Space Habitats
Extraterrestrial living

Environmental Control and Life Support System: Carbon Dioxide Recycling System

Business Plan

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Document History

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1.0	*Andre Van Der Merwe*	*1 April 2019*	*Andre Van Der Merwe*		*Baseline Document*
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Executive Summary

This Business Plan outlines how Space Habitats plans to develop a Carbon Dioxide Recycling System that will be used as a Climate Change Mitigation Technology that will help to offset the effects of Carbon Dioxide in the Earth's atmosphere and help to mitigate the effect of Climate Change.

The Carbon Dioxide Recycling System will then be further modified to form part of an Environmental Control and Life Support System (ECLSS) of a Space Habitat. The Carbon Dioxide Recycling System will be helping to remove Carbon Dioxide from the air and convert it back into breathable Oxygen. This will help to drastically reduce the resource resupply required to support life in future Space Colonies.

Issue

The current problems associated with Carbon Dioxide in the atmosphere include the following:

1. Carbon Emissions due to Fossil Fuels is estimated at over 10Gt/year, increasing between 1.5 - 3.2% annually
2. Carbon Dioxide Level in the atmosphere are increasing annually at 4.7Gt/Year
3. Technology to remove large volumes of Carbon Dioxide from the atmosphere is limited and in development phase,
4. Carbon Efficiency Technologies I.e. improve performance of Carbon Dioxide producing systems is well developed and help to lower carbon emission growth but has not stopped carbon emissions.
5. Carbon Neutral Technologies I.e. to convert Carbon Dioxide to renewable fuels are in still in the research/development stage,
6. Carbon Negative Technologies I.e. to convert Carbon Dioxide to Inert Carbon products is currently only in research/development stage.

The current problems associated with Carbon Dioxide removal in ECLSS Systems include the following:

1. The Oxygen Generation System (OGS) requires Water (H_2O) as a resource to be constantly supplied in order to operate. Currently the ISS requires 0.8kg/CM/day of Oxygen to be supplied.
2. The Oxygen Generation System produces Hydrogen (H2) as a biproduct, which needs to be utilised or disposed of. Any material that is disposed of represents a failure of the system to be 100% self-sufficient.
3. The Sabatier Reaction can convert Carbon Dioxide (CO_2) and Hydrogen (H_2) into Methane (CH_4) and Water (H_2O) but is limited by the supply of Hydrogen generated by the Oxygen Generation System and is thus only 50% efficient. 50% of the Carbon Dioxide needs to be disposed of from the ECLSS system. The Methane biproduct is currently not utilised and is required to be disposed of as well. Currently considering a 100% Efficient OGS and Sabatier Reactor 1kg Water is only able to produce 1.77kg O2 before it is disposed of as biproduct of other processes.
4. The power consumption of the Oxygen Generation System (OGS) and Sabatier Reactor are high which puts additional strain on the power requirements of habitation modules. The OGS currently consumes about 1.5kW of power for 4 Crew Members.

Preferred Solution and Justification

The Preferred solution that Space Habitats will implement will be the Liquid Metal (LM) Electrode Carbon Dioxide Recycling System with a Carbon Solid Separation System connected to ensure minimal loss of Solvent, Electrolyte and LM Electrode. The Carbon Solid is separated and collected to produce Graphite to be used in Carbon Electrodes in Battery Systems.

The aim of the Carbon Dioxide Recycling System will be to help reduce Carbon Dioxide emissions in the air. The Carbon Dioxide Recycling System can also be used as a system that forms part of an ECLSS of an Isolated Habitation System for submersible vehicles, bunkers and space or off-world habitation units by converting the Carbon Dioxide into breathable Oxygen.

The main advantages of developing the Carbon Dioxide Recycling System with Liquid Metal Electrode are:

1 **Reduced Energy Requirements:** The energy requirements of the Electrolysis System are reduced in the form of:
   a. Electrical Energy: Due to the use of a Catalyst and the Liquid Metal Electrode the Potential required for the reaction to take place is reduced when compared to other Carbon Dioxide reduction electrolysis systems.
   b. Heat Energy: The Reduction Reaction can take place at room temperatures and does not require the high heat requirements similar to Carbonate Melts systems.
2 **Improved Workability/Function:** Due to the fluidity of the Liquid Metal Electrode the Carbon Solid does not build up on the Electrode and is instead dispersed into the Electrolytic solution.
3 **Reduced Waste of Electrolytic Solution:** The System will be design such that the Solvent is separated from the Carbon Solution before the Solid Carbon is collected. The clean Solvent and Electrolyte are returned to the Electrolysis Chamber for reuse. This reduces the demand for new Solvent and Electrolyte to be supplied.
4 **Flexible Operation:** The Carbon Reduction can operate continuously or periodically due to energy fluctuations provided an electrical current and the electrolytic solution is kept at the required level.
5 **Commercial Applications for Waste Products:** The Carbon that is collected as Graphite can be used to make electrodes for batteries, and the Oxygen collected can be used in industrial applications and processes. The sale of these products can help offset the cost of operating the Carbon Dioxide Recycling System.
6 **Useable in Isolated Habitation Systems:** Since the Solvent is removed prior to the collection of the Solid Carbon it can be used in environmentally enclosed areas occupied by humans.

The main disadvantages of developing the Carbon Dioxide Recycling System are:

1 **Higher Complexity:** The system is made more complex by utilising materials that are not commonly available or easily controlled and by increasing the required sub-systems required to carry out the task effectively.
   a. Liquid Metal Electrode: The fluidity of the Liquid Metal Electrode means that it is very difficult to prevent the metal from breaking off from the Electrical Contact and dispersing into the electrolytic solution. The Liquid Metal needs to be kept in a form that allows it to be continuously connected to the Electrical Contact.
   b. Solvent/Electrolyte Reuse System: Separation of Carbon Solid from the Electrolytic Solution can be difficult since the particles are suspended in solution,
   c. Multiple systems working in unison increases the complexity of the system.
2 **Higher Energy Requirements:** Due to the added Carbon Solid Separation System additional energy is required to operate the systems. Varying design setups could be implemented to reduce the requirements of direct energy input into the system by utilising direct solar energy in the evaporation chambers.
3 **Use of Dangerous Solvents:** The Solvents currently used to help the electrolytic process are

a. Toxic and very harmful to humans and extreme care will always need to be taken to ensure no persons are affected by the substance during operation.
b. Extremely Volatile and can ignite at temperatures above 150ºC.

4 **Specialized Service Requirements:** Due to volatility Solvents and the reactivity of the electrode to oxygen, special care always needs to be taken. Any servicing of the equipment will need to be carried out in specialized environments that is devoid of oxygen.

Anticipated Outcomes

Primary goals for the development of the Carbon Dioxide Recycling System will be:

1. To develop a system that can recycle carbon dioxide at a required rate of 1kg/d/unit (1 Person Equivalent) which can then be scaled up to convert Tons of CO_2
2. To develop a system that operates on lowest power requirements to achieve its target rate,
3. To develop a system that is capable separating Carbon Solid particles in solution,
4. To develop a system to separate Oxygen from the Electrolytic Solution, and
5. To develop a safe system that will not harm humans that may come in contact with any of the harmful substances and materials in the system.

The Market

Global Graphite Market size was valued at $13 billion in 2015, and is expected to reach $18,7 billion by 2022, supported by a CAGR of 5.4% during the forecast period 2014 to 2022. Pure Graphite pricing varies from $450/ton (Fine Flake) to $1800/ton (XL Flake). Specialist products for research institutions can cost as much as $165 to $1040/kg. The pricing of manufactured Graphite based materials varies greatly from $2 000 to $14 000/ton depending on the type of product that was manufactured.

Global Industrial Oxygen market size will increase to 68.2 Billion US$ by 2025, from 43.1 Billion US$ in 2018, at a CAGR of 6.8% during the forecast period. Estimated global Oxygen pricing varies between US$ 200 - US$ 3 000/ton wholesale. The pricing of Oxygen in South Africa at retail varies greatly from $1.20 to $4.50/kg depending on the type of gas mixture and purity of the gas that is collected.

At current CRS2 rates the market value for Oxygen supply for the ISS is around $50 Million annually based on 1095kg of water required for Oxygen at a delivery rate of $46 000/kg (Excludes Containment).

Pricing for the removal of Carbon Dioxide from various countries is given below.

1. Switzerland: $99/ton
2. Europe: $20/ton
3. California $15/ton
4. USA: $50/ton (New Legislation)
5. China $5/ton
6. RSA: R120/ton (Lowered to R6-48 for companies)

Potential Customers

The current potential customers include:

1. National Government and Non-Profit Organizations dedicated to mitigating Climate Change,
2. Graphite Product Manufacturers,
3. Oxygen Product Consumers,
4. Habitation Units.

Competitors

The main competitors include the following:

1. Graphite Mining Companies
2. Oxygen Gas Producers
3. Breathable Oxygen Supply Generators for ECLSS.

Competitive Advantage

The current advantages to the Carbon Dioxide Recycling System include the following:

1. Resource is not limited to a geographical location and can be produced anywhere,
2. It is a Carbon Negative Technology and can help to reduce the impact of $CO2$ in the atmosphere by reducing it.

Funding Requirements

The estimated total funding requirements for the 1kg/Day Carbon Dioxide Recycling System Prototype Excluding CO2 Capture and O2 Purification and Liquification Systems is **US$ 340 000.** Cost to develop specialized O2 Purification and Liquification System is estimated to be an additional **US$ 176 000.** All other systems required for a fully operational Carbon Dioxide System will require and engineering design to be done as required to accommodate various sizes and locations.

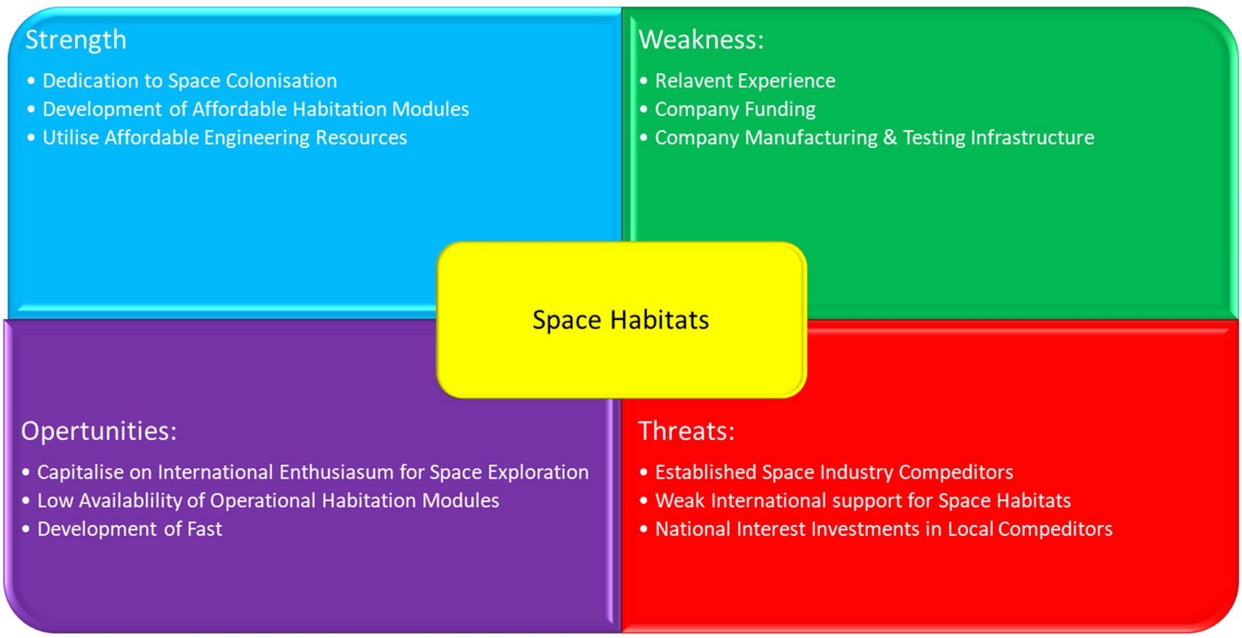
Funding Sources:

1. South African Department of Trade & Industry (Matched investment funding Grant to maximum R 2 Million)
2. Private Donors & Investors
3. Climate Change Funds

Pricing Policies

The pricing of the materials produced will be market related and mostly determined by Supply & Demand.

SWOT Analysis



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1 Introduction

1.1 About Space Habitats

Space Habitats is a new start-up company that is focused on developing new ways to help the expansion of humanity into the solar system and help society become a multiplanetary species. The way in which we hope to achieve this will be to develop low-cost habitational modules that can be produced on a commercial scale. As a company we want to focus on finding ways in which we will be able to make this a reality.

We aim to find technologies/systems/process that will help us to achieve that goal whist also being able to use the same technologies/systems/processes in a commercial application for everyday life allowing us to maintain a sustainable income to peruse our goals.

Thanks to the International Space Station we know that the technology required to realise this dream is very much possible and exists today. Unfortunately, it is currently still very expensive to achieve this goal, but we believe that we have a plan to overcome this problem by addressing some of the issues that make space exploration so expensive.

Factors which we hope will help to reduce the cost of building habitational modules;

1. Research and Development Costs
2. Design Cost of Human Resources
3. Commercial Production of Modules
4. Develop the Production and Testing Facilities
5. Company Driven Goals

There will be many more areas in which we can improve upon as the project is developed, we will aim to address all these issues.

1.2 Vision

Our vision is to help humanity achieve its goal of space exploration by giving people a place to live off planet. We believe this can be achieved with existing technology and expertise with a little tweaking involved. Space Habitats aims to be a part of the industry that will make this happen by providing the required systems necessary to achieve this goal.

1.3 Company Goals

The primary focus of the company is to develop a complete functioning habitational module that can be deployed in any low gravity environment and be fully self-reliable without requiring any need for additional set up of critical systems to be done once the module has been placed.

The primary short-term goals (0-5 Years) of the company will be:

1. To identify individual systems that form part of the Environmental Control and Life Support System (ECLSS) and develop our own range of systems that can meet these needs,
2. To develop a new Carbon Dioxide Recycling System to provide Oxygen and a Carbon Solid bi product,
3. To develop a Self-contained Waste Management Systems – Human Waste products, General Waste Materials,
4. To develop Air Quality Monitoring and Control Systems,

The secondary goals (5-10 Years) of the company will be:

1. To develop a self-reliant multifunctional module that is fitted with all the required systems needed for the module to be used in off world environments such as the Moon and Mars in low gravity and atmospheric conditions,
2. To develop a simplistic design that can accommodate many different functions and be easily adaptable to suit a variety of different missions,
3. To develop a module that has been extensively tested to handle off-world environments prior to launch,
4. To develop a suite of modules that can be used to form the basis of a Lunar colony,
5. To develop a module that is 100% operational at launch and requires only minor assembly of non-essential systems once placed in position,
6. To develop a cost effective multipurpose habitational module that is more affordable by a factor of 40 of current available options by creating a production line, and
7. To develop a module that is more affordable by a factor of 50 of current available options by 2030 by streamlining the production line.

The Tertiary goals (10+ Years) of the company will be:

1. To develop an international consortium of companies and governmental space agencies that are interested in the focused goal of developing a permanent semi-self-reliable Lunar colony,
2. To establish the requirements of a Lunar colony and what aspects are required to make it a reality,
3. To establish a demand for Space Habitats' range of habitational modules on the Lunar colony,
4. To develop larger habitational units and construction methods in which the unit cannot be launched as complete functioning unit and will require assembly at the final position. The habitational units will still be required to be deployed in any low gravity environment,
5. To establish the requirements of a Mars colony and what aspects are required to make it a reality,
6. To establish a demand for Space Habitats' range of habitational modules on the Mars colony,
7. To focus on habitational units that are capable of functioning in a micro/zero gravity environments which will enable the company to deliver habitational units to any part of the Solar System.

1.4 Development Focus

The ECLSS Systems will be developed by using existing technologies that have been or can be commercially produced. The existing systems will only need to be modified to fit within the confines of the modules. New systems that are developed will also need to find commercial applications in alternative markets in which they can be used so that the cost of producing the system/sub-system/components can be offset due to scalability.

The systems will all be developed as plug and play units that are fully functional at completion. Certain aspects of the systems may be delivered as parts that require minor assembly when delivered to its position.

The Components and Subsystems required for each module will be developed in the following manor:

1 Initial systems will incorporate existing technologies, sub-systems and components that are commercially available with minor tweaking of custom parts that are required to suit our needs.
2 Once established some of the technologies, systems and components required for more efficient closed loop habitational system design will be developed using funds generated from sales of initial systems.
3 Later the components of the systems will be developed in a manner that will allow the components to all be manufactured in off world environments without requiring complex

manufacturing processes and resources. This will allow modules to be developed and assembled off world reducing the costs required to establish an off-world colony.

Development needs will be determined by the design, assembly and testing needs of the systems.

1.5 Current Development Focus: Environmental Control System – CO2 Removal and Reduction to O2 and Carbon Solid

This new project by Space Habitats will be aimed at developing the technology required to help improve the Environmental Control and Life Support Systems (ECLSS) loop and help to make it more efficient.

The new system developed will help to reduce the demand of water resupply to habitation modules due to human respiration activities. The new system will also help to reduce the power consumption of the ECLSS. An illustration of how this new system will affect the habitational module can be seen in Figure 1-1 below.

Alternative Commercial Applications include the following:

1. Climate Change Mitigation Technology, (Current Focus)
2. Alternative High-Grade Graphite Production Method
3. Alternative High Purity Oxygen Production Method
4. Carbon Dioxide Removal in Enclosed/Environmentally Controlled Rooms/Units

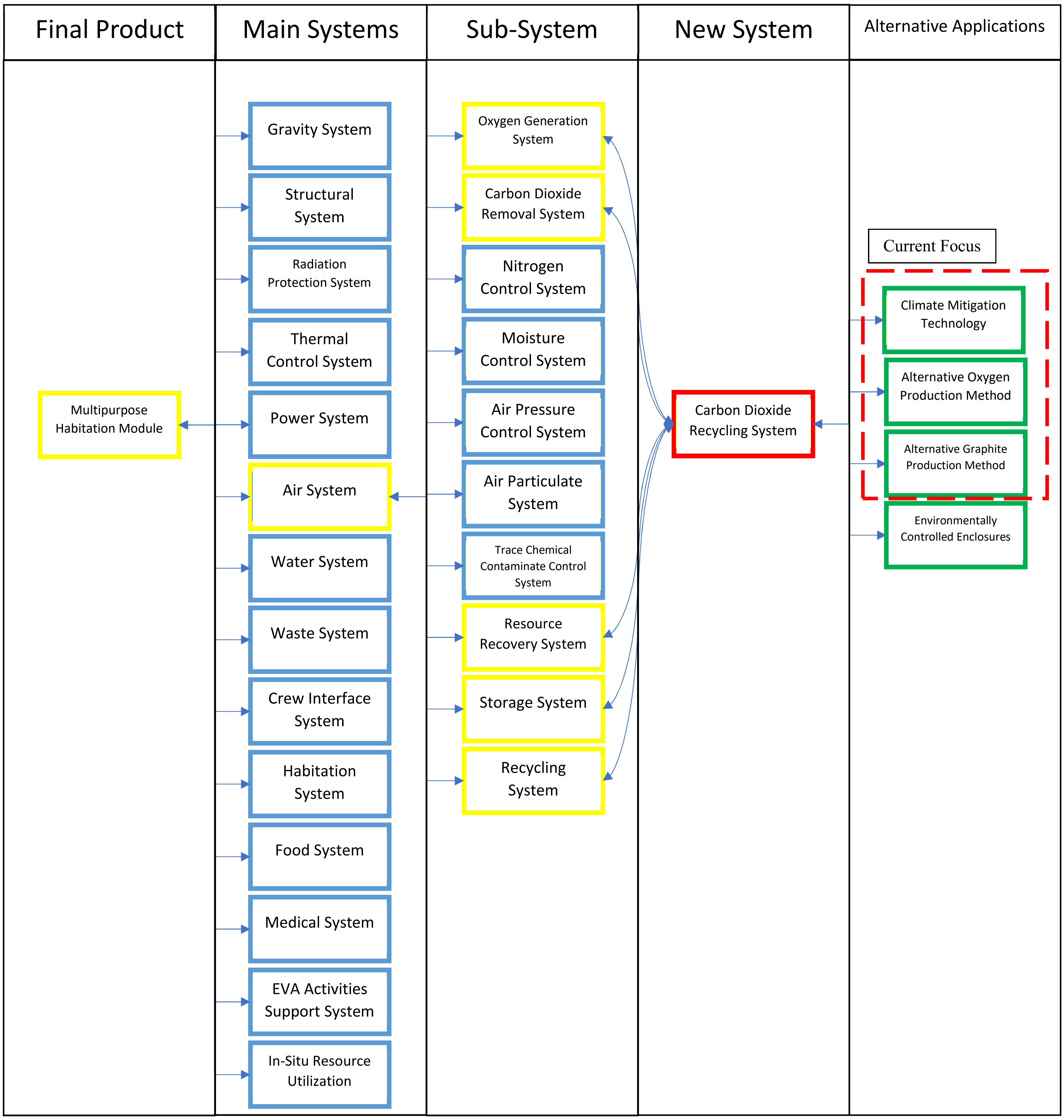


Figure 1-1: Carbon Dioxide Recycling System Integration into Habitational Module

2 Problem Definition

2.1 Brief History of Life Support Systems

When the space race first began many people believed that we as a society would reach new heights and be able to explore new worlds and so we did when America first landed a man on the moon in 1969. After that robotic exploration missions to all parts of the solar system were planned and executed with some failed missions but mostly with a lot of successful missions. The expansion of humanity into the solar system on the other hand has been a lot more limited and advancements have been slow. The first space station was deployed in 1971 as a short stay habitational unit. In 1986 Mir was deployed and the first long duration stay habitational unit was developed and allowed a continuous presence in space for up to 3 644 days in space. A lot of new technologies were developed and improved upon and later the International Space Station (ISS) was deployed which has enable the continuous presence of humans in space since November 2000.

2.2 Problem Statement

2.2.1 ECLSS

The current problems associated with removal of Carbon Dioxide (CO_2) and production of Oxygen (O_2) in habitation modules for use in off-world environments include the following:

1. The Oxygen Generation System (OGS) requires Water (H_2O) as a resource to be constantly supplied in order to operate. Currently the ISS requires 0.8kg/CM/day of Oxygen to be supplied.
2. The Oxygen Generation System produces Hydrogen (H2) as a biproduct, which needs to be utilised or disposed of. Any material that is disposed of represents a failure of the system to be 100% self-sufficient.
3. The Sabatier Reaction can convert Carbon Dioxide (CO_2) and Hydrogen (H_2) into Methane (CH_4) and Water (H_2O) but is limited by the supply of Hydrogen generated by the Oxygen Generation System and is thus only 50% efficient. 50% of the Carbon Dioxide needs to be disposed of from the ECLSS system. The Methane biproduct is currently not utilised and is required to be disposed of as well.
4. The power consumption of the Oxygen Generation System (OGS) and Sabatier Reactor are high which puts additional strain on the power requirements of habitation modules. The OGS alone currently consumes about 1.5kW of power for 4 Crew Members.

