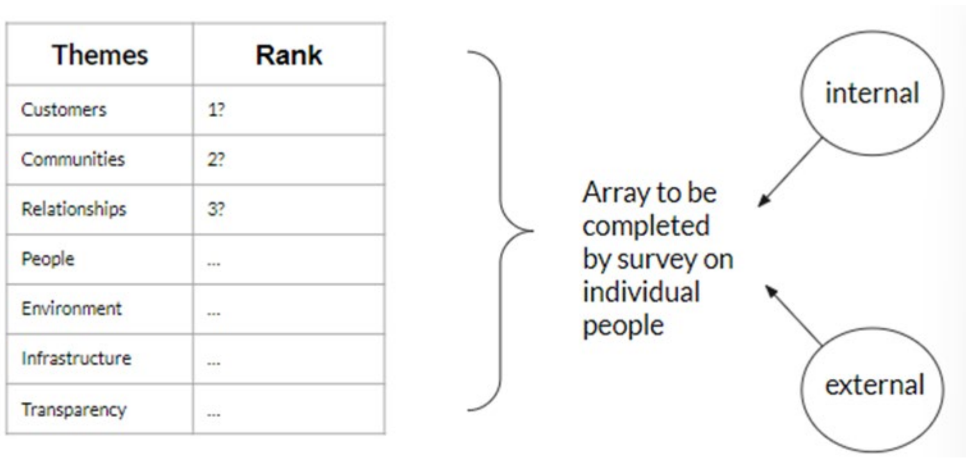

Figure 3-6: SLO survey / inputs for decision engine.

By comparing the aggregate survey inputs with the resource allocation for qualitative themes of net zero, the organisation can understand if its priorities are in the same order as the collective expressions of public interest. Figure 3-7 highlights how the resource allocation against both 'engagement and partnerships' and 'communication and information' can be displayed against the seven themes displayed in order of preference. The ideal scenario would be for the greatest number of activities and resource allocation to match the order for the most important themes identified in the surveys. This approach will reveal both the strengths in existing organisational activities, in addition to opportunities to improve. For instance, if the resource allocation suggests a bias towards organisational transparency but environmental outcomes are identified as the top priority in the survey, the organisation should consider a re-allocation of resources for better environmental outcomes. Alignment between the prioritisation of themes and resource allocation (both engagement and communication) between an organisation and the collective expressions of public interest foster a social licence to operate, reducing the risk profile for the organisation. This presents the optimal pathway to net zero.

Themes	Rank	Level of Engagement	Level of Communication
Customer	#	[Activity, $$$]	[Activity, $$$]
Community	#	[Activity, $$$]	[Activity, $$$]
Relationships	#	[Activity, $$$]	[Activity, $$$]
People	#	[Activity, $$$]	[Activity, $$$]
Environment	#	[Activity, $$$]	[Activity, $$$]
Infrastructure	#	[Activity, $$$]	[Activity, $$$]
Transparency	#	[Activity, $$$]	[Activity, $$$]

Figure 3-7: SLO survey/inputs for decision support platform.

3.6 Concluding remarks

The SLO has become an important decision factor that imposes challenges in integrating the decision making of the net zero emissions strategies. Thematic analysis of annual reports from diverse Australian industry groups revealed seven key themes: customer, community, relationships, people, environment, infrastructure, and transparency, each linked to engagement and communication actions. These themes could be used as categories of inputs (i.e., qualitative information) into the decision support platform. Users will be asked to rank these themes in order of importance.

Our decision support platform uses this ranking to generate organisational strategies to attain/maintain the social license while implementing net zero practices. Our findings indicate that (i) SLO plays a crucial role in motivating industries to increase investments in developing tools for monitoring CO_2-e emissions and exploring various emissions reduction pathways; and (ii) We can quantify socio-political risks related to climate change, enabling their measurement and monitoring as an integral aspect of our decision support platform.

4 Modelling Techno-Economic Drivers in Influencing the Path to Net Zero Emissions

4.1 Introduction

To navigate the challenging path towards net zero emissions successfully, it is imperative to recognize the pivotal role played by techno-economic drivers. These drivers encompass a complex interplay of technological advancements and economic considerations that influence how industries and organisations can reduce their CO_2-e emissions. When it comes to the techno-economic drivers, the path to net-zero emissions is far from one-size-fits-all; rather, it is a highly nuanced endeavor that depends on a multitude of factors.

Whether in energy generation, manufacturing, agriculture, or other sectors, each industry faces a distinct array of challenges and opportunities when aiming to reduce CO_2-e emissions. Moreover, variables such as geographical location, technological resources, and economic feasibility introduce further complexity, demanding a tailored approach.

For example, in the case of a large electricity generator like AGL Energy, the techno-economic drivers revolve around the availability and viability of various renewable energy resources. This may include assessing the feasibility of transitioning from fossil fuels to wind, solar, or hydropower, considering the economic costs and benefits, and evaluating the environmental impact of each option. On the other hand, a seafood producer like the Tassal Group would focus on reducing the carbon footprint of fish feed using modern technology.

Through real-world case studies focusing on AGL Energy, Tassal Group, and Sydney Water, we delve into the complexities involved in modeling techno-economic drivers within a decision support platform. Each case study begins by examining their current CO_2-e emissions and their targets for reducing them. Then, we look at different technological options for reducing emissions, considering their financial implications. Finally, we demonstrate how these techno-economic factors fit into the decision support platform, showcasing the type of analysis they enable.

In our analysis of the first two case studies, we use a scenario-based approach to predict how various strategies might play out by 2050. For the third case study, which involves simpler emissions reduction options, we take a more direct route, sorting the choices based on their financial costs.
Through the analysis of these case studies, we emphasize that an industry-specific perspective is crucial, as different sectors face distinct challenges and opportunities in emissions reduction. Furthermore, we stress the importance of a flexible software-based decision platform to support organisations in achieving their net zero emissions goals. Such a platform serves the dual purpose of helping businesses make optimal decisions while also enabling them to track progress and adapt as circumstances change.

4.2 Case 1: AGL Energy

As the largest electricity generation portfolio in Australia, AGL Energy has an electricity generation capacity of 10330 Megawatts, accounting for approximately 20% of the electricity generation capacity of Australia's National Electricity Market (NEM). It is also the highest CO_2-e emitter of Australia with more than 40 million tonnes of Scope 1 and Scope 2 GHG emissions per year (AGL, 2022).

AGL Energy generates over 40 TWh of energy annually and supplies over 150 PJ of natural gas along with telecommunication and energy-related products and services to residential, businesses, and wholesale customers (AGL, 2022). Figure 4-1 summarises the major assets, facilities, and associated activities of AGL Energy across Australia.

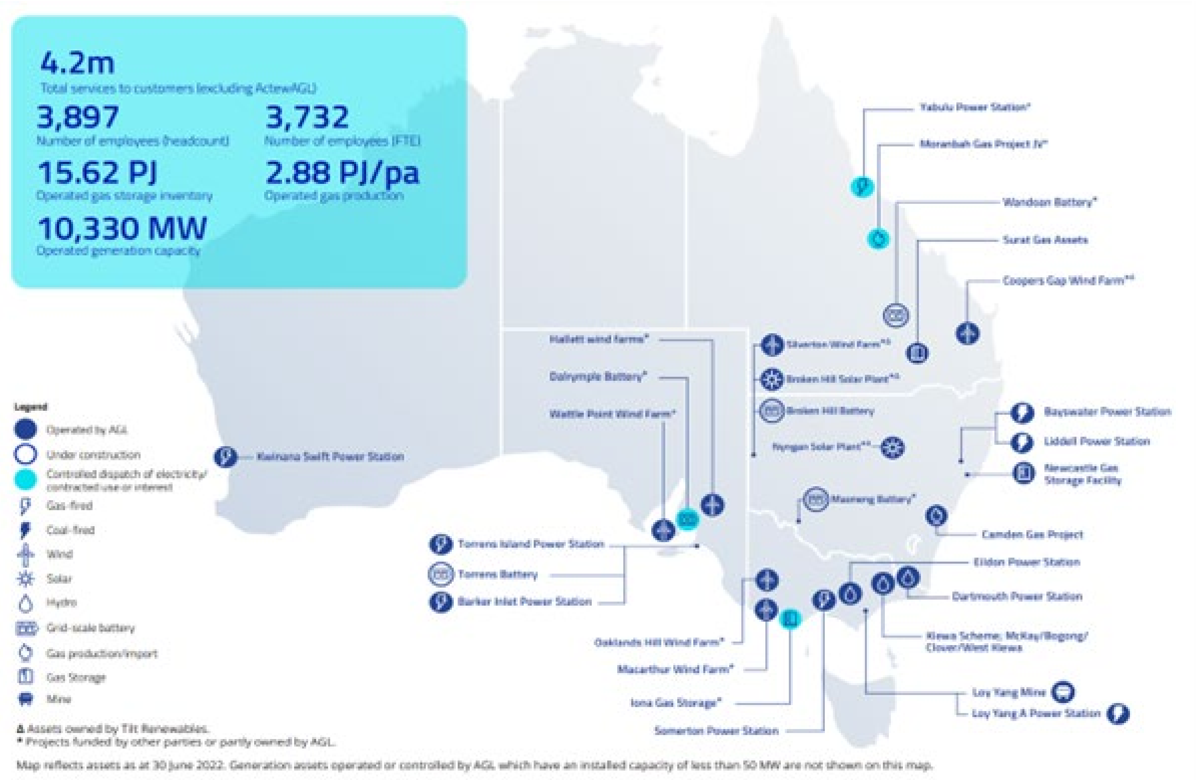

Figure 4-1: AGL Energy's assets, facilities, and associated activities in Australia (source: AGL (2022)).

4.2.1 Assessing Current CO_2-e Emissions and Future Reduction Targets

AGL Energy reported total Scope 1 and Scope 2 emissions of 40.1 million tonnes (Mt) CO_2-e for 2022, down 1.7% from 2021. The total Scope 1 and 2 emissions from the operated facilities of the company between 2017 and 2022 are summarised in Figure 4-2.

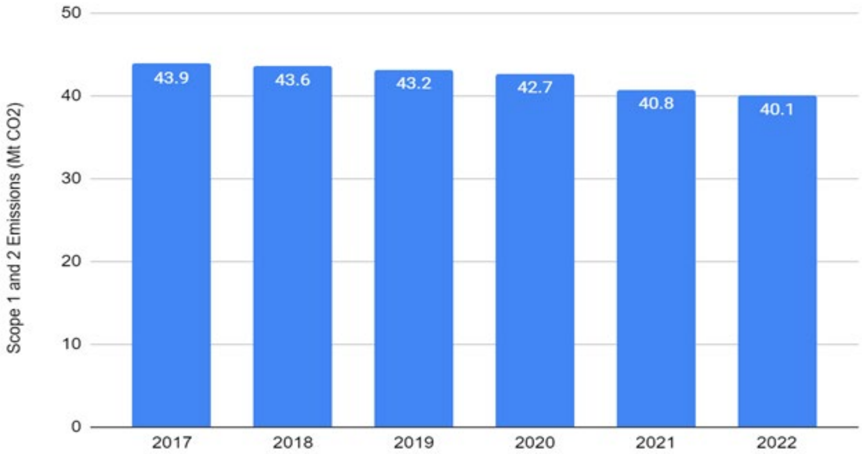

Figure 4-2: Scope 1 and 2 CO_2-e emissions between 2017 and 2022 (data: AGL (2022)).

Following, we explore the breakdown of AGL Energy's CO_2-e emissions into Scope 1, Scope 2, and Scope 3 emissions.

4.2.1.1 Scope 1 Emissions

AGL Energy's primary emissions stem from scope 1 sources, with coal-fired power stations emerging as the predominant contributor, constituting 97% of the company's total scope 1 emissions, as depicted in Figure 4-3.

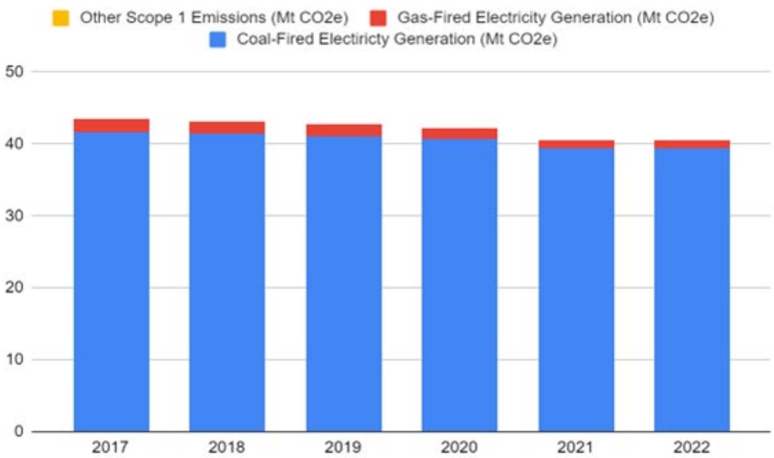

Figure 4-3: Scope 1 CO_2-e emissions between 2017 and 2022 (data: AGL (2022)).

4.2.1.2 Scope 2 Emissions

The annual Scope 2 emissions of AGL Energy have remained close to 0.5 Mt per annum between 2017 and 2021. While this is significantly lower than the Scope 1 emissions of AGL Energy, it is still larger than the total CO_2-e emissions of many medium-sized corporations in Australia (e.g., as we see in subsection 4.3, one of the largest seafood producers of the country, Tassal, emits 0.4 Mt of CO_2-e per annum (Tassal-group, 2021). Figure 4-4 illustrates the annual Scope 2 emissions of AGL Energy between 2017 and 2021.

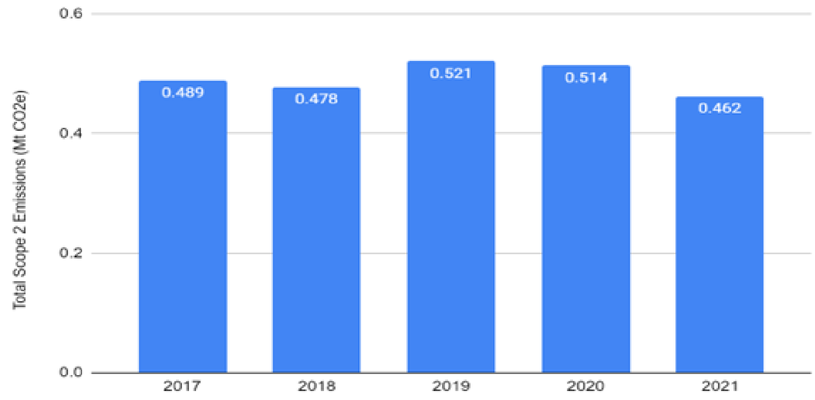

Figure 4-4: Scope 2 emissions between 2017 and 2021 (data: AGL Energy data centre: accessed on 01/08/2022).

