Environmental Challenges 6 (2022) 100418

Contents lists available at ScienceDirect

Environmental Challenges

journal homepage: www.elsevier.com/locate/envc

Lean business model canvas and sustainable innovation business model based on the industrial synergy of microalgae cultivation

Taofeeq D. Moshood[a,*], Gusman Nawanir[a], Norhana Mohd Aripin[a], Mohd Hanafiah Ahmad[a], Khai Loon Lee[a], Suhaidah Hussain[a], Yekinni Kolawole Sanusi[b], W.A. Ajibike[a]

[a] *Faculty of Industrial Management, Universiti Malaysia Pahang*
[b] *Department of Pure and Applied Physics, Ladoke Akintola University of Technology, Ogbomoso, Nigeria*

ARTICLE INFO

Keywords:
Algae Cultivation
Sustainable Development
Biofuels
Biodiesel
Biogas and Industrial Symbiosis

ABSTRACT

As a fundamental principle of natural resource management, sustainability encompasses a range of interrelated concepts, including operational efficiency, environmental effect minimization, and socioeconomic impact analysis. Microalgae have the capability to minimize CO_2 emissions while also generating a large volume of oil, which might make them useful in the development of the next generation of biofuels. The emphasis was on researching the technological possibility of biofuel microalgae cultivation with CO_2 provision from flue gas manufacturing due to various factors influencing microalgae production. Biodiesel microalgae, on the other hand, are quiet and far from commercially viable products due to numerous bottlenecks, which can be resolved by recognizing microalgae biomass manufacture as a market advantage when combined with a production facility from the perspective of a lean business model canvas for algae cultivation and sustainable business model innovation. This article aims to establish a lean canvas business model and a sustainable, innovative business model based on the industrial synergy of microalgae cultivation in the biodiesel production pathway. The results have contributed to developing scenarios for lean business model canvas and a sustainable, innovative business model for varying degrees of transition in the business model. Improved collaboration with external stakeholders and the introduction of new consumer networks were among the many examples given. The findings of the study contribute to a better understanding of how the global market for microalgae is changing.

Introduction

Climate change is often considered the most urgent global environmental challenge is facing today (Yin et al., 2020). However, the widespread use of fossil fuels has resulted in global climate change, environmental degradation, and public health issues, among other things (Ganesan et al., 2020). As a result, several countries are focusing on creating new, environmentally friendly, and long-term energy sources (Chen and Quinn, 2021). There is considerable interest in biofuels as a potential renewable energy source among many potential sources of renewable energy (Pavithra et al., 2020). Biofuels are projected to play an essential part in developing sustainable global energy infrastructure in the future (Ahmad et al., 2011). Since the Brundtland study (WCED, Our Common Future 1987), the concept of sustainable development has been internationally well recognized and is one of the world's major concerns today. Perhaps because the idea of sustainable development is too broad and intangible, it does not have any meaning (Geissdoerfer et al., 2017). The lean business model canvas has come to life as a new framework to achieve sustainable growth and to reflect a significant rethink and rework of the present linear structure based on a model of taking-over disposition manufacture (Ellen MacArthur Foundation 2015), but with the characteristics of being a far more substantial method of organizing economy and society (M. Geissdoerfer, 2019). The international community (governments, private businesses, academics) is being led by a global movement to explore alternative avenues for transforming from the linear to the lean business model canvas for algae cultivation (Kargbo et al., 2021).

The industrial symbiotic connection was a great way to improve the lean business model canvas based on industrial ecology (Angelo, 2019). Given an industrial symbiosis idea, the production of microalgae is one kind of activity with the capacity to link to various industrial processes (microscopic, oxygen-evolving photosynthetic species that survive in aquatic environments). In this way, under the concept of industrial symbiosis, microalgae production may be combined with large-scale CO_2 generation systems, which involve, for example, fossil fuel power plants and cement plants (Gholkar et al., 2021). The environmental advantages of CO_2 reduction and waste-water treatment offer microalgae a significant position in sustainable development

* Corresponding author.
E-mail address: ppo20002@stdmail.ump.edu.my (T.D. Moshood).

https://doi.org/10.1016/j.envc.2021.100418
Received 7 August 2021; Received in revised form 30 November 2021; Accepted 1 December 2021

(Zhou and Wen, 2019) and, more importantly, a promising move towards a lean business model canvas for algae cultivation. Microalgae is undoubtedly a desirable source for the production of biofuels. Due to their high lipid content, advantages over terrestrial crops as regards land requirements and a high photosynthetic and CO_2 reduction efficiency, micro-algae have been explored as a possible feedstock for biodiesel synthesis because of their high lipid content, advantages over terrestrial crops in terms of non-arable land requirements, and strong photosynthetic and CO_2 reduction efficiency, microalgae have been proposed as a possible feedstock for biodiesel synthesis (Angelo, 2019).

Moreover, the only renewable fuel to supplement fossil fuel without disrupting global food sources may be micro-algae biodiesel (Viswanath et al., 2010). Commercial symbiotic microalgae development can be beneficial (Soratana and Landis, 2011). But large-scale cultivation systems for microalgae need the amount of CO_2 provided by industrial plants (Andersson et al., 2014). The large market growth of algal biomass primarily focuses on open ponds, with relatively low capital expenditure (Ubando et al., 2016). Although microalgae are becoming more popular as a feedstock for biofuels, and the microalgae cultivation scalability is co-locating with the source of CO_2, large-scale microalgae cultivation is still problematic, particularly in terms of economic sustainability (Angelo, 2019).

As the relevance of CO_2 biological mitigation grows, the win scenario in which microalgae bio-ethanol is combined with CO_2 mitigation can increase the strategic position of the microalgae sector throughout the world (T.D. Moshood et al., 2021). While there have been numerous studies looking at both the benefits and drawbacks of using microalgae to capture CO_2 for GHG mitigation (Mata et al., 2010); algal capture of carbon dioxide (Packer, 2009); cultivating microalgae in waste-water for biomass production (Shahid et al., 2020); industrially important microalgae (Sydney et al., 2010), there have been very few studies looking at the idea of microalgal cultivation in collaboration with other industries.

Soratana & Landis (Soratana and Landis, 2011) examined 20 different microalgae growth scenarios in a closed Photobioreactor using synthetic fertilizers and CO_2. As well as this, they performed a life-cycle assessment (LCA) of these scenarios using a variety of photobioreactor construction materials, including glass, polyvinyl chloride (PVC), polycarbonate, polymethyl methacrylate, and high-density polyethene (HDPE) (synthetic CO_2 and from flue gas of thermal power plant). There was research done by Andersson et al. (Andersson et al., 2014) in Gothenburg on the Swedish west coast to see how an industrial cluster collaborated with a waste-water treatment facility and an algae culture to use the flow of materials and high industrial temperature (Banu et al., 2020). The authors used a biorefinery concept to analyze two case studies involving microalgae cultivation in open systems to treat wastewater and generate biogas and biodiesel. The results were encouraging. In order to maximize product demand, environmental footprint, and profit, Ubando et al. (Ubando et al., 2016) presented a fuzzy mixed-integer non-linear optimization method for selecting potential firms in an eco-industrial park, called by support tenants. When planning the eco-industrial park, the researchers considered everything from an integrated microalgae-to-biodiesel plant to an ethanol plant, a cement factory, and a Combined Heat and Power plant.

Without a doubt, the three investigations constitute a significant step forward in developing technological feasibility for microalgae culture for bioethanol production. However, no one of them makes a substantial contribution to evaluating microalgae production as a potential economic prospect. Even though these three articles tackle the industrial symbiosis idea and have conducted environmental assessments to demonstrate the benefits of microalgae farming, there is no indication that the industrial symbiosis principle has been adopted as a circular economy technique leaving out an essential component of the circularity concept. In order to put it another way, closed loops are not a central concern in these investigations.

Therefore, microalgae for biodiesel production are still a long way ahead (Chen et al., 2018). Several research on the production of biofuel microalgae biomass, primarily biodiesel (Anahas and Muralitharan, 2015), have been conducted. Still, most of them have concentrated on technical aspects, such as the catalog of more effective lipid extraction algal species and downstream processes. This paper aims to develop and implement a lean business model canvas for microalgae cultivation based on industrial symbiosis and examine the feasibility of biomass microalgae growth in biodiesel production raceways to aid in the transition to a lean business model canvas. The continued expansion of our nation's and the world's energy resources requires sustainable practices. A critical source of sustained competitive advantage and leverage for increasing biofuel microalgae production sustainability is the ability to transition into new market models quickly and efficiently. The causes of failure are mostly unknown. There is only a limited thorough description of the sustainable business model innovation process and lean business model canvas in the literature, despite the issue's importance. In the microalgae business model, the research conducts a comprehensive review of the literature on the idea and technique of sustainable innovation and lean business model canvas. A detailed list of significant difficulties and obstacles associated with each step of the process is provided. It also examines how a management tool may be converted into a process system and some insights into the process's operational setup and performance factors.

Research materials and methods

For this systematic literature review, this study followed the recommendations of Watson (Watson, 2015) and Durach et al. (Durach et al., 2017) to: (1) recognize current research papers, (2) select and evaluate their research results, (3) reassess and summarize the scientific proof, (4) comment on the results, and (5) recommend a business plan (T.D. Moshood et al., 2021). The following are the precise phases of a detailed and complete systematic review: The research questions were suggested in phase one; the effective literature materials were reviewed and analyzed in phase two; the retrieved research were sifted, evaluated, and verified for inclusion in the assessment in phase three in accordance with existing requirements and objectives of the research; related information and scientific proof were gathered from the materials, and explanatory assessment of the findings were conducted in phase four (Briner and Denyer, 2012; Kitchenham, 2004; Bastas and Liyanage, 2018).

Search and selection process

Articles relevant to the study were discovered and extracted using aggregator databases like Scopus (scopus.com) and publishing databases including Springer, Taylor & Francis (tandfonline.com), Elsevier (sciencedirect.com), and Google Scholar. Learning cycles, business model canvas, business model innovation, sustainable development, microalgae cultivation, biofuels, and industrial symbiosis were the prevalent keywords at the same time. While using this level of database granularity (aggregation site and publisher stage) resulted in some correlation between the two category levels, it validated the aggregation searches conducted to collect all relevant content in the literature (Bastas and Liyanage, 2019). Only peer-reviewed books, journal articles, and conference proceedings were used in the study to guarantee that the academic areas were covered by the most reliable sources and publications with outstanding management impact (Thornhill et al., 2009). They contained solely English-language articles.

