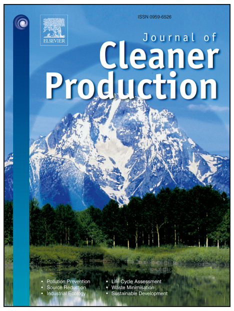


Data visualization for assessing the biofuel commercialization potential within the business intelligence framework

Bih-Ru Lea, Wen-Bin Yu, Hokey Min

PII: S0959-6526(18)30626-7

DOI: 10.1016/j.jclepro.2018.02.288

Reference: JCLP 12235

To appear in: *Journal of Cleaner Production*

Received Date: 21 July 2017

Revised Date: 24 February 2018

Accepted Date: 26 February 2018

Please cite this article as: Lea B-R, Yu W-B, Min H, Data visualization for assessing the biofuel commercialization potential within the business intelligence framework, *Journal of Cleaner Production* (2018), doi: 10.1016/j.jclepro.2018.02.288.

Data Visualization for Assessing the Biofuel Commercialization Potential within the Business Intelligence Framework

by

Bih-Ru Lea
Department of Business & Information Technology
Missouri University of Science & Technology
Rolla, MO 65409
E-mail: leabi@mst.edu

Wen-Bin Yu
Department of Business & Information Technology
Missouri University of Science & Technology
Rolla, MO 65409
E-mail: yuwen@mst.edu

Hokey Min[*]
James R. Good Chair in Global Supply Chain Strategy
Department of Management, BAA 3008C
College of Business
Bowling Green State University
Bowling Green, Ohio 43403
Tel: 419-372-3442
E-mail: *hmin@bgsu.edu*

---

[*] Corresponding author

Abstract

With the ever-increasing energy demand, triggered by the continued population growth and accelerated industrial revolution, renewable energy has emerged as the world's fastest-growing energy source. Renewable energy's popularity has grown because it is environmentally friendly and abundant in natural environments. Despite its enormous potential as a viable alternative to traditional (fossil fuel-based) energy sources, renewable energy has rarely been commercialized and utilized. Its lack of commercialization has something to do with a lack of evidence proving its eco- and cost-efficiency. With this in mind, this paper aims to assess the eco- and cost-efficiency of renewable energy such as algae-based biofuels using data visualization. It also intends to help increase public awareness and facilitate the commercialization of renewable energy such as biofuels. Through experiments, this paper found that the success of biofuel commercialization hinged on temperature, light intensity, and algae strain. Another important finding is that the low carbon footprint resulting from biofuel consumption may not directly contribute to the immediate revenue growth of a biofuel producing company, but it can foster a long-term positive image that will help attract more customers in the future with increased brand recognition. Furthermore, this paper evaluates the effectiveness, the level of user involvement, and the usability of two data visualization tools built upon the dashboard and the balanced scorecard. Based on the case study, this paper demonstrates how effective and useful the tools are in communicating the firm's strategic goals toward sustainability and thus provides easier practical guidelines for renewable energy development decisions.

Keywords: Sustainability, Data Visualization, Alternative Fuel, Business Intelligence

1. INTRODUCTION

The International Energy Outlook 2016 (IEO2016) report forecast a significant growth in worldwide energy demand over the 28-year period from 2012 to 2040. The total worldwide consumption of energy is expected to grow from 549 quadrillion British thermal units (Btu) in 2012, to 629 quadrillion Btu in 2020, and to 815 quadrillion Btu in 2040—a 48% rise from 2012 to 2040 (EIA, 2016). This rapid increase in energy demand cannot be filled by traditional fossil fuels such as oil, natural gas, and coal because these conventional energy sources have been dwindling, and they have created adverse environmental conditions though pollution resulting from carbon emissions and natural habitat destruction during their extraction. For example, the United States (U.S.) alone consumes approximately 20.5 million barrels of petroleum fuels every day. The transportation sector accounts for 68% of that consumption (Statistica, 2017; U.S. Energy Information Administration, 2017). Increasing the use of these fuels will increase air pollution, intensify global warming, and cause other environmental problems including acid rain by emitting various contaminants such as CO_2, CO, SO_x, NO_x, and other volatile organic compounds (VOCs) (Ma & Hanna, 1999; Tiwari et al., 2006; Kasteren & Nisworo, 2017; Escalera et al., 2008; You et al., 2007). Price fluctuation created further challenges for organizations and companies that are heavily dependent on fossil fuel. For example, the price of oil (adjusted for inflation) rose from $9.94 per barrel in 1931 to $53.18 as of April, 2017 (ChartsBin, 2017; Macrotrends, 2017). As such, world leaders have started recognizing the need for alternative energy sources and have enacted laws/regulations to support the development and expansion of alternative energy sources.