All the losses that are generated from this system for any long duration activities away from earth will need considerable resources to be taken with.

1. Currently considering a 100% Efficient OGS and Sabatier Reactor 1kg Water is only able to produce 1.77kg O_2 before it is disposed of as biproduct of other processes.
2. For locations such as the moon the long duration night cycles will place additional strain on the Electrical Power System (EPS) to provide sufficient power to the OGS and all other essential ECLSS systems.

The space industry has many obstacles that require attention and by addressing some of these issues we hope to improve the industry and help it to move forward.

2.2.2 Climate Mitigation Technologies (Alternative Commercial Application)

Currently Humans are producing a large amount of Carbon Dioxide into the atmosphere each year, this has caused global temperatures to rise, which is having a detrimental effect on the climates of various regions. The current problems associated with Carbon Dioxide (CO_2) producing systems include the following:

1. Carbon Emissions due to Fossil Fuels is estimated at over 10Gt/year, increasing between 1.5 - 3.2% annually
2. Carbon Dioxide levels in the atmosphere are increasing annually at around 4.7Gt/Year
3. Technology to remove large volumes of Carbon Dioxide from the atmosphere is limited, and is only in the development phase,
4. Carbon Efficiency Technologies I.e. improve performance of Carbon Dioxide producing systems is well developed and help to lower carbon emission growth but has not stopped carbon emissions. With growing economies any offset that is achieved through the introduction of a new technology/process is eventually lost.
5. Carbon Neutral Technologies I.e. to convert Carbon Dioxide to renewable fuels are in still in the research/development stage but are a promising development for the future of the industry,
6. Carbon Negative Technologies I.e. to convert Carbon Dioxide to Inert Carbon products is currently only in research/development stage with some proof of concept facilities having been constructed.

2.2.3 Alternative Graphite Production Method (Alternative Commercial Applications)

Currently graphite is mined as a natural resource from the Earth. The current problems associated with the removal of Natural Graphite from the Earth include the following:

1. The Grade of Natural Graphite varies greatly in its raw form from low grade to high grade materials,
2. Extraction of Graphite from the Earth can cause the destruction of the natural environment,
3. Graphite production is restricted to fixed locations needs the materials to be transported to various locations to be used.

2.3 Current State of Existing ECLSS and Climate Mitigation Systems

2.3.1 Oxygen Generation Systems and Carbon Dioxide Removal/Recycling Systems for ECLSS

Figure 2-1 below shows the initial setup of the International Space Station (ISS) Environmental Control and Life Support System (ECLSS). Initially the excess Hydrogen (H_2) and Carbon Dioxide was removed from the system and vented to space since it could not be used or stored for long periods. This resulted in a lot of water being shipped from Earth to the ISS on a regular basis to ensure that the crew on the ISS had sufficient air to breathe. 1kg of Water provided the equivalent of 0.89kg Oxygen for use by the crew. This method is still in operation on Crew Capsules that are launched to the ISS.

Figure 2-2 below shows the advanced setup of the ISS ECLSS. The Sabatier reactor was developed to help resolve the issue of wasting valuable resources on the ISS. The Sabatier reactor converted Carbon Dioxide (CO_2) and Hydrogen (H_2) into Methane (CH_4) and Water (H_2O) which could be reused. Unfortunately, the Sabatier reactor was limited by the supply of Hydrogen generated by the Oxygen Generation System and is thus only 50% efficient at converting waste Carbon Dioxide (CO_2). 1kg of Water (0.89kg O_2) provided the equivalent of 1.77kg Oxygen for use by the crew.

Both variations relied on a supply of oxygen and as such would continuously need to be resupplied. Even if the additional Hydrogen was supplied to help improve the efficiency of converting Carbon Dioxide the ECLSS would still require resupply missions to cover the waste of Methane.

In future developments the Methane could be utilised and used as a fuel source for space vehicles. This would allow the system to be more efficient but would still require a resupply of Water and Hydrogen to provide Oxygen to the crew. This maybe an acceptable option only if a source of Water can be provided to the habitation system and ensure continuation of the process. For long duration missions that will not have access to a Water resource, this option will not be acceptable.

New methods are required that will enable the waste CO_2 in the system to be completely recycled and reused indefinitely.

2.3.2 Climate Mitigation Technologies

Currently large-scale climate mitigation technology is being developed along various different fields that will all in turn help to reduce our carbon footprint. The following technologies are currently under development:

2.3.2.1 Carbon Dioxide Conversion to Fuel

The current technology is in development stage with working prototypes. The technology is currently too expensive to be utilised as a mainstream replacement of oil-based fuel but is aiming to be improved soon.

2.3.2.2 Carbon Dioxide Conversion to Rock

The current technology is in the development stage with a working facility that has been established. The technology currently has no short-term economic benefit and is subsidised by increasing the cost of the product being generated by the CO2 producing process and any tax credits that it is able to earn from the process. The technology has a good potential to permanently lock away the CO2 in a safe manor.

2.3.2.3 Carbon Dioxide Storage Underground

Several large installations have been constructed all over the world with the aim of directly capturing the CO2 at the source and storing it in large underground reservoirs that can store the CO2 as a gas. The technology currently has no short-term economic benefit and is subsidised by increasing the cost of the product being generated by the CO2 producing process and any tax credits that it is able to earn from the process.

The technology has the potential to remove CO2 from the atmosphere in the short term but there are several concerns that the CO2 gas will eventually escape through the cracks that are present in the underground reservoir thus negating the benefit of storing the gas.

2.3.3 Graphite Production

Currently graphite is mined as a raw natural resource from the Earth. The Raw graphite is then processed to form pure graphite and further sorted into different grades of material which can be used in various industrial processes.

2.3.4 Oxygen Production

Oxygen is produced by extracting it from the atmosphere. There are currently 2 main large-scale methods that are used to perform this process are Pressure Swing Absorption (PSA) and Cryogenic Liquid Distillation. Other methods include the Electrolysis of Water into Hydrogen and Oxygen which is used in space habitation modules such as the ISS to provide an oxygen source.

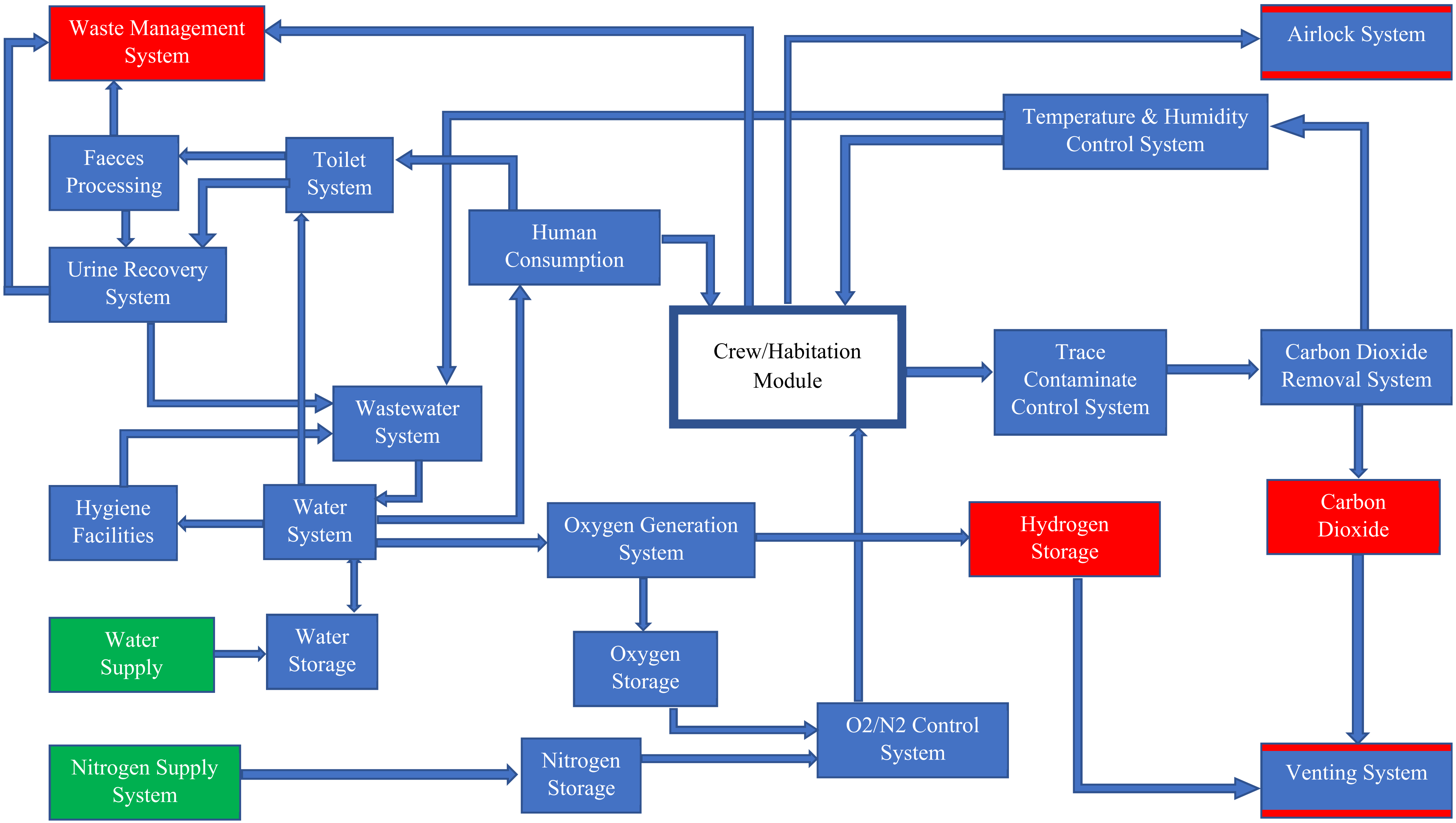


Figure 2-1Previous ISS ECLSS Set Up

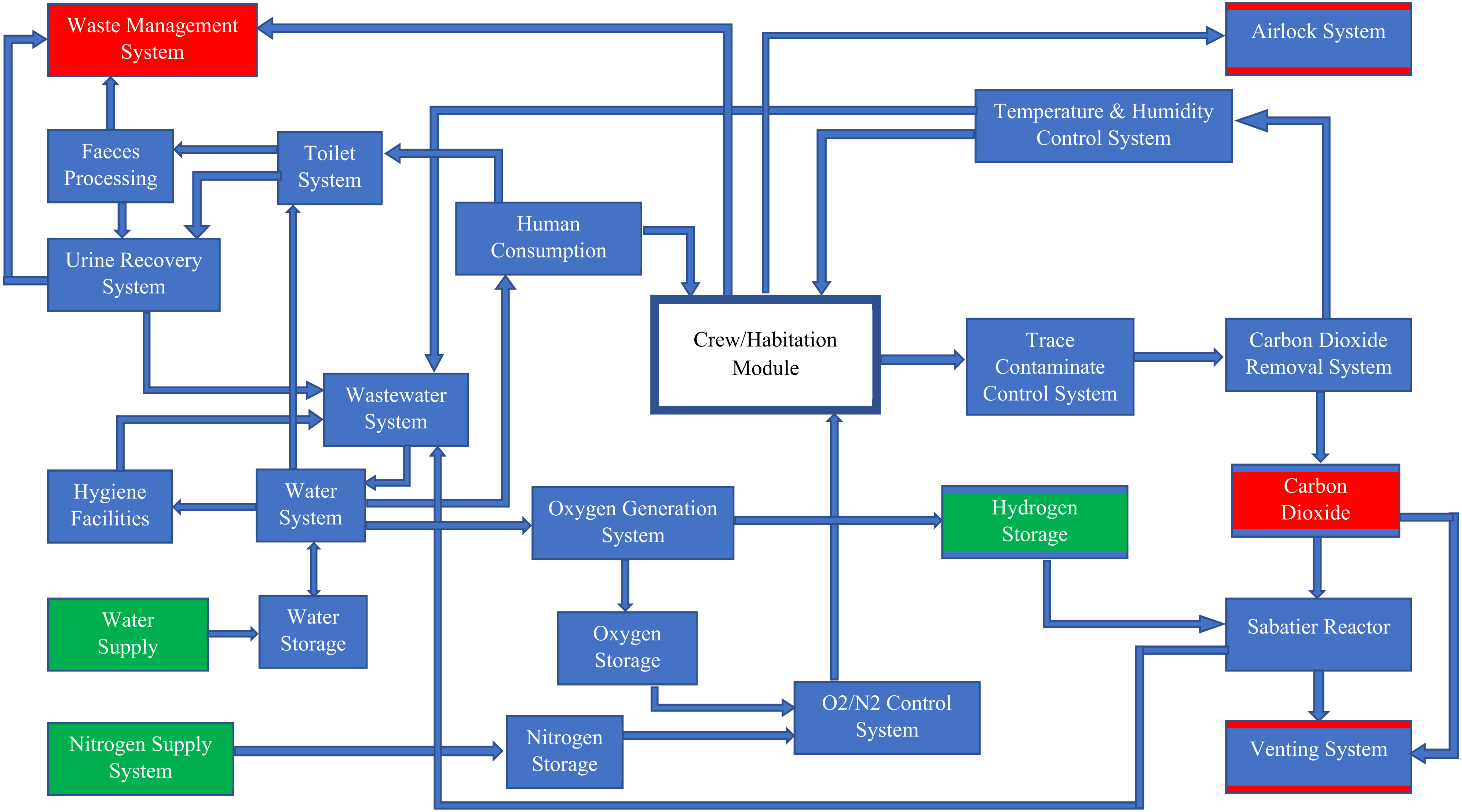


Figure 2-2Advanced ISS ECLSS Set Up with Sabatier Reactor

3 Project Overview – Carbon Dioxide Recycling System

3.1 Project Description

The project that Space Habitats is looking to undertake is the development of a Carbon Dioxide (CO_2) recycling system with Graphite and Oxygen production. This would entail reducing Carbon Dioxide (CO_2) to Oxygen (O_2) and Carbon Solid (C) with its current focus being to develop climate mitigation technologies which can be tried and tested before developing focused/specialised system.

This project will allow the Design, Test and Construction of a Prototype that will be used to safely convert Carbon Dioxide (CO_2) into Oxygen (O_2) and Carbon Solid (C) at room temperature and lower power input than current available designs.

The Oxygen biproduct will be collected and stored to be sold for industrial use. The Carbon biproduct will be collected and used to produce high grade Graphite that can be used as raw material for products such as high-quality carbon electrodes used in battery systems and other possible future commercial applications.

The Carbon Dioxide Recycling System will eventually be developed to operate in 3 different environments which are:

1 **Earth Environment:** Used as a method of reducing Carbon Dioxide (CO_2) in
   a. The atmosphere on a large scale as a method of combating Climate Change, and
   b. ECLSS to convert Carbon Dioxide (CO_2) back into Oxygen (O_2) as part of the ECLSS of Isolated Habitation Units such as
      i. Submarines
      ii. Isolated Bunker Systems
      iii. Environmentally Controlled Rooms

2 **Low Gravity Environment (Future):** Used as a method of converting Carbon Dioxide (CO_2) back into Oxygen (O_2) as part of the ECLSS of a habitat on the Moon or Mars or other celestial body.

3 **Micro/Zero Gravity Environment (Future):** Used as a method of converting Carbon Dioxide (CO_2) back into Oxygen (O_2) as part of the ECLSS of an orbiting Space Station or Space Transit Vehicle.

The delivery of the project will be broken down into various phases of which each has specific tasks and goals that need to be met to achieve the final goal of developing a Carbon Dioxide Recycling System. The Phase break down of the project is shown below:

1 Approval Phase,
2 Initiation Phase,
3 Research/Experimentation Phase,
4 Engineering Phase,
5 Manufacturing Phase,
6 Prototype Testing Phase, and
7 Real World Applications

For a more In-depth phase break down of the output required see Appendix A

The main systems that will be developed for this Carbon Dioxide Recycling System include the following:

1 Carbon Dioxide Direct Air Capture System (Supplier)
2 Carbon Dioxide Storage System
3 Carbon Dioxide Dispersion System
4 Electrolytic Mixture Preparation System
5 Electrolysis System
6 Oxygen Purification System (Supplier)
7 Oxygen Pressurization/ Liquification System (Supplier)
8 Oxygen Storage System (High Pressure, Supplier)
9 Oxygen Storage System (Liquid, Supplier)
10 Oxygen Dispersion System
11 DMF Removal System
12 Carbon Vaporization System
13 Solvent Separation System
14 Carbon Collection System
15 Electrical Power System (EPS)
16 Electrical Power Generation System (Solar PV)
17 Heat Energy Generation (50-200 DegC)
18 General Cooling System (10-20 DegC)
19 Remote Monitoring & Control System
20 Environmental Monitoring and Containment
21 Fire Detection & Suppression System
22 Housing

A more detailed breakdown of each system can be found in Appendix B

To successfully develop the Carbon Dioxide Recycling System industry experts will be required to help ensure that the module is developed in the correct manner and that all the required systems needed to operate the Carbon Dioxide Recycling System are adequately designed. Young talented but inexperienced engineers will be used to perform the “Grunt Work” whilst the industry experts will ensure that the right method is followed. Currently selected industry experts that will be utilised in the development of the Carbon Dioxide Recycling System include the following:

1 **Nelson Mandela University:** Research Expertise and Laboratory Controlled Environment to help conduct experiments required to select the best materials and most efficient methods and system set ups. Research will be conducted by the Chemistry department under the Supervision of Dr Adeniyi Ogunlaja.
2 **FME Consult Engineering:** Mechanical & Electrical engineers. Approached to act as the Projects mechanical & Electrical Engineers to help develop a system that will operate effectively and for a long period. Design will be led by Gideon van den Burg PrEng.

Additional industry experts will be required and selected based on their abilities in the relative field and how those abilities can be implemented into the development of the Carbon Dioxide Recycling System.

To help reduce the costs of developing new technologies and systems for the Carbon Dioxide Recycling System certain local suppliers have been selected to provide material/component/systems required for the development of the Carbon Dioxide Recycling System. Some of these suppliers are:

1 Crystallite (EL): Manufacture Plastic Products
2 Eyro Steel (EL): Stainless Steel Products
3 Aeochem (China): N,N-Dimethylformamide anhydrous, 99.9%
4 Henan Allgreen Chemical Co.,Ltd: (China): Tetrabutylammonium hexafluorophosphate
5 Shanghai Runwu Chemical Technology Co., Ltd. (China): Cerium
6 Wuhan Dongxin Mill Import and Export Trade Co., Ltd (China): Tin, Indium, Gallium

For a full List of potential suppliers which might be utilised for the development of the Carbon Dioxide Recycling System are listed in Appendix C.

Once the prototype has been developed to the required design specifications it will require extensive testing to be carried out on the system to ensure it functions effectively. Existing testing facilities can help to test certain aspects of the Carbon Dioxide Recycling System and how it will react to varying environmental and operating conditions. Project Specification to be followed are found in Appendix D.

Once the Carbon Dioxide Recycling System has been developed and thoroughly tested Space Habitats will find partners that are looking to develop large scale Carbon Capture System to help in the production of Graphite.

3.2 Goals & Objectives

Primary goals for the development of the Carbon Dioxide Recycling System will be:

1. To develop a system that can recycle carbon dioxide at a required rate of 1kg/d/unit (1 Person Equivalent)
2. To develop a system that operates on lowest power requirements to achieve its target rate,
3. To develop a system that is capable separating Carbon Solid particles in solution,
4. To develop a system to separate Oxygen from the Electrolytic Solution, and
5. To develop a safe system that will not harm humans that may encounter any of the harmful substances and materials in the system.

The current operating parameters for the Carbon Dioxide Recycling System will be the following:

1. **Structural/Housing Design Life:** Safe expected operation under use will be 20 years excluding components required to be replaced at regular service intervals of operation. (I.e. pumps)
2. **CO2 Removal Rate:** 1 kg/d/unit.
3. **Solvent and Electrolyte Loss to Environment:** 1mL/d (Max allowable for Isolated Habitation Systems due to toxic material)

Major system components required for the Carbon Dioxide Recycling System will be:

1. Carbon Dioxide Capture, Storage and Dispersion System,
2. Electrical Power System,
3. Electrolysis System,
4. Oxygen Capture, Storage and Dispersion System,
5. Carbon Solid Separation System,
6. Solvent Preparation System,
7. Carbon Solid Collection System.

3.3 Project Key Performance Indicators

The project's success will be measured using 4 primary indicators which are:

1. **Cost:** The cost performance of the project will be measured by comparing Planned vs. Actual costs.
2. **Schedule:** The schedule performance of the project will be measured by comparing Planned vs. Actual schedule.
3. **User Satisfaction:** The user satisfaction of the system will be measured by the feedback of users when the systems are placed under environmental testing conditions, and
4. **Project Quality:** The project quality performance will be measured by Quality Control and Quality Assurance inspections of the systems.

3.4 Project Assumptions

Key assumptions that have been made that will ensure the success of the Carbon Dioxide Recycling System:

1. Technology is sufficiently acceptable and safe to operate by humans on large scale systems to utilise the Carbon Dioxide Recycling System,
2. Technology is sufficiently economically viable to allow mass production of the Carbon Dioxide Recycling System for Climate Change reversing technologies,
3. Suspended Carbon solid in solution can successfully be removed from a closed system that will not leak the electrolyte or the solvent,
4. Carbon Dioxide Recycling System can be developed in an automated manner that will require minor human interaction, and
5. Increased interest by governments, companies and private client's once system is proven, leading to actual sales of the module,

3.5 Project Constraints

The current project constraints include the following:

1. **Project Funding:** The current project requires an initial investment with no returns expected over 1 year. We are currently looking for investors that are able to handle this type of investment or who have similar goals in their own business model or goals.
2. **Technology Expertise:** The current project requires expert knowledge in chemistry/chemical engineering as well as mechanical experts to help develop the full Carbon Dioxide Recycling System. To overcome this challenge, we will utilize the expertise of the original developers of the system as well as experts in the relevant fields to help us successfully deliver the project.
3. **Business Experience:** The current business is a start-up company that will require a strong team to complete the project. Additional members will be hired that both have the expertise and experience to handle this project in the current field and also have a desire to achieve the goals set out by the company.
4. **Alternate Solvents and Electrolytes:** Due to the dangerous nature of the solvent and electrolyte to humans when directly exposed to the substances the Carbon Dioxide Recycling System has added inherent risks. The use of these solvents in a closed environment such as the ISS would most likely not allow its use. As such alternative substances may need to be tried and tested to confirm if they are able to achieve the same outcome. Which substances would be best suited to the job are still currently unknown.
5. **Full Systems Testing Facilities:** Facilities do exist that may be able to partially test the Carbon Dioxide Recycling System for certain aspects such as strength and stress tests, vibrational testing, material testing etc. Currently South Africa does not have any infrastructure in place that is able to perform full systems testing on the Carbon Dioxide Recycling System for low gravity and micro/zero gravity applications

3.6 Project Risks/Issues

Risks/Issues

Risks that have been identified as major issues regarding the development of the Carbon Dioxide Recycling System are shown in Table 4.1 below.