4.2.1.3 Scope 3 Emissions

For AGL, Scope 3 emissions are strongly correlated with its Scope 1 and Scope 2 emissions. More than 95% of Scope 3 emissions are related to the supply and end use of the products AGL Energy sells (AGL-Energy, 2021). Figure 4-5 illustrates the annual Scope 3 emissions of AGL Energy between 2017 and 2020.

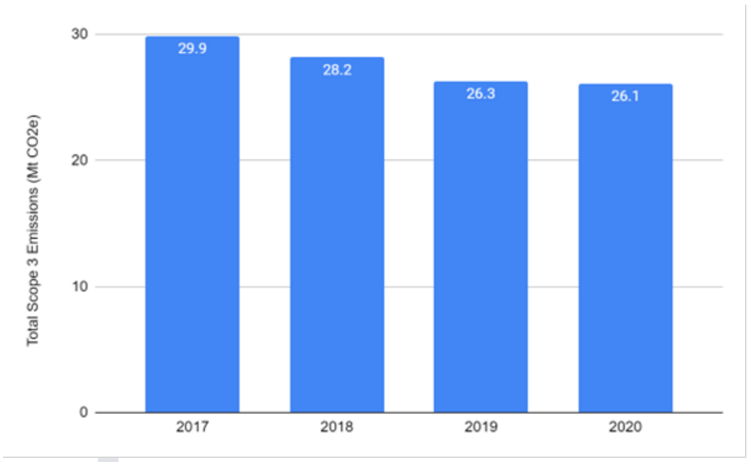

Figure 4-5: Scope 3 emissions between 2017 and 2020 (data: AGL-Energy (2021)).

4.2.1.4 Emissions Reduction Targets

In September 2022, AGL Energy published its Climate Transition Action Plan which describes the company's targets and ambitions to become net zero for operated Scope 1 and Scope 2 emissions by 2035 and net zero for Scope 3 GHG emissions by 2050. The following is a concise summary of AGL Energy's climate-related targets:

- Reducing annual greenhouse gas emissions by at least 17% by FY2024 from FY2019 baseline following the closure of Liddell Power Station in April 2023.
- Targeting the closure of Bayswater and Loy Yang A Power Stations by the end of FY2033 and FY2035, respectively. These targets facilitate an accelerated exit from coal-fired generation and reach net zero for operated Scope 1 and 2 emissions, advancing the timeline by up to a decade compared to the previous announcements.
- Developing a decarbonisation pathway to achieve our ambition of being net zero for Scope 3 greenhouse gas emissions by 2050.

- Seeking to supply the customer demand with ~5 GW of additional renewable and firming capacity by 2030 and increasing this figure to ~12 GW by 2036.

4.2.2 Economic Evaluation of Technological Solutions

AGL Energy faces three main challenges in its path to net zero emissions: shutting down fossil fuel plants, expanding renewable capacity, and increasing electricity storage capacity. Success in all these areas is vital for emissions reduction goals.

To keep our economic evaluation tractable, we need to make assumptions about various parameters. We assume that AGL Energy desires to maintain its current market share of ~20% of total electricity generation of NEM. Additionally, we assume that the NEM demand remains constant at around 190 Terawatt hours (TWh) until 2050. This agrees with the Australian Energy Market Operator's (AEMO's) Central and Progressive Change scenarios (AEMO, 2022a) illustrated in Figure 4-6. While we expect more electrification of the economy in the coming years, the excess demand for electrical energy is predicted to be compensated mainly by decentralised small scale electricity generators such as rooftop photovoltaics (PVs) systems, reductions of transmission loss, and higher energy efficiency of the network.

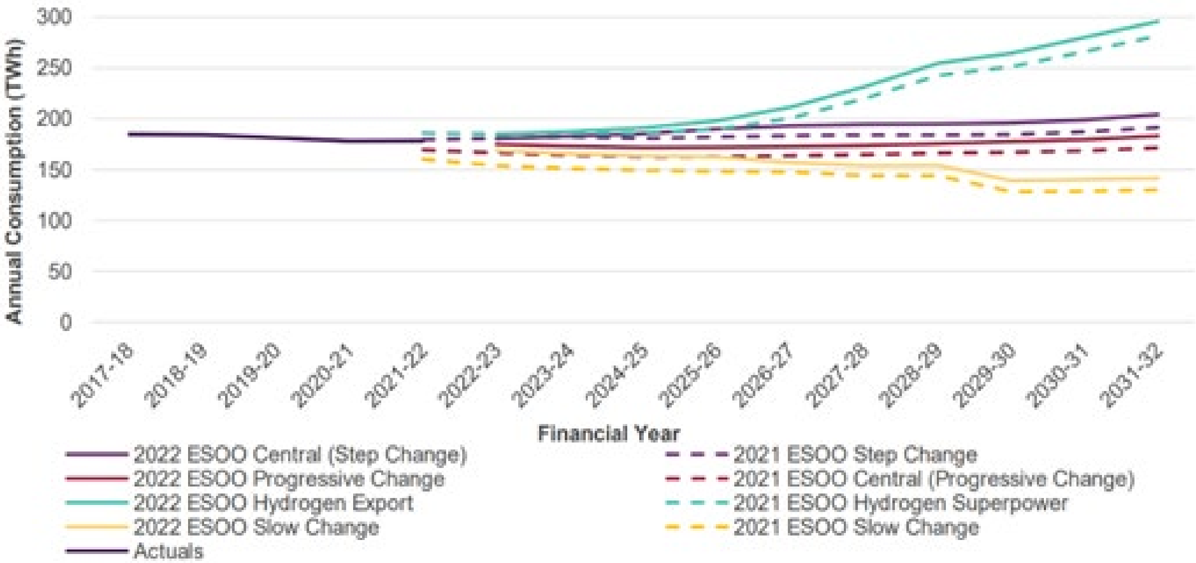

Figure 4-6: NEM demand prediction (Source: AEMO (2022a).

Currently, most of the renewable energy in Australia is generated by wind turbines, large scale solar farms, hydroelectric, and rooftop PVs. Different predictions including AGL Energy's scenario analysis (AGL-Energy, 2020a) expect large scale solar farms and wind turbines each having around half the share of electricity generated by NEM by 2050. Hence, we restrict our option space to a mix of solar, wind, and grid-scale battery storage technologies.

To estimate the cost of constructing solar and wind farms, we employ the financial analysis prepared by CSIRO where the capital expenditure (CAPEX) of generating 1 MW solar energy is estimated at around 1.441 million dollars in 2021 and is expected to reduce over time due to the technological advancements (CSIRO, 2021). AGL Energy needs to invest in constructing grid-level battery storage systems proportional to its renewable energy capacity to ensure network stability particularly during the night hours when solar farms cannot generate electricity. Figure 4-7 shows the predicted CAPEX of solar farms, wind farms, and battery storage systems for the next 30 years (CSIRO, 2021).

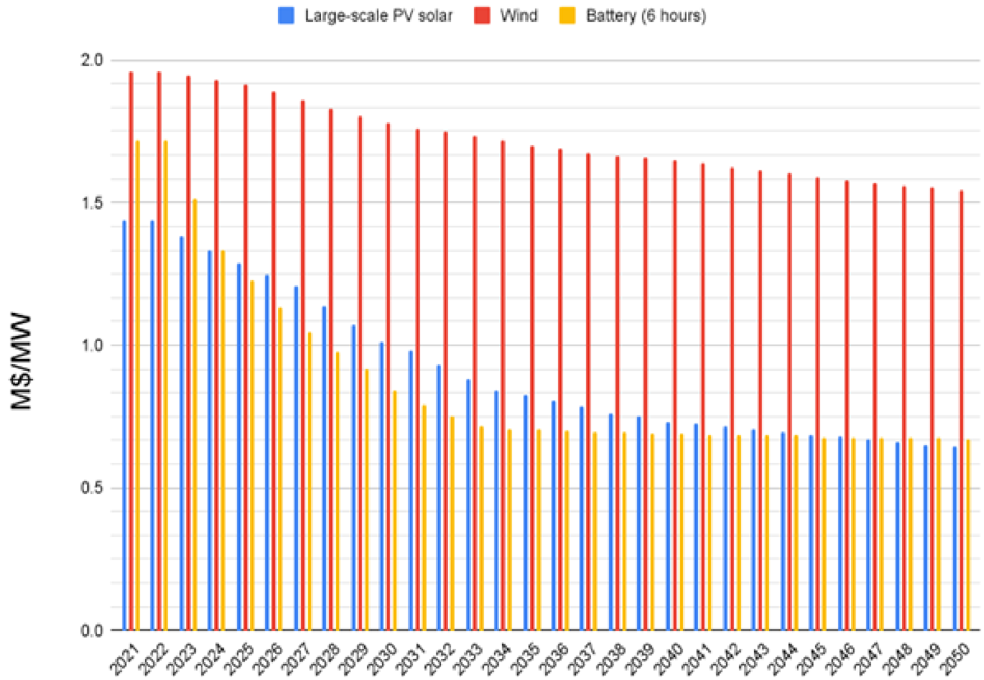

Figure 4-7: Technology expenditure for installing new renewable electricity generation capacity (data: CSIRO (2021))

In a recently published report, AEMO predicts that almost all the renewable energy in NEM will come from utility-scale solar and wind farms where each contributes to half of the total demand (AEMO, 2022b). This is mainly motivated by the need to diversify energy resources and reduce the sensitivity of the network to weather events. Therefore, we assume that solar farms and wind turbines each will account for 50% of the new renewable energy capacity that AGL Energy will install in three stages, each occurring during the closure of one of the coal-fired power station. Additionally, we assume that AGL Energy installs 0.2 MW of battery storage per 1 MW of renewable energy capacity it installs. This is consistent with the analysis conducted by AGL-Energy (2020a).

Considering all these factors, we assume that for each MW of coal-fired electricity generation capacity removed from the network AGL Energy installs 0.5 MW solar PV, 0.5 MW wind turbine, and 0.2 MW battery storage. Depending on the installation time, the expected CAPEX of new renewable capacity for AGL Energy is given in Figure 4-8. In obtaining the expected CAPEX of renewable technologies, we have assumed an economical lifetime of 30, 25, and 15 years for solar PVs, wind turbines, and grid-scale battery systems, respectively.

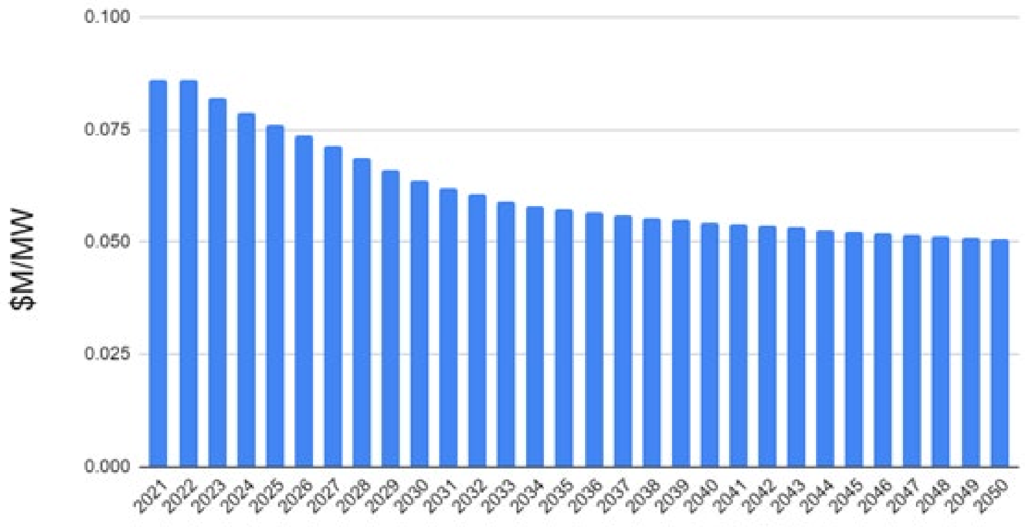

Figure 4-8: CAPEX of renewable electricity generation capacity normalised by technology lifetime (50% solar, 50% wind, backed up by 20% battery for 6 hours).

The closure dates of coal-fired power stations play a crucial role in assessing pathways to achieve net-zero emissions. Figure 4-8 indicates that postponing closure dates could reduce AGL Energy's CAPEX for procuring renewable electricity generation capacity. However, extending the operational life of coal-fired power stations will offset some of these savings, given their substantial operational expenditures (OPEX) driven by coal prices. To compute the OPEX of the coal-fired power plants (Liddell, Bayswater, and Loy Yang A), responsible for nearly 97% of AGL Energy's combined Scope 1 and Scope 2 emissions, we utilise a fixed coal fuel cost of 100 USD per tonne for this analysis based on market forecasts, including reports published by (KPMG, 2022) and (AEMO, 2019).

A more sophisticated analysis, possibly in the next phase of this project, could consider various scenarios depending on the fuel cost predictions. Using these inputs, we estimate the fixed and variable OPEX of coal-fired power plants to be about 53200 $/MW and 4.21 $/MW, respectively. This is in line with the model suggested by Farnoosh (2022), the CSIRO's GenCost 2021-22 report (CSIRO, 2021), and Aurecon's analysis (AEM, 2018). Considering their generation respective capacities and actual energy generation as detailed in Table 4-1, we estimate the annual OPEX of AGL Energy's coal-fired power stations to be around 146.4 M$ for Liddell Power Station, 205.3 M$ for Bayswater Power Station, and 164.5 M$ for Loy Yang A Power Station.

Table 4-1: Estimated annual OPEX of AGL Energy's coal-fired power stations.

Power Station	Generation Capacity (MW)	Annual Energy Generation (TWh)	Annual OPEX (M$)
Liddell	2051	8.85	146.4
Bayswater	2640	15.4	205.3
Loy Yang A	2210	11.15	164.5

4.2.3 Leveraging techno-economic analysis for decision support platform

We explore different pathways that AGL Energy could possibly follow to become a net zero electricity generator. More specifically, we define four alternative scenarios and provide estimations on the financial burden and environmental impacts of each scenario. The scenario analysis presented here is not predictive of what is likely to happen nor is it precisely evaluated against

different uncertainties. This is an indicative high-level analysis based on several restrictive assumptions to demonstrate a first version of the analytical model that we aim to implement as part of the proposed decision support software in the future.
The scenarios considered in this analysis vary in two dimensions: i) the closure data of coal-fired power stations, and ii) the possibility of a government-mandated carbon tariff, a.k.a. carbon price or carbon tax. The carbon pricing mechanism, initially introduced by the Australian government through the Clean Energy Act 2011, compelled the highest carbon emitters to pay taxes for each tonne of CO_2-e emitted into the atmosphere (Australian-Government, 2021). Although the carbon tariff scheme was repealed in 2014, major entities like AGL Energy must still contemplate the prospect of its reinstatement in the future, considering that an increasing number of countries worldwide are adopting similar measures to compel industries to curtail their GHG emissions (Bray, 2022; Government-of-Canada, 2020). Even if the Australian government does not enforce direct carbon taxes, indirect socioeconomic factors such as carbon restrictions on the electricity generation sector, heightened governmental taxes on fossil fuels, or potential legislation mandating high emitters to install carbon capture systems could impose an implicit financial burden similar to the impact of potential future carbon tariffs on AGL Energy.