Examples of alternative energy sources include nuclear, solar, hydro, wind, geothermal, and biomass. With the exception of nuclear, these alternative energy sources provide clean, non-toxic, and renewable energy that is environment-friendly, but many of these sources failed to completely replace fossil fuels and satisfy growing energy demands. A lack of clean energy use is attributed to the limited technology for extracting it and commercialization failures. For instance, biofuel has been regarded as a viable source of renewable energy, but it still requires various food sources such as soy beans, corn, coconuts, peanuts, cottonseeds, rapeseeds, and sunflowers which are essential for daily living and thus can be expensive with limited food supplies. To overcome such drawbacks, today's bio-technology allows biofuels to be created from microalgae which offer various advantages over crop plants since they do not require cultivable land and clean water, and they tend to grow faster than crop plants. In particular, microalgae is capable of doubling their biomass within 24 hours. Its biomass productivity is estimated to be 50 times more than the fastest growing terrestrial plant, such as switchgrass. It usually provides oil levels of 20–50%, but the oil content can exceed 80% by weight of dry biomass, and thus, it is far more efficient than crop plants in terms of converting sunlight into oil (Chisti, 2007; Li, et al., 2008). In addition to its high oil content, microalgae is easier to clean and refresh if contaminated since it can convert carbon dioxide to potential biofuels. However, despite the aforementioned merits, the generation of biofuel from the microalgae poses a major challenge associated with complicated fuel production, commercialization processes, and data. Furthermore, the multi-faceted nature of corporate sustainability results in a diversified set of influential interrelated factors and data to be monitored, analyzed, and managed as an organization attempts to balance its financial and social goals against its ecological targets (Hahn & Figge, 2016).

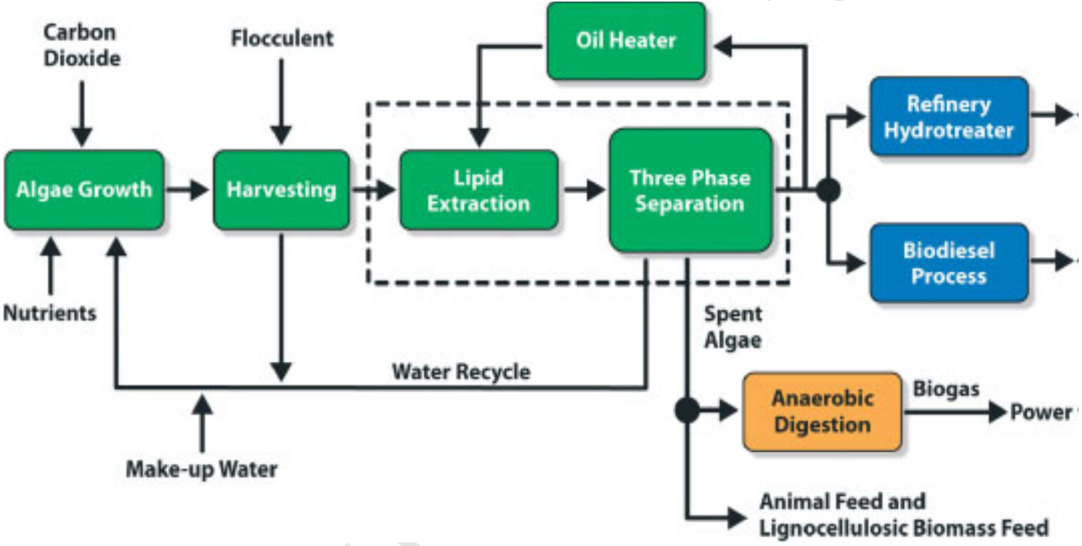
Data visualization presents a promising solution for overcoming the challenges facing microalgae-based biofuel production and commercialization as it aims to identify patterns in the data and present that data more clearly. Data visualization can be implemented via a dashboard approach or a balanced scorecard approach (Lea, 2011). Therefore, this research aims to improve biofuel production and commercialization processes by utilizing data visualization monitoring prototypes based on these approaches. A case study based on the authors' cooperation with a microalgae biofuel research lab is utilized to validate the research model and improve prototype adoptability and generalizability. Both of the proposed prototypes (dashboard-based and balanced scorecard driven) are built upon the Business Intelligence (BI) concept supported by a strategy map. This map can help biofuel developers better understand the positive impacts of biofuel and succeed in commercializing biofuel extracted from microalgae. More importantly, this research focuses on the monitoring, analysis, and management of various means to produce biofuel and fine-tuning those means to produce it commercially and affordably.