Table 3.1Project Risk Assessment and Mitigation Measures

Risk Description	Inherent Risk	Risk Owner	Risk Mitigation/Risk Acceptance	Residual Risk
Under Estimation of Costs	High	Estimation/ Procurement Manager	Ensure that the complete design is estimated before the start of manufacturing. Ensure quoted costs of services include all required tasks and materials required to complete the work.	Medium
Energy Requirements of CO2 Recycling System	High	Design Manager	Ensure that the most efficient components are used within the system. Ensure efficient used of heat insolation/capture/transportation methods/systems to reduce energy loss to the environment. Energy requirements should be limited to the production of energy from 1kg of Coal.	Medium
Efficiency of Solvent/Electrolyte/Carbon Removal	High	Design Manager /Researchers	Ensure that the Carbon removal from the system is done in such a way that the Solvent & Electrolyte are not lost from the system. Replacement of new Solvent & Electrolyte should be kept to a minimum.	Medium
Operational System Failure	High	Design/Project/ Production/Quality Managers	Ensure that design safety factors are in place for possible failures, ensure the systems are constructed as design, ensure that sufficient testing is carried out on all aspects of the system from structural to equipment functionality.	Medium
Cash Flow	High	Financial Manager	Ensure that a safety net of a minimum 3 months is put in place to ensure that continuation of operations will not be adversely affected by funding requirements.	Medium
Inexperience of space module design and development	High	Project & Design Manager	Seek the help of industry experts and ask for consultations of each aspect of the module	Medium
Habitation Development of Moon/Mars Capabilities	Medium	Project Manager	**Risk Acceptance:** The rate of development of Habitation modules for future Space habitation units is not clearly defined and has a lot of industry hurdles to overcome. Development to be focused on areas in which the technology is currently viable for such Climate Change and Isolated Habitation Systems on earth	Medium

3.7 Preferred Solution – Liquid Metal Electrode Carbon Dioxide Recycling System with Reusable Solvent/Electrolyte System

The Preferred solution that Space Habitats will implement will be the Liquid Metal Electrode Carbon Dioxide Recycling System with a Carbon Solid Separation System connected to ensure minimal loss of Solvent, Electrolyte and LM Electrode. The Carbon Solid is separated and collected to produce Graphite to be used in Carbon Electrodes in Battery Systems.

The aim of the Carbon Dioxide Recycling System will be to help reduce Carbon Dioxide emissions in the air. The Carbon Dioxide Recycling System can also be used as a system that forms part of an ECLSS of an Isolated Habitation System for submersible vehicles, bunkers and space or off-world habitation units.

The fundamental aspects of the Carbon Dioxide Recycling System will remain the same, but the final commercial systems will vary based on the energy availability, production requirements and specific aspects of the environment in which it will be used.

3.7.1 Advantages:

The main advantages of developing the Carbon Dioxide Recycling System with Liquid Metal Electrode are:

1 **Reduced Energy Requirements:** The energy requirements of the Electrolysis System are reduced in the form of:
   a. Electrical Energy: Due to the use of a Catalyst and the Liquid Metal Electrode the Potential required for the reaction to take place is reduced when compared to other Carbon Dioxide reduction electrolysis systems.
   b. Heat Energy: The Reduction Reaction can take place at room temperatures and does not require the high heat requirements similar to Carbonate Melts systems.

2 **Improved Workability/Function:** Due to the fluidity of the Liquid Metal Electrode the Carbon Solid does not build up on the Electrode and is instead dispersed into the Electrolytic solution.

3 **Reduced Waste of Electrolytic Solution:** The System will be designed such that the Solvent is separated from the Carbon Solution before the Solid Carbon is collected. The clean Solvent and Electrolyte are returned to the Electrolysis Chamber for reuse. This reduces the demand for new Solvent and Electrolyte to be supplied.

4 **Flexible Operation:** The Carbon Reduction can operate continuously or periodically due to energy fluctuations provided an electrical current and the electrolytic solution is kept at the required level.

5 **Commercial Applications for Waste Products:** The Carbon that is collected as Graphite can be used to make electrodes for batteries, and the Oxygen collected can be used in industrial applications and processes. The sale of these products can help offset the cost of operating the Carbon Dioxide Recycling System.

6 **Useable in Isolated Habitation Systems:** Since the Solvent is removed prior to the collection of the Solid Carbon it can be used in environmentally enclosed areas occupied by humans.

3.7.2 Disadvantages:

The main disadvantages of developing the Carbon Dioxide Recycling System are:

1 **Higher Complexity:** The system is made more complex by utilising materials that are not commonly available or easily controlled and by increasing the required sub-systems required to carry out the task effectively.

   a. Liquid Metal Electrode: The fluidity of the Liquid Metal Electrode means that it is very difficult to prevent the metal from breaking off from the Electrical Contact and dispersing into the electrolytic solution. The Liquid Metal needs to be kept in a form that allows it to be continuously connected to the Electrical Contact.
   b. Solvent/Electrolyte Reuse System: Separation of Carbon Solid from the Electrolytic Solution can be difficult since the particles are suspended in solution,
   c. Multiple systems working in unison increases the complexity of the system.

2 **Higher Energy Requirements:** Due to the added Carbon Solid Separation System additional energy is required to operate the systems. Varying design setups could be implemented to reduce the requirements of direct energy input into the system by utilising direct solar energy in the evaporation chambers.

3 **Use of Dangerous Solvents:** The Solvents currently used to help the electrolytic process are
   a. Toxic and very harmful to humans and extreme care will always need to be taken to ensure no persons are affected by the substance during operation.
   b. Extremely Volatile and can ignite at temperatures above 150^{o}C.

4 **Specialized Service Requirements:** Due to volatility Solvents and the reactivity of the electrode to oxygen, special care always needs to be taken. Any servicing of the equipment will need to be carried out in specialized environments that is devoid of oxygen.

3.8 Alternative Analysis

Different options were considered for the development of the Carbon Dioxide Recycling System with the focus of the selection being based on;

1. Cost of Development,
2. Cost of Continued Operation,
3. Safety of Materials, and
4. Complexity of Development.

Alternative options that were considered for development are expanded upon below.

3.8.1 Alternative A – Conventional Solid Working Electrode

A solid Platinum (or similar Variation) can be used to electrolyze Carbon Dioxide in the Electrolytic Solution to form Carbon and Oxygen. The reaction unfortunately is limited to a certain period as the Carbon Solid builds up on the electrode until it is no longer able to perform the electrolysis.

3.8.1.1 Advantages:

The advantages of Solid Working Electrode include the following:

1. **Reduced Cost of Development:**
   a. The electrodes are readily available and can be produced on a commercial scale.
   b. Development of a specialized electrode is not required,
   c. Materials that are non-toxic and non-volatile can be utilized in the electrolysis process
2. **Reduced Complexity:**
   a. Specialized electrodes will not be required to be developed for the system.
   b. The Oxygen in the environment will not react with the electrode during installation which will remove the need for specialized installation requirements.
   a. The requirements of Carbon Solid separation system will not be necessary since all the carbon will collect on the electrode.

3.8.1.2 Disadvantages:

The disadvantages of developing a Solid Working Electrode include the following:

1. **Increased Costs to Continued Operation:** Due to the continued carbon build up on the electrode the performance of the electrode will start to deteriorate and require continued maintenance or replacement.
2. **Increased Energy Costs:**
    a. The energy requirements of the conventional electrolysis are higher due to higher potential difference required to drive the reaction,
    b. Higher temperatures are required to drive the reaction due to the electrolytic solution being solid at room temperatures, and
    c. Carbon Separation System has additional energy requirements.
3. **Reduced Carbon Solid Production per cycle:** Due to continued buildup of Carbon on the Electrode the amount of Carbon that can be produced becomes periodic and will result in reduced overall production when the electrodes are not replaced on a continuous basis.
4. **Specialized Service Requirements:** Due to high head and large current requirements of the electrode, special care always needs to be taken. Any servicing of the equipment will need to be carried out by trained personal.

3.8.1.3 Reason for Rejection:

The main reason for the rejection of this alternative was that the energy costs during operation and costs associated with continuous replacement of the electrodes would not be beneficial for commercial applications.

3.8.2 Alternative B – Carbon Dioxide Recycling System with Non-Recycled Solvent/Electrolyte

The Carbon Dioxide Recycling System could be designed to not include the Solvent/Electrolyte purification system. This will allow a system that is less complex and allow lower operating energy requirements. This method will only be applicable to Systems that are in areas that have access to Solvent treatment facilities. It will not be possible to use this system as part of an Isolated Habitation System that does not have a separate treatment facility. New electrolytic material will need to be continuously supplied. Material could however be taken to a central processing facility if multiple units are used in close proximity to each other and the facility.

3.8.2.1 Advantages:

1 **Lower Operating Energy Requirements:** Since individual separation systems are no longer required, the energy requirements of the system will be reduced.
2 **Reduced Complexity:** Without the Separation Sub-System the Carbon Dioxide Recycling System will become less complicated. The Solvent/Electrolyte can be treated by other means.

3.8.2.2 Disadvantages:

1 **Higher Operating Material Cost**: Due to the solvent/electrolyte not being reused by the system new clean material will need to be constantly supplied and used material will need to be continuously removed and safely disposed of by other means. The Carbon solid will also not be directly usable and require further treatment.
2 **Not Applicable to Isolated Habitation Systems:** The system can not be used by Isolated Habitation Systems that do not have a separate solvent treatment facility.
3 **Use of Dangerous Solvents:** The Solvents currently used to help the electrolytic process are
    a. Toxic and very harmful to humans and extreme care will always need to be taken to ensure no persons are affected by the substance during operation.
    b. Extremely Volatile and can ignite at high temperatures.
4 **Specialized Service Requirements:** Due to volatility Solvents and the reactivity of the electrode to oxygen, special care always needs to be taken. Any servicing of the equipment will need to be carried out in specialized environments that is devoid of oxygen.

5 **Separate Treatment Facility:** The Solvent contaminated with Carbon will need to be treated at a separate treatment facility which will lead to increased costs in transportation.

3.8.2.3 Reason for Rejection:

This option can be very useful as an alternative for global climate change systems which will have more flexibility in their operating parameters that allows for a single treatment facility with smaller scale Carbon reduction systems set up at separate small scale industries that produce CO_2 as a biproduct of their processes. This option also increases the overall costs associated with Carbon Reduction by added additional transportation costs required to transfer the carbon solution to the treatment facilities.

3.8.3 Alternative D – Do-Nothing

The alternative of doing nothing will always be an option but will also lead to lost opportunities that may be beneficial not only to Space Habitats but also to related space industries and global climate change efforts. The do-nothing approach would assume that the Carbon Dioxide Recycling System will not be developed, or it will be developed by other companies who have more experience and access to financial resources to handle this type of development.

3.8.3.1 Advantages:

1 **No Capital Investment for High Risk Project Required:** The advantage of do nothing is that it will not cost anything and allow the investors to allocate the same resources to other areas which they believe are more suited to their needs. The project is a high-risk endeavour and would not be in the best interest of many investors.

2 **The Risks associated with Carbon Dioxide Recycling Systems are Borne by Others:** Some of the high risks involved with Carbon Dioxide Recycling System is that you will be responsible for the users of the module and any harm caused to the users due to the system failures of the Carbon Dioxide Recycling System. If the system fails, it will lead to a lot of negative feedback from the public which could end business in their tracks and result in high loss of capital that can't be returned.

3.8.3.2 Disadvantages:

1 **No alternative to Effective Carbon Storage Systems:** Currently there is no save way to storage large quantities or Carbon Dioxide that is captured from the atmosphere.

2 **Continued Use of alternative Carbon Dioxide Systems in ECLSS**: Current alternative Carbon Dioxide controls for Isolated Habitation Systems are not near 100% Reusability of materials at the moment.

3 **Continued High Cost Habitational Modules:** Space technologies and systems have all come with a price that was too high for many users to ever develop. If the current industry does not see a change in some way then it will continue to be out of the reach of many governments, businesses and people.

3.8.3.3 Reason for Rejection:

Space Habitats plans to ensure that humanity is able to colonize off-world locations by making it more affordable to do so. Having identified some of the causes that make habitational modules so expensive we believe that Space Habitats will be able to deliver on this challenge and as such cannot allow an option of do-nothing.

3.9 Major Project Milestones

The major project milestones are indicated in Table 3.3 Below.

Table 3.2Project Schedule and Milestones

Work Breakdown Structure					2019					2020												2021	
Phase	**Task**	**Duration**	**Start**	**Finish**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**
Approval Phase																							
Initiation Phase																							
Small Prototype	Create small prototype that is able to produce Graphite at higher rate than Experiment at 1kg/day or 1 kg/h as proof of concept	122	01 Aug 19	01 Dec 19																			
Experimentation Phase 2	Perform experiments to determine most efficient system	273	01 Feb 20	31 Oct 20																			
Engineering Phase	Design requirements for modular Electrolysis System to be scaled up	295	01 Mar 20	21 Dec 20																			
Manufacturing Phase	Manufacture modular system with sufficient cappacity for basic operation. Capacity TBD	244	01 Apr 20	01 Dec 20																			
Testing Phase	Test System for synchronicity and unforeseen issues	21	01 Dec 20	22 Dec 20																			
Real Word Application	Develop Small Scale Production facility for Niche market Applications. Capacity TBD	360	02 Jan 21	28 Dec 21																			

4 The Market

4.1 Industry Analysis

The following section provide an overview of industries that will use have a need for the Carbon Dioxide Recycling System and will be able to utilise it.

4.1.1 Industry analysis – Carbon Capture and Storage Technologies from Carbon Dioxide

An overview of the Carbon Capture related technology industry is given in the below sections. The current technologies include Carbon Dioxide Capture, Carbon Dioxide use in Fuel production and various Carbon Dioxide Storage systems.

4.1.1.1 Current methods for Carbon Dioxide Capture, Storage and Utilisation

4.1.1.1.1 Vegetation – Trees, Crops, Grass, Algae

Plants can convert Carbon Dioxide through photosynthesis and can enable the storage of Carbon Dioxide in the form of Carbohydrates in the plants. The rate of carbon capture is dependent on the type of plant, availability of water and its conversion rate of sunlight to allow the production of the carbohydrate in the plant. Limitations to this type of technology is the rate of carbon capture of the plant, available land area, rate of trees planted and use of the vegetation after growth is complete (The vegetation can produce Carbon Dioxide back into the atmosphere (forest fires, decomposition etc.) resulting in an increased natural/human Carbon Dioxide production.

An average tree absorbs 21kg Carbon Dioxide per year. Assuming an average coverage of 36m^2 per tree we would require around 68 million km2 of trees (1.9x10^{12} Trees) to accommodate the 39.7 $GtCO_2$/Year (Global Carbon Project, 2018) human related Carbon dioxide production. The earth has 148.9 million km^2 of land area of which only 31 million km^2 of it is arable. The requirement of the trees also does not include natural sources of carbon dioxide. Currently arable land is being lost at an estimate 100 000 km^2/year. Currently Vegetation is estimated to process 11.6 $GtCO_2$/Year (Global Carbon Project, 2018) which accounts for both natural and human sources.

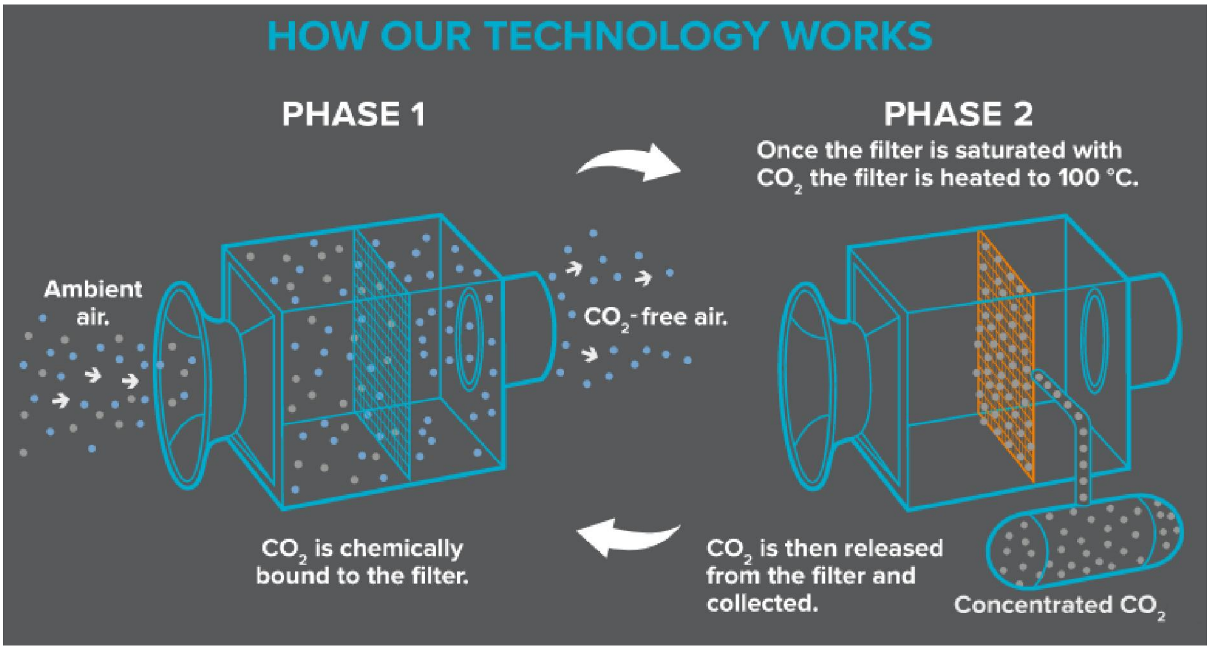
4.1.1.1.2 Water Sinks – Oceans, Lakes

The use of Oceans as a Carbon Dioxide sink has been suggested as an initial method to help reduce the Carbon Dioxide levels in the atmosphere. Unfortunately, the effects of increasing the concentration in oceans also results in the creation of a toxic environment for the aquatic life. The main cause is the presence of carbonic acid that started to form and damaged the marine habitats such as coral reefs. The increase of Carbon Dioxide in the Oceans is also directly proportional to the concentration of the Carbon Dioxide in the atmosphere, thus as the concentration of Carbon Dioxide in the atmosphere increased so too does the concentration in the Oceans.

The Oceans are currently absorbing the 9.2 $GtCO_2$/Year (Global Carbon Project, 2018) Carbon Dioxide use which accounts for both natural and human sources. In 1960's the Ocean was only required to absorb less than 5 $GtCO_2$/Year but from 2008 to 2017 the Ocean Carbon Dioxide absorption increased from 8.9 to 9.2 $GtCO_2$/Year. The concentration of Carbon Dioxide has been continually increasing over the years from 1960 to 2017. The Ocean Sink accounts for around 22% of Carbon Dioxide use.

4.1.1.1.3 Carbon Dioxide Direct Air Capture

In Switzerland a company called Climeworks has developed large scale Carbon Dioxide Direct Air Capture units that are able to suck the Carbon Dioxide straight out of the air. The technology is designed to be used in tandem with other Carbon Dioxide conversion technologies and processes that will be able to use the Carbon Dioxide produced to produce new materials and allow carbon neutral or negative technologies to become a reality.



Source: Climeworks

Figure 4-1How Climeworks removes CO_2 from the Atmosphere

4.1.1.1.4 Carbon Dioxide Conversions to Fuel

In Canada a company called Carbon Engineering is developing a method to capture Carbon Dioxide from the atmosphere and convert it into fuel. The technology is aimed at providing a carbon neutral fuel that is more efficient than current biofuel options.

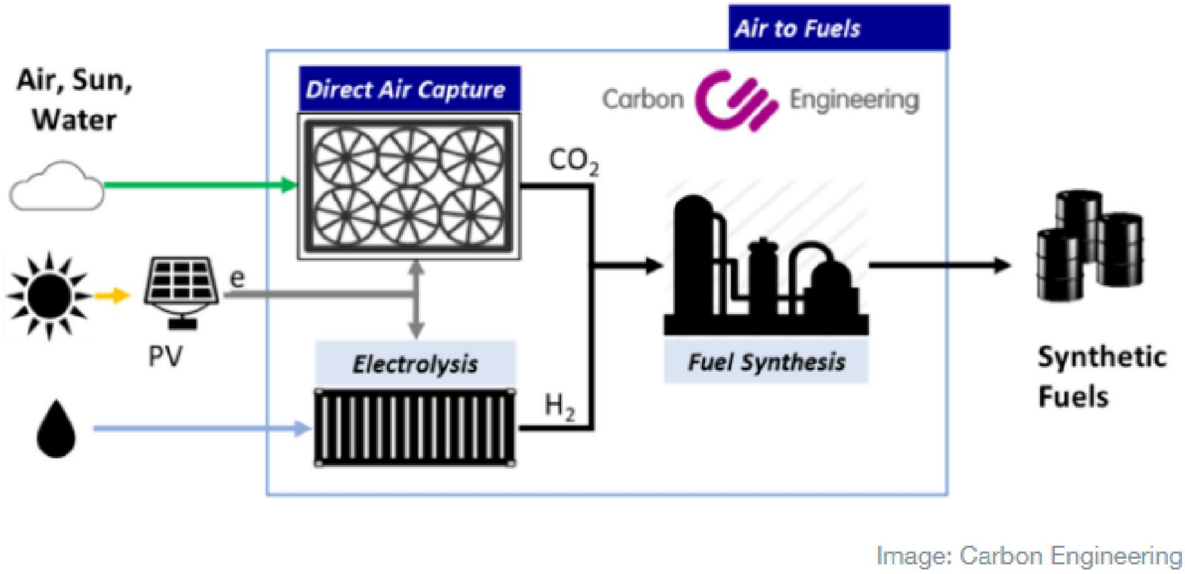


Figure 4-2 Carbon Engineering method of CO_2 Conversion to Fuels

4.1.1.1.5 Carbon Dioxide Conversion to Rock

The CarbFix Project in Iceland at the Hellisheidi Power Plant has successfully converted Carbon Dioxide in the air into Basalt rock over a 2 year period. The technology is designed to be a Carbon negative technology that will help the reduced the Carbon Dioxide levels in the atmosphere.