4.2.3.1 Scenario definition

Following, we define the four scenarios that we employ in our analysis:

- Scenario 1: Early Closure

In Scenario 1, we assume that AGL Energy shuts down its major GHG emitter facilities on the earliest dates that the company has anticipated following 2021 annual report, i.e.,

- Liddell Power Station closure date: in 2023.
- Bayswater Power Station closure date: in 2030.
- Loy Yang A Power Station closure date: in 2035.

Moreover, we assume that the company compensates for the electricity generation capacity of each carbon-fired power station, with solar and wind farms integrated with battery storage systems. We calculate the cost of constructing the solar farms and battery storage systems on the date that the respective power plant is going to be closed. In this scenario, we assume that the Australian governments will not impose any new direct or indirect carbon tariffs.

- Scenario 2: Early Closure + Carbon Price

Scenario 2 is the same as Scenario 1 with the only difference being that in this scenario, we assume a financial cost of $50 per each tonne of CO_2-e emissions starting from 2030 onward.

- Scenario 3: Late Closure

In Scenario 3, we assume that AGL Energy shuts down its major coal-fired power stations on the latest dates that the company has anticipated in its 2021 annual report, i.e.,

- Liddell Power Station closure date: in 2024.
- Bayswater Power Station closure date: in 2033.
- Loy Yang A Power Station closure date: in 2045.

Other assumptions are like Scenario 1, therefore, in this scenario the government will not impose any new direct or indirect carbon tariffs.

- Scenario 4: Late Closure + Carbon Price

Scenario 4 is the same as Scenario 3 with the only difference being that in this scenario, we assume a financial cost of $50 per each tonne of CO_2-e emissions starting from 2030 onward.

4.2.3.2 Findings

Figure 4-9 illustrates our system model as well as the relationships between different assumptions that we use in our analysis.

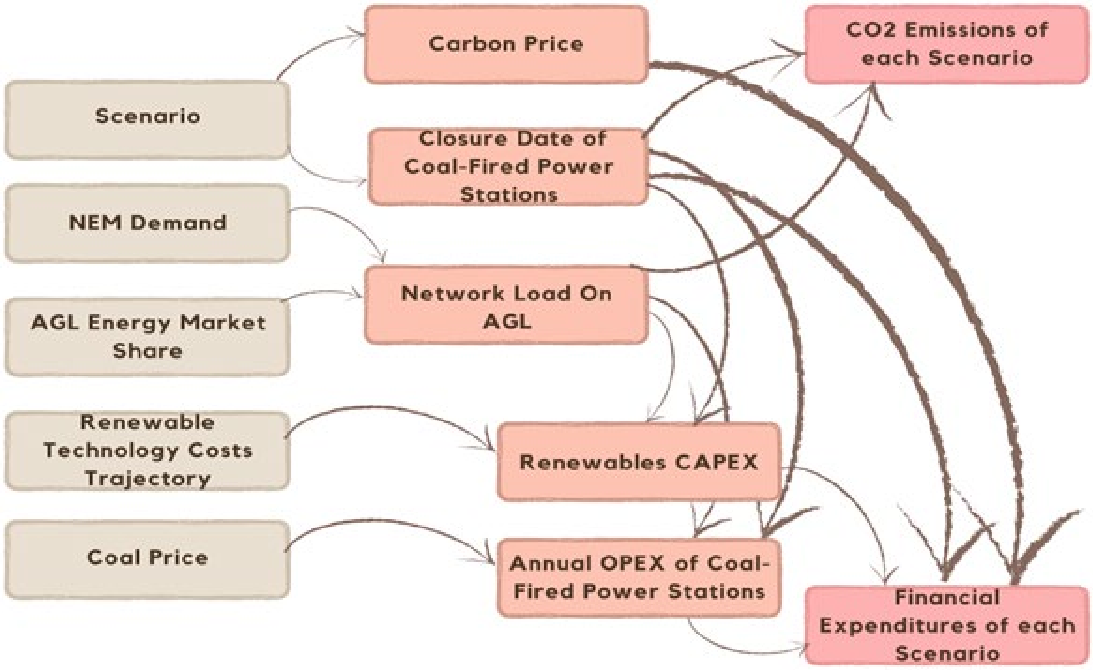

Figure 4-9: The system model employed in our analysis.

Employing this system model and utilising the economic assessment of technological solution, we estimate the cumulative expenditure to be 15.5 billion dollars, 21.4 billion dollars, 15.4 billion dollars, 28.4 billion dollars by 2050 for Scenario 1, 2, 3, and 4, respectively. Figure 4-10 illustrates the cumulative expenditures over time for each scenario.

Figure 4-10: The estimated cumulative expenditures for each scenario.

It is worth highlighting that the cumulative expenditures for Scenario 1 and Scenario 3 are very close. In other words, assuming zero carbon price, bringing the closure date of coal-fired power stations forward doesn't result in additional expenses. Under the late closure scenario, Scenario 3, the cumulative cost of migration to renewable energies is expected to increase by 2.5 billion dollars, however, this amount will be fully offset by the savings obtained from reducing the OPEX of coal-fired power stations.

Compared with Scenario 1 and Scenario 3, Scenario 2 and Scenario 4 will incur an extra 5.9 billion dollars and 13 billion dollars in total expenditures due to the carbon price assumption, respectively. Furthermore, the total expenditures due to technology migrations for Scenario 3 and Scenario 4 are generally lower than their respective early closure scenarios. This is because, as the company continues operating its coal-fired power stations, it can postpone the purchase date of renewable energy equipment to a later date. This is likely to reduce the total expenditures in general since the cost of renewable technology equipment is expected to reduce over time due to the technology advancements. Figure 4-11 compares the estimated costs of migration to renewables under early and late closure scenarios.

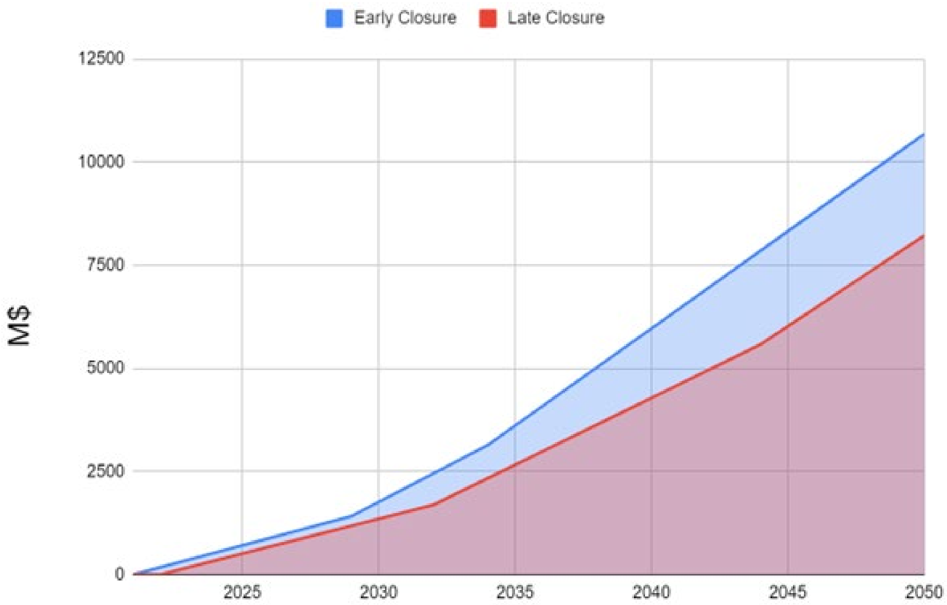

Figure 4-11: The estimated cumulative expenditures on renewable technology installation.

However, when we consider the possibility of future carbon tariffs, the late closure of coal-fired power stations may result in significantly higher expenditures even though the technology migration costs may be reduced. Our analysis shows that a late closure of coal-fired power stations may result in a 12% increase in total expenditures, or 7 billion dollars extra by 2050, if there is a $50 carbon price per tonne of CO_2-e emissions.

Looking into the environmental aspects of the four considered scenarios, illustrated in Figure 4-12, we realise that early closure of coal-fired power stations could result in a 180 Mt reduction in CO_2-e emissions when compared to the late closure scenarios. This is a significant difference that is roughly equal to 37% of Australia's total emissions in 2022. Therefore, the late closure of coal-fired power plants is likely to bring a huge socio-economic burden on AGL Energy, possibly resulting in direct financial losses.

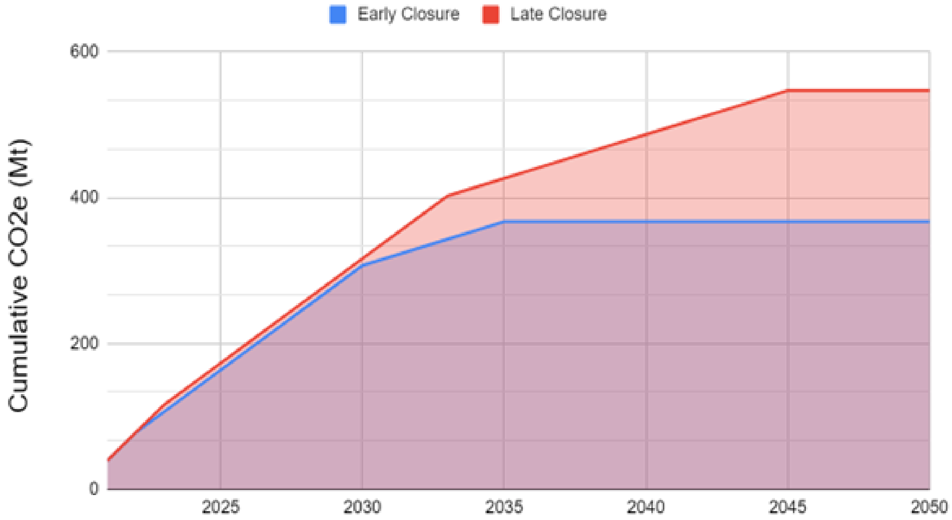

Figure 4-12: The estimated cumulative CO_2-e emissions.

4.3 Case 2: Tassal group

In this section, we will study the CO_2-e emissions of Tasmanian based Tassal Group, the largest Australian producer of Atlantic salmon. Tassal owns several production facilities including three directly controlled salmon hatcheries, four diverse marine farming zones, and five processing facilities. Moreover, the Tassal group provides distribution, wholesale, export, and retail activities. Figure 4-13 depicts facilities of the company across Australia.

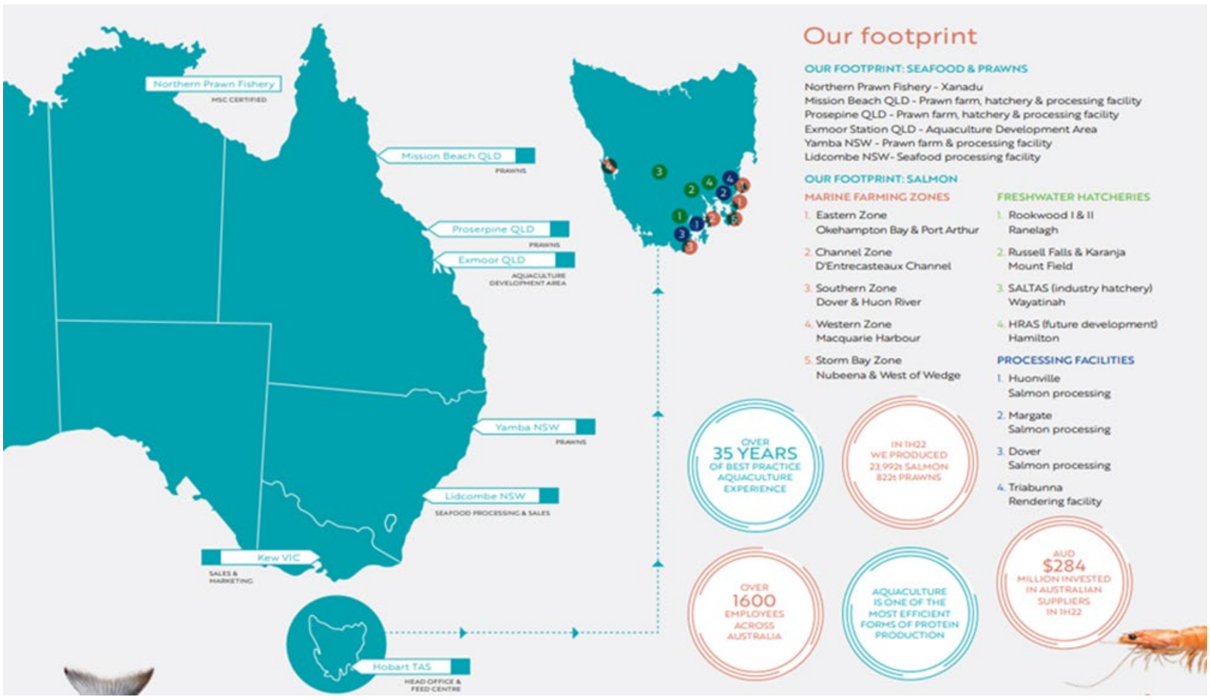

Figure 4-13: Facilities (source: Sustainability highlights, Tassal, 2022).

Salmon farming accounts for most of the operations. However, Tassal started prawn farming since 2018 (Tassal-group, 2019). Figure 4-14 illustrates the total amount of harvested salmon and prawn between 2017 and 2021.

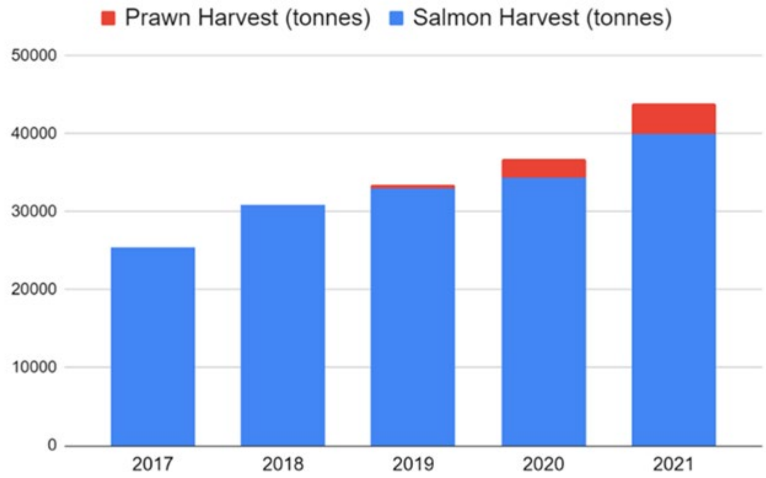

Figure 4-14: Harvested salmon and prawn (data source: Annual report, Tassal, 2022).