The Kyoto Protocol's ratification in 2005 was recognized as a remarkable achievement in global sustainable practices, with the majority of sustainability integration research aligned with the study's research goal adopting this global endeavor (Rajeev et al., 2017). The search period for this research was selected from 2005 to 2021, based on these major accomplishment's inefficiency, learning

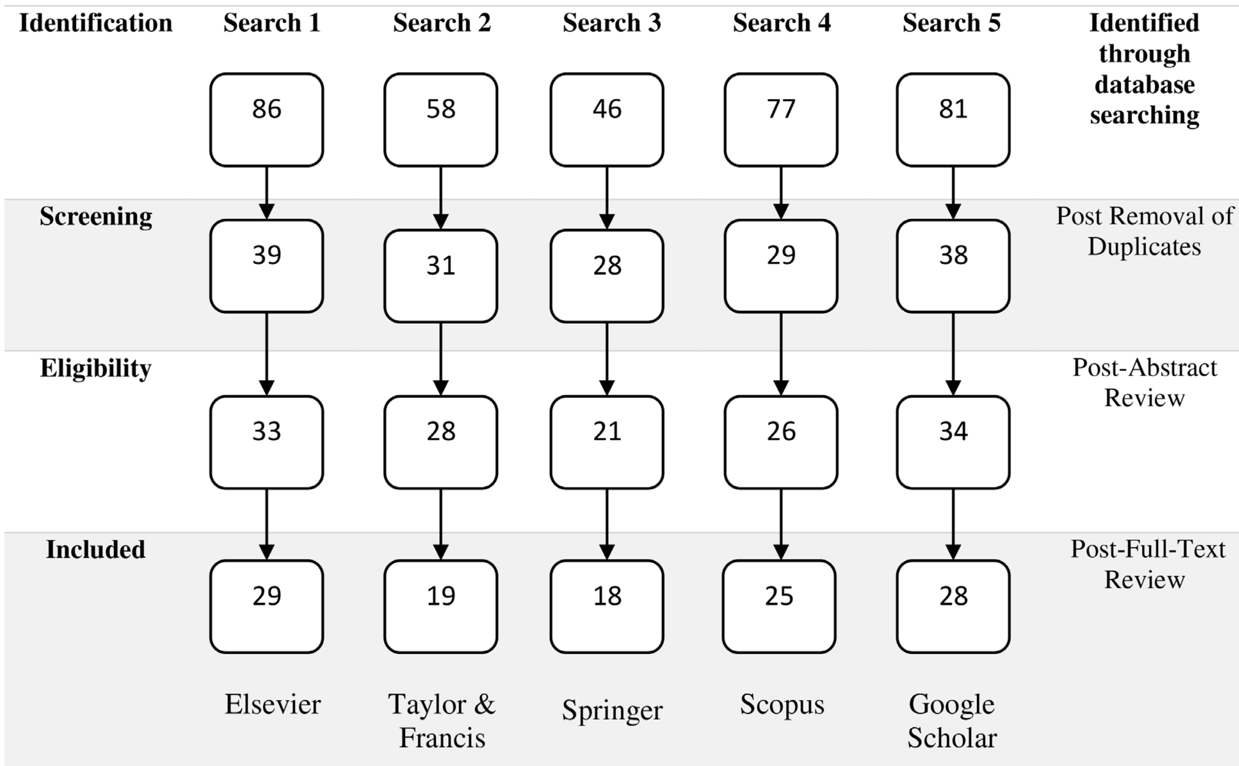

Fig. 1. Overview of paper identification, selection, and inclusion process.

cycles, sustainability management, business model canvas, global sustainability, business model innovation, and collecting state-of-the-art publications.

Analysis process

The method described in this paper demonstrates one method of applying qualitative research to text findings. Various steps are mentioned in ATLAS.ti 9 software's business model canvas for preparing and investigating microalgae production (T.D. Moshood et al., 2021). Each stage of the assessment phase is divided into parts for procedures, results, and discussion, helping the reader better understand how the data is assessed and the implications and data that arise (Chang and Hsieh, 2020). Following the comprehensive literature review approach indicated in Fig. 1, the publications found were screened, filtered, and verified for inclusion in the evaluation using an iterative method of selecting.

The 348 papers were screened (discovered via database searches, 348 articles), screened (after duplication were removed, 165 articles remained), eligible (after abstract review, 142 articles remained), and verified for inclusion (post-full-text review, 119 articles were utilized). The complete content of outstanding papers has been checked in the context of the study issues for the final judgement regarding the microalgae biofuels production, algae fuel production areas under examination. Duplicates have been excluded as part of this process, and eligibility has been verified from abstracts. The 119 articles were reviewed and validated as legitimate according to this research's systematic literature review procedure.

Analysis using ATLAS.ti 9 software

This section follows the methodology segment's structure, detailing each phase of the testing procedure. This study's information can be stored, recognized, and analyzed using the ATLAS.ti 9 software (Chang and Hsieh, 2020). To people unfamiliar with ATLAS.ti 9, using ATLAS.ti 9 technical language (quotation, relations, and network) would be meaningless. Fig. 2 shows a network view in ATLAS.ti 9 software that shows how the data codes are linked to the two main themes of the integrated lean business model.

The open coding feature of the ATLAS.ti 9 software package, the researcher will recognize numerous words, phrases, and other terms of interest linked to this article or topic of interest after an initial examination of text findings. Open coding is used to mark a "quotation," which employs the same words to create a message from the same material. As we start creating codes with new ideas, it's not uncommon for us to end up with more than a few pages of code (Friese et al., 2018). We may then investigate the codes to identify relationships and categorize them into groups based on their common features. The dimensions of the codes, which represent the property's position along a continuum or set, may also be considered by researchers (Moshood et al., 2020). The category's name can be different from the codes to better explain its scope, and we can even build sub-categories from the codes and apply them to the categories if necessary (Soratto et al., 2020). The first step in qualitative data analysis is generally open coding. Depending on the researcher's methodology, gravitational and selective coding may be used following open coding. Such coding allows for the creation of models in an inductive approach at a later research stage. Fig. 2 depicts the information needed to complete the proposed integrated lean business model canvas and carbon footprint.

Data Analysis: The main investigator had a clear overview of the event after establishing the coding frame. The codes that were utilized to decode and re-read the data were optimized. The next stage in the study issue was to organize the codes into a logical pattern. It entails creating a storyline in which the topic is comprised of a portion of the narrative. In order to analyze the case study data, twenty-three code groups were established, which were then summarized into two topic areas that served as the first suggestions for themes (see Fig. 2). Fig. 2 shows how the codes relating to work-related concerns were further investigated during the theme design phases.

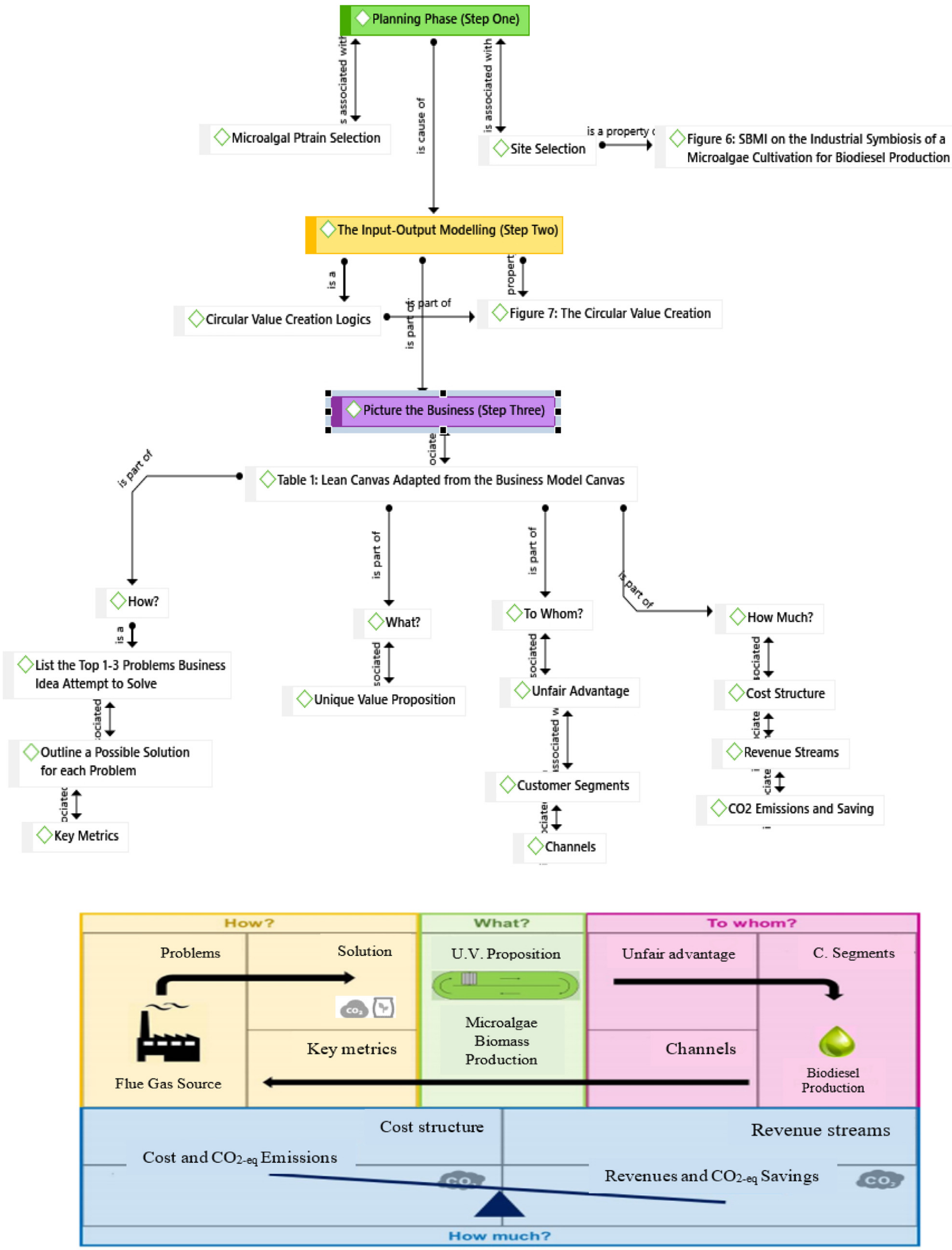

Fig. 2. Atlas.ti network view on the integrated Lean Business Model canvas and Carbon footprint proposed.

The step-by-step structured mode allows relevant facets of microalgae-based diesel fuel production to be discussed and illustrated under the concept of smart manufacturing. The collection of microalgae strains and locating the raceway must be handled at the planning stage. The microalgae strains are known to be an essential issue for the large-scale production of microalgae as it is influenced by any procedures of the microalgae chain (Langholtz et al., 2016). There are different biological characteristics, physical and chemical, to be carried into consideration for each species. One such exception is research carried out by He et al. (He et al., 2018), which studied the growth, lipid aggregation, and fatty acid profiles of five microalgae and chose two for scale-up and race culture, given their higher environmental adaptability productivity of lipids and improved biodiesel quality. It should be remembered that when grown in outdoor ponds, strains can have different outputs relative to laboratories under specific incubation conditions due to various factors, including pollution, daily and seasonal temperature, and slight variations.

Therefore, the difficulties facing the selection of microalgae strains for biodiesel production include assessing a non-laboratory scale of their results and the parameters applicable to the decision-making process. Even though this can make for the right decision, it often frequently considers many criteria, making the study too confusing and complicated, forcing a multi-criteria approach to be followed. Site selection is based on the co-location with an established manufacturing facility (e.g., power plant, cement factory) of a microalgae cultivation method (raceway) to use the waste, resulting in advantages for one or all co-located activities. Location selection, loosely speaking, requires finding possibilities for industrial symbiosis.