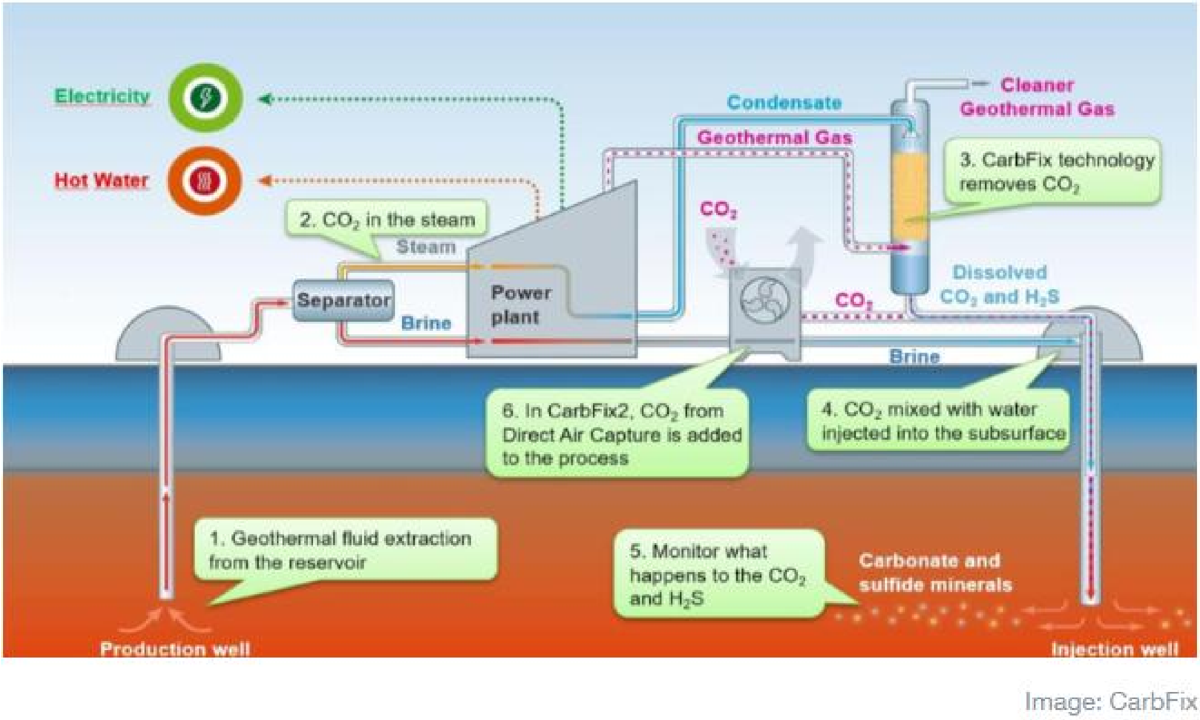


Figure 4-3CarbFix method of CO_2 Conversion to Basalt Rock

4.1.1.1.6 Carbon Dioxide Storage Underground

New research by ENOS is being used to establish the requirements and safety concerns of storing Carbon Dioxide deep in the ground across sites in Europe. The aim is to provide large scale storage locations for Carbon Dioxide that will be removed from the atmosphere. The technology aims to be Carbon negative by helping to reduce the Carbon Dioxide level in the atmosphere.

4.1.1.1.7 Alternative Carbon Dioxide Conversion to Carbon Solid and Oxygen

Currently Carbon Dioxide can be converted into Carbon Solid and Oxygen using high temperatures which require a high energy input.

4.1.1.1.8 Current Human Carbon Dioxide Emissions

As of 2017 the global Carbon Dioxide emissions from Fossil Fuels and Land Use Change amounted to 41.2 $GtCO_2$ (11.3 GtC)

4.1.1.2 Carbon Storage from Carbon Dioxide Technology Market Value

Currently carbon storage technologies that are being developed do not offer a direct monetary return to investors but rather an indirect investment to a more sustainable environment that is able to reduce or offset the financial impact of climate change.

> *A study by CitiGroup found that rampant warming could shave up to $72 trillion off the world's gross domestic product, while another report in the journal Nature found it could reduce average global incomes by nearly a quarter. A four-degree Celsius jump would also batter sectors like agriculture, real estate, timber, and emerging market equities. All told, that would make for a toxic environment for businesses large and small. (World Bank, 2016)*

Currently a lot of development and investment is happening in Green Technologies that are aimed at reducing the reliability of people and businesses on the use of oil or carbon dioxide producing technologies. These technologies are helping to offset the impact of carbon dioxide producing energy systems by making systems more efficient and partially substituting the energy requirements with cleaner options.

Sustainable business models have the potential to unlock [$12 trillion] in new market value, according to a report by the Business and Sustainable Development Commission.

The transition to electric vehicles (EVs) is accelerating rapidly. Automakers have already announced more than [$150 billion] in investments to achieve collective production targets of over 13 million EVs annually by around 2025.(World Economic Forum, 2019)

The Carbon Dioxide Capture and Storage is currently in the development stages with full research being conducted into methods of safely storing the Carbon Dioxide or converting it to another form. Currently these technologies are being funded by Government and Non-profit Organisations with the aim of reducing the impact of Carbon Dioxide on the Climate.

4.1.1.3 Carbon Storage Technology Industry Stakeholders

The current stakeholders in the Carbon storage technologies are Governments and Non-profit Organisation aimed at reducing the effects of carbon dioxide on the atmosphere, private businesses and individuals who are affected by the impact of climate change in various ways.

The Governments are the 195 signatories of the Paris Agreement at the 21st Conference of the Parties of the UNFCCC. The Paris Agreement's long-term goal is to keep the increase in global average temperature to well below 2 °C above pre-industrial levels; and to limit the increase to 1.5 °C, since this would substantially reduce the risks and effects of climate change. Under the Paris Agreement, each country must determine, plan, and regularly report on the contribution that it undertakes to mitigate global warming.

Non-Profit Organisations are those who have been established to help develop technologies and improve the awareness of climate change impact on the Earth. These organisations also include specific funds that have been established to carry out the required research and development of technologies to mitigate climate change such as the Green Climate Fund.

Private business stakeholders include the business directly/indirectly involved with developing technologies to reduce the impacts of Climate Change as well as businesses directly/indirectly affected by climate change related impacts/disasters.

The hurricane trio of Harvey, Irma and Maria will cost the insurance industry a record amount in 2017: the final insurance bill for those and other natural catastrophes, including a severe earthquake in Mexico, is expected to come to US$ 135bn – higher than ever before. And overall losses – i.e. including uninsured losses – amounted to US$ 330bn, the second-highest figure ever recorded for natural disasters. (Munich RE, 2018)

Private individual stakeholders include the individuals directly/indirectly involved with developing technologies to reduce the impacts of Climate Change as well as individuals directly/indirectly affected by climate change related impacts/disasters. Due to climate change extreme weather event frequencies are increasing which results in individuals that could have their property destroyed as a result of extreme weather events and as the worst-case scenario could lose their lives as a result of increased extreme weather events.

4.1.1.4 Access to Carbon Storage Related Technology

Currently a wide range of new Carbon Storage related technologies are available as research papers with ideas of how carbon can be stored in various forms. A few Carbon Storage systems have gone into prototype development phases. Currently the only available Carbon Dioxide Storage systems that are commercially available are high pressure gas or liquid containment units that are used to provide Carbon Dioxide to various industry related applications. The Carbon Dioxide containment units are only used as temporary storage solutions and are not a permanent solution for storing Carbon Dioxide.

The main factor that will govern the industry will be the need to combat climate change and the supply and demand of the various technologies. The competitiveness of a supplier will be based on their costs incurred in production/assembly, reliability, safety features and any other specialist requirements for the client of the system and its location of use.

4.1.1.5 Carbon Storage Related Technology Agencies

Currently there is no agency that directly oversees the development and use of Carbon Capture and Storage devices in South Africa. There are international committees that monitor the production Carbon Dioxide and its effects on the climate. Governmental agencies are in place that oversee the remuneration/penalising of companies that remove/produce carbon dioxide emissions which is for the most part operated by the Tax Revenue Service of the country in question.

The use of certain technology will come with inherent risks that will need to be dealt with in manner that is appropriate. Currently the only method of ensuring the quality and safety of the product will be to ensure that they are compliant with internationally recognised standards such as ISO 9001, 14001 and OHSAS 18001.

4.1.1.6 Major Carbon Storage Related Technology Companies and Organisations

The following lists represents companies that are currently involved in the development/commercial application of carbon capture/& storage technologies from Carbon Dioxide:

1. Carbon Dioxide Capture (Potential Suppliers/Customers)
    a. Climeworks
    b. Carbon Engineering
    c. Global Thermostat
2. Carbon Dioxide Storage (Potential Competitor/Alternative Use for CO_2)
    a. Bioenergy with Carbon Capture & Storage related companies
    b. Shell (Quest)
    c. ENOS
3. Carbon Dioxide used in manufacturing, bottling, and distribution
    a. Linde Group
    b. Universal Industrial Gases Inc.
    c. INOX Air Products
    d. Air Products & Chemicals Inc.
    e. Universal Gases Inc.
    f. Praxair,
    g. Air Liquide

4.1.2 Industry Analysis – Human Space Exploration

An overview of the Space Industry in given in the below sections based on various industry expert institutions.

4.1.2.1 Space Industry Market Value

The Space Industry is emerging as one of the most lucrative industry globally. The Space Industry, is valued at US$ 360 billion in 2018, is projected grow at a CAGR of 5.6%, to value US$ 558 billion by 2026. Demand for nano-satellites and re-usable launch vehicle systems is anticipated to be driven by the massive investment made by countries like US, China, Russia and the European Union in the development of next generation satellite systems and the large scale procurement of such systems by countries like Saudi Arabia, India, Japan and South Korea. The United States is the largest spender in the domain with China, European Union, India, Russia, Japan and South Korea anticipated accounting for the bulk of spending.

Technavio's analysts forecast the global space habitat market to grow at a CAGR of 13.83% during the period 2017-2021.

North America is expected to account for the largest share of the total global expenditure followed by the Asia Pacific Region where countries like China, India, South Korea and Japan are investing billions to procure such systems.

(ReportBuyer, 2018)

4.1.2.2 Space Industry Stakeholders

Space industry stakeholders are national space agencies, system integrators, subsystem suppliers, equipment suppliers, service and ground support companies. The customers in the space industry are classified into institutional and commercial ones.

The institutional ones are national and intergovernmental civil space (and defence), meteorological agencies (i.e. EUMETSAT, NOAA). Today, agencies such as NASA in the USA, Russian Federal Space Agency (i.e. Roscosmos) in Russia, ESA in Europe, JAXA in Japan, ISRO in India, are responsible for the majority of space programs.

The commercial customers in the space market are commercial satellite operators and launch service providers. Commercial satellite operators are often referred to as telecommunications operators and are specialised in satellite operations and the provision of communications, broadcast and mobile personal and professional communications. These are companies such as InmaRoscosmost, Eutelsat, SES Astra and Intelsat. There are also launch service operators that integrate and operate to provide commercial launch services to institutional and commercial customers.

Launch service providers are companies such as United Launch Alliance (ULA), Arianespace, and International Launch Services or Sea Launch. The suppliers in the space industry are system integrators, subsystem suppliers, equipment suppliers, as well as service and ground support companies.

System integrators are the companies that have the competencies and knowledge to design, develop and integrate a complete space satellite. These are companies such as Lockheed Martin and Boeing in the USA, and EADS Astrium and Thales Alenia Space (TAS) in Europe.

Subsystem suppliers are companies that design, develop and produce space-based subsystems (i.e. solid booster, solar generator, engine, etc.).

Equipment suppliers are companies that develop and produce equipment for the successful integration of space systems and subsystem levels (solar cells, EEE components, valves, mechanical parts, software suppliers).

Services and ground support companies are companies that provide ground system design, development, manufacturing, operations of non-commercial systems (including raw data sales from EO satellites), and engineering services (Eurospace, 2011).

4.1.2.3 Access to Space

Access to space represents the first and indispensable element of the space-related value chain, its costs determine to a substantial degree the costs of entry into the space market and its dynamics. Furthermore, access to space, that is the provision of launch services, represents a business field of its own.

Recently, two American launch providers succeeded not only in recovering the first stages of their launchers, but also in successfully re-flying them. It is expected that in the mid- to long-term reusability will allow substantial reductions in the cost of access to space.

The major challenges posed by reusability are not only of technical but also of economic nature. The latter, since the introduction of reusability into a launch service, comes with three major economic penalties:

1. *Loss of performance and thus loss of related income, due to additional structural and component masses and additional amounts of fuel needed for the recovery of the stage(s),*
2. *Refurbishment costs,*
3. *Loss of economies of scale in production lines.*

As a consequence, a key requirement for the successful introduction of reusability is a high enough launch volume, in order to make full use of the gained mission flexibility (launcher can in principle be economically flown with less than maximum payload) and to mitigate the effects of loss of economies of scale in production.

Due to its potential for cost reductions, reusability will in the long-term likely become a key determinant for the competitiveness of commercial launch providers.

With a view to the emergence of capable small satellite and small satellites constellations, also small launch vehicles are showing a promising commercial potential.

The development of such small launchers may also be helpful for low-cost testing a variety of technologies needed for reusability, be it for small or for heavy launchers. (ESRE, 2017).

4.1.2.4 Space Exploration and Human Space Flight

Space science and human spaceflight were very much at the origin of the global space effort. They have not only been vital sources of inspiration and international cooperation but were also key for the technological advancement of space technologies.

Questions related to the history of the universe and the solar system, the origin of life and the possibilities of the extension of the human presence beyond Earth will continue to remain focal areas of space exploration.

Two general trends are expected to influence the sector particularly strongly in the upcoming future.

First, due to the progresses in computational and robotic powers, autonomous capabilities will become much more advanced, both related to unmanned missions and to the assembly of human spaceflight infrastructure in space.

This trend also comprises the use of artificial intelligence in support of in-situ autonomous mission control, also by e.g. integrating collaborative teams (or swarms) of robots into mission concepts.

Second, the cost for human spaceflight activities will be further brought down substantially by cousing launchers and infrastructures being commercially available on the global market for unmanned missions or space tourism (e.g. reusable launchers, inflatable habitable modules, etc.).

These possibilities arise in particular because of the aforementioned possibilities for robotic assembly (ESRE, 2017).

4.1.2.5 Space Agencies

The are many different space agencies around the world who are mostly involved in the operation of satellites or ground based observation systems and only a few of them are directly involved in space exploration activities.

The combined budget of all these space agencies is only around $43 Billion. Of which NASA’s share is the largest at an estimated $19 Billion. The major space agencies include the following:

1. National Aeronautics and Space Administration (NASA)
2. European Space Agency (ESA)
3. Russian Federal Space Agency (Roscosmos)
4. China National Space Administration (CNSA)
5. Japan Aerospace Exploration Agency (JAXA)
6. Indian Space Research Organisation (IRSO)
7. Canadian Space Agency (CSA)

Only 14 Countries currently have the ability to launch payloads to space, of which only 3 have the ability to launch humans into space. The establishment of private businesses with the ability to launch payloads and soon humans to space is steadily increasing.

4.1.2.6 Major Space Industry Companies

A list of major industry companies is given in Table 4.1 below. Companies who deal with Human Rated Systems will be potential customers once our product has undergone testing and is proven flight ready. Some companies will be competitors due to existing systems that are able to provide a similar service such as United Technologies/Colins Aerospace who developed the current systems in use on the ISS habitation modules and current system in development that are being tested. Other companies will be partners in the supply of Space Rated materials, components and sub systems, and some will be needed to deliver the habitation module to its required destination.

Table 4.1Companies Involved in the Space Industry

Company	Government Funding	Private Funding	Customers Preference	Technical Services
Lockheed Martin **– Launch Services, Components & Satellite Manufacture,**	NASA, US DoD	Satellites, Payloads (United Launch Alliance), Aerospace	High – Good track record	Research, Design, Engineering, Development, Manufacture, Deployment, Support,
Northrop Grumman **– Launch Services, Satellite Manufacture**	NASA, US DoD	Satellites, Payloads (Orbital ATK), Aerospace	High – Good track record	Design, Engineering, Development, Manufacture, Deployment,
Honeywell International **– Component Manufacture**	NASA	Satellite, Modules systems, Commercial Unit	Very High – Intentionally recognised, Brand loyalty	Research, Design, Engineering, Development, Manufacture, Support,
United Technologies/Colins Aerospace **– Component/Systems Manufacture**	NASA, US DoD	Aerospace, Module systems, Commercial	High – Good track record	Design, Engineering, Development, Manufacture,
Boeing **– Launch services, Module development**	NASA	Aerospace, Payloads (United Launch Alliance), Modules systems, Commercial	Very High - Intentionally recognised, Brand loyalty	Research, Design, Engineering, Development, Manufacture, Deployment, Support
Bigelow Aerospace **– Habitable modules**	NASA	Owner Funding, Habitable Module,	Low – Prototype testing complete.	Design, Engineering, Development, Manufacture,
Blue Origin **– Tourist Rides to Space, Launch services**	US Air force	Owner/Pvt Funding (+$2.5B),	Medium – Development Stage, New contracts awarded	Design, Engineering, Development, Manufacture, Deployment
Energia (Russian) – Launch Services	Roscosmos, Russian DoD,	Payloads,	High – Low cost and relatively good track record	Research, Design, Engineering, Development, Manufacture, Deployment, Support,
SpaceX **– Launch Services**	NASA	Owner/Pvt Funding, Payloads, Global Internet service	Very High – increase success rating and lower costs,	Research, Design, Engineering, Development, Manufacture, Deployment, Support,
Virgin Galactic **- Tourist Flights**		Owner/Pvt Funding,	Medium – Tickets already sold, Development	Research, Design, Engineering, Development, Manufacture, Deployment,
Sierra Nevada Corporation **– Developing Space Habitats (NASA NextSTEP-2)**	NASA, US DoD	Space Industry Components, Orbital Flights (Dev), Habitable Module (Dev)	Medium – Development contracts awarded,	Research, Design, Engineering, Development, Manufacture, Deployment,
Made in Space **- Space Manufacturing**	NASA	Owner/Pvt Funding, Orbital Construction	Low – Protype and development stages	Research, Design, Engineering, Development
Ad Astra Rocket Company	NASA	Owner/Pvt Funding, Rocket Propulsion		Research, Design, Engineering, Development, Manufacture
Planetary Resources (Asteroid Mining)/ConsenSys	Gvt Luxembourg	Owner/Pvt Funding,		Research, Design, Engineering, Development, Manufacture
Airbus Defence & Space **– Ariane Rockets, ISS Modules**	ESA, Gvt Defence	Ariane Rockets, Spacecraft, Satellites, Defence Tech,	Very High – Good Track Record	Research, Design, Engineering, Development, Manufacture, Deployment, Support
Aerojet Rocketdyne	NASA	Rocket Systems,	High	Research, Design, Engineering, Development, Manufacture,
Astrobotic Technology, Inc		Lunar Payload Delivery	Low – Protype and development stages	Payload delivery,
Axiom Space		Pvt Space Station, Tourism	Low – Protype and development stages	Developer
Cislunar Space Development Company		Pvt, Earth Orbit and Lunar Transfer vehicle	Low – Protype and development stages	Research, Design, Engineering, Development, Manufacture,
Deep Space Systems, Inc.				Research, Design, Engineering, Development, Manufacture,
Paragon	NASA	Aerospace, Module systems, Commercial	Medium – Protype and development stages	Research, Design, Engineering, Development, Manufacture

4.1.3 Industry Analysis – Isolated Habitats Environmental Control and Life Support Systems (ECLSS)

An overview of the Isolated Habitats Industry is given in the below sections. An Isolated Habitat is any structure which is isolated from its surrounding environment and requires an independent Environmental Control and Life Support System (ECLSS) to operate and be occupied by humans. Examples of these systems are Submersible vehicles such as submarines, bunkers such as nuclear fallout shelters and underground installations far removed from the surface such as deep mines.

4.1.3.1 Isolated Habitats Industry Market Value

Currently Sweden has over 65 000 nuclear shelters and in 2019 its expecting to increase this number whilst also conducting renovations on existing shelters. Switzerland has over twice that amount shelters compared to Sweden. Other countries such as US, UK, Russia and many others all have nuclear shelters that have been built as a precaution in the event of a Nuclear war.

All these shelters currently can provide shelter for short durations depending on the amount of storage that is allowed for food storage, water storage and air quality control systems. Currently all the Air regulation systems operate using nuclear, biological, and chemical (NBC) filtration systems which remove particles down to 0.3 microns.

There are currently an estimated 500 military submarines in service around the world and around 50 commercial/tourist/research vehicles with submersible capabilities. These vehicles operate using either a stored Oxygen Supply or an Oxygen Generation System (OGS) with a single use and renewable Carbon Dioxide Scrubber to remove the Carbon Dioxide.

There are currently around 2300 active mineral exploitation sites around the world. Deep Shaft Mining Facilities use a series of large fan systems and specially design tunnels and shaft pathways to circulate the air inside the mine. Air enters from one shaft and exits from another shaft. The systems could be adapted to incorporate Air Revitalisation Systems to help remove the Carbon Dioxide from the air in shafts and ensure the current levels of Oxygen for the workers is maintained.

4.1.3.2 Isolated Habitats Industry Stakeholders

The current stakeholders in the Isolated Habitat technologies are governments, research organisations, private businesses and individuals who are involved with the development, manufacturing and operation of Environmental Control and Life Support Systems (ECLSS), sub-systems and components.

The government stakeholders are those that operate isolated habitation units such as Submarines operated by military branch of the government and Nuclear/Bomb Shelters operated by various government departments.

Research organisations stakeholder include the organisations that operate civilian submersible vehicles used in oceanic research or laboratory set-ups that have isolated environments which require a self-regulating ECLSS.

Private business stakeholders include the business directly/indirectly involved with developing/manufacture/operation of technologies/systems/sub-systems/components used in an ECLSS.

Private individual stakeholders include the individuals own private nuclear bunker systems or will use the bunker systems in the event of an emergency.

4.1.3.3 Isolated Habitat Related Agencies

Space Habitats is not currently aware of any Agency in South Africa or in the World that has been established to monitor the development and use of Isolated Habitat and related systems. Bunker system in various countries will most likely be monitored by government facilities who are tasked with maintaining these facilities.

The use of certain technology will come with inherent risks that will need to be dealt with in manner that is appropriate. Currently the only method of ensuring the quality and safety of the product will be to ensure that they are compliant with internationally recognised standards such as ISO 9001, 14001 and OHSAS 18001.