4.3.1 Assessing current CO_2-e emissions and future reduction targets

The electricity consumed in fish feed production is the largest source of CO_2-e emissions in aquaculture. The combustion of fossil fuels including diesel and petrol consumed in feed barges, vessels, and transportation (trucks, ships, and airplanes) is another major source of CO_2-e emissions in salmon farming. Some CO_2-e emissions also occurs due to activities in hatcheries, as well as the operation of processing and distribution facilities. Figure 4-15 illustrates different activities related to salmon farming and their respective CO_2-e emissions.

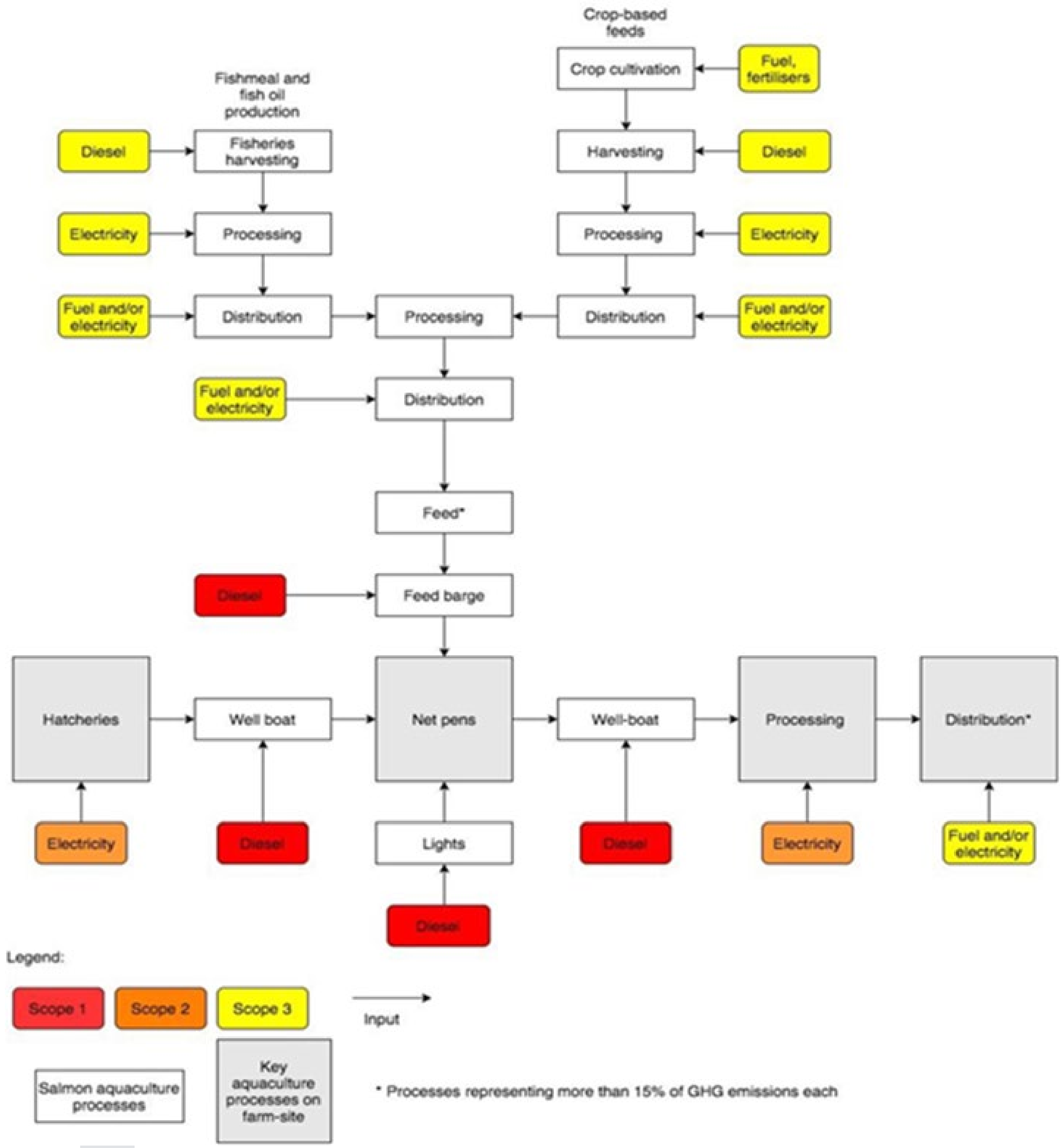

Figure 4-15: CO_2-e emissions in salmon farming (source: Hammer, Alienor Jue, Charles Millar, and Sebastian John Hennige. "Reducing carbon emissions in aquaculture: Using Carbon Disclosures to identify unbalanced mitigation strategies." Environmental Impact Assessment.

4.3.1.1 Scope 1 emissions

Tassal's Scope 1 emissions are mostly due to the combustion of diesel used in operating feed barges, vessels, and boats as well as lighting net pens. During the past 4 years, total Scope 1 emissions of Tassal have increased. This is due to the expansion of the business and the growth in total biomass controlled by Tassal. Figure 4-16 shows Scope 1 emissions of Tassal between 2018 and 2021.

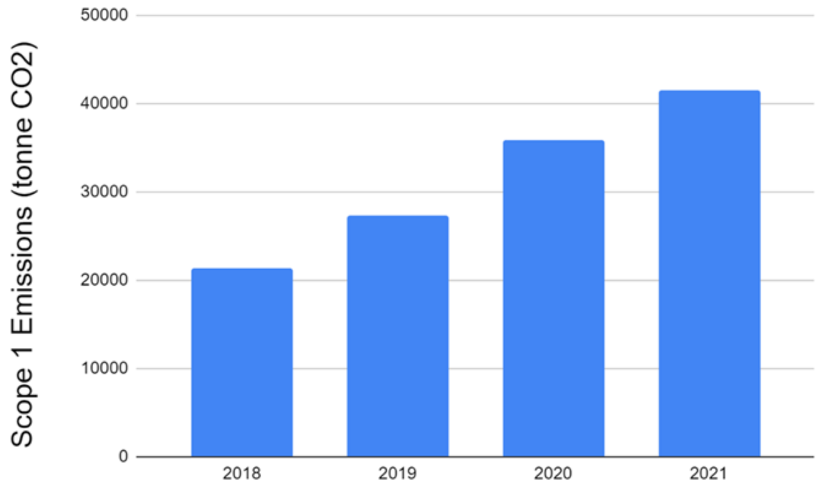

Figure 4:16: Scope 1 emissions (data source: Sustainability report, Tassal, 2022).

4.3.1.2 Scope 2 emissions

Tassal's Scope 2 emissions are mostly due to the consumption of electricity used for operating hatcheries and the processing facilities. During the past 4 years, total Scope 2 emissions have increased, primarily due to the expansion of the business and the growth in total biomass controlled by Tassal. Figure 4:17 presents Scope 2 emissions.

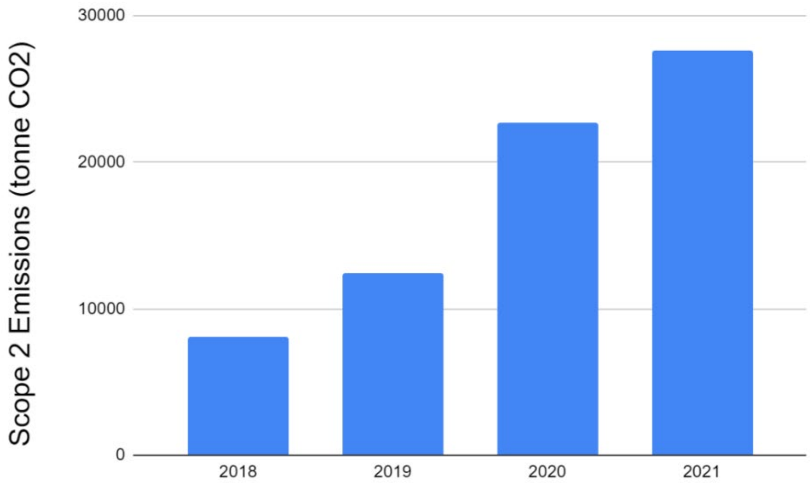

Figure 4:17: Scope 2 emissions (data source: Sustainability report, Tassal Group, 2022).

4.3.1.3 Scope 3 emissions

Tassal has not disclosed its Scope 3 emissions since 2017. However, an estimate by Blueshift Consulting, as outlined in a report for the Fisheries Research and Development Corporation, suggests CO_2-e emissions of approximately 8.5 kg/kg for farmed salmon and 15.2 kg/kg for farmed prawn (Boyer, 2022). Using these emissions factors and applying them to Tassal's total salmon and prawn production allows for an estimation of the company's annual emissions. By subtracting reported total Scope 1 and 2 emissions, we can derive an estimate for the total Scope 3 emissions, as illustrated in Figure 4-18.

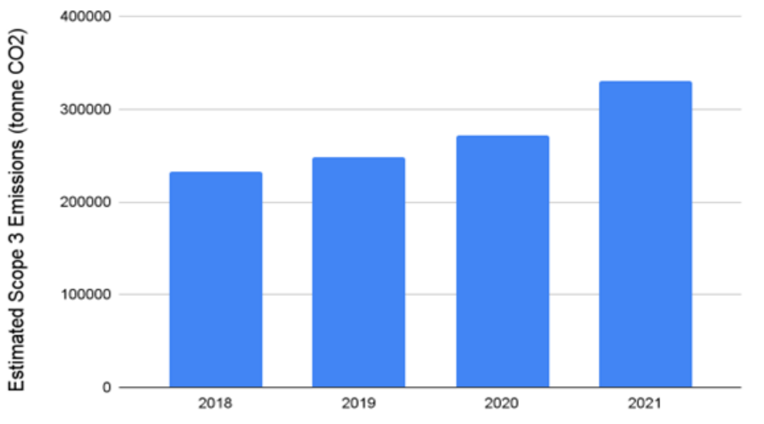

Figure 4-18: Estimated Scope 3 emissions.

4.3.1.4 Emissions reduction targets

In its latest sustainability report published in 2021, Tassal has set the following targets (Tassal-group, 2021):

- Aspiring to become net zero by 2050.
- Planning to assess science-based datasets to set a climate roadmap to 2030.
- Establish a flagship carbon-neutral farm program - one salmon farm and one prawn farm.
- Spend $60 million over three years on initiatives and R&D to reduce the impact of climate change on Tassal's operations.

4.3.2 Economic evaluation of technology

To pinpoint technological solutions for reducing CO_2-e emissions, it is crucial to identify the primary sources of these emissions. Research shows that between 75% and 83% of the CO_2-e emissions of salmon farming is due to the consumption of fish feed (Winther, Hognes, Jafarzadeh, & Ziegler, 2020). The total amount of fish feed consumed by Tassal can be estimated by multiplying the reported economic Feed Conversion Ratio (eFCR) by the annual production of salmon and prawns. This resulting figure, when multiplied by the CO_2-e emissions coefficient of 1 kg of feed, provides an estimation of the total emissions stemming from fish feed consumption. Figure 4-19 illustrates total CO_2-e emissions due to fish feed for three consecutive years.

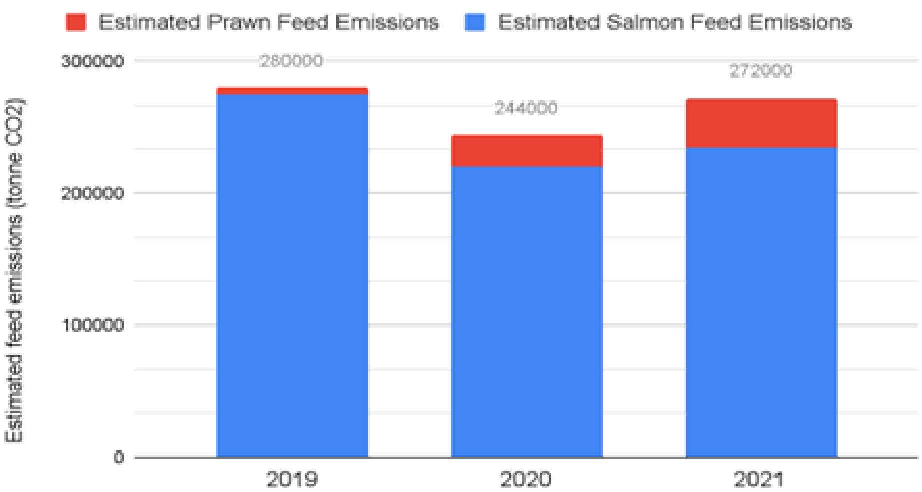

Figure 4-19: Estimated emissions due to the purchase of fish feed.

The reduction in feed emissions from 280000 tonnes in 2019 to 199000 tonnes in 2020 is driven by the reduction in per kg emission factor of the fish feed used, as well as improvements to the eFCR. While a reduction to the feed emissions factor continues in 2021, the growth of harvested biomass increased the total feed consumption of the company, in turn increasing total emissions.
According to Tassal Group's sustainability report, in 2019, Tassal achieved a 12% reduction in the emission factor of the fish feed compared to the previous year, followed by an additional 10% reduction in 2020. Fish feed producers such as Skretting already adopted new technologies than enable production of fish feed without using fishmeal or fish-oil (Skreeting, 2022). These new technologies can drastically reduce the emission factor of fish feed in upcoming years.

Despite fish feed consumption, key contributors to CO_2-e emissions in salmon aquaculture include electricity usage in production and processing facilities, combustion of diesel for marine operations, and emissions linked to transportation for product distribution nationally and internationally.

In Tassal's case, electricity consumption has a minimal impact on CO_2-e emissions as nearly 100% of the electricity generated in Tasmania is derived from renewable sources.

To mitigate CO_2-e emissions associated with transportation for local market distribution, Tassal can consider adopting electric trucks gradually. A recent study suggests that zero-emissions electric trucks will become the most cost-effective transportation option from 2030 (Tol, Frateur, Verbeek, Riemersma, & Mulder, 2022). Hence, gradual implementation of this solution after 2030 should not result in additional costs for Tassal Group.
Tassal currently exports around 20% of its products, and while emissions data for international exports is undisclosed, studies suggest that salmon export can lead to significant CO_2-e emissions, especially with airfreight. Despite potential pricing advantages in international markets, the socio-economic impacts of climate change could lead to expenses for exported products. Consequently, future financial incentives may increasingly prioritise local markets. With Australia importing 60% of its seafood, focusing solely on the local market seems to be a practical option without significant additional expenses.

Therefore, Tassal Group's primary technological strategies to diminish CO_2-e emissions include:

- Obtaining low-emissions fish feed products developed through new technologies.
- Phasing in electric trucks to replace diesel trucks gradually.
- Concentrating efforts on the local market.

While the first option may entail additional expenses, a preliminary analysis indicates that implementing the second and third options can be done without significant additional costs.