2. RELEVANT LITERATURE

2.1 Algae-based Biofuel Production Process and Performance Evaluation

Over the last few years, there has been an increased focus on research surrounding the conversion of microalgae biomass to biofuels (Liew, et al., 2014). However, the microalgae-based biodiesel might incur a higher environmental impact than the biomass-based diesel fuel due to the excessive use of water and nutrients during cultivation (Holma, et. al., 2013; Aitken, et al., 2014). The entire biofuel production process, starting from the cultivation of raw materials (e.g., microalgae) to the extraction of fuel, is fairly complex (Aitken, et al., 2014). The entire process can be broken down into various sub-processes: algae cultivation, algae harvesting, algae processing, and fuel production. Figure 1 illustrates the typical biofuel production process using algae. Each sub-process can be completed in various ways.

Figure 1. Process Flow Diagram of Algal Lipid Production System (Source: Pienkos & Darzins, 2009)



The algae cultivation, for example, can be done in both closed and open environments. The open environment reduces costs but limits the ability to control the production volume, since such capability heavily relies on critical input parameters such as sunlight and temperature. These parameters, such as the extent of sunlight exposure, could drastically change the volume and cost of production. Thus, it has been an onerous task to determine the most cost-efficient process and optimum production plant location for the producer to maximize profit potentials and improve the chance for commercialization (Borowitzka, 1992). Though still scarce, a vast majority of prior literature focused on identifying various input parameters that could significantly affect the volume and cost of biofuel production using algae. Borowitzka (1992) was one of the first to find the functional relationship between algae growth (volume of production) and the cost of biofuel production. In particular, a decrease in the annual algae growth period - the number of days in a year when the environmental conditions are in favor of algae growth – from 300 to 250 days can increase the cost by 33%. Ma and Hanna (1999) found that the cost could be reduced by continuously running the transesterification process, shortening the reaction time, and increasing the production capacity. Ma and Hanna (1999) also noted that the cost and volume were dependent on the quality of the microalgae. Later, Chisti (2007) discovered that the algal growth rate and the oil content of the biomass could dictate the oil productivity that represented the mass of the oil produced per unit volume of the microalgae broth per day. Pienkos and Darzins (2009) observed that the biomass was reduced in the absence of sunlight because the rate of respiration depended on the sunlight’s intensity during growth as well as the temperature during growth and at night. They also noticed that, in small- and medium-scale production, the productivity and cultivation costs were higher in controlled environments (e.g., photo-bioreactor). In large-scale production, they learned that a lack of sunlight limited the yield to a maximum of $100 gm^{-2}$ day^{-1}. Additionally, they found that the particular harvesting method such as centrifugation, flotation, filtering, micro screening, gravity settling, and flocculation affected the cost. The harvesting cost was also affected by the cultivation process and microalgae species (Aitken, et al., 2014). Based on the aforementioned literature review, it should be noted that evaluating the technical and economic feasibility of algae-based biofuel production is a complex and onerous task.