4.1.3.4 Access to Isolated Habitats Industry

Certain industries such as those related to military or national security government institutions will require the use of national companies or companies that are able to achieve a security clearance rating associated with the project. The way to overcome these issues would be to partner with a company that does have the necessary clearance and act as a supplier or sub-contractor to the partnering company.

There are currently no major restrictions or obstacles to the Isolated Habitat Industry for commercial or private use. The main factor that governs the industry is supply and demand. The competitiveness of a supplier will be based on their costs incurred in production/assembly, reliability, safety features and any other specialist requirements for the client of the system and its location of use.

4.1.3.5 Major Isolated Habitats Related Technology Industry Companies

Isolated Habitation industry companies are those that are involved in the supply of systems/components that are required to constructed self-sustaining system. Examples in clude companies that are able to provide air purifiers that can be used to clean the air of harmful gases and replenish oxygen supplies.

4.1.4 Industry Analysis – Carbon Related Products (Mainly Graphite)

The Carbon Dioxide Recycling system produces Carbon Solid flakes as a bi product of the process. The Carbon flakes can be used as a source of Graphite.

An overview of the Graphite Industry is given in the below sections based on various industry expert institutions. Graphite production can be used to help offset the costs incurred by the Carbon Dioxide Recycling System.

4.1.4.1 Graphite Industry

Graphite can behave like a metal and conduct electricity but also as a non-metal that resists high temperatures. Graphite is mostly used in the production of electrodes and refractories. Graphite is also used to make dry lubricant, brake lining and moulds in foundries.

4.1.4.2 Graphite Industry Stakeholders

The current stakeholders in the Graphite Industry are governments, research organisations and private businesses who are involved with the development, mining, production and manufacturing of graphite-based products.

The government stakeholders are those that have a vested interest in the mining and industrial applications of Graphite, and the related industries that they can create.

Research organisations stakeholder include the organisations that are currently conducting research into the various methods for which graphite can be used or modified.

Private business stakeholders include the business directly/indirectly involved with mining/production/manufacture of graphite-based technologies/systems/sub-systems/components.

4.1.4.3 Access to Graphite Industry

There are currently no major restrictions or obstacles to the Graphite industry. The main factor that governs the industry is supply and demand. The competitiveness of a supplier will be based on their costs incurred in the production of the materials and its location of use. China accounted for 65%of world graphite mining 2017, and 35% of consumption.

4.1.4.4 Major Graphite Related Technology Companies

Mining: (2017)

- China: 780 000t
- India: 150 000t
  - Tirupati Carbon & Graphite,
  - Chotanagpur Graphite Industries and Carbon & Graphite Products.
- Brazil: 95 000t
  - Extrativa Metalquimica
  - Nacional de Grafite
- Canada: 30 000t
  - Berkwood Resources (TSXV:BKR),
  - Canada Carbon (TSXV:CCB),
  - Canada Strategic Metals (TSXV:CJC),
  - Eagle Graphite (TSXV:EGA),
  - Focus Graphite (TSXV:FMS),
  - Lomiko Metals (TSXV:LMR),
  - Noram Ventures (TSXV:NRM),
  - Northern Graphite (TSXV:NGC)
  - Zenyatta Ventures (TSXV:ZEN)
- Mozambique: 23 000t
  - Syrah Resources (ASX:SYR) (2018 – 104 000t, 2019 Expected 250 000t at US$460-470/t average)
  - Triton Minerals (ASX:TON)
- Russia: 19 000t
- Ukraine: 15 000t
  - Zavalyevskiy Graphite
- Pakistan: 14 000t
- Norway: 8 000t
- Madagascar: 7 000t
  - Bass Metals (ASX:BSM),
  - BlackEarth Minerals (ASX:BEM)
  - NextSource Materials (TSX:NEXT)

Graphite Product Manufactures

- Northern Graphite Corporation
- Asbury Carbons.
- Next Source
- Mason Graphite
- Flinders Resources Ltd.
- Focus Graphite Inc.
- Showa Denko K.K.
- SGL Carbon SE
- SEC Carbon Limited
- Graphite India Limited

Graphite Product Consumption Companies:

- Aluminium Smelter (Large Electrode – Graphite to CO2)
- Battery Manufacturers (Small Electrode)
- Dry Lubrication Users
- Crucible Users

4.1.5 Industry Analysis - Oxygen

The Carbon Dioxide Recycling system produces Oxygen as a bi product of the process. An overview of the Oxygen Industry is given in the below sections based on various industry expert institutions. Oxygen production can be used to help offset the costs incurred by the Carbon Dioxide Recycling System.

4.1.5.1 Oxygen Industry

> *Industrial oxygen is used across manufacturing, chemical, metal, and other industries owing to its excellent combustion, oxidation and fermentation properties. It is used to improve yield, maximize performance by lowering production cost across applications. Primarily, oxygen is used for respiratory purpose in healthcare facilities but has expanded its use in space rocket engines, pulp manufacturing, blast furnace, smelters, knits, etc. (Value Market Research, 2019)*

4.1.5.2 Oxygen Industry Stakeholders

The current stakeholders in the Oxygen Industry are governments, research organisations and private businesses who are involved with the development, procurement/production and manufacturing of Oxygen-based/process required products.

The government stakeholders are those that have a vested interest in the production and industrial applications of Oxygen and the related industries that they can create.

Research organisations stakeholder include the organisations that are currently conducting research into the various methods for which Oxygen can be used in products or processes.

Private business stakeholders include the business directly/indirectly involved with production/manufacture of Oxygen-related technologies/processes/systems/sub-systems/components.

4.1.5.3 Access to Oxygen Industry

There are currently no major restrictions or obstacles to the Oxygen industry. The main factor that governs the industry is supply and demand. The competitiveness of a supplier will be based on their costs incurred in the production of the materials and its location of use.

> *Industrial oxygen is used across manufacturing, chemical, metal, and other industries owing to its excellent combustion, oxidation and fermentation properties. It is used to improve yield, maximize performance by lowering production cost across applications. Primarily, oxygen is used for respiratory purpose in healthcare facilities but has expanded its use in space rocket engines, pulp manufacturing, blast furnace, smelters, knits, etc. (Value Market Research, 2019)*

4.1.5.4 Major Oxygen Related Companies

The main companies involved in the industry include the following:

1. Linde Group
2. Air Liquide
3. Praxair

4. Air Products and Chemicals
5. Taiyo Nippon Sanso
6. Air Water
7. Messer
8. Yingde Gases
9. Sasol

4.2 Market analysis

4.2.1 Market analysis – Human Space Exploration

4.2.1.1 Existing Market

Currently the only off-world habitable modules currently exist on the International Space Station (ISS) and the Chinese space station which is only periodically occupied.

Currently prototype habitation modules are being developed for the possible future habitation requirements of humans that are looking to explore the Moon and Mars.

Interest in returning to the Moon is growing and the consensus is that this time when we go, it will be to stay there. This will require the use of habitation modules that can be placed on the Moon and enable tasks to be performed. Current ECLSS for these habitation units utilise Carbon Capture technology coupled with a Sabatier Reactor System. Unfortunately, the combined system has a maxed Oxygen conversion rate efficiency of 75%. The new Carbon Dioxide Recycling System is aiming to have an Oxygen conversion rate efficiency of 100%.

The potential market for habitational module is limited only by the financial capabilities and common drive of a nation, business or individual to explore space. The more accessible the industry becomes the greater the potential for growth in the industry will be.

At current CRS2 rates the market value for Oxygen supply is around $50 Million annually based on 1095kg of water required for Oxygen at a delivery rate of $46 000/kg.

4.2.1.2 Potential Customers

Initial customers for the Carbon Dioxide Recycling System will be national space agencies and private companies who are looking for new ways to explore and perform research in Space and on the Lunar and Mars surface. Customers could also include private companies that are developing human rated orbital transit vehicles. The main clients for initial development could include the following:

1. National space Agencies:
    a. National Aeronautics and Space Administration (NASA)
    b. European Space Agency (ESA)
    c. Russian Federal Space Agency (Roscosmos)
    d. China National Space Administration (CNSA)
    e. Japan Aerospace Exploration Agency (JAXA)
    f. Indian Space Research Organisation (IRSO)
    g. Canadian Space Agency (CSA)
2. Private Companies: Orbital/Interplanetary Transit Vehicles
    a. SpaceX
    b. Boeing,
    c. Northrop Grumman,
    d. Airbus/Ariane Space
    e. Sierra Nevada Corporation
3. Private Companies: Orbital/Planetary Habitation Units
    a. Bigelow Aerospace

b. Boeing
c. Sierra Nevada Corporation
d. Lockheed Martin
e. Nano Racks

Following the initial development of the Lunar Base additional customers are expected, which include companies and individuals who are interested in commercial exploitation of the Moon and its resources. As the demand of habitation units increases the demand for Carbon Dioxide Recycling Systems will also increase.

It should also be noted that multiple Lunar and Mars bases will be developed since each location will offer a different opportunity. Multiple outposts will help to increase the demand of Carbon Dioxide Recycling Systems. The driving force for multiple bases will include the requirement of individual nations and business to individually operate separate lunar colonies for their own needs. The opportunities provided by different locations on the Lunar surface are given below:

1. **Lunar South Pole:** Has access to area of surface ice (Potential Water Sources), Certain area can receive long durations of sunlight during the summer periods. Currently the location of the first lunar Base.
2. **Lunar Equatorial Regions Earth Facing**: Has large deposits of Iron and Titanium that will benefit future industries.
3. **Far Side of the Moon:** During periods when the moon is facing away from the Sun it can allow Deep Space monitoring to bd conducted with a greater potential than what is currently available. During the periods of Sun research and monitoring can be conducting on the Sun.
4. **Crater Cold Spots:** Certain craters on the Lunar south pole don't receive any sun light and are very cold and allow IR devices that operate at near absolute zero conditions to be utilised.

4.2.1.3 Competitors

The main competitors involved in the development of Carbon Dioxide Recycling Systems are companies that provide Carbon Scrubbers Systems and Carbon Capture Systems coupled with a Sabatier Reactor. The choice of which system to used is based on the maximum duration the vehicle or habitation unit is required to operate and the limit on the amount of resources it can utilize before requiring additional supplies/resupply.

The current competitors for Carbon Dioxide Recycling Systems include the following:

1. United Technologies/Collins Aerospace (CO_2 Scrubber): CAMRAS Regenerable CO_2 Scrubbing System was developed and tested to be flight ready for installation on the ISS.
2. United Technologies/ Hamilton Sundstrand (Sabatier Reactor): Built and installed on the ISS in 2010.
3. Honeywell – Space (CO_2 Scrubber): The Carbon Dioxide Removal Assembly (CDRA) provides continuous removal of carbon dioxide (CO_2) from cabin air onboard the International Space Station (ISS). The CDRA employs a two-cycle, four-bed regenerative process to selectively remove carbon dioxide from the cabin air. A desiccant bed reduces the humidity of the air stream, allowing more efficient CO_2 removal.
4. Airbus (CO_2 Capture and Sabatier Reactor): Advanced Closed Loop System (ACLS). ACLS can produce water from carbon dioxide exhaled by astronauts inside spacecraft. This water then is used to produce oxygen for the crew. It has three major functions:
   a. The Carbon dioxide Concentration Assembly (CCA) concentrates carbon dioxide from cabin air and keeps carbon dioxide within acceptable levels.
   b. The Oxygen Generation Assembly (OGA) is an electrolyser that separates water into oxygen and hydrogen.

c. The recycling step takes place in the Carbon dioxide Reprocessing Assembly (CRA) or 'Sabatier reactor'. Hydrogen, coming from the Oxygen Generation Assembly, and carbon dioxide react over a catalyst to form water and methane. The water is condensed and separated from the product gas stream and fed back to the electrolyser. Methane is vented into space together with excess carbon dioxide, which explains why only 50% of the recovered CO2 is actually recovered.

It should be noted that all these Carbon Dioxide Recycling Systems that have been developed will be operated in zero/micro gravity environments which are more complex and expensive than habitation units that are design for low gravity environments.

4.2.1.4 Carbon Dioxide Recycling Systems Pricing

The ISS currently requires around 1095kg of water to be used exclusively for Oxygen generation per year. Current cost to deliver cargo to the ISS are estimated to be the following:

1. SpaceX Cargo Delivery (Lowest Estimate Possible): $6 078/kg (Excludes Vehicle/containment costs)
2. SpaceX Dragon Cargo ISS Resupply Costs/kg as part of CRS2: $46 000/kg (Excludes containment mass)
3. Orbital ATK Cygnus Cargo ISS Resupply Cost/kg as part of CRS2: $70 000/kg (Excludes Containment mass)
4. Soyuz Cargo ISS Resupply (Estimated) Cost/kg: $20 000-30 000/kg (Excludes containment)
5. Other service providers priced at higher rates include:
    a. Boeing,
    b. Lockheed Martin
6. Moon Delivery Costs (Estimates):
    a. Orion: $15 000/kg (Excludes vehicle and containment mass)
    b. Falcon Heavy $ 9 000/kg (Excludes vehicle and containment mass)
    c. Astrobotic
        1. Lunar Orbit: $300 000/kg (Payload cost)
        2. Lunar Surface $1 200 000/kg (Payload cost)

Thus, at current CRS2 Rates the market value for Oxygen is around $50 Million annually and the pricing of Oxygen supply to ISS can be adjusted accordingly.

Current development costs of space rated habitation modules and scientific research robots are:

1. Habitable modules on the ISS cost around $ 2 Billion each to design, construct and test,
2. Mars exploration missions (Mars Lab & Insight) have cost around $ 500 Million/ton to develop and that was just for scientific equipment with no Habitational requirements,
3. Near future developments such as Bigalow BA330 Expandable habitats are still expected to cost $150 million/330 m3/month to lease when made available,
4. Annual ISS operating costs are estimated to be around $4,0 Billion/year

4.2.1.5 Competitive Advantage

Currently most habitation modules that are being developed are to be used as habitation module in zero/micro gravity environments. As such these modules are generally more expensive to develop and require additional systems to be integrated into the module to ensure that they function correctly. Space Habitats will be primarily be focus on habitational modules that operate in low gravity environments such as the Moon and Mars. This allows reduced technology and system requirements to function. At a later stage the Carbon Dioxide Recycling Systems will be adapted to micro/zero gravity conditions.

Factors which will help to reduce the cost of building habitational modules and improve our competitive advantage include the following;

1. **Research and Development Costs:** Thanks to researchers at RMIT that were able to develop the liquid metal electrode that would be capable of breaking down carbon dioxide into oxygen and carbon solid. The reaction was able to take place at a low temperature with a relatively low voltage. The method of how-to breakdown the carbon dioxide is known, and the development costs will now need to focus on increasing the quantity of carbon produced and finding a method to effectively separate the carbon and oxygen from the system with minor losses to the electrolyte and LM Electrode.
2. **Design Cost of Human Resources:** Space exploration is a niche market with very few competitors and as such companies charge a premium for their services which adds considerable costs to a project without it having even produced any viable product that can be used. To overcome this, we are looking to hire young people from South Africa where there is an abundance of talented engineers available in the local market. The lower cost of living in South Africa will enable us to offer them a competitive salary which is substantially lower than what an engineer from a developed country would earn like the USA or Europe would cost. To help offset their inexperience to Space related technologies we also aim to hire experienced consultants which will be able to offer their input into our designs to ensure we are on the right track. We do the "Grunt Work" but make sure its check by leading experts.
3. **Commercial Production of Modules:** The Carbon Dioxide Recycling System has applications in a variety of different industries. Once the initial protype have been proven the aim will be the reproduce the modules on a larger scale to help reduce the costs of producing new systems.
4. **Develop the Production and Testing Facilities:** Once established we aim to develop our own production and testing facilities so that a unit can be assembled and tested in one location to help reduce the costs of transporting the unit to various locations. A streamlined production facility will also allow the assembly of the module at a lower cost to help reduce the cost of the modules.
5. **Company Goals:** Unfortunately, due to the extreme lack of competition and available knowledge of space technologies many contracts offered to companies are cost plus based. Due to this it is usually in the best interest of the company to extend the term of the project in any way possible. This leads to delayed projects and costly programs that inhibit progress of space technologies. As a company that is dedicated to space exploration and who wants to find ways of exploring space, we are willing to find ways of overcoming any issues that may be obstructing our end goals.

There will be many more areas in which we can improve upon as the project is developed, we will aim to address all these issues as they arise and ensure that protocols are put in place to address them.

4.2.2 Market analysis – Carbon Capture and Storage (CCS) Technology

4.2.2.1 Existing Market

Some governments have implemented tax credits for companies that remove Carbon Dioxide from the atmosphere or tax penalties for companies that produce Carbon Dioxide as a bi product of their manufacturing process.

Currently over 41.2 $GtCO_2$ (11.3 GtC) is produced from fossil fuels which is contributing to climate change. The higher concentration of CO2 in the atmosphere needs to be removed and stored in a manner that permanently removes it from the atmosphere or allows the reuse of the carbon in another manner.

Carbon Dioxide can also be used as a material for other industrial processes such as carbonation of fizzy drink, increasing the concentration of Carbon Dioxide in greenhouses to improve plant growth, used in pumping gas to help improve Oil production and various other industrial processes.

The global carbon dioxide market size was valued at USD 7.4 billion in 2018 and is expected to register a CAGR of 3.4% over the forecast period. Increasing application of carbon dioxide (CO2) in enhanced oil recovery (EOR) in the oil and gas sector is expected to be a major driving factor for the global market.

The application of CO2 in the medical industry is increasingly gaining significance, as the gas finds application in modern medicine to minimize invasive surgeries. In medicinal baths, it induces warm sensations and acts as a vasodilator for the skin by stimulating its heat receptors. In addition, insufflation with carbon dioxide makes it easier to perform endoscopic procedures.

In the U.S. market, production of CO2 by ethyl alcohol was the largest segment in 2018 with revenue of USD 672.0 million. However, CO2 production by substitute natural gas is anticipated to be the fastest growing segment in the country and is projected to register a CAGR of 3.7% over the forecast period. (Grand View Research, 2018)

4.2.2.2 Potential Customers

The potential customers for this technology are limited to Governments that are committed to combating climate change, form part of the Paris Agreement on Climate change and have implemented various tax rebates/credits/penalties for companies that are directly/indirectly involved with Carbon Dioxide emissions.

Other customers include various industries that require the use of Carbon Dioxide as a material in their manufacturing process or production. Carbon Dioxide is used in the following industries:

1. Food & Beverage
2. Oil & Gas
3. Medical
4. Rubber
5. Fire Fighting

4.2.2.3 Competitors

The market is very competitive with many different companies involved in the distribution and production of the Carbon Dioxide gases from alternative sources. The main competitors include the following:

1. Linde AG;
2. Universal Industrial Gases Inc.;
3. INOX Air Products Ltd.;
4. Air Products and Chemical, Inc.;
5. Praxair, Inc.; and
6. Air Liquide.

Some companies like Air Products & Chemicals Inc. and Universal Industrial Gases Inc. are vertically integrated allowing them to become economies of scale.

It should be noted that the companies in this market will most likely act as suppliers rather than direct competition. Competition may stem from alternative projects such as Carbon Capture and Storage which will store the Carbon Dioxide in areas that we will not have access to.

4.2.2.4 Carbon Dioxide Capture & Storage Pricing

Income from Carbon Dioxide Captured in the air can have 2 possible revenue streams which include Tax credits/Carbon Credits from the government as well as revenue from sales of the Carbon Dioxide to consumers in the industrial and mining sectors.

Income from Carbon Credits varies greatly from country to country depending on their commitment and ability to afford higher paying credits. Pricing for the removal of Carbon Dioxide from various countries is given below.

7. Switzerland: $99/ton
8. Europe: $20/ton
9. California $15/ton
10. USA: $50/ton (New Legislation)
11. China $5/ton
12. RSA: R120/ton (Lowered to R6-48 for companies)

Carbon Dioxide can be sold to retail users at a rate of R50/kg (R50 000/ton) in South Africa and estimated global Carbon Dioxide pricing varies between $900-1200/ton wholesale. Pricing of the gas can vary depending on method of production and supply and demand.

4.2.2.5 Competitive Advantage

We will not be direct competitors to Carbon Dioxide capture and suppliers but rather offer an alternative to the method of Carbon Storage. Our technology used in conjunction with other Direct Air Capture units will be able to make them more cost effective as a method of removing Carbon Dioxide from the atmosphere.

By converting the Carbon Dioxide captured from the air and converting it to another form of carbon that can be used in industry allows us to make Direct Air Capture more affordable.

Some of the advantages the company is aimed to capitalise on include the following:

1. **Alternative Carbon Dioxide Storage System:** The Carbon Dioxide Recycling System is aimed at providing an alternative to storing Carbon Dioxide underground by utilising the bi products of the Carbon Dioxide Recycling System and creating an alternative revenue streams with which to offset the cost of removing Carbon Dioxide from the atmosphere.
2. **Environmentally Friendly Products:** Products produced by the Carbon Dioxide Recycling System can be sold at a premium to certain companies that are more environmentally aware and have active policies in place to combat climate change.
3. **Research and Development Costs:** Thanks to RMIT for developing the original concept we are looking to improve on the concept and make it more viable as an alternative on an industrial scale. With the help of Nelson Mandela University, we are aiming to make the process more efficient and allows for a larger production of Carbon solid per unit that can be scaled up.
4. **Not Geologically Fixed:** The Carbon Dioxide Recycling System can be built/installed anywhere in the world as long as it has access to a supply of Carbon Dioxide (Coal Power Plant, DAC of CO_2) and Electrical Energy (Preferably Renewable)
5. **Design Cost of Human Resources:** We are looking to hire young people from South Africa where there is an abundance of talented engineers available in the local market. The lower cost of living in South Africa will enable us to offer them a competitive salary which is substantially lower than what an engineer from a developed country would earn like the USA or Europe would cost. To help offset their inexperience we aim to hire experienced consultants which will be able to offer their input into our designs to ensure we are on the right track. We do the "Grunt Work" but make sure its check by leading experts.

6. **Commercial Production of Modules:** Once the initial protype have been proven the aim will be the reproduce the Carbon Dioxide Recycling System as modules that can be built on a larger scale to help reduce the costs of producing new units.
7. **Develop the Production and Testing Facilities:** Once established we aim to develop our own production and testing facilities so that a unit can be assembled and tested in one location to help reduce the costs of transporting the unit to various locations. A streamlined production facility will also allow the assembly of the Carbon Dioxide Recycling System at a lower cost to help reduce the cost of the modules.
8. **Company Goals:** Space Habitats is determined to help combat climate change so that we can all have a better tomorrow.

There will be many more areas in which we can improve upon as the project is developed, we will aim to address all these issues as they arise and ensure that protocols are put in place to address them.

4.2.3 Market analysis – Isolated Habitations ECLSS

There is currently insufficient data available in this industry segment to make any informed decision and will require further research as the products that can be used in this segment are developed.