The next step is to simulate an input-output of waste streams, algae oil, industrial flue gas, microalgae biomass, and biodiesel according to the concept of circular processing of value. Input-Output simulation renders microalgae cultivation dimensions feasible and thus processes biomass microalgae linked to CO_2 and nutrient inputs in the industrial plant to provide technical experience in microalgae learning cycles during the decision-making period. Finally, by combining the carbon footprint and lean business model canvas to measure the business's feasibility, the third stage relates to the organization's image. Key elements of the structural interpretation of the integrated circular lean business model suggested by a logical sequence given by the proposed integrated circular lean business model are defined. Carbon footprint research carried out the future environmental consequences of the proposed integrated circular lean business model. One of the circular economy's main drives is environmental benefits, which is why the lean business model canvas emerges.

The integrated solution connects all the lean business model canvas framework and nine critical components with carbon footprint blocks. Regarding technological, economic, and environmental aspects, the aim is to place all the related facets of the circular business model suggested in the same framework.

Microalgae biomass production

Algae have gotten a lot of interest lately since they are a unique biomass source for clean, renewable energy production (A.N. Abdalla et al., 2019). Along with other biomass sources, algae has a high biomass production per unit of light and area, may include a significant amount of starch or oil, does not require freshwater or agricultural land, and its nutritional requirements can be met by either wastewater or seawater, among other advantages (Langholtz et al., 2016). The vast majority of algae species are excellent sources of sustainable biofuel production owing to their rapid growth rates and capacity to spread widely in oceans and seas without the need for artificial fertilizers (Mahmud et al., 2021). Micro-algae and macro-algae were used as wet biomass in the third generation of biofuels.

Macroalgae are known for their rapid growth and ability to grow to lengths of up to 60 metres in length (Moreno-Garcia et al., 2017). The growth rates of macroalgae outpace those of terrestrial plants by a wide margin. They are only available at certain seasons in natural water basins (Mahmud et al., 2021). The cultivation of macroalgae at sea, which does not necessitate the use of arable land or fertilizer, may provide a solution to the world's energy dilemma. Crop algae are mostly used for food production and the extraction of hydrocolloids, but it is also feasible to manufacture ethanol from algae (dos Santos et al., 2021). The sugar content of macroalgal biomass (at least 50%) makes it a good candidate for use in the manufacturing of ethanol fuel (Langholtz et al., 2016).

Microalgae are oxygen-developing, photosynthetic microorganisms (pro artists and protists) using sunlight, CO_2, as well as nutrients (nitrogen, phosphor, ammonia, and other elements), in which a variety of high-quality added products (cosmetic products, biofertilizers, animal feed, humans, supplements, nutraces) could be used to convert and update lipids, proteins and carbohydrates (i.e., biodiesel, biogas) (Lu et al., 2020). More than 90percent of the total global production of microalgae is used for food products, and over 15,000 tons of biomass is produced annually worldwide (Richmond, 2008).

Microalgae have the potential to produce a variety of various types of renewable biofuel. Some examples are methane produced by bacterial digestion of algae biomass (Spolaore et al., 2006), biodiesel derived from microalgal oil (Thomas et al., 2016), and biohydrogen created by a photobiological process (Gavrilescu and Chisti, 2005). Microalgae may be grown in water from second-use outlets (e.g., commercial, urban, agriculture, or aquaculture waste-water) depending on the strain, which is a significant advantage in terms of environmental benefits (Ramakrishnan et al., 2010). The microalgae biomass as the feedstock can be produced using various goods such as biodiesel, green hydrocarbons, industrial enzymes, alcohols, bioplastics, biogas, surfactants, feed, and human health (Angelo, 2019). These end products may be categorized by a value-added scale and the output volume (Fig. 3).

This theoretical interpretation of microalgae products' value and volume reveals that low-value-added objects correspond with high volumes of energy (for example, biofuels) and bioremediation (e.g., wastewater treatment and CO_2 capture). Output volume declines as value-added increases (A.N. Abdalla et al., 2019). The more significant added benefit of products dependent on microalgae is personal care products such as medicines for skin treatment (e.g., hyaluronic acid) manufactured at small processing rates by medications (Beckstrom et al., 2020). Nutraceuticals are medical and medicinal products, including human dietary supplements such as astaxanthin, omega-3 fatty acid, cattle, and aquaculture additives. Additives include bioplastics, fertilizers, and enzyme lubricants (DOE, 2010; Herrador, 2016; Usmani et al., 2020).

Microalgae biomass production process

Many ways have been employed to process microalgae, and their efficacy varies. Some of the most often used methods are given in Table 1, along with their advantages and disadvantages (Mathushika and Gomes, 2021).

The processing method for microalgae biomass involves planting microalgae and downstream processes such as harvesting and drying (Angelo, 2019). Microalgae cultivation includes solar radiation or artificial light as an energy source, nutrients, water, soil abundance, and $CO_{2,}$ regardless of cultivated species (see Fig. 4).

- Ø **Cultivation classifications**
  The cultivation systems for microalgae are split into two major types: closed systems and open systems (Muhammad et al., 2020). As the name implies, open systems require cultivating open areas that attract direct sunshine, such as ponds and lagoons. Closed systems consist of micro-algae production in translucent tanks or vessels under the sun or artificial illumination (Langholtz et al., 2016).

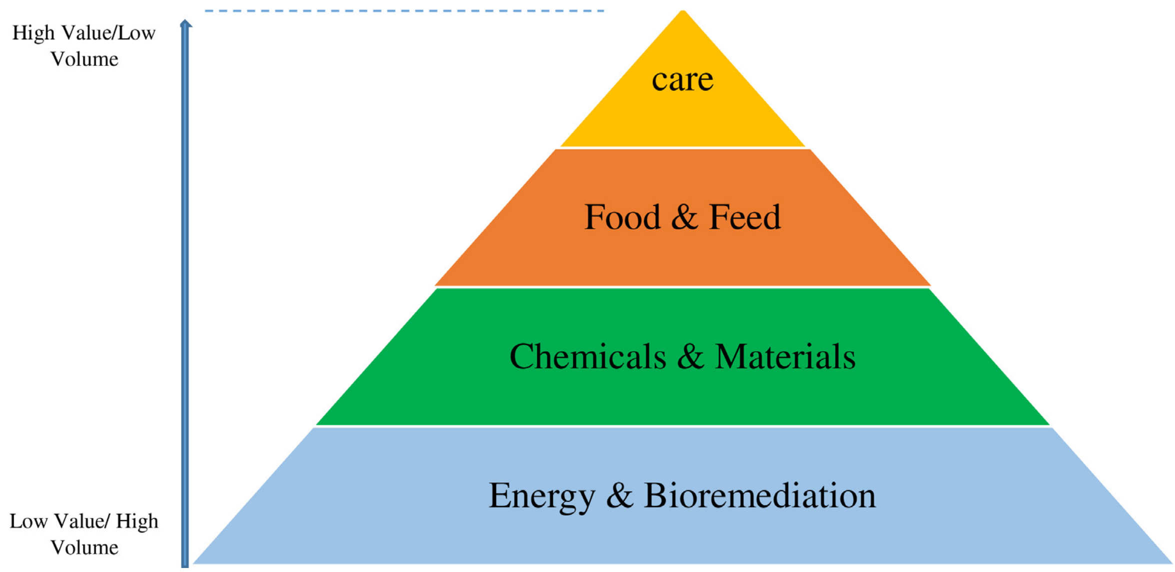

Fig. 3. Pyramid value and volume for possible microalgae products.

Table 1
Advantages, drawbacks, and cost involvement of various methods of processing of micro-algae (Mathushika and Gomes, 2021).

Method	Advantages	Disadvantages	Cost Involvement
Expeller Press	There is no need for a solvent. The operation is simple.	Mechanical processes need a lot of energy. Very expensive	High cost
Bead-beating /mill	There is no need for any solvent.	Mechanical processes consume a lot of energy.	Cost-effective
Pressurized solvent extraction	The usage of solvents is quite affordable.	High-energy-demanding (distillation is needed for the extraction of lipid from the solvents). The solvent might be poisonous.	High cost due to the cumulative expenses incurred by the use of solvent and pressurized nitrogen
Soxhlet extraction	The cost of using solvents is quite low.	It takes a long time and is not appropriate for a large scale.	High cost
Ultrasonic extraction	Reduce the time required for chemical conversion by as much as 90%. The company is environmentally conscious. It is possible to substitute GRAS solvents for the solvents used in this procedure.	The solvent is needed to improve the recovery of lipid. The decline of power with time. No uniform distribution of ultrasound energy.	Initial investment and maintenance costs high
Osmotic shock	Unlike other procedures, there are no expensive processes or solvent requirements.	Longer duration of treatment time.	Low-cost method
Supercritical fluid extraction	Extraction with less hazardous solvents. Thermo-labile substances are suitable. Friendly to the environment.	Power consumption is higher, and scaling up is more complicated. High initial capital investment. There are no polar substances extracted.	High cost
Microwave-assisted extraction	Reduced use of solvents. Increased extraction rate and yield.	High capital cost	initial investment and maintenance costs high
Pyrolysis	Cost-effective. Ease of storage, transport, and preparation of biofuels by upgrading the bio-oil.	High viscosity, abrasiveness, and a lack of thermal stability. It has a low calorific value, similar to the reactant oil since oxygenated molecules predominate. Deactivation of the catalyst will occur.	Low-cost method
Direct Bio photolysis	Hydrogen is produced directly from water and sunshine.	It requires a lot of light, has low photochemical efficiency, and is inhibited by oxygen.	Economically feasible.
Indirect bio photolysis	Blue-green algae have the ability to create hydrogen from water and fix nitrogen from the atmosphere.	It is necessary to remove uptake hydrogenates.	Economically feasible.
Enzyme-Assisted Extraction	It is a nontoxic and ecologically friendly method. The yield is high. Due to the use of food-grade enzymes, the technique is quite inexpensive.	It is troubled by the lipid class composition and type of microalgae. It needs operation at reduced temperatures with high specificity/selectivity for better efficiency. Cost intensive.	High cost
Pulsed Electric Field Assisted Extraction	High productivity. Energy consumption is reduced.	The initial investment and maintenance costs expenditures are also high.	Although the initial investment and maintenance expenses are higher, they may be operated at a cheaper cost.

Ø **Harvesting**

The cultivation of high microalgae biomass is followed by microalgae processing from water isolation, as seen in Fig. 4. Several harvesting methods have benefits and drawbacks (such as sedimentation, filtration, flocculation, centrifugation, and flotation) (Singh and Patidar, 2020). The chosen or mixture of harvesting methods depends on the microalgae species, the medium of growth, the pace of development, the nature of the end product, and the production cost (Langholtz et al., 2016).