4.3.3 Leveraging techno-economic analysis for decision support platform

To assess the influence of techno-economic factors on Tassal Group's efforts to reduce CO_2-e emissions, four alternative scenarios are considered in this analysis. These scenarios differ in two dimensions: i) whether the company pursues quick climate change response or maintains its usual operations, and ii) the potential imposition of a government-mandated carbon tariff, also known as a carbon price or carbon tax. This is an indicative high-level analysis based on several restrictive assumptions to demonstrate a first version of the analytical model that we aim to implement as part of the proposed decision support software in the future.

Unlike the AGL Energy case, estimating the costs of a quick response approach for Tassal is challenging. This is primarily because the swift response involves the consumption of low-emissions fish feed products, a technology still in its early stages. Consequently, determining the additional cost for Tassal Group to acquire this new product remains uncertain. Hence, our objective is to evaluate the economic viability of the added cost associated with implementing a quick response scenario for low-emissions fish feed.

4.3.3.1 Scenario definition

Next, we outline four scenarios that are examined in our analysis.

- Scenario 1: Business as usual, no carbon price
  - Tassal maintains the current level of salmon production using the same feeding, transportation, and processing technologies over the next 30 years.

- Scenario 2: Business as usual + carbon price
  - Tassal maintains the current level of salmon production using the same feeding, transportation, and processing technology over the next 30 years.
  - Government imposes a $50 per tonne of CO_2-e emissions carbon price starting from 2030.

- Scenario 3: Quick response, no carbon price
  - Tassal maintains the current level of salmon production.
  - Tassal uses more environmentally friendly fish feed from 2023, reducing the emission factor of 1kg feed by 5% each year.
  - Tassal gradually employs electrical trucks, mainly targets local markets, and delivers all its exports through sea freight instead of air freight by 2030, reducing total emissions due to activities other than fish feed consumption by 50% from 2021 levels.

Scenario 4: Quick response + carbon price
  - Tassal maintains the current level of salmon production.
  - Tassal uses more sustainable fish feed from 2023, reducing the emission factor of 1kg feed by 5% each year.
  - Tassal gradually employs electrical trucks, mainly targets local markets, and delivers all its exports through sea freight instead of air freight by 2030, reducing total emissions due to activities other than fish feed consumption by 50% from 2021 levels.
  - Government imposes a $50 per tonne of CO_2-e emissions carbon price starting from 2030.

4.3.3.2 Findings

Using current emissions data and the projections made, we first assess the carbon price associated with each scenario. As can be seen in Figure 4-20, assuming a constant carbon price of $50 per tonne of CO_2-e emissions, the quick response modelled in Scenario 4 would incur a financial cost of $190 million over 20 years. This figure could be as high as $420 million for Scenario 2. The difference between these two numbers provides the value that Tassal Group could allocate to procuring low-emissions fish feed without incurring additional expenses, under the assumption of a $50 per tonne of CO_2-e emissions carbon price. In other words, the higher the carbon price is, the stronger the financial incentive would be for Tassal Group to invest in procuring more expensive low-emissions fish feed.

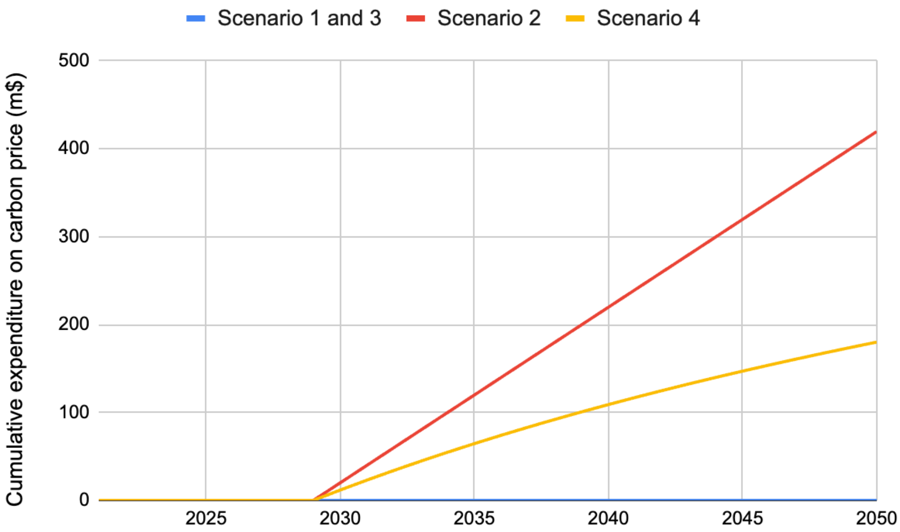

Figure 4-20: Comparison of total expenditures by 2050 across the considered scenarios.

Figure 4-21 demonstrates the trade-off between financial viability of low-emissions fish feed and the carbon price under two scenarios: i) 5% reduction in eFCR per annum, and ii) 10% reduction in eFCR per annum.

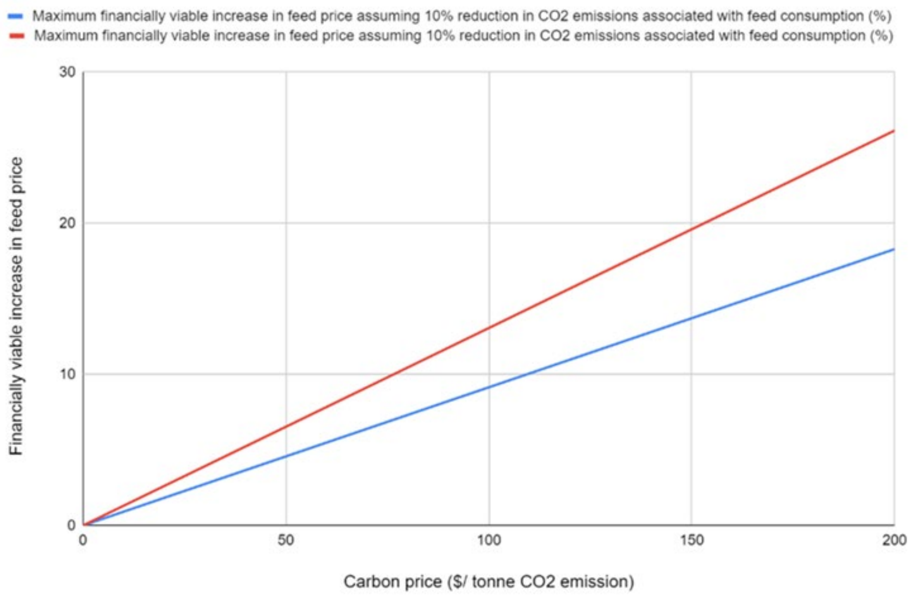

Figure 4-21: Trade-off between financial viability of low-emissions fish feed and the carbon price.

Finally, Figure 4-22 compares the four scenarios introduced above in terms of their cumulative CO_2-e emissions until 2050.

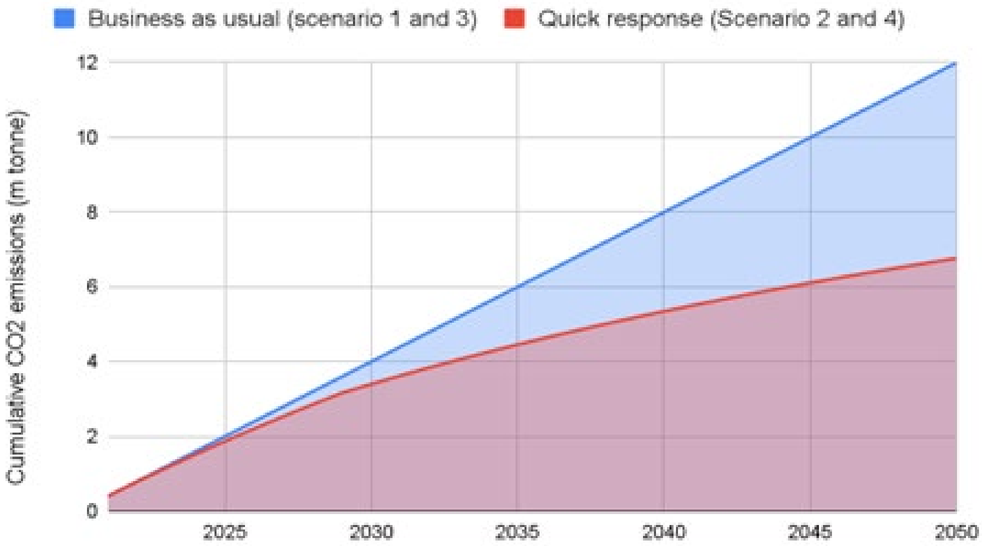

Figure 4-22: Comparison between future scenarios in terms of their total CO_2-e emissions by 2050.

A 5% reduction in CO_2-e emissions from fish feed consumption combined with a 50% reduction in CO_2-e emissions from transportation from 2030 (Scenario 2 and Scenario 4) would reduce cumulative CO_2-e emissions of Tassal Group by an estimated 44% by 2050.

4.4 Case 3: Sydney water

Sydney Water Corporation is a fully government-owned corporation responsible for supplying water, wastewater, recycled water, and stormwater services in New South Wales. As illustrated in Figure 4-23, most CO_2-e emissions associated with the activities resulted from the consumption of grid-sourced electricity (84%), followed by fugitive emissions (10.9%) and emissions from stationary fuel (14.4%).

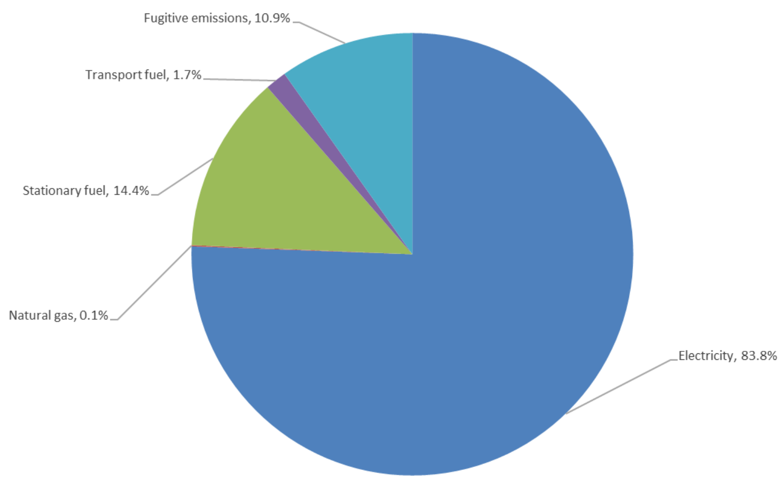

Figure 4-23: GHG emissions sources in 2020-21, Sydney Water.

4.4.1 Assessing current CO_2-e emissions and future reduction targets

Electrical energy consumption has consistently held the position of being the Sydney Water's primary source of CO_2-e emissions, as illustrated in Figure 4-24. Therefore, Sydney Water should give foremost priority to the reduction of its Scope 2 emissions due to the consumption of non-renewable electricity.

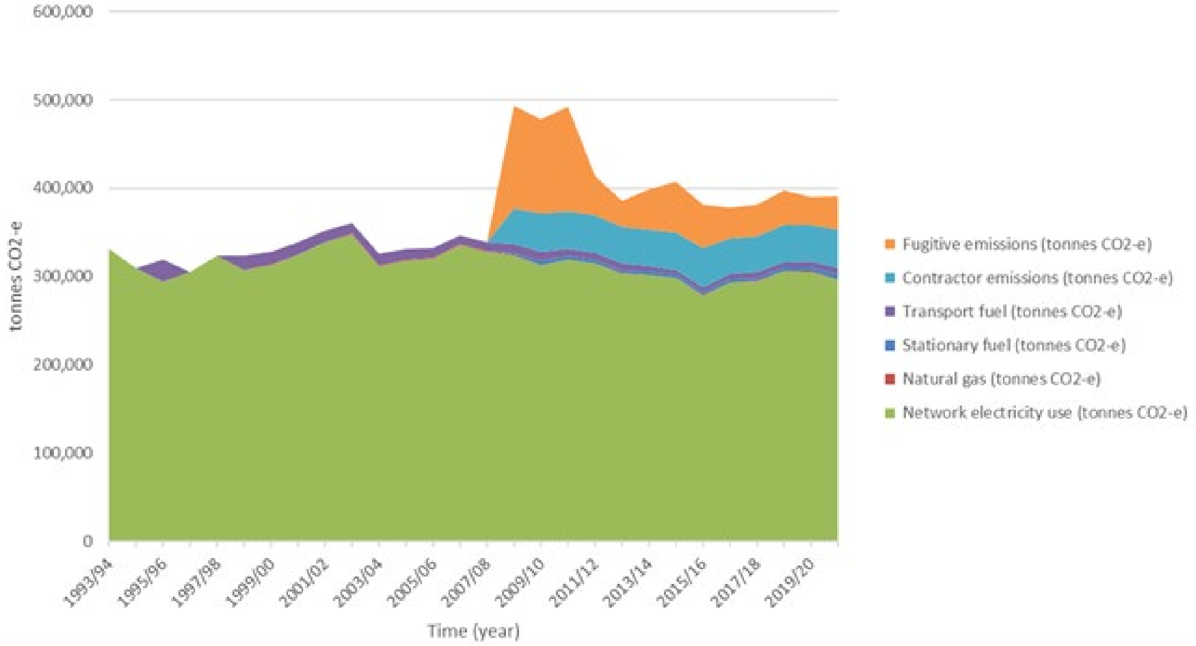

Figure 4-24: GHG emissions Sources from 1993-94 to 2020-21, Sydney Water.

Next, we discuss the Scope 1, 2, and 3 emissions of the company.

4.4.1.1 Scope 1 emissions

The emissions for Sydney Water from Scope 1 contain different types of fuels that are used for stationary, transport, and industrial activities requiring natural gas and biofuels. Stationary fuels include diesel and LPG used for machines and different equipment inside the Sydney Water stations and properties. ULP, diesel, and ULP E10 are used to fuel high-duty and light vehicles. Figure 4-25 provides information on the annual fuel consumption for the mentioned activities which contribute to emissions Scope 1.

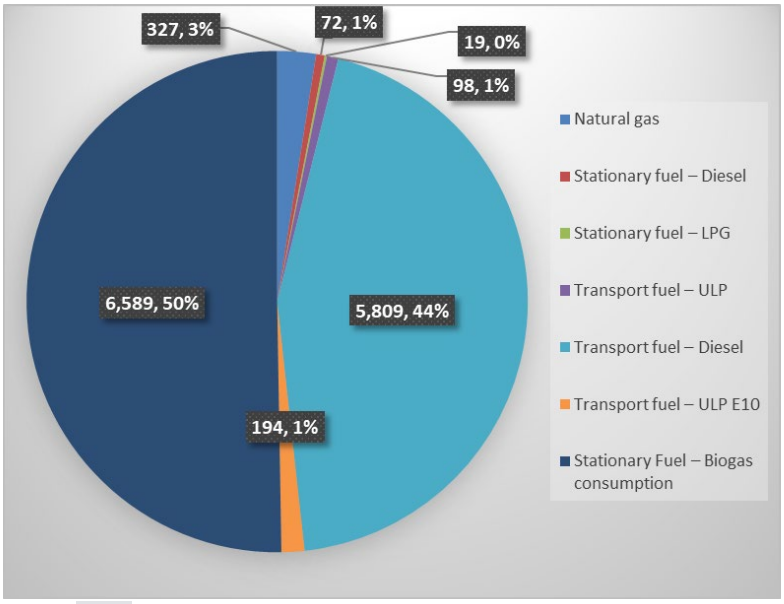

Figure 4-25: Sources of Scope 1 emissions in 2020-21.