4.2.4 Market analysis – Graphite/Carbon Related Industry

4.2.4.1 Existing Market Size

Global Graphite Market size was valued at $13 billion in 2015, and is expected to reach $18,7 billion by 2022, supported by a CAGR of 5.4% during the forecast period 2014 to 2022.Graphite is flexible in nature and has both metallic and non-metallic properties, which makes it appropriate for a diverse range of industrial applications. The non-metallic properties of graphite include high thermal resistance, chemical inertness, and lubricity, while the metallic properties include electrical and thermal conductivity. The demand for natural graphite is directly proportional to the growth of the industrial applications including lubrication, refractories, battery production, and foundry. The global graphite market is segmented based on type, application, and geography. Based on type, itis divided into natural graphite and synthetic graphite. The natural graphite segment is further sub-categorized into flake graphite, amorphous graphite, and vein graphite. The synthetic graphite segment is further classified into graphite electrode, graphite block, carbon fiber, graphite powder, and others. (Allied Market Research, 2017)

4.2.4.2 Potential Customers

The Carbon Dioxide Recycling Systems can be sold to companies that are interested in producing high quality raw graphite material from Carbon Dioxide in the air, coal power plants or other Carbon Dioxide sources. The graphite bi product can be sold to graphite product manufacturers.

Space Habitats could create a new division to use the Carbon Dioxide Recycling System to produce its own graphite and supply directly to graphite product manufacturers.

At a later stage Space Habitats could create a new division to use the Carbon Dioxide Recycling System to produce graphite material which can be used to manufacture certain graphite products and sell these products to the end user.

4.2.4.3 Competitors

Mining companies that primarily mine Graphite will be direct competitors in Graphite production which will directly/indirect affect Space Habitats/Clients that use the Carbon Dioxide Recycling System.

Mining: (2017)

- China: 780 000t
- India: 150 000t
    - Tirupati Carbon & Graphite,
    - Chotanagpur Graphite Industries and Carbon & Graphite Products.
- Brazil: 95 000t
    - Extrativa Metalquimica
    - Nacional de Grafite
- Canada: 30 000t
    - Berkwood Resources (TSXV:BKR),
    - Canada Carbon (TSXV:CCB),
    - Canada Strategic Metals (TSXV:CJC),
    - Eagle Graphite (TSXV:EGA),
    - Focus Graphite (TSXV:FMS),
    - Lomiko Metals (TSXV:LMR),
    - Noram Ventures (TSXV:NRM),
    - Northern Graphite (TSXV:NGC)
    - Zenyatta Ventures (TSXV:ZEN)
- Mozambique: 23 000t
    - Syrah Resources (ASX:SYR) (2018 – 104 000t, 2019 Expected 250 000t at US$460-470/t average)
    - Triton Minerals (ASX:TON)
- Russia: 19 000t
- Ukraine: 15 000t
    - Zavalyevskiy Graphite
- Pakistan: 14 000t
- Norway: 8 000t
- Madagascar: 7 000t
    - Bass Metals (ASX:BSM),
    - BlackEarth Minerals (ASX:BEM)
    - NextSource Materials (TSX:NEXT)

If Space Habitats uses the Carbon Dioxide Recycling System to produce its own graphite and use this graphite to further produce graphite related products, then all graphite product manufacturers will become competitors as well.

Graphite Product Manufactures

- Northern Graphite Corporation
- Asbury Carbons.
- Next Source
- Mason Graphite
- Flinders Resources Ltd.
- Focus Graphite Inc.
- Showa Denko K.K.
- SGL Carbon SE
- SEC Carbon Limited
- Graphite India Limited

4.2.4.4 Graphite Pricing

The pricing of raw graphite is determined by flake size as well as demand and supply. The estimated pricing of the Graphite is given in table 4.2 below.

Table 4.2 Raw Graphite Pricing

Flake Size	Size	Price (US$)/ton
XL lake	>300 Microns	1800-2000
Large Flake	180-300 Microns	830-1300
Medium Flake	150-180 Microns	700-1100
Small Flake	75-150 Microns	550-750
Fine Flake	<75 Microns	450

The pricing of manufactured/processed Graphite based materials varies greatly from $2 000 to $14 000/ton depending on the type of product that was manufactured. In specialist markets the price of high-quality graphite products can sell for $1300/kg. If Space Habitats is able to manufacture it own Graphite products a lot of the costs associated with transportation and overheads can be eliminated and allow the Carbon Dioxide Recycling System to become more cost effective.

4.2.4.5 Competitive Advantage

The Carbon Dioxide Recycling system produces a few bi products which can be used as raw materials in other industrial processes. The Carbon produced forms Graphite and is used as a material for industrial products. The Source of the Carbon for the Graphite comes from the air and thus does not require the materials to be mined from the ground which leads to environmental damage. By helping to remove the Carbon Dioxide from the air the material produced is also Carbon Negative and helps to combat Climate Change.

The Carbon Dioxide Recycling System can either be sold to companies interested in producing Graphite or implemented by Space Habitats to produce Graphite for sale to Graphite users. Space Habitats can also vertically integrate the graphite materials by further processing the graphite into end products that can be sold to end users at a higher value such as carbon electrodes for batteries.

Some of the advantages the company is aimed to capitalise on include the following:

1. **Alternative Carbon Dioxide Storage System:** The Carbon Dioxide Recycling System is aimed at providing an alternative to storing Carbon Dioxide underground by utilising the bi products of the Carbon Dioxide Recycling System and creating an alternative revenue streams with which to offset the cost of removing Carbon Dioxide from the atmosphere.
2. **Environmentally Friendly/Sustainable Products:** Products produced by the Carbon Dioxide Recycling System can be sold at a premium to certain companies that are more environmentally aware and have active policies in place to combat climate change. Since the Carbon comes from the air and not the ground,
    a. Environmental destruction is limited to only the building footprint.
    b. The Graphite product is Carbon Negative
3. **Research and Development Costs:** Thanks to RMIT for developing the original concept we are looking to improve on the concept and make it more viable as an alternative on an industrial scale. With the help of Nelson Mandela University, we are aiming to make the process more efficient and allows for a larger production of Carbon solid per unit that can be scaled up.
4. **Not Geologically Fixed:** The Carbon Dioxide Recycling System can be built/installed anywhere in the world as long as it has access to a supply of Carbon Dioxide (Coal Power Plant, DAC of CO_2) and Electrical Energy (Preferably Renewable),

5. **Design Cost of Human Resources:** We are looking to hire young people from South Africa where there is an abundance of talented engineers available in the local market. The lower cost of living in South Africa will enable us to offer them a competitive salary which is substantially lower than what an engineer from a developed country would earn like the USA or Europe would cost. To help offset their inexperience we aim to hire experienced consultants which will be able to offer their input into our designs to ensure we are on the right track. We do the "Grunt Work" but make sure its check by leading experts.
6. **Commercial Production of Modules:** Once the initial protype have been proven the aim will be the reproduce the Carbon Dioxide Recycling System as modules that can be built on a larger scale to help reduce the costs of producing new units.
7. **Develop the Production and Testing Facilities:** Once established we aim to develop our own production and testing facilities so that a unit can be assembled and tested in one location to help reduce the costs of transporting the unit to various locations. A streamlined production facility will also allow the assembly of the Carbon Dioxide Recycling System at a lower cost to help reduce the cost of the modules.
8. **Company Goals:** Space Habitats is determined to help combat climate change so that we can all have a better tomorrow.

There will be many more areas in which we can improve upon as the project is developed, we will aim to address all these issues as they arise and ensure that protocols are put in place to address them.

4.2.5 Market analysis – Oxygen Production & Supply

4.2.5.1 Existing Market Value

> *Global Industrial Oxygen market size will increase to 68.2 Billion US$ by 2025, from 43.1 Billion US$ in 2018, at a CAGR of 6.8% during the forecast period. In this study, 2018 has been considered as the base year and 2019 to 2025 as the forecast period to estimate the market size for Industrial Oxygen.*
>
> *According to its production process, industrial gases can be dived into atmospheric gases and process gases. For atmospheric gases, the raw material is air and the key production unit is air separation plant. Oxygen is mainly produced via air separation plant. When considering the industry oxygen supply mode, three modes are preferred: on-site, bulk/merchant and packaged/cylinder. Each supply mode has its own characteristics and all of industrial gases manufacturers operate their gas business under the three modes. Globally, on-site type oxygen accounts for about 50% (Research Reports World, 2019)*

Currently over 1.2Mt Oxygen is produced per day globally (Gasworld, 2007).

4.2.5.2 Potential Customers

The Carbon Dioxide Recycling Systems can be sold to companies that are interested in producing Oxygen from Carbon Dioxide in the air, coal power plants or other Carbon Dioxide sources. The Oxygen bi product can be sold to graphite product manufacturers. The Steel Industry current has the largest share of Oxygen market (40-50%) followed by Chemical Industry (20%) users.

Space Habitats could create a new division to use the Carbon Dioxide Recycling System to produce its own Oxygen and supply directly to manufacturers that use Oxygen in their manufacturing processes.

4.2.5.3 Competitors

The main companies that will be competitors for Oxygen Supply to end users are listed below:

1 Linde Group

2 Air Liquide
3 Praxair
4 Air Products and Chemicals
5 Taiyo Nippon Sanso
6 PSA type Oxygen Generators

The main competitors could also become clients by selling our Oxygen to them directly removing the need to create our own distribution network.

4.2.5.4 Oxygen Pricing

The pricing of Oxygen in South Africa at retail varies greatly from R18.50 to R67.20/kg depending on the type of gas mixture and purity of the gas that is required.

Estimated global Oxygen pricing varies between US$ 200 - US$ 3 000/ton wholesale. Pricing of the gas can vary depending on method of production, purity and supply and demand.

4.2.5.5 Competitive Advantage

The Carbon Dioxide Recycling system produces a few bi products which can be used as raw materials in other industrial processes. The Oxygen produced can be used as a material for industrial processes. By helping to remove the Carbon Dioxide from the air the Oxygen produced is also Carbon Negative and helps to combat Climate Change.

The Carbon Dioxide Recycling System can either be sold to companies interested in producing Oxygen or implemented by Space Habitats to produce Oxygen for sale to Oxygen users.

Some of the advantages the company is aimed to capitalise on include the following:

1. **Alternative Carbon Dioxide Storage System:** The Carbon Dioxide Recycling System is aimed at providing an alternative to storing Carbon Dioxide underground by utilising the bi products of the Carbon Dioxide Recycling System and creating an alternative revenue streams with which to offset the cost of removing Carbon Dioxide from the atmosphere.
2. **Environmentally Friendly/Sustainable Products:** Products produced by the Carbon Dioxide Recycling System can be sold at a premium to certain companies that are more environmentally aware and have active policies in place to combat climate change. Since the Carbon comes from the air and not the ground,
    a. Environmental destruction is limited to only the building footprint.
    b. The Graphite product is Carbon Negative
3. **Research and Development Costs:** Thanks to RMIT for developing the original concept we are looking to improve on the concept and make it more viable as an alternative on an industrial scale. With the help of Nelson Mandela University, we are aiming to make the process more efficient and allows for a larger production of Carbon solid per unit that can be scaled up.
4. **Not Geologically Fixed:** The Carbon Dioxide Recycling System can be built/installed anywhere in the world as long as it has access to a supply of Carbon Dioxide (Coal Power Plant, DAC of CO_2) and Electrical Energy (Preferably Renewable i.e. Solar),
5. **Design Cost of Human Resources:** We are looking to hire young people from South Africa where there is an abundance of talented engineers available in the local market. The lower cost of living in South Africa will enable us to offer them a competitive salary which is substantially lower than what an engineer from a developed country would earn like the USA or Europe would cost. To help offset their inexperience we aim to hire experienced consultants which will be able to offer their input into our designs to ensure we are on the right track. We do the “Grunt Work” but make sure its check by leading experts.

6. **Commercial Production of Modules:** Once the initial protype have been proven the aim will be the reproduce the Carbon Dioxide Recycling System as modules that can be built on a larger scale to help reduce the costs of producing new units.
7. **Develop the Production and Testing Facilities:** Once established we aim to develop our own production and testing facilities so that a unit can be assembled and tested in one location to help reduce the costs of transporting the unit to various locations. A streamlined production facility will also allow the assembly of the Carbon Dioxide Recycling System at a lower cost to help reduce the cost of the modules.
8. **Company Goals:** Space Habitats is determined to help combat climate change so that we can all have a better tomorrow. The Carbon Dioxide Recycling System can also be further developed to allow a more sustainable colonisation of other worlds.

There will be many more areas in which we can improve upon as the project is developed, we will aim to address all these issues as they arise and ensure that protocols are put in place to address them.

5 Sales and Marketing Strategy

5.1 Marketing

The Carbon Dioxide Recycling System will be marketed using the performance of the prototype to show that the Carbon Dioxide Recycling System can be a viable option for creating Carbon (Graphite) and Oxygen from Carbon Dioxide in the air at a competitive price. The prototype testing will help to garner confidence for Space Habitats as a capable company in the development of Carbon Dioxide Recycling Systems.

The materials produce by the Carbon Dioxide Recycling System can also be marketed as products that have a negative Carbon Footprint. These materials can then be used to produce other products and reduce their resulting total Carbon Footprint.

The Carbon Dioxide Recycling System will be marketed to companies that are interested in:

1. Producing their own source of Graphite and/or Oxygen that they will either
   a. sell wholesale or
   b. use in their manufacturing process to further develop new products.
2. Producing environmentally friendly products and helping to combat climate change.

Further Development of the Carbon Dioxide Recycling System will be marketed to Space Agencies and Companies that are interested in colonising the Moon or Mars as a method to helping to reduce cost of resupplying stations/outposts with materials for Oxygen Production. Initial attempts will be made to agencies and business who will be able to afford to buy the Carbon Dioxide Recycling System and have it integrating into their systems.

Any clients that can afford the initial systems can have additional clauses put into their sales that will allow the replacement of their existing systems with new and improved systems that can operate at higher efficiencies. Due to the majority of the cost of our systems being based on the LM metal and counter electrode we will be able to recycle these components into the new system at much lower costs and in some instances where less LM electrode is required could allow a saving to be made.

5.2 Sales

The sales of the Carbon Dioxide Recycling System will most likely only start after the prototype system has been proven to work and is a feasible option to alternative suppliers. Sale orders for the module will most likely only start in January 2021. Prior to this date Space Habitats will still accept any interest from parties that wish to purchase Carbon Dioxide Recycling Systems.

Depending on the success of the Space Habitats Carbon Dioxide Recycling Systems, units will be sold to perspective clients as complete functioning units with initial Service Contracts of the unit to be handled by Space Habitats.

5.2.1 Carbon Dioxide Recycling System Unit Sales

Complete Carbon Dioxide Recycling System unit sales will be done during the early stages of the project to ensure that the cost of development of the modules is completely recuperated. Multiple pricing options have been calculated and based on the demand of these modules; the appropriate pricing strategy will be utilised.

Based on current estimates the first Full Carbon Dioxide Recycling System will have an initial capacity of 135 kgCO2/day (36.8kgC/Day, 98.2kgO2/Day) due to the availability of standard CO2 capture systems that have been developed and are ready from production.

The initial Systems will start at US$ 1.04 Million/System to help recover costs. Once a steady demand of the modules is secured and production facilities are established the cost of a single Carbon Dioxide Recycling System is estimated to be $850 000/System. Once the production process has been streamlined sufficiently the Carbon Dioxide Recycling System could sell at US$ 600 000/System due to improved efficiency and bulk order prices for materials. An additional $ 1.1million should be budgeted for to accommodate the Carbon Capture, Oxygen Purification & Liquification System and the Energy requirements for all the systems to operate.

Due to the 1kg/day modular Carbon Dioxide Recycling System the costs of starting a Graphite & Oxygen production facility can be relatively low at the start and can be increased according to required production volumes relatively quickly depending on available demand and funding. Thus, the Carbon Dioxide Recycling System can be sold to both large- and small-scale businesses. Although specialized alternative smaller systems for Carbon Dioxide capture will be required to be developed.

To show the financial viability of buying the Carbon Dioxide Recycling System as a producer of Carbon and Oxygen a few Case Studies were done for various locations and conditions that are currently possible. The Case Studies can be found in Appendix E.

It should be noted that the following items are excluded from any Carbon Dioxide Recycling System unit pricing:

1. **Delivery of system to final location:** Different companies in different location will have varying costs related to transport that will be incurred and cannot be estimated.
2. **Cost of Electrical Power:** The Carbon Dioxide Recycling System uses a lot of power to operate the electrolysis system as well as generate the heating and cooling requirements. The cost and source of this electrical energy varies from country to country and can be a large determining factor in the selection of the plant location.
3. **Type of Carbon Dioxide Capture System:** There are various types of systems available that can capture Carbon Dioxide either directly from the atmosphere or form a source of heavy carbon dioxide producing process such as coal fired power plants. The wide varying costs of each system can impact the feasibility of the system.
4. **Type of Oxygen Purification and Storage System:** Depending on the purity of the Oxygen required and the final use of the oxygen the cost of the whole system can vary substantially. Final system use will ned to be established.
5. **Cost of Modifications:** Additional Costs may be incurred due to
    a. Unit requirements for site installation. E.g. foundations, cooling systems, energy supply systems, housing etc.,
    b. Modification of the complete system due to changes in the set up or replacement or certain sub-systems. E.g. changing the current evaporation chamber design with a modified design to account for varying weather conditions experienced in various locations I.e. Deserts vs. Cold Climate.
6. **Providing required resources:** The Carbon Dioxide Recycling System will require Liquid Metal material, Solvent and Electrolyte replacement at regular intervals due to losses in the system. The current replacement rate is unknown and could be a large determining factor in the final pricing of the unit. All these items can only be supplied by Space Habitats due to specialised mixes of the materials that only Space Habitats will have.

5.2.2 Sales of Graphite and Oxygen Material

Considering that the technology will be new and that there may not be an immediate need for the Carbon Dioxide Recycling Systems Space Habitats will endeavour to create our own Graphite and Oxygen production facility. The products that are produced will be sold to potential customers.

Initially Space Habitats will approach potential buyers of the products that can be produced using the Carbon Dioxide Recycling System and establish MOU with these companies to allow Space Habitats to acquire the funding to develop a production plant. At the start the aim will be to provide materials to niche markets that are willing to pay a premium for the materials. At present research institutions tend to pay a higher rate for smaller and more quality controlled materials than manufacturers who deal in high volumes at reduces rates.

Smaller plants can be developed in individual cities are is able to accommodate the required demand of that city. This will help to reduce costs of transportation of materials to various locations.

If the cost of production can be reduced significantly then the Graphite and Oxygen can be sold as a wholesale product.

As the effect of Carbon Dioxide in the Atmosphere becomes a more serious problem in the future, world governments will start to implement developments that can effectively remove, and safety store the Carbon Dioxide in the atmosphere. Demand for the Carbon Dioxide Recycling Systems will increase since it will be suitable alternative to current options. The Carbon Dioxide Recycling System will need to be subsidised for it to be feasible.

The cost analysis of the proposed Carbon Dioxide Recycling System for various scenarios can be found in Appendix E.

5.2.3 Sales of Graphite Product (Carbon Electrodes)

To help with feasibility Space Habitats could further improve on the Graphite materials by developing graphite-based products such as carbon electrode manufacturing capabilities to build carbon electrodes and sell these products to aluminium producers or battery manufacturing companies. The products produced can then be marketed as environmentally beneficial products that have a negative carbon footprint. In developed markets requirements for sustainably developed products with low carbon footprints are more in demand than in other parts of the world.

The more processed a material is the higher the value of the material becomes. By implementing all the required steps in developing graphite-based products, we will be able to cut a lot of costs and use these savings to help offset the higher cost of our graphite material.

Initially Space Habitats will approach potential buyers of the products that can be produced using the Carbon Dioxide Recycling System with a processing plant and establish MOU with these companies to allow Space Habitats to acquire the funding to develop a production plant. At the start the aim will be to provide materials to niche markets that are willing to pay a premium for the materials.

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6 Financial Statements and Projections

6.1 Estimate Return on Investment for Carbon Dioxide Recycling Systems

6.1.1 Estimated Production Costs – Climate Mitigation Technology

The cost of production is determined by:

1. **The Materials required to build the systems:** of which the largest contributing factors are the LM alloy, Electrolyte, Counter Platinum coated Titanium electrode and Electrolysis Containment materials. The less materials required the lower the cost,
2. **The Current Density and Carbon Dioxide Conversion Rate of the System:** These factors are determined by the Potential Difference (Voltage) across the system and the effect of the catalyst in the LM Electrode. The higher the conversion rate the lower the costs,
3. **Energy Input:** The energy requirements of the system are the largest part of the operating costs of the system and vary based on type of energy used and the geographical location of the system.

Based on calculations the cost per ton of Carbon can range anywhere from US$ 3 444 to US$ 25 700/tonC. The most likely scenario Space Habitats believes it can achieve is between US$ 4 500 to US$ 5 000/tonC.

Note: Production Costs are based on 1tonC/h system. Smaller systems may have higher costs and vice versa.

6.1.2 Estimated Sales Return – Climate Mitigation Technology

The expected Sales from products produced are determined by:

1. **Oxygen Purity & Demand:** The cost of Oxygen is determined by the purity of the oxygen in the system and the relevant demand for the Oxygen product. Most Oxygen products are mixtures of Oxygen and other gases. The higher the purity of the oxygen the higher the cost of the Oxygen.
2. **Graphite Purity, Size & Demand:** The cost of graphite products is determined by the purity of the graphite in the system as well as the flake size of the graphite. The higher the purity and larger the flake size the higher the cost of the Graphite.
3. **Carbon Capture:** Certain countries have tax credits/rebates that offer incentives for the removal of Carbon dioxide. Other countries have tax penalties on companies that produce Carbon dioxide. In certain economies these tax credits/penalties can be traded among companies to help reduce their impact on the environment.

Based on company pricing and market estimations the cost of Raw graphite varies between US$ 450 to US$ 1200/TonC depending on demand. The cost of Graphite products can vary between US$ 2 000 to US$ 14 000/tonC.

Based on Company pricing and market estimations the cost of Oxygen products can vary between US$ 200 to US$ 3 000/TonO2. Additionally, it should be noted that 1 Ton Carbon production is the equivalent to 2.667 Tons Oxygen.

Based on Available data the Tax credit/rebate available to companies that remove Carbon Dioxide from the atmosphere varies from US$ 5 to US$ 100/tonCO2. Additionally, it should be noted that 1 Ton Carbon production is the equivalent to 3.667 Tons Carbon Dioxide.

6.1.3 Profitability of Carbon Dioxide Recycling Systems – Climate Mitigation Technology

The profitability of the Carbon Dioxide Recycling System over a 20 year lifespan will vary from Negative to US$ 0 to US$ 2 300/tonC (Expected) to US$ 5 000/tonC (Highest possible current estimate) Production capacity. The profitability is mostly determined by the efficiency of the Electrolysis System.