The physiognomy of the selected micro-algae, the size and density of the micro-algae cell, and the qualities of the final product all play a role in the harvesting process. Microalgae harvesting is one of the essential aspects of microalgae growth. Because of its high energy

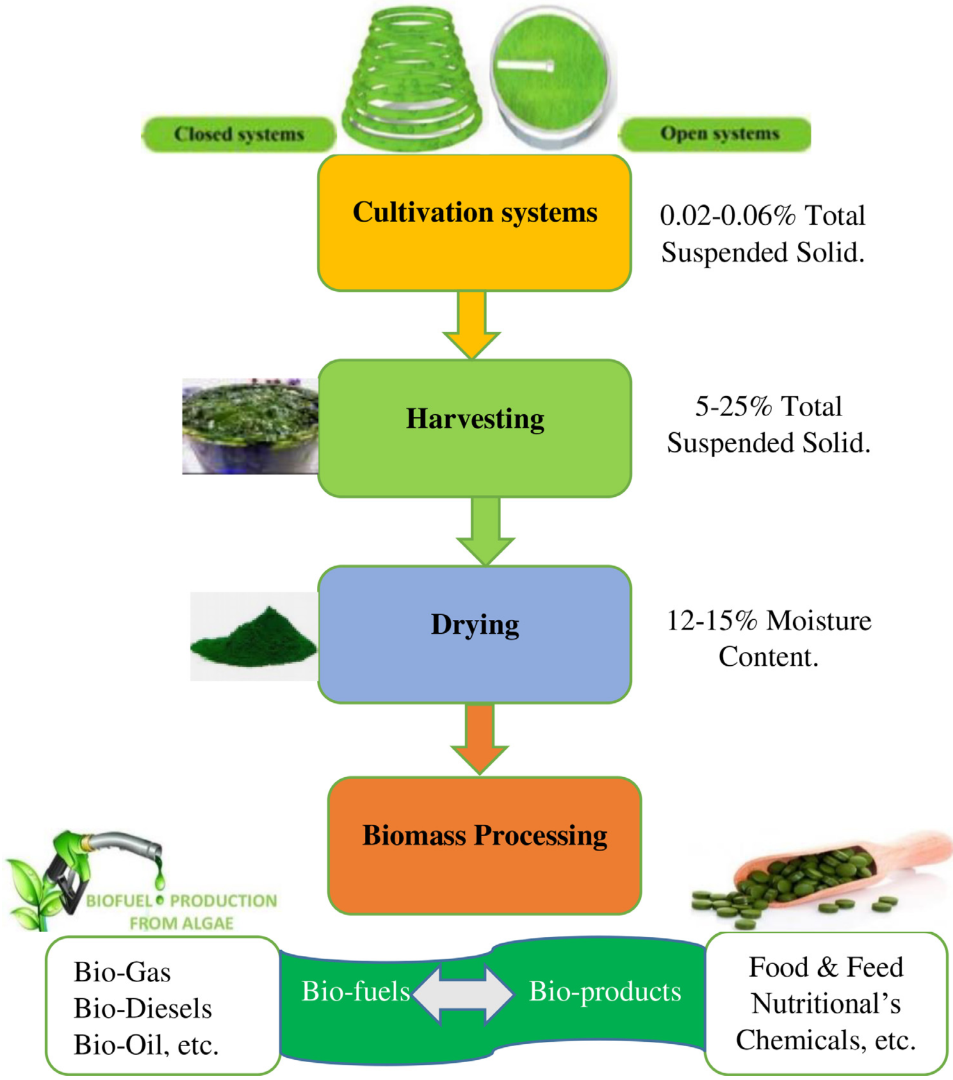

Fig. 4. Microalgae biomass production process.

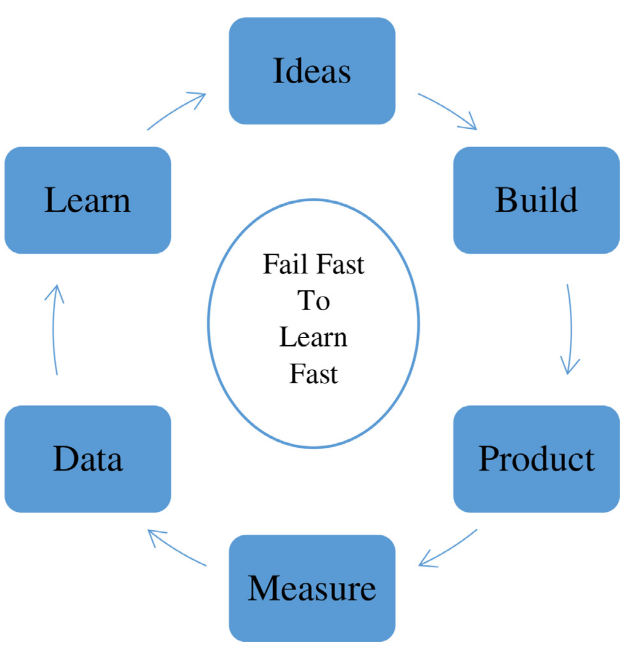

Fig. 5. Lean start-up process.

requirement, it has been estimated to contribute 20–30% of overall production costs (Mathushika and Gomes, 2021). Filtration, centrifugation, flocculation, and flotation are some of the mechanical, chemical, biological, and electrical harvesting processes that have been employed to collect biomass (Singh and Patidar, 2020). In certain circumstances, a combination of two or more approaches is used to increase harvesting productivity. Table 2 shows a list of harvesting strategies, together with their target microalgae species, advantages, and disadvantages (Mathushika and Gomes, 2021).

- Ø **Drying**
  It is essential to dry the extracted microalgae further to eliminate the residual water material (dehydration). Spray drying, freeze-drying, drum drying, and sun-drying are the most popular techniques (Langholtz et al., 2016).
- Ø **Oil extraction**
  The microalgae cells are disrupted and removed into extra biodiesel by internal components such as lipids during the drying process (Moges et al., 2020). Several microalgae cell disruption procedures are used depending on the ultimate product's cell wall properties and nature. The algal paste and crude micro-algae oil give two benefits. In terms of emissions and energy content, they differ from one another. Oil trans can be sterilized with any other oil. The cake, the essential volume and composition co-product, can be used to feed or

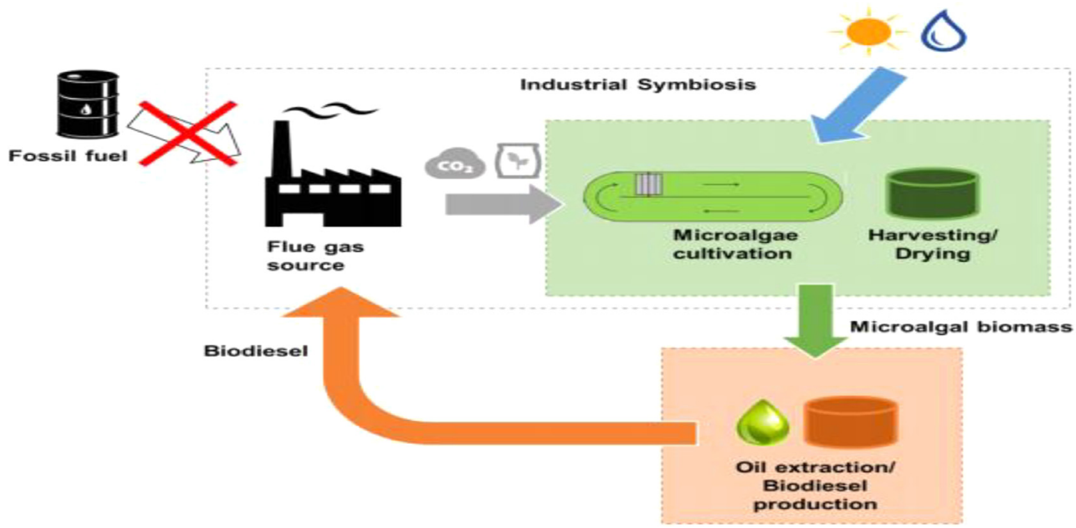

Fig. 6. SBMI for manufacturing symbiosis of biodiesel microalgae production.

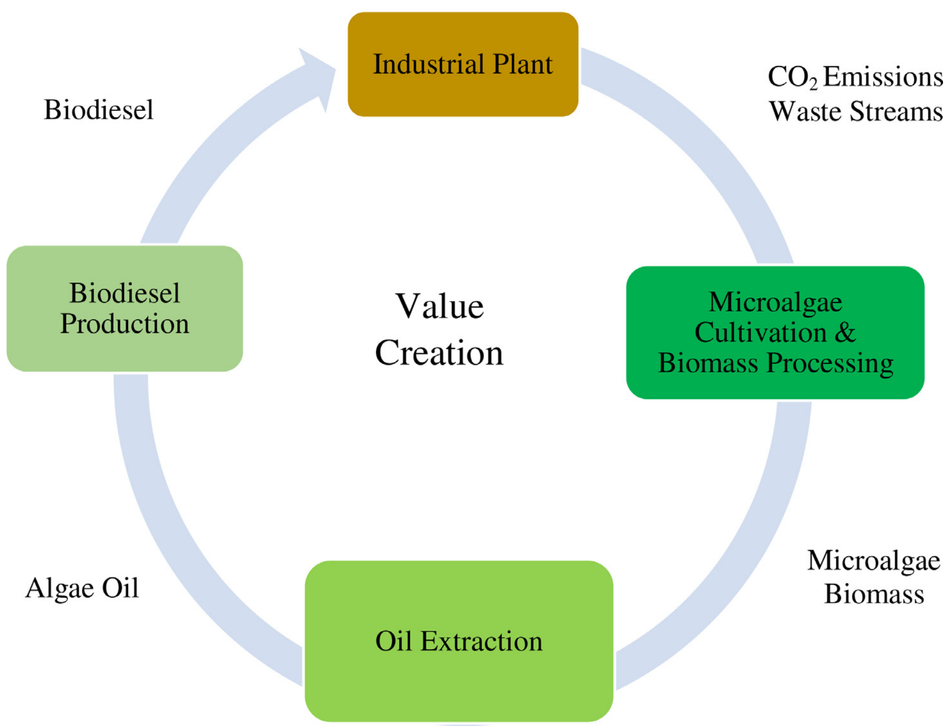

Fig. 7. The circular value creation.

process biogas by anaerobic digestion as a feedstock (Angelo, 2019; Langholtz et al., 2016).

Financial feasibility

As with most first and second-generation biofuels, micro-algae biofuels are not yet competitive with fossil fuels (T.D. Moshood et al., 2021). As with most first and second-generation biofuels, they are not viable in the absence of subsidies (Doshi et al., 2017). Because of their low weight and high energy content can serve as alternative aviation fuels (Norsker et al., 2011). They were of particular relevance to pilot-scale businesses. A study found potential advancements in both manufacturing and culture that may reduce capital costs by utilizing low-cost technology primarily meant for microalgae processing and other benefits. Purchasing low-cost CO_2, fertilizer, and water and recycling in the house can help reduce high expenses as well (Perin and Jones, 2019). The needed quantities, particularly in terms of nutrients and water, are considered a limiting factor in developing microalgae that can be achieved. As long as real production is restricted to tiny research and development organizations, it is impossible to test the viability of such concepts in industrial practices (Rahman et al., 2020).