4.4.1.2 Scope 2 emissions

The largest share of emissions comes from Sydney Water’s electricity consumption, resulting from supplying their demand from the electricity grid. the total electricity demand of Sydney Water is satisfied in three different ways, including purchasing renewable electricity (a.k.a. green power), on-site renewable electricity production, and purchasing electricity from the grid (i.e., fossil fuel power). Sydney Water has consumed electricity for four main purposes: 1) wastewater services, 2) water services, 3) water recycling, and 4) onsite buildings. Wastewater and water processes are the largest consumers of electricity. As illustrated in Figure 4-26, the total electricity consumption increased by 11.2% from 1993 to 2021. This increase is due to the significant rise in the electricity consumption of wastewater and water processes, which results from population growth and the increasing need for water and wastewater activities.

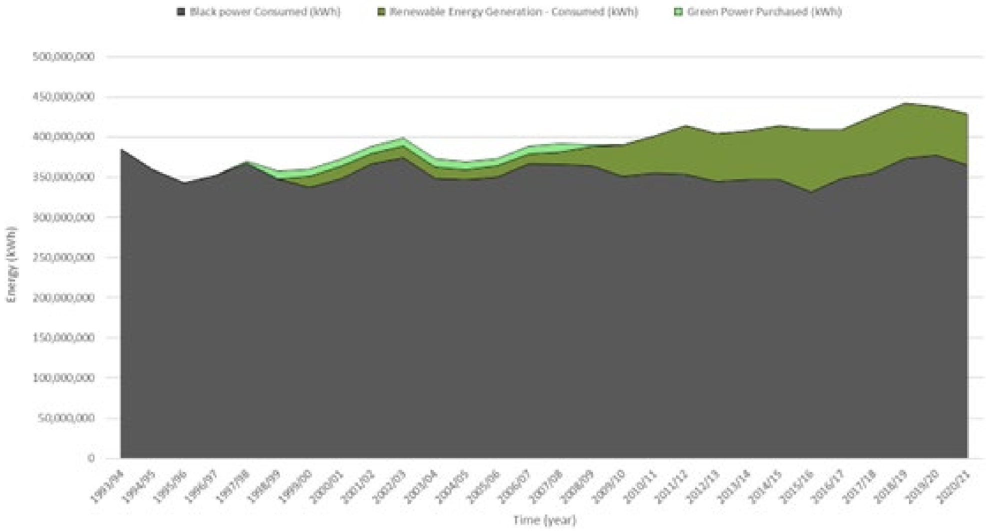

Figure 4-26: Sydney Water’s electricity use by source from 1993-94 to 2020-21.

4.4.1.3 Scope 3 emissions

Scope 3 emissions contribute to 19% of Sydney Water's total emissions. These emissions arise from contractors' electricity consumption and the operation of machinery, equipment, and vehicles fuelled by various sources, including diesel, ULP, gasoline, and LPG. While the Sydney Water’s data provided in Appendix B.3 shows the annual fuel consumption of contractors, it lacks information regarding the electricity usage by contractors that contributes to emissions.

4.4.1.4 Emissions reduction targets

Sydney Water's current CO_2-e emissions reduction targets are:

- Net zero for Scope 1 and 2 by 2030.
- Net zero for Scope 3 by 2040.

It is important to acknowledge that these targets, although commendable, are currently at an aspirational stage.

4.4.2 Economic evaluation of technological solutions

Given that electricity consumption is the primary contributor to most of Sydney Water's greenhouse gas (GHG) emissions, renewable energy sources naturally emerge as the primary technological solutions.

A tentative economic evaluation needs to be performed to rank different renewable energy technologies incorporating factors such as current electricity consumption, the expected consumption growth rate, and the lifecycle of each renewable technology.

Based on the current electricity consumption by Sydney Water, a growth rate of 0.4% is being annually realised. Accordingly, the system capacity of the investigated potential technologies has been determined to offset the non-renewable electricity consumption. Table 4-2 illustrates the obtained capacity for each technology and relevant technical parameters. The technical parameters are collected from the 2021 Costs and Technical Parameter Review published in 2022 by Aurecon (2021).

Table 4-2. Renewable energy technologies' system capacities, life services, and annual degradation factors.

No.	System Alternative	System capacity (kW)	Service life (Years)	Annual degradation factor (%)
1	PV with backup batteries	340,471	25	-
1.1	PV system	340,471	25	0.05
1.2	Storage battery – 8 hours	7,517,607.80*	20	2
2	Hydropower – 24 hours storage	56,227	50	0.01
3	Hydrogen reciprocating generator with imported hydrogen	50,633	25	0
4	Hydrogen reciprocating generator with alkaline electrolyser	50,633	25	-
4.1	Hydrogen reciprocating generator	50,633	25	0
4.2	Alkaline electrolyser	50,633	10	1
5	Hydrogen reciprocating generator with PEM electrolyser	50,633	25	-
5.1	Hydrogen reciprocating generator	50,633	25	0
5.2	PEM electrolyser	50,633	10	1
6	Fuel cell with imported hydrogen	71,313	8	5
7	Fuel cell with alkaline electrolyser	71,313	8	-
7.1	Fuel cell	71,313	8	5
7.2	Alkaline electrolyser	71,313	10	1
8	Fuel cell with PEM electrolyser	71,313	8	-
8.1	Fuel cell	71,313	8	5
8.2	PEM electrolyser	71,313	10	1
9	CSP – 12 hours storage	58,230	40	0.2
10	Biogas	51,653	30	0

*Electrical storage battery system capacity in kWh.

Measuring the economic performance of a renewable energy technology is intricately sensitive to input data and economic factors such as the discount rate, inflation rates, energy escalation rates, initial investment cost, annual maintenance and operating cost, and future replacement cost.

The following financial factors are assumed in this analysis:

- Real discount rate - 5%.
- General average annual inflation rate - 4.9%.

- Inflation adjusted discount rate for energy - 10.145%.
- Expected electricity escalation rate per year – 5.4%.

A real discount rate should be determined to discount future costs and revenues; it should be enough to reflect the financial costs of the investment. Since real data is not available at this stage, 5% is assumed as a discount factor for Sydney Water. This discount factor has been adjusted to reflect a historical general inflation rate of 4.9% calculated from historical data available in the Australian Bureau of Statistics. This percentage has been evaluated to be large enough to cover probable future inflation scenarios, and hence, the discount rate has been adjusted to be 10.145%. Similarly, the Australian Energy Council reports an electricity price index of 125.7 in 2021 compared to 63.1 in 2007-08. This change yields 5.44% as an average annual electricity price escalation rate for the same period (IRENA, 2022).

The GenCost 2021-22 report published by the Commonwealth Scientific and Industrial Research Organisation (CSIRO, 2021) is used as a reference for technologies' initial costs and annual operating and maintenance costs. The report also provides future cost projections for a wide spectrum of energy generation technologies.

In Appendix B.3, we provide the estimated economic performance assessment of these technologies, ranked by equivalent annual worth (EAW). Hydropower takes the lead, followed by CSP, hydrogen reciprocating generator with alkaline electrolyser, hydrogen reciprocating generator with PEM electrolyser, and hydrogen reciprocating generator with imported hydrogen. It's crucial to note that these evaluations treat these technologies as standalone options, not mutually exclusive investments.

Considering these results, a mix of technologies has been explored. The mixed technologies scenario is deemed likely to happen due to certain technical constraints that may apply to the Sydney Water case such as the inability of a standalone technology to meet the total energy demand by Sydney Water, which has different locations for its activities. This mix includes 50% hydropower, 25% CSP, and 25% hydrogen generator with alkaline electrolyser. These percentages reflect their respective economic worth weights when assessed together.

4.4.3 Leveraging techno-economic analysis for decision support platform

The capacity of each renewable energy technology assessed in this report is selected based on the objective function mentioned above. Our analysis shows that hydropower (with 24-hour storage capacity) and hydrogen generation with an alkaline electrolyser can meet the total non-renewable energy imports, including annual increases, until the end of their respective lifespans. For a detailed dataset supporting this analysis, please consult Appendix B.3. In this analysis, we assume that renewable technologies are operating at full capacity from the start. Consequently, we anticipate an initial surplus in capacity, which can generate revenue by selling excess energy to the grid. Over time, this surplus will gradually diminish in line with growth and technology degradation rates.

In Figure 4-27, we illustrate the scenario involving mixed energy sources, representing 50% hydropower, 25% hydrogen generator with alkaline electrolyser, and 25% CSP (12-hour storage). Specific details and figures related to "hydropower (24-hour storage), hydrogen generator with alkaline electrolyser, and CSP (12-hour storage)" can be found in Appendix B.3.

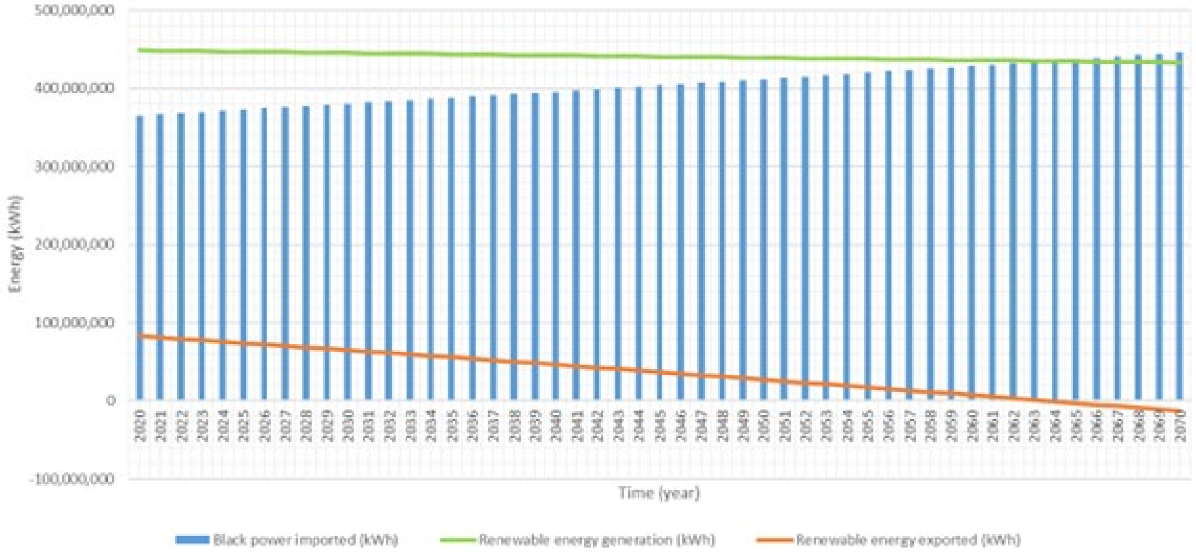

Figure 4-27: Annual estimated electrical energy flow using mix technologies (50% Hydropower (24-hour storage), 25% hydrogen generator with alkaline electrolyser, and 25% CSP (12-hour storage)) investment alternatives.

Based on the energy consumption trends, Scope 2 emissions are projected to reach 8.78 megatons CO_2-e by 2050. Our analysis factors in annual CO_2-e reductions for each technology throughout the lifespan. These technologies are optimized to eliminate CO_2-e emissions from non-renewable energy sources over their lifecycles, considering demand growth and degradation. As we explained above, this approach leads to oversized capacity at the starting years when demand has not reached its peak. A surplus of renewable energy will be generated which can offset Scope 1 and 3. Figure 4-28 illustrates the estimated CO_2-e reduction for the mixed technology scenario. Similar figures are attached in Appendix B.3 for hydropower (24-hour storage), hydrogen generation with alkaline electrolyser, CSP (12-hour storage).

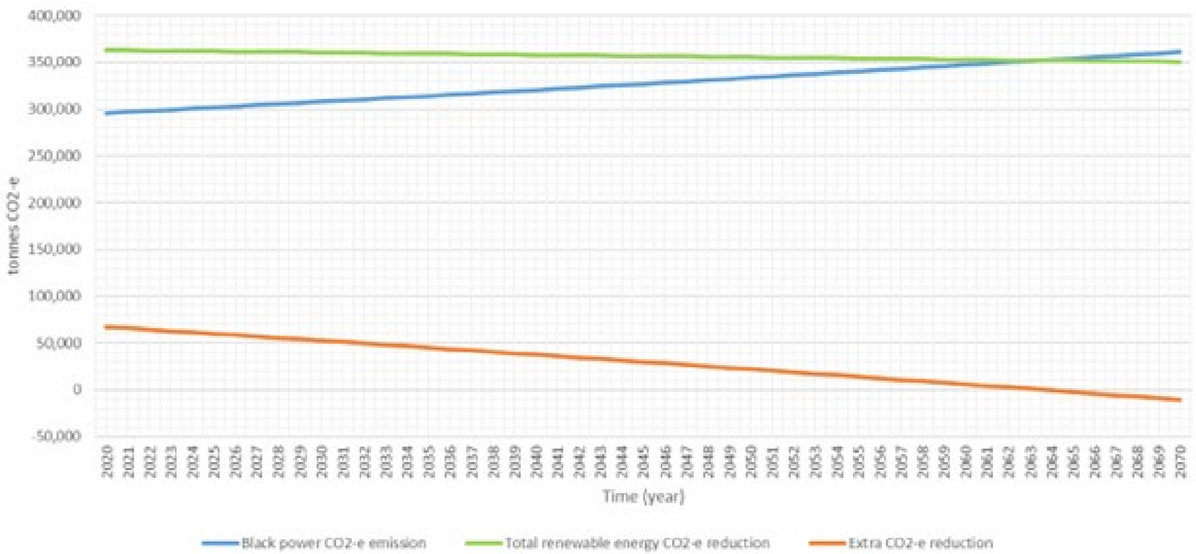

Figure 4-28: Annual estimated CO_2-e reduction using mix technologies (50% Hydropower, 25% hydrogen generator with alkaline electrolyser, and 25% CSP) investment alternatives.

In summary, hydropower technology (24-hour storage) and hydrogen generation with alkaline electrolysis can cover annual CO_2-e emissions from imported non-renewable energy until their respective lifespans. It can also be noted that that the total CO_2-e reduction of the CSP technology

(12-hour storage) and the mixed technologies scenario can fully cover the demand until 2059 and 2064, respectively. Afterward, minimal emissions are expected (Table 4-3).

Table 4-3: CO_2-e reduction in 2022 and at the end life service of the four best alternatives.