The profitability of the Carbon Dioxide System is mostly determined by the pricing of Oxygen more than the pricing of Graphite, and the pricing of Oxygen is also heavily reliant on the demand. The lower the demand is the less return will be possible on the Carbon Dioxide Recycling System.

Thus, to make the System profitable Space Habitats will need to secure contracts with clients that have a high need for pure Oxygen or Carbon.

To help reduce the impact of oversupply in a particular economy Space Habitats proposes that smaller 100kgC/day systems be developed in various cities where the increase in demand will not be immediately recognised and then further develop additional systems as the demand increases.

6.1.4 Return on Investment – Climate mitigation Technology (Carbon/Oxygen Production Facility)

The Carbon Dioxide Recycling facility with an estimated profitability of US$ 2 300/TonC will cost around US$ 780 Million to build. It will have a capacity of 8 700TonC, 23 000TonO2 and 32 000/TonCO2.

This will require substantial capital to develop some of which could be procured through the Green Climate Fund. To break even on the project could take an estimated 6.5 Years depending on product demand.

6.2 Funding Requirements

6.2.1 Electrolysis & Graphite Separation System

The estimated total funding requirements for the development of the Carbon Dioxide Recycling Electrolysis and Separation System is R 5 085 000 (US$ 340 000) as illustrated in table 6.1 below showing the funding requirements of each phase. The costs are aimed at covering 2 years of development and testing.

Largest single costs are the costs associated with research laboratory equipment into making the system more efficient and Intellectual Property/Patent costs. The aim is to develop a Carbon Dioxide Recycling System that can accommodate 1 kgC/day and as such 8 Electrolysis systems are required to meet that demand which increases the manufacturing costs. The costs of the Electrolysis System are also mostly due to costs associated with the liquid metal electrode and counter platinum electrode required to drive the system. The cost breakdown for individual categories is shown in Table 6.2.

It should be noted that the funding requirements of each phase needs to be partially met prior to the start of the phase to ensure that the project does not experience delays in the development of the Carbon Dioxide Recycling System due to insufficient funding.

Table 6.1Estimated Funding Requirements for each Project Phase

Phase	Duration (Months)	Total Investment Required (R)	Total Investment Required (US$)
Initiation, Planning & Procurement	4	R 708 817.00	$ 47 254.47
Research & Engineering Design	5	R 1 458 443.04	$ 97 229.54
Manufacturing & Assembly	7	R 1 963 923.39	$ 130 928.23
Prototype Testing	2	R 954 204.09	$ 63 613.61

Table 6.2Estimated Costs Breakdown

Category	Prototype Cost (R)	Prototype Costs (US$)
Lab Equipment - Research	R 392 673.52	$ 26 178.23
Materials - Chemicals & Rare Earth Metals	R 521 782.58	$ 34 785.51
Research - Nelson Mandela University	R 204 360.00	$ 13 624.00
Engineering & Design	R 815 062.50	$ 54 337.50
Human Resources	R 1 065 000.00	$ 71 000.00
Project Expenses	R 310 640.11	$ 20 709.34
IP Registration	R 611 000.00	$ 40 733.33
Manufacturing Expenses	R 37 990.00	$ 2 532.67
Material Expenses - System Components	R 766 312.01	$ 51 087.47
Business Expenses	R 360 566.79	$ 24 037.79

A proposed breakdown of sources of funding is shown in table 6.3 below. It should be noted that the breakdown of funding sources is not fixed and will vary depending on investor appetite, interest and involvement in the project.

Another source of funding would be the sale of Carbon Dioxide Recycling Systems during the development phase of the project. The sooner a full system can be sold, and the initial deposit fee can be placed the less funding would be required from investors and help to ensure project success due to adequate funding.

Table 6.3Estimated Funding from Various Sources

Investment Source	Total Funding (R)	Total Funding (US$)
Owner	R 460 000.00	$ 30 666.67
Angel Investors	R 800 000.00	$ 53 333.33
Venture Capitalists	R 915 000.00	$ 61 000.00
General Investors	R 915 000.00	$ 61 000.00
Department Trade and Industry (RSA) Support Programme for Industrial Innovation (SPII) (Grant)	R 2 000 000.00	$ 133 333.33

For a detailed breakdown of how the funding will be spent can be found in the Cash Flow projections in Section 6.4 Table 6.4 and 6.5 below.

6.2.2 Additional Requirements of Full System Carbon Dioxide Recycling System Development

It should be noted that for this project the full Carbon Dioxide Recycling System has additional systems that are required to be procured for the system as a whole to operate effectively.

6.2.2.1 *Carbon Dioxide Capture, Pressurization/Liquification and Storage System*

A Carbon Dioxide Capture unit will be required to supply the Carbon Dioxide required for the reaction. The system that will be used is either existing and readily available or in prototype development. The cost of the Carbon Capture units from Climeworks starts from US$ 600 000 each with a capacity of 135 kgCO2/day. An additional cost of US$ 300/TonCO2 is required for maintenance of the unit during operation. The units also require 2GWh of Heat energy and 650 kWh of electrical energy per ton Carbon Dioxide produced. Additional costs related to Transport and site modification will also need to be considered prior to installation.

6.2.2.2 *Oxygen Purification, Pressurization/Liquification and Storage System*

For the Oxygen purification, pressurization and storage system there are multiple existing systems available that can be used to provide the oxygen in its required form. The smaller PSA or Cryocooler type systems can be developed for US$ 170 000 for a full system which has a capacity of 120 kgO2/day. Additional Capacity of 120 kgO2/day can be added for an additional US$ 130 000 to cover component costs once a unit is developed. The energy requirement of 13kW/h will also need to be addressed. Larger capacity units with 2 400 kgO2/day can also be developed for US$ 900 000 with an energy requirement of 54kW/h. All these systems can be designed to fit in containers thus reducing the need for additional housing and assembly. The transportation costs of the units will also need to be addressed.

6.2.2.3 *Energy Generation and Supply System*

Renewable sources of energy will be preferred over other available energy systems due to the aim of making the products being produced as Carbon negative as possible. As such Solar heating systems and Solar PV systems will need to be procured. Currently the cost of these systems various from region to region and would require an estimated additional investment of US$ 1675/kW of solar energy production in South Africa. The costs of large-scale Solar PV facilities vary between US$ 790-2 430/kW production capacity depending on location and system set up. This is relatively cheaper than the cost of using grid power at US$ 0.12/kWh which equates to an equivalent US$ 7 000/kW production capacity system.

6.2.2.4 *Additional Costs for Full System Carbon Dioxide Recycling System Implementation*

Depending on the size of the facility and existing infrastructure already in place additional funding will be required for the following items:

1. Land Acquisition,
2. Environmental Impact Studies
3. Location Feasibility Studies
4. Engineering Requirements (Geotechnical, Structural analysis)
5. Infrastructure Development requirements
6. Facility Operational Costs

6.3 Additional Potential Sources of Funding

The funding sources mentioned below are current available options that may be utilised during the development of the Full Carbon Dioxide Recycling system in various stages of the development lifecycle.

6.3.1 Department of Trade and Industry (DTI) South Africa - Support Programme for Industrial Innovation (SPII)

Provides financial assistance to small, very small and micro-enterprises and individuals in the form of a non-repayable grant. A percentage of 'qualifying' costs incurred in the pre-competitive development activities associated with a specific project.

At present the maximum amount available to this project and company is R2 Million, of which only 50% of qualifying costs incurred will be subsidised. The project will also not be able to exceed R10 million in total costs for the development.

For Additional information see Appendix G, or check out the DTI website in the Link.

6.3.2 South African Industry Development Funds

The main use of these funds will be to generate capital for the business and establish a production facility to manufacture/assembly of the Carbon Dioxide Recycling Systems and the Graphite Separation Systems once the need arises.

6.3.2.1 Industrial Development Corporation (IDC)

The IDC has multiple funds available that may be able to help with providing the funding for the production facility to be developed. They can offer low cost loans, Quasi equity or Equity type investment into the business. The funds that may be available to Space Habitats are listed below:

1. **Youth Pipeline Development Programme:** To improve the readiness of potential applicants and thereby increase their probability for IDC consideration.
2. **Gro-E Youth Scheme:** To provide finance to renewable energy and energy efficiency projects of smaller scale and manufacturing of Green products in South Africa aimed at business owners under 35. (Fund initial production)
3. **AFD Green Energy Fund:** To provide finance to renewable energy and energy efficiency projects of smaller scale and manufacturing of Green products in South Africa. (Fund initial production)
4. **SMEA and Midcap Companies:** To assist SMEs and MIDCAP companies to access loan financing for CAPEX, medium- and long-term working capital. (Fund expansion/Scaling up Projects)

Additional information can be found in the links provided and in Appendix G.

6.3.2.2 Eastern Cape Development Corporation (ECDC)

The ECDC finances small to large enterprises through short- and long-term products. The ECDC finances developments for the Eastern Cape that bring a meaningful development impact to the Eastern Cape economy. The ECDC has a smaller capacity than IDC.

For further information see appendix 18.3 or follow the link.

1 **POWERplus small loan:** Small, short-term loan, Aimed at SMMEs.
2 **TERMcap loan:** A vehicle by which capital is channelled to a business to allow for financial viability and sustainability through term-defined debt financing.
3 **EQUItrader equity finance:** Provides for equity financing mainly for the manufacturing and retail sectors.

6.3.3 Climate Change Funds

The main use of these funds will be to build a small Graphite and Oxygen Production facility utilising the Carbon Dioxide Recycling Systems and the additional sub-systems. The aim would be to provide a technology demonstration of a potential large-scale production plant that could have the capacity to be increased in the future. The first plant should be design with a 1 tonC/day (3.67 tonCO2/day, 2,67 tonO2/day) capacity.

6.3.3.1 Green Climate Fund

The Green Climate Fund (GCF) was adopted as a financial mechanism of the UN Framework Convention on Climate Change (UNFCCC) at the end of 2011. It aims to make an ambitious contribution to attaining the mitigation and adaptation goals of the international community. Over time it is expected to become the main multilateral financing mechanism to support climate action in developing countries.

NOTE: This fund will only be accessible through Development Bank Southern Africa (DBSA) or any other Accredited Implementing Entity recognised by the Green Climate Fund. See Link.

For more information on the fund the follow the link.

6.3.3.2 Green Technology Fund

The Clean Technology Fund (CTF) seeks to promote scaled-up financing for demonstration, deployment and transfer of low-carbon technologies with significant potential for long-term greenhouse gas emissions savings. It aims to:

1. Provide positive incentives, through public and private sector investments, for the demonstration of low carbon development and mitigation of greenhouse gas emissions;
2. Fund low carbon programs and projects that are embedded in national plans and strategies, scaling up development and accelerating the diffusion and transfer of clean technologies;
3. Realize environmental and social co-benefits, illustrating the potential for low-carbon technologies in contributing to sustainable development and the Millennium Development Goals;
4. Support international cooperation on climate change;
5. Utilize skills and capabilities of the MDBs to raise and deliver new and additional resources, including official and concessional funding, at significant scale; and
6. Share experiences and lessons learned in responding to climate change challenges.

NOTE: This fund will only be accessible through Multilateral Development Banks such as International Finance Corporation, African Development Bank and International Bank for Reconstruction and Development.

For more information on the fund follow the Link.

6.4 Costing Methodology

The costing of the Carbon Dioxide Recycling Systems includes many different aspects which are required for the development of the Carbon Dioxide Recycling System. The potential cost of each aspect was estimated for the duration of the project to help provide a total cost estimate of the project and was used to determine the proposed pricing of the system.

6.4.1 Design Costs

The cost of the design includes the cost of designers employed by Space Habitats and external specialists hire to help develop the project. The software used for design was also included in the costing of the design.

6.4.2 System Costing

The Costing of the module was achieved by breaking up the costs of individual systems required for the development and manufacturing of the Carbon Dioxide Recycling System based on a preliminary design. The system was further broken down into major components of the systems that could be priced from suppliers.

6.4.3 Manufacturing Cost

New manufacturing equipment and buildings will be required to facilitate the manufacturing process of assembling the Carbon Dioxide Recycling Systems. The primary cost will be the production line that will be required for the assembly of the Carbon Dioxide Recycling Systems. Additional Clean rooms will be required to prevent contamination of the Electrolyte preparation. Special Environmentally controlled chambers will also need to be built to ensure that preparation of the LM is done in an Inert Gas environment with Oxygen removed.

Utilities such as water and electricity also contribute to the cost of manufacturing the module. Every effort will be made to get these as sustainable systems by utilising Solar energy where possible as well as harvesting of rainwater for industrial use and cooling.

The use of renewable technology will also help to ensure that the factory can continue production regardless of the current state of utility supply ability.

6.4.4 Testing Facilities Cost

Some aspects of the module will be tested using existing facilities and laboratories. For the final testing stage in which the module will be subjected to environmental conditions a new testing facility may be required to be developed. This facility will add a high initial cost to the development of the Carbon Dioxide Recycling System that will need to be funded.

6.4.5 Business Overheads

The cost of running the business in terms of administration, rent/loan, travel expenses and office supplies etc. were also included in the development cost of the Carbon Dioxide Recycling System.

6.5 Cash Flow Projections

The projected cash flow requirements for the development of the Carbon Dioxide Recycling Systems are illustrated below. A more detailed monthly breakdown of the cash flow projection can be found in Appendix F.

Table 6.4Planned Cash Flow Projection Phase Wise (US Dollar)

		Phase 1	Phase 2	Phase 3	Phase 4
		Initiation, Planning and Procurement	Research & Engineering Design Phase	Manufacturing & Assembly Phase	Prototype Testing
Beginning Cash Balance:		$ -	$ 998.44	$ 9 050.34	$ 9 254.44
Cash Inflows					
	Owner	$ 6 666.67	$ 13 333.33	$ 8 000.00	$ 2 666.67
	Angel Investors	$ 20 000.00	$ 30 000.00	$ 3 333.33	$ -
	Venture Capitalists	$ -	$ 6 666.67	$ 28 333.33	$ 26 000.00
	General Investors	$ -	$ 6 666.67	$ 28 333.33	$ 26 000.00
	Department Trade and Industry (RSA) Support Programme for Industrial Innovation (SPII) (Grant)	$ 21 586.24	$ 48 614.77	$ 63 132.32	$ -
Total Cash Inflows		$ 48 252.91	$ 105 281.43	$ 131 132.32	$ 54 666.67
Available Cash Balance		$ 48 252.91	$ 106 279.88	$ 140 182.66	$ 63 921.11
Cash Outflows					
	Lab Equipment - Research	$ 24 844.90	$ 1 333.33	$ -	$ -
	Materials - Chemicals & Rare Earth Metals	$ 7 435.82	$ 11 327.69	$ 15 507.15	$ 514.84
	Research - Nelson Mandela University	$ 9 536.80	$ -	$ 4 087.20	$ -
	Engineering & Design	$ -	$ 46 525.00	$ 7 812.50	$ -
	Human Resources	$ 4 000.00	$ 21 666.67	$ 34 000.00	$ 11 333.33
	Project Expenses	$ -	$ -	$ 12 122.89	$ 8 586.45
	IP Registration	$ -	$ 1 666.67	$ -	$ 39 066.67
	Manufacturing Expenses	$ -	$ -	$ 2 068.00	$ 464.67
	Material Expenses - System Components	$ -	$ 8 826.91	$ 42 260.55	$ -
	Business Expenses	$ 1 436.94	$ 5 883.26	$ 13 069.92	$ 3 647.65
	Misc. Expenses	$ -	$ -	$ -	$ -
Total Cash Outflows		$ 47 254.47	$ 97 229.54	$ 130 928.23	$ 63 613.61
Net Increase (Decrease)		$ 998.44	$ 8 051.90	$ 204.10	$ -8 946.94
Ending Cash Balance		$ 998.44	$ 9 050.34	$ 9 254.44	$ 307.50

Table 6.5 Planned Yearly Cash Flow Projection (US Dollar)

	2019	2020				2021
	Q4	Q1	Q2	Q3	Q4	Q1
Beginning Cash Balance:	$ -	$ 918.02	$ 5 622.80	$ 9 050.34	$ 3 589.72	$ 9 254.44
Cash Inflows						
Owner	$ 5 000.00	$ 7 000.00	$ 8 000.00	$ 4 000.00	$ 4 000.00	$ 2 666.67
Angel Investors	$ -	$ 40 000.00	$ 10 000.00	$ 3 333.33	$ -	$ -
Venture Capitalists	$ -	$ -	$ 6 666.67	$ 11 666.67	$ 16 666.67	$ 26 000.00
General Investors	$ -	$ -	$ 6 666.67	$ 11 666.67	$ 16 666.67	$ 26 000.00
Department Trade and Industry (RSA) Support Programme for Industrial Innovation (SPII) (Grant)	$ -	$ 42 295.22	$ 27 905.79	$ 36 127.29	$ 27 005.03	$ -
Total Cash Inflows	$ 5 000.00	$ 89 295.22	$ 59 239.13	$ 66 793.96	$ 64 338.36	$ 54 666.67
Available Cash Balance	$ 5 000.00	$ 90 213.24	$ 64 861.93	$ 75 844.30	$ 67 928.08	$ 63 921.11
Cash Outflows						
Lab Equipment - Research	$ -	$ 25 511.57	$ 666.67	$ -	$ -	$ -
Materials - Chemicals & Rare Earth Metals	$ -	$ 12 117.47	$ 6 646.05	$ 4 127.47	$ 11 379.68	$ 514.84
Research - Nelson Mandela University	$ -	$ 9 536.80	$ -	$ 2 724.80	$ 1 362.40	$ -
Engineering & Design	$ -	$ 22 150.00	$ 24 375.00	$ 5 562.50	$ 2 250.00	$ -
Human Resources	$ 3 000.00	$ 9 666.67	$ 13 000.00	$ 17 000.00	$ 17 000.00	$ 11 333.33
Project Expenses	$ -	$ -	$ -	$ 3 293.22	$ 8 829.67	$ 8 586.45
IP Registration	$ -	$ -	$ 1 666.67	$ -	$ -	$ 39 066.67
Manufacturing Expenses	$ -	$ -	$ -	$ 1 371.00	$ 697.00	$ 464.67
Material Expenses - System Components	$ -	$ 2 206.73	$ 6 620.18	$ 31 060.55	$ 11 200.00	$ -
Business Expenses	$ 1 081.98	$ 3 401.21	$ 2 837.02	$ 7 115.04	$ 5 954.89	$ 3 647.65
Misc. Expenses	$ -	$ -	$ -	$ -	$ -	$ -
Total Cash Outflows	$ 4 081.98	$ 84 590.44	$ 55 811.59	$ 72 254.59	$ 58 673.64	$ 63 613.61
Net Increase (Decrease)	$ 918.02	$ 4 704.78	$ 3 427.54	$ -5 460.63	$ 5 664.72	$ -8 946.94
Ending Cash Balance	$ 918.02	$ 5 622.80	$ 9 050.34	$ 3 589.72	$ 9 254.44	$ 307.50

6.6 Financial Controls & Procedures

Financial controls and procedures will be put in place to ensure that the Space Habitats meets its obligations of corporate governance, fiduciary duty and due diligence.

Space Habitats will adopt an accounting standard with knowledgeable staff who are accountable and responsible for its implementation.

Financial statements such as income statements, cash flow statements, balance sheets and statement of changes in equity will be issued timely and accurately. The Companies financials will also be audited by a trusted internationally recognised 3rd party company.

An approval process of spending development funds will be established and incorporate major investors to ensure that the money is being utilised correctly and efficiently.

Additional financial controls and procedures can also be included at the request of major investors to help ease any concerns that they may have.

6.7 Pricing Policies

The pricing of the Carbon Dioxide Recycling Systems will be based on the following criteria:

1. Cost of Production of the Carbon Dioxide Recycling System,
2. Cost of Overheads for business operations,
3. Costs of full system development, and
4. Pricing level to ensure the Carbon Dioxide Recycling System can be feasible and profitable for the Buyer.

If the Carbon Dioxide Recycling System are proven to work, perform at much higher efficiency and the demand for the systems is high, then the costs of the initial Carbon Dioxide Recycling System will be evenly distributed among the buyers. The fewer orders that are available the higher initial cost of the modules will be so that the cost of development can be recuperated as fast as possible. A balance between the demand for the systems and the development cost will need to be established once a better understanding of the market conditions presents itself.

7 Legal and Regulatory Environment

Space Habitats will adhere to all legal and regulatory requirements that are required for the successful completion of the Carbon Dioxide Recycling System both local and international to ensure that the development is a success.

7.1 Customs and Excise

The Customs and Excise legal and regulatory requirements will be required to be met by Space Habitats for the import and export of goods. Customs and Excise requirements of various countries will be required to be met to ensure goods are received and an understanding of what these requirements are will need to be understood by a professional in the corresponding country. Any permits that are required for the export of goods from South Africa will also need to be acquired for various goods.

Additional regulatory concerns will be the transport of hazardous and dangerous chemicals that form parts of systems and components. To help reduce the impact of these requirements dangerous chemical that can be procured from local markets should be attempted first.

Other issues that might occur will be a restriction on the product or system due to security clearance requirements of sensitive technologies. Space Habitats will need to meet these requirements so that it will be able to use the technology. Currently there are no technologies in our current design that have this requirement, but it might change as the project progresses and space applications are developed.

7.2 Labour Laws

Space Habitats will operate under South African Labour Laws and require the all employees that operate in South Africa to adhere to these laws.

All business entities that employ one or more full-time employees will be required to register with the Department of Labour. This is mandatory in terms of the Compensation for Occupational Injuries and Diseases Act (COIDA). This Act has been put in place to safeguard the rights of employees who are injured, contract a disease or get killed as a result of their work.

7.3 Tax Requirements

Space Habitats will operate under South African Tax Laws and require the all employees that operate in South Africa to adhere to these laws.

The main Tax requirement of Space Habitats will be:

1. **South African Revenue Services (SARS) Registration:** Space Habitats is currently a registered business with SARS since November 2018.
2. **Employee Tax:** The law demands that if Space Habitats employs one or more staff members who earn over R40,000 per year, will have to register for Pay as You Earn (PAYE). If payroll is more than R500,000 a month, Space Habitats must register for skills development levy (SDL). The funds are to be used to develop and improve skills of employees.
3. **Unemployment Insurance Fund (UIF) Registration:** Unemployment Insurance Fund (UIF) benefits workers when they can’t work due to maternity, adoption leave or illness. UIF registration can be done on form UF8 at any SARS office or online.
4. **VAT Tax registration:** If projected sales per year will exceed R1 million, then Space Habitats needs to register as a VAT (Value Added Tax) vendor. VAT vendor registration can be done by completing and submitting a VAT101 form, which is available at any SARS office.