Microalgae cultivation can also result in the creation of additional by-products that are of economic importance. It is estimated that approximately 30% of the biomass harvested contains lipids (which can be converted to biodiesel) or other energy-related products such as ethanol (Sander and Murthy, 2010), biogas (Odlare et al., 2011), and even hydrogen, which can be used for fuel. These products are likely to be beneficial for animal feed or other energy-related foods. One of the economic advantages of microalgae over traditional biofuels is their ability to produce high-value residual biomass co-products, which can be sold

Table 2
Different harvesting techniques and their target microalgae organisms with their benefits and drawbacks (Mathushika and Gomes, 2021).

Harvesting technique	Microalgae	Benefits	Drawbacks	References
Axial vibration membrane filtration	Chlorella pyrenoidosa	Low membrane fouling	need power enthralling pumping units	(Zhao et al., 2017)
Cross-flow filtration	Chlorella sp.	Increased energy efficiency	Susceptible to membrane fouling and shearing of fragile materials	(Giménez et al., 2018)
Ultrafiltration	Dunaliella salina	Reduced cell shearing, low energy, and chemical consumption	Greater investment cost	(Wenten et al., 2017)
Polyacrylonitrile based membrane filtration	Scenedesmus and Phaeodactylum	Low membrane fouling	Need power enthralling pumping units	(Marbelia et al., 2016)
Tilted membrane panel filtration	Wild microalgae strain	Low membrane cost and energy consumption	Membrane fouling	(Eliseus et al., 2017)
Microbial bio flocculation	Desmodesmus brasiliensis	Cost-effective and eco-friendly	Spoilage by microalgae products	(Ndikubwimana et al., 2016)
Electro-flocculation	D. salina	Cost-effective and no use of chemicals	Energy-intensive	(Sen Tan et al., 2019)
Plant bio flocculation (Moringa oleifera)	Chlorella sp.	Cost-effective and limited toxicity	Spoilage by microalgae products	(Hamid et al., 2016)
Buoy-bead flotation	Chlorella Vulgaris	No use of chemicals and greater reusability	Expensive method	(Xu et al., 2018)
Magnesium Coagulation dissolved air flotation	Chlorella zofingiensis	Does not use external coagulant and increased recyclability of coagulant and biomass	Use of toxic chemicals	(Zhang et al., 2016)
Chemical flocculation	Chlorella sp.	Cost-effective and simple to execute	Use of toxic chemicals	(Kim et al., 2017)
Foam flotation	C. vulgaris, Isochrysis galbana, and Tetraselmis suecica	inexpensive and low power demand, Easy to execute	Investment and maintenance costs are high	(Alkarawi et al., 2018)
Electrolytic flotation	C. Vulgaris	No use of chemicals reduces energy demand and can be utilized in a continuous system	Investment and maintenance costs are high	(Luo et al., 2017)
Ozone flotation	Scenedesmus sp.	High recovery of microalgae bio compounds	Need specified ozone generation tools onsite	(Oliveira et al., 2018)

to other industries. The future marketability of microalgae for biofuel production may also rely on the practical policy and marketing of microalgae for biofuel production (Jacob et al., 2020).

Implementing appropriate regulatory procedures to reflect the most cost-effective pricing can improve the feasibility and viability of producing biofuels as a long-term and sustainable alternative to fossil fuels in the short and medium-term (T.D. Moshood et al., 2021). As seen by the comparatively rapid spread of terrestrial feedstock, producers and consumers respond positively to the incentives provided by such legislation (for example, in Brazil). Microalgae production follows the same laws as agricultural production. Still, the higher start-up costs and potential dangers are an additional disincentive to investing in the company compared to more affordable agriculturally based production (Das, 2020). In light of the technological developments that will be required to justify these incentives, as well as the feasibility of the fuel, developing a policy mix that provides appropriate incentives for third-generation biofuels while transitioning away from conventional approaches and managing the risks associated with this transition is likely to be just as tricky (Shanmugam et al., 2021). However, when you examine microalgae's potential to be used as a biofuel feedstock, accepting these barriers would appear to be founded on long-term confidence rather than idealistic assumptions (T.D. Moshood et al., 2021).

Lean business model canvas for microalgae cultivation

Lean capacity for innovation helps start-ups anticipate unmet consumer desires, envision appealing specific business offerings early on, actively validate their visions and use feedback mechanisms to learn how to create business models (Struthers, 2021). The lean innovation ability is a distinct capability that represents an organization's ability to innovate with ideas that satisfy critical consumer criteria by continuously iterating the initial product to confirm learning by continuous market input to achieve sustainable business success (Bicen and Johnson, 2015). For new companies, there are several obstacles (Blank, 2013). The lean start-up has its origins in the tech-start-up environment. It appears to be similarly significant in the non-profit organizations to more prominent firms and start-ups (Alami et al., 2021). To ensure their capacity to adjust in reaction to an unpredictable and continuously developing environment, all small and large businesses in each sector or market must consistently aspire for organizational excellence and disruptive creativity (Ries, 2011). Ries defines a start-up as a human organization built under intense, complex conditions to develop innovative goods and services (Cosenz, 2017).

Also, the lean start-up stresses that entrepreneurs seem to be everywhere and that each start-up is an experiment to explore how to identify a profit design that fits for them (Blank, 2013) and creates a (financially) successful enterprise around to achieve (Ries, 2011). The lean start-up emphasizes the necessity to become an "innovation factory" and use so-called innovative reporting to identify the best ideas to develop to learn continually (Banu et al., 2020). It is essential for the ability of start-ups to become profitable businesses (Bortolini et al., 2018). This is especially relevant since a start-up works; predictions and milestones are inaccurate in the context of a start-up. Furthermore, Ries states that this is relevant since 95% of entrepreneurship emerges from the nitty-gritty job of accounting for creativity - just 5% can be traced to the "big idea" (Van der Molen and Bagrianski, 2016). The lean start-up introduces an alternative to the Waterfall preparation and management paradigm, a serial product creation method that sometimes requires many iterations to include consumers' input (Blank, 2013). It uses an agile feedback loop named build-measure-learn instead (see Fig. 5).

This canvas helps the companies and start-ups follow the lean start-up principles to validate their business concept. Lean canvas modified alexander Oster alder's business model canvas, which Ash Maurya generated throughout the lean start-up spirit (Fast, Concise and Effective start-up) (Corbo et al., 2020). Lean canvas promises an implementable and entrepreneur-focused strategic plan (Osterwalder and Pigneur, 2010). It focuses on problems, solutions, key metrics, and competitive benefits. The concept is similar to the well-known canvas of the business model, but certain sections were replaced (Maurya, 2012). The main business aspects (customers, supply, infrastructure, and commer-

Table 3
Lean canvas adapted from the business model canvas.

Problem List the **top 1–3** problems the business idea will attempt to solve. **Existing Alternatives** List how these problems are solved today. - More portable business models are required. - Measuring progress is a difficult task. - It's crucial to communicate. - Existing alternatives: Business plan, intuition, and spreadsheets **1**	**Solution** Make a rough outline of a possible remedy for each issue. -Lean Canvas. -Progress Dashboard. -Sharing Learning. **4** **Key Metrics** Make a list of the key figures that show how the company is doing. -Create Lean Canvas -Track Experiment -Invite Collaboration **8**	**Unique Value Proposition** A single, straightforward, and influential statement explains why this organization is unique and deserving of attention. -Helps start-ups raise their odds of success. -Star-up report card. **3**	**Unfair Advantage** Something that can't be readily replicated or bought. -Personal authority -Expert endorsement **9** **Channels** Make a list of the steps that lead to customers (outbound or inbound). -Blog, Book & Workshop. -Start-ups Accelerators & Investors. **5**	**Customer Segments** List the target customers and users. -Star-up founders (Creators). -Advisors & Investors (collaboration). **Early Adopter:** List the characteristics of the ideal customers. -Familiarity with Lean Start-ups, Customer Development, and Business model canvas. **2**
Cost Structure List the fixed and variable costs. -Customer Acquisition Costs, -Distribution Costs. -Hosting Costs -People Cost -Break-event point **7**		**Revenue Streams** List the sources of revenue. -Life Time Value. -Revenue -Gross Margin **6**		

cial feasibility) covered in the nine different canvases of the business model building blocks are shown in Table 3.

Problems emphasize finding issues worth addressing in lean start-ups. Organizations list the three significant challenges they are planning to solve in this aspect (Masoumi and Dalai, 2021). This aspect has been added to fix the essence of start-ups; most start-ups struggle, not because they fail to develop what they set out to build, but because they expend time, resources, and effort to produce the wrong thing (Osterwalder and Pigneur, 2010). The consumer segments show what sort of community of customers the business will concentrate on. The client is at the core of each company, as without them, it does not work. Although it may be appealing to reach as many clients as possible, a company must focus on which market to represent so that the business model can be designed around the targeted client's needs (Maurya, 2012).

A single, concise, persuasive statement explains that the company is different and worth buying. A clear commitment or deal from the company that addresses the number one issue provides a fulfilled story profit worth after a job is finished (Miehe et al., 2018). In all canvases, this aspect is included. The value proposition would respond to the consumers' needs if it is a product, a service, or a combination of goods and services. After consumer categories and after issues have been identified, it is intentionally a small box and answered. Holding the box small is entirely consistent with the definition of the minimum viable product used in the start-up of lean.

One or more outlets must target the client to market a product or service. Channels help clients discover their goods, determine the brand's value proposition, buy, produce the business model, and provide after-sales support. The revenue streams reflect the money for the purchase of goods that a business can receive. Revenues may have varying pricing structures and be either one-time fees or annual subscription revenues. There are various kinds of revenue sources, such as sales of properties, utility use fees, membership fees, renting, licensing, and ads. The cost structure of the company model demonstrates the essential costs. It will illustrate the operations and services that cost the organization the most. In order to remain sustainable, it is necessary to control the cost structure. Still, depending upon the type of company and value proposition, the cost structure strategy will be specific.

In order to build and deliver the business model, the primary metrics reflect the most critical tasks that the organization conducts. Key metrics often focus on the organization's business model and the form of the organization. Something that cannot be quickly replicated or purchased is a real unfair advantage. Organizations will have to leave this box vacant initially. Still, it is here to have organizations really thought about making their organization unique and distinguishing between organizations meaningful. Any examples of disproportionate insider data benefits, the right "expert" recommendations, personal authority. Hence, the importance of the lean business model canvasses was and still is today. The above debate enables companies to cut to the chase and easily define the critical points of policy or new business model. The company will switch to a better plan or management model from that point forward, significantly increasing achievement likelihood (Boons and Lüdeke-freund, 2013). Often it is prudent for someone to initiate the dialog and draw up a business plan.

Sustainable business model innovation for microalgae

A central mechanism for businesses to meet their environmental and social targets is the principle of innovation through a sustainable business model by exploiting socioeconomic and ecologically efficient strategies and innovations (Geissdoerfer et al., 2016). Sustainable business model technologies organizations will improve their economic, social, and environmental accomplishments (Nidumolu et al., 2009) and strengthen their environmental resilience and susceptibility to risks (M. Geissdoerfer, 2019). Innovation potential within the business model is not only expected to produce more significant benefits than a commodity or process adjustments (Lindgardt et al., 2009). They should also demonstrate that their violent 'resulting' advantage is sufficient, further increasing their organization's efficiency (Casadesus-masanell and Ricart, 2010).