2.2 Data Visualization Modeling

The main goals of data visualization are to communicate the data and ensure that it is understood (Few, 2013). In general, data visualization is designed to decode and present complex data in a pictorial or graphical format enabling the decision-maker to clearly grasp difficult and esoteric concepts/ideas. Its underlying philosophy is “a picture is worth a thousand words.” Examples of data visualization tools include Tableau, Google charts, SAP Lumira, QlikView, SAS JMP and Visual Analytics, MicroStrategy, Microsoft PowerBI, and so forth. Data visualization involves creating and studying the visual representation of data that has been abstracted in some schematic form, including attributes or variables for the units of information to facilitate the identification of patterns in the data. This allows the data to be presented in a format that is easier to explore, analyze, and use to support hypotheses (Keller, et al., 1996; Venna, et al., 2010;

Andrienko & Andrienko, 2013; Few, 2013). The use of interactive visual representations of abstracts and non-physically based data can strengthen cognition and provide a means for exploring data and information on a broader scale (Chen, et al., 2009; Yigitbasioglu, et al., 2012; Telea, 2014; Murray, 2017).

The data visualization design approaches that are intended for performance evaluation and suitable for outcome assessment are the balanced scorecard (BSC) approach and the dashboard approach (Eckerson, 2011; Lea, 2011). BSC was introduced by Kaplan and Norton (1992) to supplement traditional financial measures with criteria that measure business performance from three additional perspectives: customers, internal business processes, and innovation and learning (Min, 2015). It also links the organization's operational plans and budgets and supports continuous performance monitoring and plan adjustments, while ensuring that every decision-maker has the most recent information and analyses at their fingertips (DeBusk, et al., 2003; Andonov-Acev, et al., 2008). Researchers have developed extended scorecard designs under the following names: sustainability balanced scorecard (SBSC), sustainability scorecard, and responsive business scorecard (Van der Woerd and Van Den Brink, 2004; Möller and Schaltegger, 2005; Falle et al., 2016). Hahn and Figge (2016) argued that a BSC built upon linear cause-and-effect relationships is diametrically opposed to the complex and multi-faceted nature of corporate sustainability. Additionally, Hahn and Figge (2016) suggested that BSC is an important tool for gaining legitimacy for sustainability initiatives among profit-making firms, but that the firm's strategies should be reformulated in response to bold sustainability challenges. Möller and Schaltegger (2005) noted that BSC applications facilitated the ability to connect long-term resources and capabilities, including sustainability issues and short-term financial outcomes. Therefore, they proposed an eco-efficiency analysis tool that utilized information technology. In the BSC framework, Möller and Schaltegger (2005) introduced a *Society and Planet* perspective that measured the firm's environmental performance in an effort to balance economic and social goals against ecological goals. Hansen and Schaltegger (2016) conducted a systematic review of various SBSC architectures and suggested that the BSC could be a promising framework for integrating strategy with sustainability in a business setting. More recently, Xia, et al. (2017) developed a BSC framework to examine the sustainable nature of an operational decision-making process within the supply chain. Another alternative visualization approach that is intended for performance evaluation is a dashboard that does not require the rigid cause-and-effect relationship among KPIs, as with the BSC approach. A dashboard offers graphical diagnostic capabilities, complete with colorful graphical indicators and easy-to-read gauges, and thus can help the organization monitor its progress and identify when it must change direction to improve its performance (Min, 2015). The degree of detail in a dashboard can vary depending on particular business requirements, and the usefulness of a dashboard is dependent on its underlying database software (Marcus, 2006; DeBusk, et al., 2003; Pauwels, et al., 2009). Though similar, the dashboard is a little different from the BSC as summarized in Table 1.

Table 1. Key differences between the dashboard and the balanced scorecard (Source: Adapted from Min (2015)

Category	Dashboard	Balanced scorecard
Usage	Monitors performance improvement and then takes the necessary corrective actions	Shows performance milestones and continuously identifies any room for improvement
Update	On a real-time or near real-time basis	Provides periodic snapshots
Data	Records events	Records summaries
Measure	Mainly based on related or unrelated metrics and gauges	Primarily based on interrelated Key Performance Indicators (KPIs)
Context	Contains exceptions and alerts	Includes targets/goals and thresholds