5. **Customs and Excise Tax:** The requirements of the duties and taxes to be paid for good received vary greatly depending on the Tariff type, Valuation and Origin. Various forms will be required for various goods.

7.4 Other Regulatory Requirements

Other legal requirements for business to adhere to include the following:

1. **Business Registration with Companies and Intellectual Property Commission (CIPC):** Space Habitats has been registered with the CIPC since November 2018.
2. **Registration of Intellectual Property Rights with CIPC:** Space Habitats will register any Trademarks, Patents, Designs and Copyright articles that are developed during the development of the habitation modules.

8 SWOT Analysis

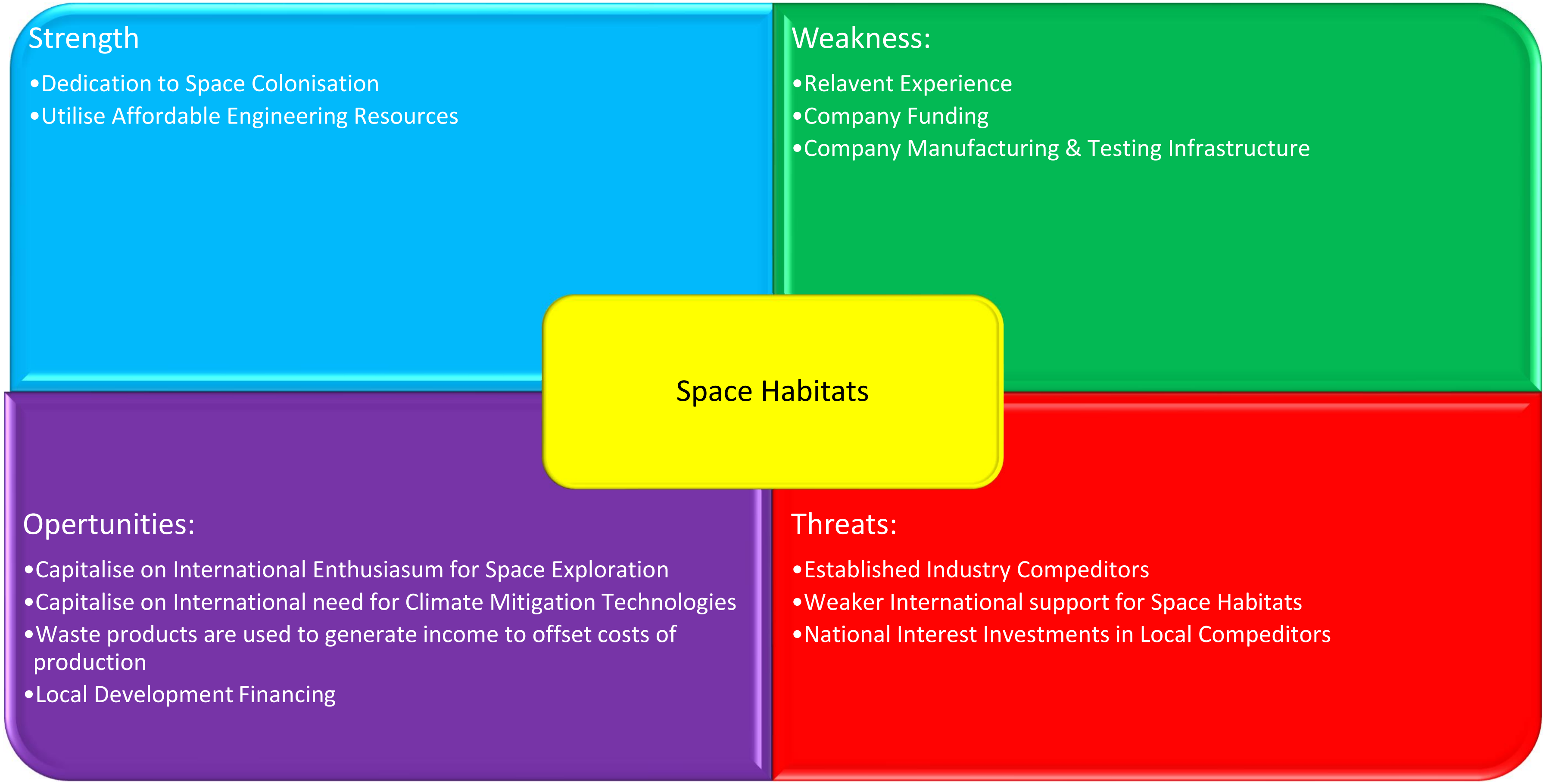


Figure 8-1SWOT Analysis of Space Habitats

9 Appendix A: Planned Program for Delivery of the Project

For full Version please contact Space Habitats.

10 Appendix B: Carbon Dioxide Recycling System Sub-Systems

For full Version please contact Space Habitats.

11 Appendix C: Potential Suppliers of Materials, Components and Systems

For full Version please contact Space Habitats.

12 Appendix D: Project Specifications

For full Version please contact Space Habitats.

13 Appendix E: Case Studies

For full Version please contact Space Habitats.

14 Appendix F: Cash Flow Projections

For full Version please contact Space Habitats.

15 Appendix G: Alternative Funding Options

For full Version please contact Space Habitats.

16 Appendix H: Company Management

16.1 The Entrepreneurs

Currently the company only has 1 entrepreneur who is Andre Van Der Merwe. Space Habitats is looking for any additional members who would be interested in joining the company in any capacity that they are able to contribute.

16.1.1 Andre Van Der Merwe

Andre has been a long-time fan of space exploration from a very young age and always dreamed of exploring space like on his favourite show Star Trek. Unfortunately, due to the national requirements need to be an astronaut and where he lived this could not be a real dream any time soon.

In 2002 the first South African went to Space and this renewed his dream of travelling to Space, unfortunately the requirement of millions of dollars was a steep price he could not afford.

Enter SpaceX a commercial company that is breaking the boundaries of space travel with an aim to make it more affordable. SpaceX success has allowed the interest in Space exploration to be rejuvenated internationally. At the Same time Andre managed to complete his degree in Civil Engineering and began working in construction management. The new space race had once again awoken a passion of Space exploration and he started to wonder how he could contribute. Enter SpaceX's plan to colonize Mars.

As a Civil Engineer building a city is something he can do, as a private company the national background is not an issue, the cost to travel is expected to be lowered so it's a dream come true in the making. But how do we build cities on Mars? We need suitable habitats. Currently there are only ideas of how to colonize a new world, but these ideas are expected to be very expensive and some of them will take years to build a viable habitat. Thus, Space Habitats is born. A dream to help the many people who are interested in space exploration have a place to call home when they do. Space Habitats is how Andre plans to contribute to the new space race and help to make it a reality.

Andre plans to use his engineering skills to help develop a new habitation module that is affordable. Andre will be in the role of Managing Director of Space Habitats and Project Manager of the Carbon Dioxide Recycling System.

16.2 The Management Team

16.2.1 Managing Director – Andre Van Der Merwe

Andre will perform the role of Managing Director of Space Habitats. In the beginning his roles will include all day to day operations and administrative requirements of the company to ensure that the company is functioning effectively. Andre will also be responsible for finding finance and investment requirements of Space Habitats to ensure it can operate. As the business develops some of these duties will be transferred to relative managers associated with the relevant tasks.

16.2.2 Project Manager – Andre Van Der Merwe

Andre will perform the duties of project manager for the development of the Carbon Dioxide Recycling System. Andre has a degree in Civil Engineering with a background in Project management of various construction activities. These duties include the management of the project scope, time, cost, risk, quality and communication requirements. Andre will also be responsible for ensuring that documentation for the project is recorded accurately and kept updated throughout the project.

16.2.3 Research Manager – Dr Adeniyi Ogunlaja (Nelson Mandela University)

Dr Adeniyi Ogunlaja currently works at the Nelson Mandela University, Department of Chemistry as a lecturer and researcher. Dr Adeniyi has currently published 45 research papers during his tenure at various institutions. Dr Adeniyi will be responsible for over seeing the experiments that ill be performed to determine a more efficient Carbon Dioxide Recycling System. The following Experimentations are outlined:

1 Synthesis & Characterisation of LMCe
2 Electro Catalytic reduction of CO2 using LM Electrode and varying electrolyte and solvent
3 Develop method of driving off generated Oxygen molecules during electrolysis
4 Develop Method for separating Carbon from electrolytic solution,
5 Develop Electrolytic Recycling Process

16.2.4 Design Manager – Gideon van den Burg PrEng (FME Consult Engineering)

Gideon is a professional registered mechanical engineer and the owner of FME Consult Engineering. Gideon will perform the duties of design manager for the development of the Carbon Dioxide Recycling System. All engineering works will be outsourced to FME Consult. The duties of the design manager will be to:

1 Ensure that the design of the Carbon Dioxide Recycling System is done to recognised international standards/specifications associated with manufactured machinery equipment,
2 Ensure any test required to be performed on materials, components, systems or full module are carried out in order to ensure the Carbon Dioxide Recycling System will operate as specified,
3 Ensure that the various internal and external design experts/consultants coordinate effectively with each other and,
4 Ensure clear and understandable documentation of the design process and drawings that will needed.

16.2.5 Junior Business Development Manager – Vacant

Space Habitats will be looking to hire a new Junior Business Development Manager to start during the Manufacturing & Assembly Phase of the project. The Main function of the Junior Business Development Manager will be to identify possible industries and business that will be able to use the products that will be produced by Space Habitats. The Junior Business Development Manager will need to meet with prospective clients and help to secure potential orders/contract for the future product supplies that will be produced. This will help in securing future finance for further development of production facilities. The Junior Business Development Manager will also need to familiarise themselves with potential sources of funding and establishing their approval requirements.

The role of Junior Business Development Manager will be open to any person that has a background in business development, economics or business administration. An experienced individual is preferred but a person with no/little experience will also be acceptable if they can show a greater understanding of the requirement needed to fulfil the role of Business Development Manager. The candidate will need to have personal drive and be able to work without supervision, plan their activities well and be able to properly report back what work has been done and report any issues or problems that may arise. The Candidate should also have a passion for Space related activities and believe in what Space Habitats is trying to achieve.

The Candidate will also need to be willing to travel long distances nationally and overseas. The Candidate should have or be able to apply for the necessary travel documents (Passport/visas) if required to do so.

Due to the start-up nature of the business the expected renumeration for the Junior Business Development Manager will be relative to lower market rate for a Business Development Managers. In South Africa this rate is currently R20 000/month total cost to company including benefits. The rate is low for highly experienced individuals, but the position will allow development of candidate for future prospects. If the Candidate can perform exceptionally well during the period, then a high position and better salary may be negotiated later.

16.2.6 Junior Engineer (Mechanical) – Vacant

Space Habitats will be looking to hire a new Junior Engineer to assist the Engineering & Design Phase of the project. The main function of the Junior Engineer will be to assist the Engineers from FME Consult and perform all the required "Grunt Work" whist also learning from the Engineers on how the process of design is done. The position will work like an internship role at the engineering office for the first 4 months. Once we enter the Manufacturing Phase the Junior Engineer's role will focus more on Quality control and assemble of the product. The aim will be to identify processes for more efficient assembly and design modifications to allow the system to be more efficient or economical. During the Testing Phase the role of the Junior Engineer will be observe how the system works together and improve simulation models that were developed during the Engineering & Design Phase to closer represent the actual working system.

The Role of the Junior Engineer will be open to any person that is from an engineering background who has recently completed their university degree in Engineering as an undergraduate or higher. Experience in the relative field is not required but will be helpful. The candidate will need to have personal drive and be able to work without supervision, plan their activities well and be able to properly report back what work has been done and report any issues or problems that may arise. The Candidate should also have a passion for Space related activities and is always looking into what new developments are currently being explored in science and technology today.

Due to the start-up nature of the business the expected renumeration for the Junior Engineer will be relative to lower market rate for a new Engineering Graduate. In South Africa this rate is currently R35 000/month total cost to company including benefits. If the Candidate is able to perform exceptionally well then, the role may eventually lead to a higher position such as Specialist Engineer/Lead Engineer/Design Manager once they are able to get certified as a Professional Engineer.

16.3 Personnel:

The immediate personnel requirement of the company is outlined as follows:

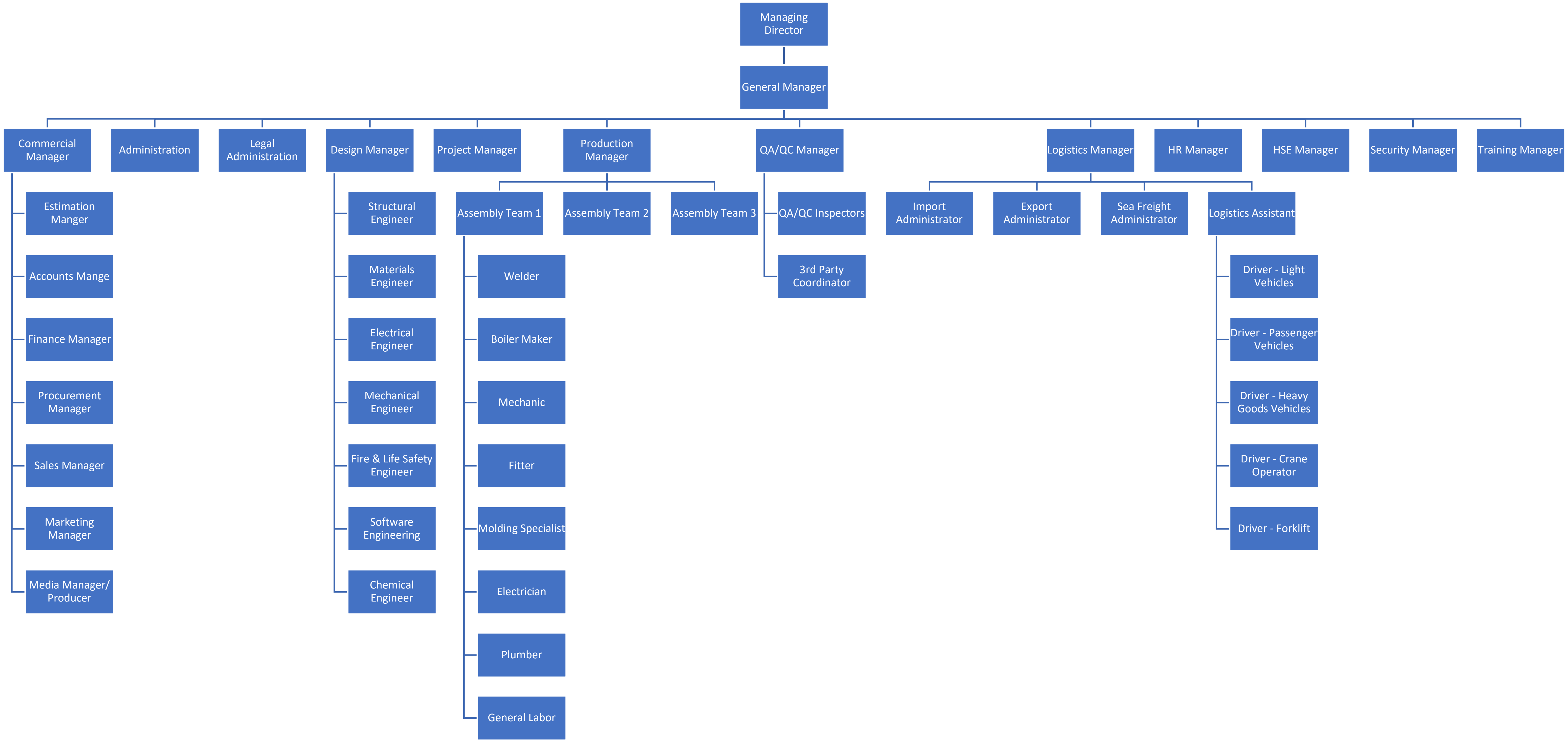
1 Initiation, Planning & Procurement Phase:
   a. 1 Project Manager
2 Research & Engineering Design Phase:
   a. 1 Project Manager
   b. 1 Junior Engineer
3 Manufacturing & Assembly Phase:
   a. 1 Project Manager
   b. 1 Junior Engineer
   c. Business Development Manager
4 Prototype Testing Phase:
   a. 1 Project Manager
   b. 1 Junior Engineer
   c. Business Development Manager

Personnel required for various phases is given below in Table 18.1.

Table 16.1 Planned Employed Personnel for Multipurpose Habitation Module

Project Phase	Planned Personnel
Initiation, Planning & Procurement	1
Research & Engineering Design	2 (7 Outsourced)
Manufacturing & Assembly	3 (2 Outsourced)
Prototype Testing	3

16.4 Management Structure of Space Habitats



17 Appendix J: Company Documentation

17.1 Business Profile

Company Name:		Space Habitats
Enterprise Number:		9149402083
Date of Registration:		15 November 2018
Country of Incorporation:		Republic of South Africa (RSA)
Registered Office Address:		16 Old Transkei Rd Sterling East London Eastern Cape South Africa 5241
Tel:		+27 67 406 2684
Email:		andre.van@spacehabitats.co.za
Website:		https://spacehabitats.co.za
Current Management:		
Incorporator:		Andre Van Der Merwe RSA ID: (8607105178085) Address: 16 Old Transkei Rd Sterling East London Eastern Cape South Africa 5241
Director:		Andre Van Der Merwe RSA ID: (8607105178085) Address: 16 Old Transkei Rd Sterling East London Eastern Cape South Africa 5241
Shareholders:		
No. Shares:	1000 (Ordinary Shares)	Andre Van Der Merwe RSA ID: (8607105178085) Address: 16 Old Transkei Rd Sterling East London Eastern Cape South Africa 5241

Business Profile:
Space Habitats is start-up company that is aimed at designing, assembling and testing habitational modules for use in extreme low gravity environments of space such as on the Moon and Mars. The aim is to make space more accessible to humanity and allow the colonization of space.

Industry Information:
Space industry refers to economic activities related to manufacturing components that go into Earth's orbit or beyond, delivering them to those regions, and related services. Owing to the prominence of the satellite-related activities, some sources use the term satellite industry interchangeably with the term space industry.

Key Processes:
Design, Construct and Readiness Testing of human rated habitation modules.

17.2 : Company Registration

Document issued by the Commissioner of Companies & Intellectual Property Commission on Thursday, November 15, 2018 at 13:53

Companies and Intellectual Property Commission
a member of the dti group

Company Registration | Captured on 15/11/2018

Tracking Number: 9149402083
Customer Code: AN4451

9149402083

ENTERPRISE INFORMATION

Transaction Date	15/11/2018
Tracking Number	9149402083
Name Reservation Application Number	9149403737
Financial Year End	OCTOBER
Number of Authorised Shares	1000 SHARES

Addresses

POSTAL ADDRESS	ADDRESS OF REGISTERED OFFICE
16 OLD TRANSKEI RD STERLING EAST LONDON EASTERN CAPE 5241	16 OLD TRANSKEI RD STERLING EAST LONDON EASTERN CAPE 5241

DIRECTORS & INCORPORATORS

Surname and First Names	Director Type	ID Number / Date of Birth	Addresses
VAN DER MERWE, ANDRÉ	Incorporator	8607105178085	Postal: 16 OLD TRANSKEI RD, STERLING, EAST LONDON, EASTERN CAPE, 5241 Residential: 16 OLD TRANSKEI RD, STERLING, EAST LONDON, EASTERN CAPE, 5241
Signature		16/11/2018 Date - Cannot be before 15/11/2018	
VAN DER MERWE, ANDRÉ	Director	8607105178085	Postal: 16 OLD TRANSKEI RD, STERLING, EAST LONDON, EASTERN CAPE, 5241 Residential: 16 OLD TRANSKEI RD, STERLING, EAST LONDON, EASTERN CAPE, 5241
Signature		16/11/2018 Date - Cannot be before 15/11/2018	

Page 1 of 1

Physical Address
the dti Campus - Block F
77 Meintjies Street
Sunnyside 0001

Postal Address: Companies
P O Box 429
Pretoria
0001

Docex: 256
Web: www.cipc.co.za
Contact Centre: 086 100 2472 (CIPC)
Contact Centre (International): +27 12 394 9573

17.3 Tax Registration

SARS

INCOME TAX

Notice of Registration

Enquiries should be addressed to SARS:

Contact Detail

SARS
Alberton
1528

Contact Centre Tel: 0800 00 SARS (7277)
Website: www.sars.gov.za

SPACE HABITATS
16 OLD TRANSKEI RD
STERLING
EAST LONDON
EASTERN CAPE
5241

Details

Taxpayer Reference No: 9017034282

Always quote this reference number when contacting SARS

Date: 2018-11-16

Dear Taxpayer

NOTICE OF REGISTRATION

The South African Revenue Service (SARS) confirms registration of the following taxpayer:

Registered name: SPACE HABITATS
Taxpayer registration number: 2018/595501/07
Taxpayer reference number: 9017034282

Your tax obligation

Every Company/Close Corporation which conducts business or has an office in South Africa must, within one month thereof appoint a representative as the Public Officer of the Company. The relevant particulars of the representative must be furnished to a SARS branch.

Every company is regarded as a provisional taxpayer. The Company/Close Corporation is required to make provisional tax payments as from the 2020 tax period.
Date of liability for provisional tax : 201911
Provisional payments must be made twice a year on or before the following dates: April and October

Your attention is drawn to the provisions of section 89*bis* of the Income Tax Act and paragraph 27 of the Fourth Schedule to the Income Tax Act, in terms of which interest at the prescribed rate and a penalty of ten percent will be charged on any amount not paid on or before the date on which payment for the relevant period is due.

Kindly notify SARS of any change to your registered particulars within 21 business days of such change.

Should you have any queries please call the SARS Contact Centre on 0800 00 SARS (7277). Remember to have your taxpayer reference number at hand when you call to enable us to assist you promptly.

Sincerely

ISSUED ON BEHALF OF THE SOUTH AFRICAN REVENUE SERVICE

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18 Environmental Control and Life Support System: CO2 Removal and Reduction to O2 and Carbon Solid Business Plan Approval

The undersigned acknowledge that they have reviewed the **Environmental Control and Life Support System: Carbon Dioxide Recycling System Business Plan** and agree with the information presented within this document. Changes to this **Environmental Control and Life Support System: Carbon Dioxide Recycling System** will be coordinated with, and approved by, the undersigned, or their designated representatives.

Signature: ______________________________ Date: ____________

Print Name: ______________________________

Title: ______________________________

Role: ______________________________

Signature: ______________________________ Date: ____________

Print Name: ______________________________

Title: ______________________________

Role: ______________________________

Signature: ______________________________ Date: ____________

Print Name: ______________________________

Title: ______________________________

Role: ______________________________

Space Habitats

Extraterrestrial living