Innovation in the business model is often viewed as a process of discovering, evolving, developing, constructing, revising, producing, advancing, embracing, and transitioning the business model to recognize the conventional innovators in the business model (Geissdoerfer et al., 2018). The strategy is an innovative sustainable business model aimed at; 1) positive development or stable or minimized adverse effects on the industrial, community, and long-term competitiveness of the enterprise and its stakeholders, respectively; 2) integrating into its economic model, production, and capture components techniques or features that encourage sustainability and value (Casadesus-Masanell and Zhu, 2012). In business models, there are four ways of sustainable innovation, equivalent to traditional business model developments.

v Sustainable start-ups: a sustainable business model is used to build a new enterprise.

- v Sustainable business model transition: a rethinking of the present business model leads to a more long-term one.
- v Without significant changes to existing industry business models and adopting a new, sustainable business model, sustainable business model diversification is impossible.
- v Sustainable business model acquisition: exploration, incorporation, and integration into an option, sustainable business model organization.

It is expected that these four technologies seek to incorporate certain styles and techniques of sustainable business models. These styles include creativity in the circle market paradigm (Geissdoerfer et al., 2018), bottom-of-the-pyramid firms in social organizations (Defourny and Nyssens, 2014), and product-service networks (Pigosso et al., 2016).

Organizations are in a situation where their operations are for an essential purpose (Loorbach and Wijsman, 2013). Also, suppose organizations are working to adopt sustainability. In that case, organizations will still frequently utilize traditional modification methods that ultimately aim to industry extension from the financial aspect, attempting to reach their business purposes alone (Daae and Boks, 2015). Modernization applications are concentrating on developing and intensifying the current technologies and production methods with improving performance in energy and sources, however not so many regarding successfully utilizing another sustainable key driver like mixing technological achievement with consumer interests to improve consumption models towards more sustainability (Nitkiewicz et al., 2020).

For a long time, humans have possessed unfavorable impacts on the planet. For instance, the earth's rising air, temperature, and water pollution (Peruccio and Vrenna, 2019). In modern days, there must be something to do about it. Some suggest transforming our systems by improving our economic impact, environmental influence, and social arrangements that are the sustainability elements. Sustainability is multidimensional, including social impact, environmental impact, and economic impact (Mallette and Mallette, 2008). The purpose of sustainability is to provide today's requirements without jeopardizing tomorrow's demands (Ansari et al., 2020). It can be provided if all nations make their role; various countries continue operating on this purpose (Jørgensen and Pedersen, 2018). Most of the countries recognize that new energy roots are not working to sustain the growing community, and existing non-renewable people will consume without the population increase (Winickoff and Mondou, 2017). However, the sustainable business model invention varies in value generation with conventional methods and offers an aspect that closes resource loops (Angelo, 2019). centered on the principle of industrial symbiosis, the proposed concept for a sustainable business model aims at closing resource loops in which waste flows are converted into valuable resources that contribute to the source of supply (see Fig. 6) (Angelo, 2019).

In this scenario, the microalgae culture facility is near an industrial flue gasification agent, from which CO_2 is being used as an input for converting microalgae biomass and the supply of solar radiation, water, soil, and nutrients (Gendy and El-Temtamy, 2013). Using waste streams (e.g., soil, waste-water) from manufacturing plants as a source of nutrients is also possible in some situations (Angelo, 2019). The biomass extracted and refined is then used as feedstock to manufacture biodiesel, i.e., as an agricultural resource, thereby returning to the industrial facility. This illustrates the regeneration of CO_2 with environmental advantages due to bio-fixed CO_2 and eliminates the consumption of fossil fuels substituted by biodiesel based on microalgae, thus preventing CO_2-eq as predicted in the circular economy model (Rosenlund and Legrand, 2019). In order to consider all the critical value-creating processes involved, from waste sources to microalgae-based biodiesel, the proposed sustainable business model innovation must be converted into a value chain. Established in 1985 by Michael Porter, a value chain collects actions that a company addresses to distribute its goods to consumers (Angelo, 2019) (see Fig. 7).

The output of one activity is coupled with the input of another, resulting in the creation of value (Donner and de Vries, 2021). In other words, the value of the converted resources is added during the transition phase, which begins with the flow of flue gas and trash from the industrial facility and concludes with the biodiesel utilized as an input in the industrial process (Bigliardi and Filippelli, 2021). Fig. 7 shows the microalgae-focused biodiesel macro value chain processes that connect each aspect of the sustainable innovation business model: the market, the microalgae development facility, and the biodiesel processing plant (Somers et al., 2021). Any component in the value generation process serves a dual purpose: Inputs are received by customers, while providers produce outputs. In this way, a significant aspect of sustainable business model creativity is that, due to the transition process's circularity, the first supplier of the supply chain is often the buyer of the finished product.

Conclusion

This analysis's key issue is how microalgae biomass production can be turned into a business driver to improve the lean business model, assuming that the circular economy is central to climate change. A market-lean towel model was proposed based on biodiesel raceways' high-scale microalgae production under industrial synergy. The nine-building pieces of the well-known business model, the lean business model canvas, were used to investigate the factors that assure microalgae as market potential. A circular model could be converted into those nine components as a circular transformation process from flue gas (waste streams) to micronutrient biodiesel which provides a straightforward approach to how micronutrient becomes a real strategy for lean business model canvas. The lean business model canvas suggests an applied carbon footprint analysis. A lean business model canvas strategy's minimum prerequisite is to deliver environmental benefits. This integration will take account of both GHG emissions and savings. When it comes to company modeling, any entrepreneur needs to make its business the best of all industries. Using the blueprint, lean canvas, and strategic drawing will generate more value for the business. The researcher explains in table 3 how and when to use the models. The organization needs to be vigilant when selecting the best platform to improve its profitability. In contrast, the Sketch plan would replace an enterprise's general approach, search for a lack and build based on new chances.

Therefore, a lean business model canvas provides the essence of a business with a "language" for communicating. Simultaneously, the lean canvas allows entrepreneurs and start-ups to quickly validate their business concept according to lean start-up principles. For and client section that has been defined and validated, a canvas is generated. This canvas has, though, been used, and it is a realistic and intricate canvas. This article clarifies that the transition from a product-orientated approach to a service emphasis includes formating revenue stream changes. Most notably, the service the organization provides its clients is explicitly publicized by customers. However, additional sales can be introduced for a corporation to meet consumer specifications. One of the company's solutions is to provide various types of participation where, depending on customer needs, different types of values are combined.

Moreover, having a lean business model that fits well will add a lot of value to the enterprise. Besides, it is an ideal way to build a strategic edge. One of the tactics is to build a canvas for a lean business model. A company can establish strategic benefits using business model creativity and learn to extract more value by researching its business models. Market concept advancement, however, has its challenges. A company can only alter its business plan to a particular stage and improve it. The old business model is replaced with a new one if the company changes its main operations significantly. Replacing an established business model is often essential, but this step can be problematic for organizations if the established business model is comfortable and familiar. Using the sketch approach lets entrepreneurs find things simpler and saves a lot of time to build a comfortable and essential lean business concept canvas.

It understands the business plan as executing the approach into a logical blueprint of the organization's money-earning logic. In other words, the company's mission and philosophy were converted into value offerings, partnerships with consumers, and value networks.

Declaration of Competing Interest

I have no conflict of interest to report.

Funding

We would like to acknowledge the Universiti Malaysia Pahang for providing financial support for this research through the UMP Research Grant Scheme (Internal/Flagship) number RDU1703124.

References

Abdalla, A.N., Awad, O.I., Tao, H., Ibrahim, T.K., Mamat, R., Hammid, A.T. 2019. Performance and emissions of gasoline blended with fusel oil that a potential using as an octane enhancer. Energy Sources, Part A Recover. Util. Environ. Eff. 41, 931–947.

Abdalla, A.N., Tao, H., Bagaber, S.A., Ali, O.M., Kamil, M., Ma, X., Awad, O.I., 2019b. Prediction of emissions and performance of a gasoline engine running with fusel oil—gasoline blends using response surface methodology. Fuel 253, 1–14.

Ahmad, A.L., Yasin, N.H.M., Derek, C.J.C., Lim, J.K., 2011. Microalgae as a sustainable energy source for biodiesel production: a review. Renew. Sustain. Energy Rev. 15, 584–593.

Alami, A.H., Alasad, S., Ali, M., Alshamsi, M., 2021. Investigating algae for CO2 capture and accumulation and simultaneous production of biomass for biodiesel production. Sci. Total Environ. 759, 143529.

Alkarawi, M.A.S., Caldwell, G.S., Lee, J.G.M., 2018. Continuous harvesting of microalgae biomass using foam flotation. Algal Res 36, 125–138.

Anahas, A.M.P., Muralitharan, G., 2015. Isolation and screening of heterocystous cyanobacterial strains for biodiesel production by evaluating the fuel properties from fatty acid methyl ester (FAME) profiles. Bioresour. Technol. 184, 9–17.

Andersson, V., Viklund, S.B., Hackl, R., Karlsson, M., Berntsson, T., 2014. Algae-based biofuel production as part of an industrial cluster. Biomass and Bioenergy 71, 113–124.

Angelo, A.C.M., 2019. Circular business model based on industrial symbiosis of microalgae cultivation for biodiesel production. (Doctoral dissertation, PhD Thesis. Federal University of Rio de Janeiro, UFRJ, Rio de Janeiro, Brazil www. producao. ufrj. br/index. php/br/teses-e-dissertacoes/teses-e-dissertacoes).

Ansari, F.A., Nasr, M., Guldhe, A., Gupta, S.K., Rawat, I., Bux, F., 2020. Techno-economic feasibility of algal aquaculture via fish and biodiesel production pathways: a commercial-scale application. Sci. Total Environ. 704, 135259.

Banu, J.R., Kavitha, S., Gunasekaran, M., Kumar, G., 2020. Microalgae based biorefinery promoting circular bioeconomy-techno economic and life-cycle analysis. Bioresour. Technol. 302, 122822.

Bastas, A., Liyanage, K., 2019. Setting a framework for organisational sustainable development. Sustain. Prod. Consum. 20, 207–229.

Bastas, A., Liyanage, K., 2018. Sustainable supply chain quality management: a systematic review. J. Clean. Prod. 181, 726–744.

Beckstrom, B.D., Wilson, M.H., Crocker, M., Quinn, J.C., 2020. Bioplastic feedstock production from microalgae with fuel co-products: a techno-economic and life cycle impact assessment. Algal Res 46, 101769.

Bicen, P., Johnson, W.H.A., 2015. Radical innovation with limited resources in high-turbulent markets: the role of lean innovation capability. Creat. Innov. Manag. 24, 278–299.

Bigliardi, B., Filippelli, S., 2021. Investigating Circular Business Model Innovation through Keywords Analysis. Sustainability 13, 5036.