No.	Best Alternative	Total renewable energy CO_2-e reduction in 2022 (tCO_2-e)	Extra CO_2-e reduction in 2022 (tCO_2-e)	Total renewable energy CO_2-e reduction at the end life* (tCO_2-e)	Extra CO_2-e reduction at the end life* (tCO_2-e)
1	Hydropower (24-hour storage)	363,136	67,190	361,324	0
2	Hydrogen reciprocating generator with alkaline electrolyser	327,005	31,060	327,005	0
3	CSP (12-hour storage)	376,071	80,125	347,129	-56
4	Mixed technologies (50% Hydropower (24-hour storage), 25% Hydrogen Generator with Alkaline Electrolyser, and 25% CSP (12-hour storage))	363,141	67,195	350,646	-10,678

* The end life service of each alternative is provided in Table 4-2.

4.5 Conclusion

In this chapter, we have explored the intricate interplay of technology and economics that shapes the unique path toward emissions reduction for each industry and organization. Rather than a one-size-fits-all approach, achieving net-zero emissions demands a tailored strategy that considers industry-specific challenges and opportunities. The complexity arises from the industry-specific nature of these techno-economic drivers, which present diverse challenges and opportunities in emissions reduction across different sectors.

We explored case studies on Sydney Water, AGL Energy, Tassal Group emissions reduction targets and strategies. These case studies have allowed us to delve into the practical intricacies of modelling techno-economic drivers within a decision support platform. These real-world examples emphasise the significance of adopting an industry-specific perspective, given the distinct landscape of challenges and opportunities in emissions reduction.

Furthermore, we demonstrated the pivotal role of a flexible, software-based decision support platform in guiding organisations and companies towards achieving net zero emissions. Given the constant emergence of new technologies and the variability in critical factors, it is imperative to continually update decisions as circumstances evolve and fresh data emerges. This principle is exemplified in our case studies, where we emphasise the dependence of optimal decisions on a range of factors, including fossil fuel prices, renewable technology expenses and lifetime, product demand in the market, carbon pricing, viability, and availability of electric trucks in the future, and more. A software-based decision support platform not only streamlines optimal decision-making but also provides the capacity to monitor progress and adapt to evolving conditions.

5 Concluding Remarks and Way Forward

5.1 Introduction

Setting revenue, sales, and other key business metrics goals, as well as measuring performance against those goals, are essential components of every successful company plan. Setting a GHG emissions reduction goal is a common corporate strategy that ensures that a problem is maintained on senior management's "radar screen" and considered when making choices about what goods and services to provide, as well as what materials and technology to utilise. GHG targets that are publicly disclosed provide openness, accountability, and credibility to the target-setting process.

The challenge addressed in this project is how to turn GHG reduction targets into plans in achieving net-zero goals. The first difficulty is understanding how the organisation-level objective will transfer to the individual asset level, when each asset has fundamental objectives contributing to the organisation's overarching objective. By enabling companies to plan their path to net zero, this project aims to convert promises into action. The goal is a serious reduction in greenhouse gas emissions, and the successful commercialisation of this research will result in many large companies achieving the major reductions in their carbon footprint that they have been promising.

The project has designed a Proof of Concept (PoC) platform to explore the requirements of businesses and organisations seeking a path to net zero and elicit the research and data requirements needed to enable consistent, globally informed optimal path planning. A plan with actions and deadlines is essential to meet the net zero deadline. The platform is designed to support the decisions: when to make which choices, under which assumptions, using which technology, to reach which milestones, with which contingency plans in case a milestone cannot be achieved.

5.2 Inputs from current practice

The project surveyed current practice in devising and meeting GHG reduction targets. These targets were broken down into the three Scopes (i.e., 1,2 and 3), social and community impacts of their targets and plans, cost and organisational commitment. Specific issues were addressed for different kinds of organisation: management, transport, utilities, buildings and the production chain. Responses were provided by several members of our Industry Reference Group, including the Salvation Army and Boral. However, it proved difficult to access much information beyond what is publicly available on the web.

Consequently, the project took a deeper dive into the GHG reduction targets and plans of three organisations: our industry project partners, AGL and Sydney Water, and the Tasmanian company Tassal. For each organisation we elicited detailed emissions data. It was noted that good quality data is crucial for decision-making and reporting purposes. The GHG data was broken down by energy usage and sources, scopes, assets and time periods. Accurate calculation of the amount GHG emissions due to energy consumption from different sources was of key importance.

For each organisation a set of investment alternatives for reducing their GHG emissions were elicited. Each potential investment was assessed for its costs and resulting GHG reduction. These costs and reductions were depending on the timing of investments, making assumptions about future energy costs, inflation, discount rates and the changing cost of green (renewably sourced) electricity in the grid.

A number of scenarios were then explored, including, in every case, the "business as usual" scenario. In each case a fixed set of actions/changes were evaluated in the context of their deployment to different degrees at different times. Until a decision support platform is available, only a relatively small number of alternative scenarios could be explored. Each scenario costed a set of actions/changes performed at different times. Additionally, the scenarios were evaluated against different socio-political aspects, where GHG emissions incurred a greater or lesser cost.

These case studies besides being of value in themselves, have provided three real decision support examples on which to base the design of our platform.

5.3 Constraints and options

Besides the case studies, the project elicited the key social and technical constraints impacting plans for GHG reduction. On socio-political constraints the project applied system theory to model the interaction of the environment, activity and resources of an organisation. A critical result of this interaction, especially with regards to GHG emissions, is the organisation's social license to operate (SLO). Indeed, SLO has arguably become as important as any regulatory licence. In Australia, social drivers are also placing a downward pressure on regulatory emissions targets. Analysing annual reports of four organisations (Sydney Water, AGL, Salvation Army and Monash net zero) seven key themes were identified. The decision support platform can then deploy the stakeholders' priorities among these themes, to ensure SLO is considered in the GHG reduction plans.

Technical constraints are imposed not only by the processes that are carried out by each asset of an organisation, but also by their energy sources, form of energy use (heating, driving, pumping, chemical processing etc.), energy generation and location. Naturally energy generation is undergoing a significant transformation, and the future costs, or even availability, of different energy sources is uncertain. Clearly appetite for risk (or lack of it) is an important input into the planning process. Outsourcing the risk – for example by simply buying green energy – could be a very expensive option in the longer term compared with investing in renewable generation technology. The decision platform can apply complex calculations automatically in order to compare alternative, based on inputs such as CAPEX, OPEX, Service Life, Discounting etc.

5.4 The design of the decision support platform

The decision support platform underpins the process of mapping a set of GHG reduction targets to an agreed plan, termed a "Decarbonisation Roadmap".[5]

- The first stage, *data collection*, enables the platform to provide a consistent understanding of current assets, processes, energy sources and usage, and emissions to all stakeholders of the GHG reduction target.
- The second stage, *scenario development and modelling*, uses the platform to help users generate alternative actions/changes which can be combined into scenarios. The platform user can then simply change the parameters of the scenario (which actions/changes to

[5] "Path to Net Zero Planning Current State-of-the-art," in Monash Presentation at the first project workshop, 2021.

deploy and when; the assumptions about the environment (energy prices; carbon tax; carbon intensity of grid electricity) and compare the scenarios under these assumptions.

- The third stage, *decarbonisation roadmap development*, chooses an optimal (or pareto optimal) scenario and starts implementing the actions/changes. However, as the environment evolves, the original assumption may become less valid, prompting further scenario development, comparison, and optimisation.

  The current proof of concept comprises data definitions reflecting the categories of data:

- Energy usage (e.g., heat flow – max/min);
- Energy sources (e.g., solar output (max/avg);
- Scope (e.g., 1: fuel combustion, 2: purchased black energy, 3: distribution and transport);
- Assets: (e.g., buildings; transport; production); and
- Time periods (e.g., Year 1; years 5-10; 2035-2050)

The next stage requires the social inputs (SLO priorities) and technical inputs (specifications of solar panels, batteries, green hydrogen). These are supplemented by environmental assumptions (carbon price; cost of green energy; electric vehicle costs and rebates; discounting and inflation)

The platform deployment plan is in three stages:

- PoC: Trial with CRC partners:
  - Early adopter group.
- Beta: Improve and refine platform:
  - Develop success stories.
- Release: SAAS/Cloud version:
  - Consulting with software.
  -

Due to the wide variety of organisations encountered in the fast-track project, it has become apparent that the Stage 2 metadata for distinct industries is quite different. Consequently, even for the development of the Proof of Concept, it was not possible to develop a single version of the platform for all partners.

5.5 Way Forward

The project has indeed been fast. Three case studies have been completed from which the team has learnt what decisions must be supported by the platform. We have understood how to integrate social license to operate into the GHG reduction planning process. We have assessed a range of organisational GHG assessments, and formulated metadata to accommodate this analysis. In this process, we have detailed a detailed survey questionnaire which can generate good quality data in future. This is attached in Appendix A. It has also been possible to explore technical specifications about energy supply in order to embed current-day numbers into some scenario constructions.

However, we have recognised that the decision support platform needs to be more focussed on industry verticals that have some commonality in the processes causing their GHG footprint.

The proof of concept platform can be implemented and tested during the course of the project. In particular industry users will be enabled to input data about their current processes and GHG footprint, but also to construct scenarios and input parameters reflecting their SLO priorities and the technical specifications of alternative energy sources, and their usages in buildings, heating and transport. The platform will then support them in changing the environmental parameters and comparing future scenario to understand under what circumstances the advantages of one scenario are outweighed by those of other alternative scenarios.

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Appendices

A. Survey Questionnaire

This survey has five sections: *Management*, *Transportation*, *Utilities*, *Buildings*, and *Production Chain*. Each section can be submitted separately; therefore, the responding decision-maker may assign completion of each section to the most relevant expert in their organisation.

Management			
	Required Information	Response	Scope
GENERAL INFORMATION			
1	Respondent’s information:	Name: Role: Email:	NA
2	Organisation name:		NA
3	Industry sector:	Agriculture Manufacturing Mining Services Other (please specify):	NA
4	Size of the business:	Small Medium Large	NA
5	Annual revenue (in million AUD):		NA
6	Expenditure (in million AUD):	Operating expenditure: Capital expenditure:	NA
7	Earnings before interest, taxes, depreciation, and amortization (EBITDA; in million AUD):		NA
8	Main product(s)/services:		NA
9	Postcode of primary activities:		NA
10	Working days per week for this organisation:		3
11	Number of employees on-site on a normal working day:		3
12	Does this organisation have any equity investments? Please specify the current value of the investments in each sector in AUD:	Yes/No Energy: Materials: Industries: Utilities: Healthcare: Financial: Consumer discretionary:	3

		Consumer staples: Information technology: Communication services: Real estate: Other (please specify):	
13	Does this organisation finance or has debt investments in external projects? Please specify the current value of investments in each sector (in AUD):	Yes/No Materials: Industries: Utilities: Healthcare: Financial: Consumer discretionary: Consumer staples: Information technology: Communication services: Real estate: Other (please specify):	3
CARBON-FOOTPRINT-RELATED ISSUES			
14	Targets for reducing total greenhouse gases emissions:	Short term (specify the year): Medium-term (specify the year): Long-term (specify the year): None at this stage	NA
15	Targets for reducing CO_2-e emissions due to Scope 1 activities:	Short term (specify the year): Medium-term (specify the year): Long-term (specify the year): None at this stage	NA
16	Targets for reducing CO_2-e gases emissions due to Scope 2 activities:	Short term (specify the year): Medium-term (specify the year): Long-term (specify the year): None at this stage	NA
17	Targets for reducing CO_2-e gases emissions due to Scope 3 activities:	Short term (specify the year): Medium-term (specify the year): Long-term (specify the year): None at this stage	NA
SOCIAL & COMMUNITY IMPACT			
18	Market demands for the organisation's products/services will decrease unless the organisation fulfils the net zero emissions targets:	Not probable Somewhat improbable Neutral Somewhat probable Very probable	NA

19	Loss of revenue is expected due to the new regulations in meeting net zero emissions targets:	Not probable Somewhat improbable Neutral Somewhat probable Very probable	NA	
20	Attracting workforces with required knowledge will be difficult due to climate-change-related issues:	Not probable Somewhat improbable Neutral Somewhat probable Very probable	NA	
21	The negative effects of environmental disasters, such as increasing floods, bushfires, and other natural calamities, will affect the organisation:	Not probable Somewhat improbable Neutral Somewhat probable Very probable	NA	
22	The costs of production and services are expected to increase as a result of climate change:	Not probable Somewhat improbable Neutral Somewhat probable Very probable	NA	
23	Climate-related risks and opportunities have affected the organisation's strategies and financial planning:	No effect Nominal effect Neutral Moderate effect Major effect	NA	
24	Does this organisation provide a Task force on Climate-Related Financial Disclosure (TCFD)?	Yes/No	NA	
25	How important is government policy in your CO_2-e emissions reduction targets?	Not at all important Slightly important Neutral Moderately important Extremely important	NA	
26	Does this organisation have climate-related training programs in place?	No Yes (10 hours or less training per year) Yes (more than 10 hours per year)	NA	
27	Overall, does climate change play a positive or a negative role in increasing financial revenue?	Negative Neutral Positive	NA	
28	The estimated cost of the organisation in transitioning net zero pathway (please insert number in million AUD):	2020: 2021: 2022: 2023: 2024: 2025: 2026: 2027: 2028: 2029: 2030: Please provide any estimated values you have if this is not available for every year.	NA	
29	Any strategy to reduce emissions of the suppliers across the supply chain?	No, and not considered No, but considered Yes If yes, please specify:	NA	
30	Estimated total CO_2-e emissions in entire supply chain last year:		3	

31	Does this organisation receive any financial assistance or subsidies from the government in reducing CO_2-e emissions?	No, but we will be receiving No, and we do not expect to receive Yes If yes, please specify:	NA	

Transportation			
	Required Information	Response	Scope
1	Respondent's information:	Name: Role: Email:	NA
2	Transport fuels (in AUD) for the primary activities (transport owned by the organisation):	Vans: Trucks: Automobile: Others (please specify): Total:	1
3	Transport fuels (in AUD) for the primary activities (transport leased by the organisation):	Vans: Trucks: Automobile: Others (please specify): Total:	3
4	Total cost of shipment of materials, products, and fuels to the organisation's facilities (in AUD):	By road shipment: By rail shipment: By air shipment: By marine shipment:	3
5	Total cost of shipment of materials and products from the organisation's facilities towards the customers (in AUD):	By road shipment: By rail shipment: By air shipment: By marine shipment:	3
6	Total spending on business travel during the last year (in AUD):	Air travel: Rail travel: Bus travel: Automobile travel: Other modes of travel:	3

Utilities			
	Required Information	Response	Scope
1	Respondent's information:	Name: Role: Email:	NA
2	Use of fossil fuels for primary activities (including leased facilities, in litres):	Petroleum: Natural Gas: Oil: Coal: Diesel: Other (please specify):	1
3	Electricity purchase (in KWh):		2