Blank, S.G., 2013. Why the Lean Start-up Changes Everything. Harv Bus Rev. http://host.uniroma3.it/facolta/economia/db/materiali/insegnamenti/611_8959.pdf. (accessed 12 January 2021).

Boons, F., Lüdeke-freund, F., 2013. Business models for sustainable innovation : state-of-the-art and steps towards a research agenda. J. Clean. Prod. 45, 9–19. doi:10.1016/j.jclepro.2012.07.007.

Bortolini, R.F., Cortimiglia, M.N., de M.F. Danilevicz, A., Ghezzi, A., 2018. Lean Startup: a comprehensive historical review, Manag. Decis..

Briner, R.B., Denyer, D., 2012. Systematic review and evidence synthesis as a practice and scholarship tool, Handb. Evidence-Based Manag. Companies, Classrooms Res 112–129.

Casadesus-masanell, R., Ricart, J.E., 2010. From Strategy to Business Models and onto Tactics. Long Range Plann 43, 195–215. doi:10.1016/j.lrp.2010.01.004.

Casadesus-Masanell, R., Zhu, F., 2012. Business Model Innovation and Competitive Imitation : the Case of Sponsor-Based. Strateg. Manag. J. doi:10.1002/smj.

Chang, Y., Hsieh, S., 2020. A Review Of Building Information Modeling Research For Green Building Design Through Building Performance Analysis. J. Inf. Technol. Constr. 25, 1–40. doi:10.36680/j.itcon.2020.001.

Chen, J., Li, J., Dong, W., Zhang, X., Tyagi, R.D., Drogui, P., Surampalli, R.Y., 2018. The potential of microalgae in biodiesel production. Renew. Sustain. Energy Rev. 90, 336–346.

Chen, P.H., Quinn, J.C., 2021. Microalgae to biofuels through hydrothermal liquefaction: open-source techno-economic analysis and life cycle assessment. Appl. Energy. 289, 116613.

Corbo, L., Mahassel, S., Ferraris, A., 2020. Translational mechanisms in business model design: introducing the continuous validation framework. Manag. Decis. 58 (9), 2011–2026.

Cosenz, F., 2017. Supporting start-up business model design through system dynamics modelling, Manag. Decis..

Daae, J., Boks, C., 2015. A classi fi cation of user research methods for design for sustainable behaviour. J. Clean. Prod. 106, 680–689. doi:10.1016/j.jclepro.2014.04.056.

Das, S., 2020. The National Policy of biofuels of India–A perspective. Energy Policy 143, 111595.

Defourny, J., Nyssens, M., 2014. The EMES approach of social enterprise in a comparative perspective. Soc. Enterp. Third Sect. Chang. Eur. Landscapes a Comp. Perspect. 12, 42–65.

Donner, M., de Vries, H., 2021. How to innovate business models for a circular bio-economy? Bus. Strateg. Environ. 30, 1932–1947.

dos Santos, M.G.B., Duarte, R.L., Maciel, A.M., Abreu, M., Reis, A., de Mendonça, H.V., 2021. Microalgae biomass production for biofuels in brazilian scenario: a critical review. BioEnergy Res 14, 23–42.

Doshi, A., Pascoe, S., Coglan, L., Rainey, T., 2017. The financial feasibility of microalgae biodiesel in an integrated, multi-output production system. Biofuels, Bioprod. Biorefining 11, 991–1006.

Durach, C.F., Kembro, J., Wieland, A., 2017. A new paradigm for systematic literature reviews in supply chain management. J. Supply Chain Manag. 53, 67–85.

Eliseus, A., Bilad, M.R., Nordin, N., Putra, Z.A., Wirzal, M.D.H., 2017. Tilted membrane panel: a new module concept to maximize the impact of air bubbles for membrane fouling control in microalgae harvesting. Bioresour. Technol. 241, 661–668.

Ellen MacArthur Foundation, "Growth Within: a Circular Economy Vision For A Competitive Europe.," (2015) pp.1–98.

Friese, D., Soratto, S., Pires, J., 2018. Carrying out a computer-aided thematic content analysis with ATLAS. ti..

Ganesan, R., Manigandan, S., Samuel, M.S., Shanmuganathan, R., Brindhadevi, K., Chi, N.T.L., Duc, P.A., Pugazhendhi, A., 2020. A review on prospective production of biofuel from microalgae. Biotechnol. Rep. e00509.

Gavrilescu, M., Chisti, Y., 2005. Biotechnology—A sustainable alternative for chemical industry. Biotechnol. Adv. 23, 471–499.

Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J., 2017. The Circular Economy–A new sustainability paradigm? J. Clean. Prod. 143, 757–768.

Geissdoerfer, M., 2019a. Sustainable Business Model innovation: Process, Challenges and Implementation. Doctoral dissertation, University of Cambridge.

Geissdoerfer, M., 2019b. Sustainable Business Model innovation : Process, Challenges and Implementation. University of Cambridge PhD diss..

Geissdoerfer, M., Bocken, N.M.P., Jan, E., 2016. Design thinking to enhance the sustainable business modelling process e A workshop based on a value mapping process. J. Clean. Prod. 135, 1218–1232. doi:10.1016/j.jclepro.2016.07.020.

Geissdoerfer, M., Morioka, S.N., de Carvalho, M.M., Evans, S., 2018. Business models and supply chains for the circular economy. J. Clean. Prod. 190, 712–721.

Gendy, T.S., El-Temtamy, S.A., 2013. Commercialization potential aspects of microalgae for biofuel production: an overview. Egypt. J. Pet. 22, 43–51.

Gholkar, P., Shastri, Y., Tanksale, A., 2021. Renewable hydrogen and methane production from microalgae: a techno-economic and life cycle assessment study. J. Clean. Prod. 279, 123726.

Giménez, J.B., Bouzas, A., Carrere, H., Steyer, J.-.P., Ferrer, J., Seco, A., 2018. Assessment of cross-flow filtration as microalgae harvesting technique prior to anaerobic digestion: evaluation of biomass integrity and energy demand. Bioresour. Technol. 269, 188–194.

Hamid, S.H.A., Lananan, F., Khatoon, H., Jusoh, A., Endut, A., 2016. A study of coagulating protein of Moringa oleifera in microalgae bio-flocculation. Int. Biodeterior. Biodegradation. 113, 310–317.

He, B.-.J., Zhao, D.-.X., Zhu, J., Darko, A., Gou, Z.-.H., 2018. Promoting and implementing urban sustainability in China: an integration of sustainable initiatives at different urban scales. Habitat Int 82, 83–93.

Herrador, M. 2016. "The Microalgae/Biomass Industry in Japan: an Assessment of Cooperation and Business Potential With European Companies." https://www.eujapan.eu/publications/microalgae.

Jacob, A., Ashok, B., Alagumalai, A., Chyuan, O.H., Le, P.T.K., 2020. Critical review on third generation micro algae biodiesel production and its feasibility as future bioenergy for IC engine applications. Energy Convers. Manag., 113655.

Jørgensen, S., Pedersen, L.J.T., 2018. Restart Sustainable Business Model Innovation. Springer Nature, p. 253.

Kargbo, H., Harris, J.S., Phan, A.N., 2021. Drop-in" fuel production from biomass: critical review on techno-economic feasibility and sustainability. Renew. Sustain. Energy Rev. 135, 110168.

Kim, D.-.Y., Lee, K., Lee, J., Lee, Y.-.H., Han, J.-.I., Park, J.-.Y., Oh, Y.-.K., 2017. Acidified-flocculation process for harvesting of microalgae: coagulant reutilization and metal-free-microalgae recovery. Bioresour. Technol. 239, 190–196.

Kitchenham, B., 2004. Procedures for performing systematic reviews. Keele, UK, Keele Univ. 33, 1–26.

Langholtz, M.H., Stokes, B.J., Eaton, L.M., 2016. 2016 Billion-ton report: advancing domestic resources for a thriving bioeconomy. In: Volume 1: Economic availability of feedstock, Oak Ridge Natl. Lab. Oak Ridge, Tennessee, Manag. By UT-Battelle. LLC US Dep. Energy., pp. 1–411 2016.

Lindgardt, Z., Reeves, M., Stalk, G., Deimler, M.S., 2009. Business Model Innovation: when the Game Gets Tough, Change the Game. Own the future: 50 ways to win from The Boston Consulting Group 291–298.

Loorbach, D., Wijsman, K., 2013. Business transition management : exploring a new role for business in sustainability transitions. J. Clean. Prod. 45, 20–28. doi:10.1016/j.jclepro.2012.11.002.

Lu, W., Alam, M.A., Liu, S., Xu, J., Saldivar, R.P., 2020. Critical processes and variables in microalgae biomass production coupled with bioremediation of nutrients and CO2 from livestock farms: a review. Sci. Total Environ. 716, 135247.

Luo, S., Griffith, R., Li, W., Peng, P., Cheng, Y., Chen, P., Addy, M.M., Liu, Y., Ruan, R., 2017. A continuous flocculants-free electrolytic flotation system for microalgae harvesting. Bioresour. Technol. 238, 439–449.

Mahmud, R., Moni, S.M., High, K., Carbajales-Dale, M., 2021. Integration of techno-economic analysis and life cycle assessment for sustainable process design–A review. J. Clean. Prod., 128247.

Mallette, M.D., Mallette, M.D. 2008. Sustaniable Development Through The use of Bio-Fuel and Quantitative Metrics.

Marbelia, L., Mulier, M., Vandamme, D., Muylaert, K., Szymczyk, A., Vankelecom, I.F.J., 2016. Polyacrylonitrile membranes for microalgae filtration: influence of porosity, surface charge and microalgae species on membrane fouling. Algal Res 19, 128–137.

Masoumi, S., Dalai, A.K., 2021. Techno-economic and life cycle analysis of biofuel production via hydrothermal liquefaction of microalgae in a methanol-water system and catalytic hydrotreatment using hydrochar as a catalyst support. Biomass and Bioenergy 151, 106168.

Mata, T.M., Martins, A.A., Caetano, N.S., 2010. Microalgae for biodiesel production and other applications: a review. Renew. Sustain. Energy Rev. 14, 217–232.

Mathushika, J., Gomes, C. 2021. Development of Microalgae-based Biofuels as a Viable Green Energy Source: challenges and Future Perspectives.

Maurya, A., 2012. Running lean: Iterate from Plan A to a Plan That Works. O'Reilly Media, Inc..

Miehe, R., Bauernhansl, T., Schwarz, O., Traube, A., Lorenzoni, A., Waltersmann, L., Full, J., Horbelt, J., Sauer, A., 2018. The biological transformation of the manufacturing industry–envisioning biointelligent value adding. Procedia CIRP 72, 739–743.

Moges, M.E., Heistad, A., Heidorn, T., 2020. Nutrient recovery from anaerobically treated blackwater and improving its effluent quality through microalgae biomass production. Water (Basel) 12, 592.

Moreno-Garcia, L., Adjallé, K., Barnabé, S., Raghavan, G.S.V, 2017. Microalgae biomass production for a biorefinery system: recent advances and the way towards sustainability. Renew. Sustain. Energy Rev. 76, 493–506.

Moshood, T.D., Nawanir, G., Mahmud, F., 2021a. Microalgae biofuels production: a systematic review on socioeconomic prospects of microalgae biofuels and policy implications. Environ. Challenges., 100207.

Moshood, T.D., Nawanir, G., Mahmud, F., 2021b. Sustainability of biodegradable plastics: a review on social, economic, and environmental factors. Crit. Rev. Biotechnol. 1–21.

T.D. Moshood, G. Nawanir, F. Mahmud, F. Mohamad, M.H. Ahmad, A. Abdul Ghani, Expanding Policy for Biodegradable Plastic Products and Market Dynamics of Bio-Based Plastics: challenges and Opportunities, Sustainability. 13 (2021). https://doi.org/10.3390/su13116170.

Moshood, T.D., Nawanir, G., Sorooshian, S., Mahmud, F., Adeleke, A.Q., 2020. Barriers and Benefits of ICT Adoption in the Nigerian Construction Industry. A Comprehensive Literature Review, Appl. Syst. Innov. 3, 46.

Muhammad, G., Alam, M.A., Xiong, W., Lv, Y., Xu, J.-L., 2020. Microalgae Biomass production: an Overview of Dynamic Operational Methods. Microalgae Biotechnol. Food, Heal. High Value Prod, pp. 415–432.

Ndikubwimana, T., Zeng, X., Murwanashyaka, T., Manirafasha, E., He, N., Shao, W., Lu, Y., 2016. Harvesting of freshwater microalgae with microbial bioflocculant: a pilot-scale study. Biotechnol. Biofuels. 9, 1–11.

Nidumolu, R., Prahalad, C.K., Rangaswami, M.R., 2009. Why Sustainability Is Now the Key Driver of Innovation. Harv. Bus. Rev. 57–64.

Nitkiewicz, T., Wojnarowska, M., Sołtysik, M., Kaczmarski, A., Witko, T., Ingrao, C., Guzik, M., 2020. How sustainable are biopolymers? Findings from a life cycle assessment of polyhydroxyalkanoate production from rapeseed-oil derivatives. Sci. Total Environ. 749, 141279.

Norsker, N.-.H., Barbosa, M.J., Vermuë, M.H., Wijffels, R.H., 2011. Microalgal production—A close look at the economics. Biotechnol. Adv. 29, 24–27.

Odlare, M., Nehrenheim, E., Ribé, V., Thorin, E., Gavare, M., Grube, M., 2011. Cultivation of algae with indigenous species–potentials for regional biofuel production. Appl. Energy. 88, 3280–3285.

Oliveira, G.A., Carissimi, E., Monje-Ramírez, I., Velasquez-Orta, S.B., Rodrigues, R.T., Ledesma, M.T.O., 2018. Comparison between coagulation-flocculation and ozone-flotation for Scenedesmus microalgal biomolecule recovery and nutrient removal from wastewater in a high-rate algal pond. Bioresour. Technol. 259, 334–342.

Osterwalder, A., Pigneur, Y., 2010. Business Model generation: a Handbook For visionaries, Game changers, and Challengers. John Wiley & Sons.

Packer, M., 2009. Algal capture of carbon dioxide; biomass generation as a tool for greenhouse gas mitigation with reference to New Zealand energy strategy and policy. Energy Policy 37, 3428–3437.

Pavithra, K.G., Kumar, P.S., Jaikumar, V., Vardhan, K.H., SundarRajan, P., 2020. Microalgae for biofuel production and removal of heavy metals: a review. Environ. Chem. Lett. 1–19.

Perin, G., Jones, P.R., 2019. Economic feasibility and long-term sustainability criteria on the path to enable a transition from fossil fuels to biofuels. Curr. Opin. Biotechnol. 57, 175–182.

Peruccio, P.P., Vrenna, M., 2019. Design and microalgae. Sustainable systems for cities. AGATHÓN| Int. J. Archit. Art Des. 6, 218–227.

Pigosso, D.C.A., McAloone, T.C., Rozenfeld, H., 2016. Characterization of the state-of-the-art and identification of main trends for Ecodesign Tools and Methods: classifying three decades of research and implementation. J. Indian Inst. Sci. 95, 405–428.

Rahman, A., Agrawal, S., Nawaz, T., Pan, S., Selvaratnam, T., 2020. A review of algae-based produced water treatment for biomass and biofuel production. Water (Basel) 12, 2351.

Rajeev, A., Pati, R.K., Padhi, S.S., Govindan, K., 2017. Evolution of sustainability in supply chain management: a literature review. J. Clean. Prod. 162, 299–314.

Ramakrishnan, B., Megharaj, M., Venkateswarlu, K., Naidu, R., Sethunathan, N., 2010. The impacts of environmental pollutants on microalgae and cyanobacteria. Crit. Rev. Environ. Sci. Technol. 40, 699–821.

Richmond, A., 2008. Handbook of Microalgal culture: Biotechnology and Applied Phycology. John Wiley & Sons.

Ries, Eric, 2011. The lean startup: how today's entrepreneurs use continuous innovation to create radically successful businesses. Currency.

Rosenlund, J., Legrand, C., 2019. The circular economy business model of Algoland. Iran. J. Energy Environ. 10, 33–37.

Sander, K., Murthy, G.S., 2010. Life cycle analysis of algae biodiesel. Int. J. Life Cycle Assess. 15, 704–714.

Sen Tan, J., Lee, S.Y., Chew, K.W., Lam, M.K., Lim, J.W., Ho, S.-.H., Show, P.L., 2019. A review on microalgae cultivation and harvesting, and their biomass extraction processing using ionic liquids (Reprinted from Bioengineered, 2020). Bioengineered 11, 116–129.

Shahid, A., Malik, S., Zhu, H., Xu, J., Nawaz, M.Z., Nawaz, S., Alam, M.A., Mehmood, M.A., 2020. Cultivating microalgae in wastewater for biomass production, pollutant removal, and atmospheric carbon mitigation; a review. Sci. Total Environ. 704, 135303.

Shanmugam, S., Hari, A., Kumar, D., Rajendran, K., Mathimani, T., Atabani, A.E., Brindhadevi, K., Pugazhendhi, A., 2021. Recent developments and strategies in genome engineering and integrated fermentation approaches for biobutanol production from microalgae. Fuel 285, 119052.

Singh, G., Patidar, S.K., 2020. Development and Applications of Attached Growth System for Microalgae Biomass Production. BioEnergy Res 1–14.

Somers, M.D., Chen, P., Clippinger, J., Cruce, J.R., Davis, R., Lammers, P.J., Quinn, J.C., 2021. Techno-economic and life-cycle assessment of fuel production from mixotrophic Galdieria sulphuraria microalgae on hydrolysate. Algal Res 59, 102419.

Soratana, K., Landis, A.E., 2011. Evaluating industrial symbiosis and algae cultivation from a life cycle perspective. Bioresour. Technol. 102, 6892–6901.

Soratto, J., de Pires, D.E.P., Friese, S., 2020. Thematic content analysis using ATLAS.ti software: potentialities for researchs in health. Rev. Bras. Enferm. 73.

Spolaore, P., Joannis-cassan, C., Duran, E., Isambert, A., De Génie, L., Paris, E.C., 2006. Commercial Applications of Microalgae. J. Biosci. Bioeng. 101, 87–96. doi:10.1263/jbb.101.87.

Struthers, B.A. 2021. Algae Cultivation and Hydrogen Production From The Waste Streams Of Electricity Generation.

Sydney, E.B., Sturm, W., de Carvalho, J.C., Thomaz-Soccol, V., Larroche, C., Pandey, A., Soccol, C.R., 2010. Potential carbon dioxide fixation by industrially important microalgae. Bioresour. Technol. 101, 5892–5896.

Thomas, D.M., Mechery, J., Paulose, S.V., 2016. Carbon dioxide capture strategies from flue gas using microalgae: a review. Environ. Sci. Pollut. Res. 23, 16926–16940.

Thornhill, A., Saunders, M., Lewis, P., 2009. Research methods for business students. Essex Pearson Educ. Ltd..

Ubando, A.T., Culaba, A.B., Aviso, K.B., Tan, R.R., Cuello, J.L., Ng, D.K.S., El-Halwagi, M.M., 2016. Fuzzy mixed integer non-linear programming model for the design of an algae-based eco-industrial park with prospective selection of support tenants under product price variability. J. Clean. Prod. 136, 183–196.

Usmani, Z., Sharma, M., Lukk, T., Karpichev, Y., Thakur, V.K., Kumar, V., Allaoui, A., Awasthi, A.K., Gupta, V.K., 2020. Developments in enzyme and microalgae based biotechniques to remediate micropollutants from aqueous systems—A review. Crit. Rev. Environ. Sci. Technol. 1–46.

U.S. DOE., "National Algal Biofuels Technology Roadmap." doi:public Law No. 106-554., (2010).

Van der Molen, T., Bagrianski, A. 2016. Strategic Sustainable Trigger Questions: how Strategic Sustainable Development might be introduced in the Lean Startup through the Business Model Canvas.

Viswanath, B., Mutanda, T., White, S., Bux, F., 2010. The microalgae–A future source of biodiesel. Dyn. Biochem. Process Biotechnol. Mol. Biol. 4, 37–47.

Watson, R.T., 2015. Beyond being systematic in literature reviews in IS. J. Inf. Technol. 30, 185–187.

WCED, Our Common Future, Oxford University Press, Oxford, U.K., (1987).

Wenten, I.G., Steven, S., Dwiputra, A., Hakim, A.N., 2017. From lab to full-scale ultrafiltration in microalgae harvesting. J. Phys. Conf. Ser. 12002 IOP Publishing.

Winickoff, D.E., Mondou, M., 2017. The problem of epistemic jurisdiction in global governance: the case of sustainability standards for biofuels. Soc. Stud. Sci. 47, 7–32.

Xu, K., Zou, X., Wen, H., Xue, Y., Zhao, S., Li, Y., 2018. Buoy-bead flotation harvesting of the microalgae Chlorella vulgaris using surface-layered polymeric microspheres: a novel approach. Bioresour. Technol. 267, 341–346.

Yin, Z., Zhu, L., Li, S., Hu, T., Chu, R., Mo, F., Hu, D., Liu, C., Li, B., 2020. A comprehensive review on cultivation and harvesting of microalgae for biodiesel production: environmental pollution control and future directions. Bioresour. Technol. 301, 122804.

Zhang, X., Wang, L., Sommerfeld, M., Hu, Q., 2016. Harvesting microalgal biomass using magnesium coagulation-dissolved air flotation. Biomass and Bioenergy 93, 43–49.

Zhao, F., Chu, H., Zhang, Y., Jiang, S., Yu, Z., Zhou, X., Zhao, J., 2017. Increasing the vibration frequency to mitigate reversible and irreversible membrane fouling using an axial vibration membrane in microalgae harvesting. J. Memb. Sci. 529, 215–223.

Zhou, H., Wen, Z., 2019. Solid-state anaerobic digestion for waste management and biogas production. Solid State Ferment. Res. Ind. Appl. 147–168.