4	Percentage of purchased electricity that is generated from renewable sources (%):		2
5	Please share high-resolution energy profile and bills data (e.g., 5 mins, 30 mins), including both energy generation and consumption, if this organisation has any:		2
6	Hot water purchased (in litre):		3

Buildings			
	Required Information	Response	Scope
1	Respondent’s information:	Name: Role: Email:	NA
2	Number of refrigeration units by type:	Total number of refrigeration units: Evaporative cooling: Mechanical-compression refrigeration systems: Absorption: Thermoelectric:	1
3	Number of air-conditioning units by type:	Total number of air-conditioning units: Central air conditioner: Ductless mini-split: Portable air conditioner: Floor-mounted AC: Other (please specify):	1
4	Any replacement of refrigerant gases in the organisation’s facilities last year? Please specify the unit if known.	Freon: R-22: HFC-134a: CFC-12: Other:	1
5	Spending on capital goods (in AUD):	Buildings: Machinery: Equipment: Vehicles: Tools: Total:	3
6	Specify the total floor area leased last year (m^2):		3
7	Number of shops/factories/branches:		3
8	Specify the total floor space of shops/factories/branches/franchises (m^2):		3
9	Total electricity bills (please supply the breakdown if the data are available for each shop/factory/branch/franchise in AUD):		3
10	Total water bills (please supply the breakdown if the data are available for each shop/factory/branch/franchise in AUD):		3

Production Chain			
	Required Information	Response	Scope
1	Respondent’s information:	Name: Role: Email:	NA
2	Please provide organisation's spending for purchasing goods (in AUD):	Desktop computer:	3

		Laptop: Paper and boxboard: Stationery other than paper: Timber and materials made from wood: Raw or processed metal: Raw or processed plastic: Glass: Lamp, wire, and cable: Rubber: Textiles: Ceramics: Leather:	
3	How much solid waste was generated in your facilities during the last year (in kgs)?	Landfill: Incinerated: Recycled:	3
4	Total wastewater in the facilities during the last year (please provide a number in litres):		3
5	Total dollar value of products sold last year (in AUD):		3
6	Products sold by your organisation using any type of fuel and used as input in the production process for other companies (estimated revenue [in AUD], CO_2-e emissions and product name):		3
7	Estimation of the total mass of waste that is being or will be generated as a result of consumption of product/s sold:	Landfill: Incinerated: Recycled:	3
8	Estimated total CO_2-e emissions in entire production last year:		

B.1. AGL Energy

For detailed data about CO_2-e emissions of AGL Energy and the underlying data used in our analysis in Section 4.1 please use the following web link:

https://docs.google.com/spreadsheets/d/16_UHvpIrGR67F9-8WRDpIRKbgMx9sW91ma5-A_GHUrU/edit?usp=sharing

B.2. Tassal Group

For detailed data about CO_2-e emissions of Tassal Group and the underlying data used in our analysis in Section 4.2 please use the following web link:

https://docs.google.com/spreadsheets/d/11AiWJ7xnRLTo-5yYEXJugqG8ptiz7wtZ/edit?usp=sharing&ouid=103313859639286518113&rtpof=true&sd=true

B.3. Sydney Water

The annual energy flow using hydropower (24-hour storage), 25% hydrogen generator with alkaline electrolyser, and 25% CSP (12-hour storage)) alternatives are illustrated in Figures B-1, B-2, and B-3, respectively.

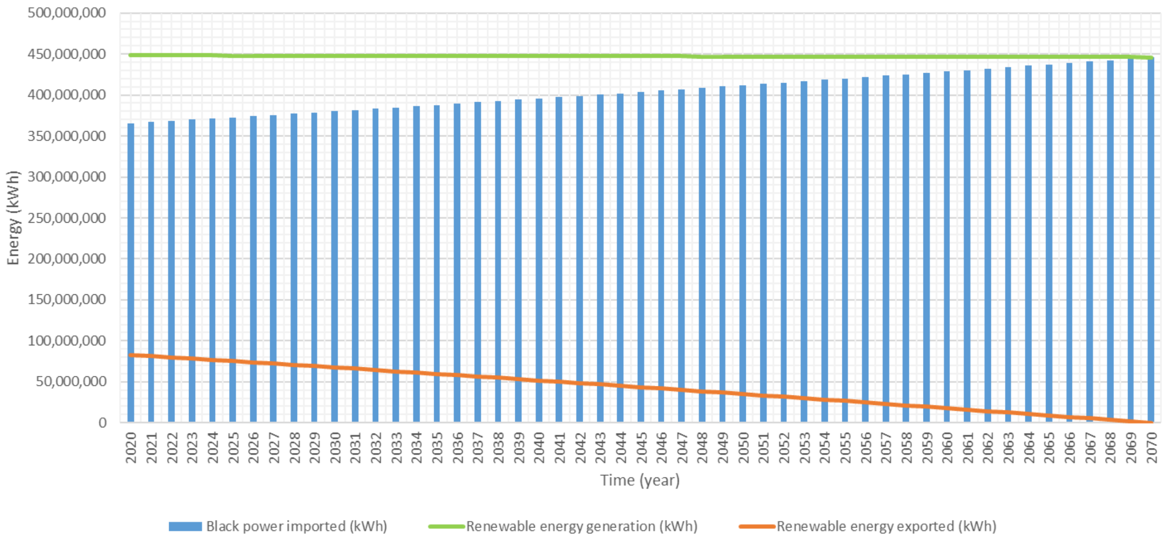

Figure B-1: Annual estimated electrical energy flow using hydropower (24-hour storage) investment alternative.

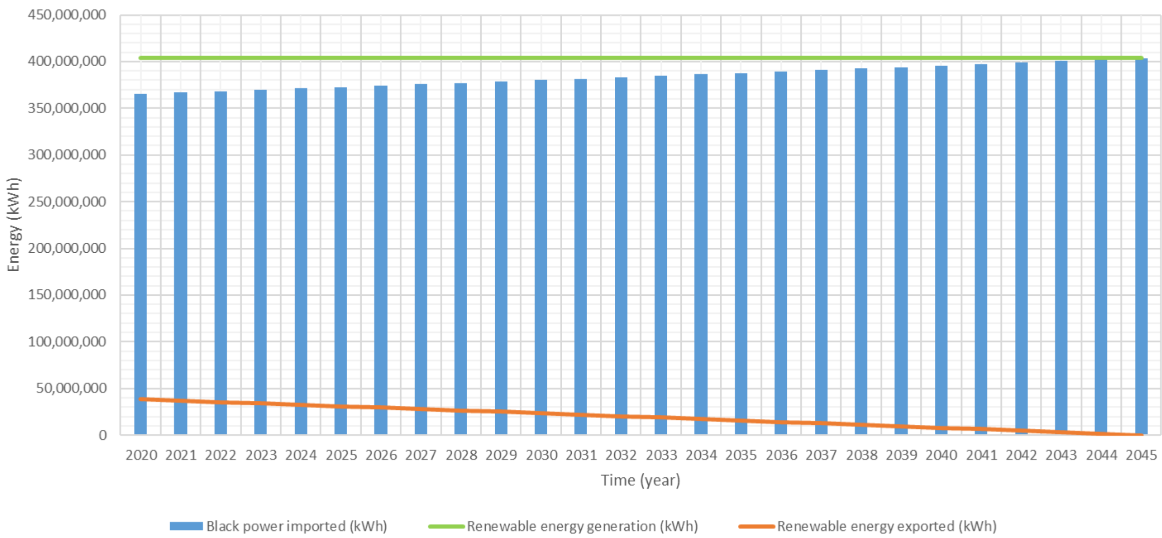

Figure B.2: Annual estimated electrical energy flow using hydrogen generator with alkaline electrolyser investment alternative.

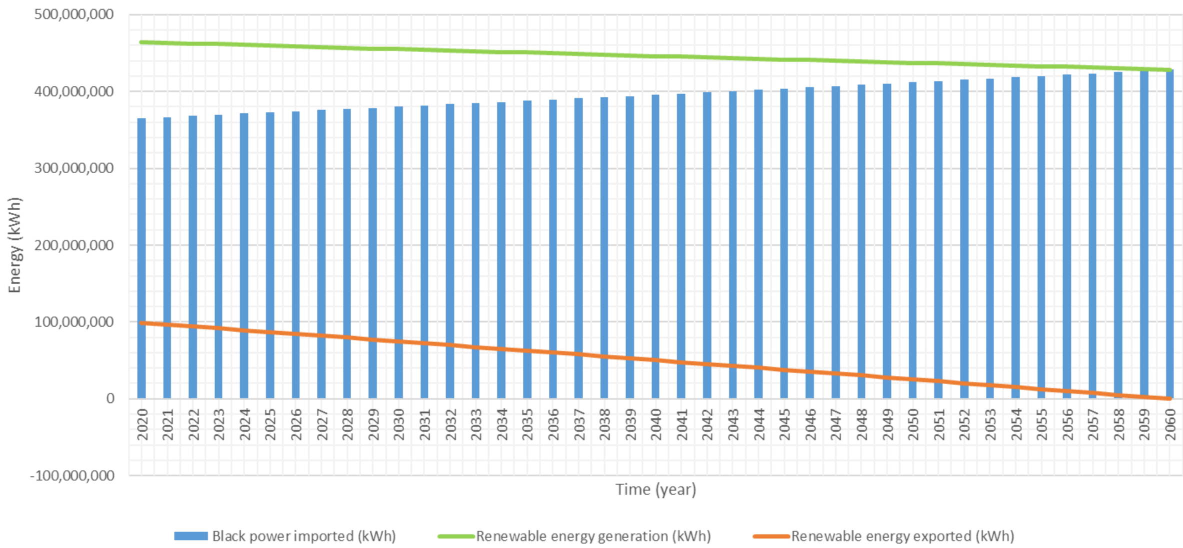

Figure B-3: Annual estimated electrical energy flow using CSP (12-hour storage) investment alternative.

Moreover, the estimated CO_2-e reduction using hydropower (24-hour storage), 25% hydrogen generator with alkaline electrolyser, and 25% CSP (12-hour storage)) alternatives are illustrated in Figures B-4, B-5, and B-6, respectively.

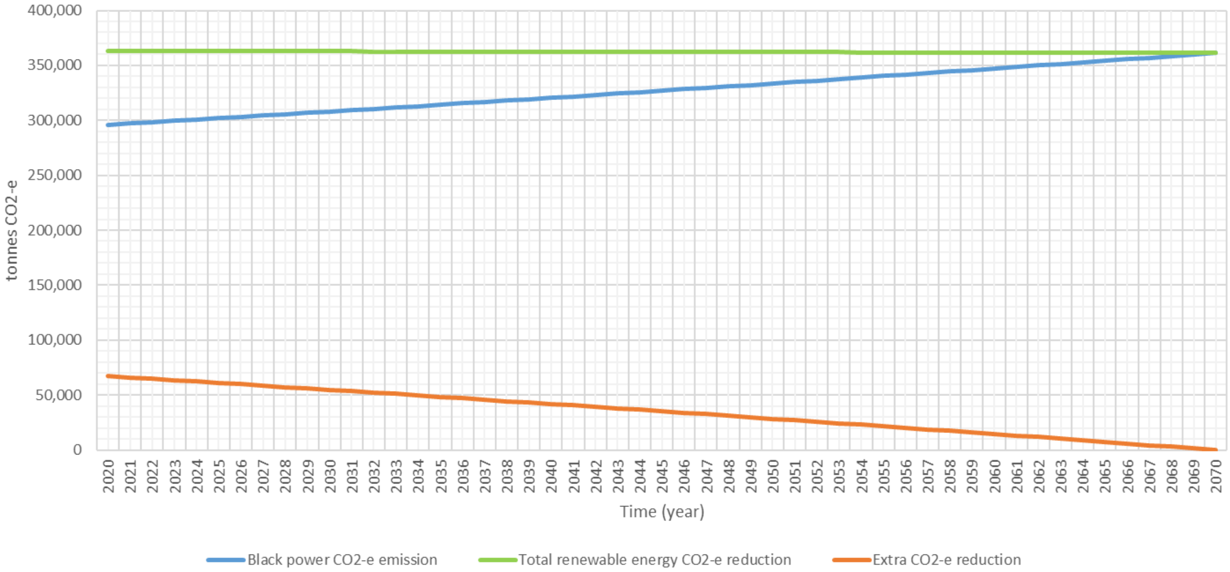

Figure B-4: Annual estimated CO_2-e reduction using hydropower investment alternative.

Figure B-5: Annual estimated CO_2-e reduction using hydrogen generator with alkaline electrolyser investment alternative.

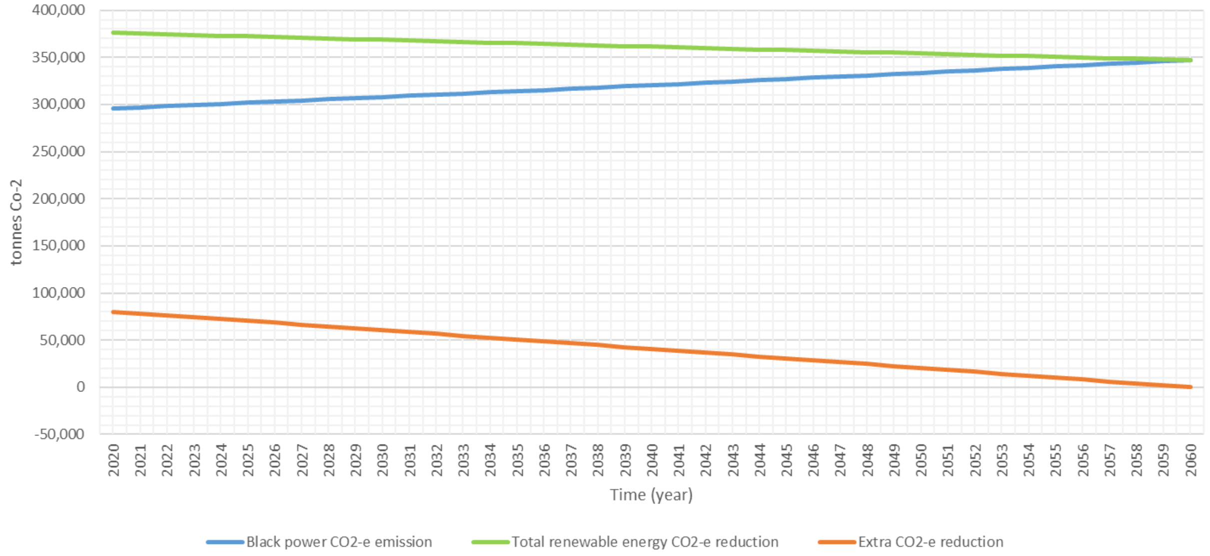

Figure B-6: Annual estimated CO_2-e reduction using CSP investment alternative.

For detailed data about CO_2-e emissions of Sydney Water and the underlying data used in our analysis in Section 4.3 please use the following web link:

https://docs.google.com/spreadsheets/d/1p8zLkQQ9in6MSLmP7DzKFMfb8LF93-DxALZmGu1iNhA/edit?usp=sharing

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