The dashboard focuses on operational and tactical aspects by monitoring the core operational processes that drive the business on a day to day basis, whereas the BSC focuses on strategic aspects by charting the progress toward achieving long-term goals (Min, 2015, Lea, 2011). Both dashboards and BSC approaches require a list of Key Performance Indicators (KPI) for monitoring, managing, and analyzing. KPIs used in a BSC visualization approach are often interrelated with cascading cause-and-effect relationships that are used to construct a strategy map (Kaplan & Norton, 1992). As a result, a BSC-based visualization model provides additional linked and cascading ad hoc analyses through Online Analytical Processing (OLAP) operations. KPIs used in a dashboard approach do not need to depict causal relationships, although related KPIs are typically grouped together (Lea, 2011).

3. Research Methodologies

As prior literature revealed, there are many research gaps to fill. Specifically, improvements in the bio-refinery process and advances in photo-bioreactor engineering are required to reduce the cost of production. More importantly, prior research has failed to provide detailed evaluations of the algae cultivation process (e.g., mixing, optimal cultivation scale, heating/cooling, evaporation, CO_2 build-up, and CO_2 administration) and its true cost impact. This process is tied to the potential improvement of land utilization and yield. In addition to the challenges of monitoring, analyzing, and managing variables and data important in the algae species selection, cultivation, and production processes for commercialization success, an organization also needs to track its performance by balancing its financial, social, and ecological goals.

To fill the aforementioned gaps left by prior research, this paper intends to propose and adopt data visualization modeling techniques to systematically monitor, assess, analyze, and manage the impact of various biofuel production processes on both the cost and volume of biofuel production while evaluating the commercialization potential of algae as a viable alternative energy source. A case study was conducted to explore the visualization modeling process. Additionally, this paper describes the general process of developing a list of relevant Key Performance Indicators (KPI) and a biofuel relevant BSC framework, to be used in both dashboard-based and BSC driven data visualization models for the case organization.

3.1 Case Organization Description

Data visualization techniques were utilized to evaluate the extent of the impact of various biofuel production alternatives on commercialization potentials in terms of their cost and volume. As the current biofuel production process has not yet matured, the process needs to be refined and perfected in terms of affordability and demand in order to compete with fossil fuels. Thus, the process needs to be constantly evaluated from different perspectives and at different levels until it reaches perfection. For such an evaluation, the proposed dashboard was used to pinpoint various issues and concerns associated with the current process, because it can respond to the increasing complexity and diversity of market conditions to be handled by the senior management. To improve adoptability in this pilot study, the authors worked with a biofuel research lab located in Taiwan to better understand and model various issues considered in microalgae production processes. Figure 2 shows various stages of the biofuel project that were presented to and observed by the researchers in field visits throughout the research period. The data used to construct the visualization models was provided by the biofuel research lab or collected from field visits.

Microalgae sampling and screening were conducted on the costal line of Kaohsiung, Taiwan. Growth rate tests were performed under various light intensities and with different algae strains through microalgae colonies, amplification, and small scale culture. Seven strains in high temperature (32^{o} C or higher) and high sodium (20% - 50%) environments were cultivated at the Algal Ecology Laboratory, Chia Nan University (AELCNU) under controlled conditions (32°C, 40-60 μmol photon m-2 s-1, 14/10 light/dark cycle) and a modified f/2 medium in a culture room in 600 ml culture vessels containing 500 ml of f/2 medium. The indoor culture consisted of three stages and took approximately 22 days before the selected algae strains were moved into outdoor cultivation. Specifically, the 200ml culture took about six days, the one liter culture took about six days, and the ten liter culture required about ten days. The outdoor photo bioreactor (PBR) culture followed the ten liter cultivation and required 18 to 20 days before being moved to the raceway cultivation. The algae culture was controlled for light intensity, length of light, salinity, pH, and temperature. The experiment factors were continuously recorded in three minute intervals. The algae concentration was recorded daily during the experiment period. After the experiment was tested in a 20-ton raceway for feasibility, an additional experiment was conducted in a 100-ton raceway to test open environment cultivation. Figure 3 shows the microalgae culture process. A performance dashboard system was proposed to monitor and identify improvement opportunities throughout the different project stages.

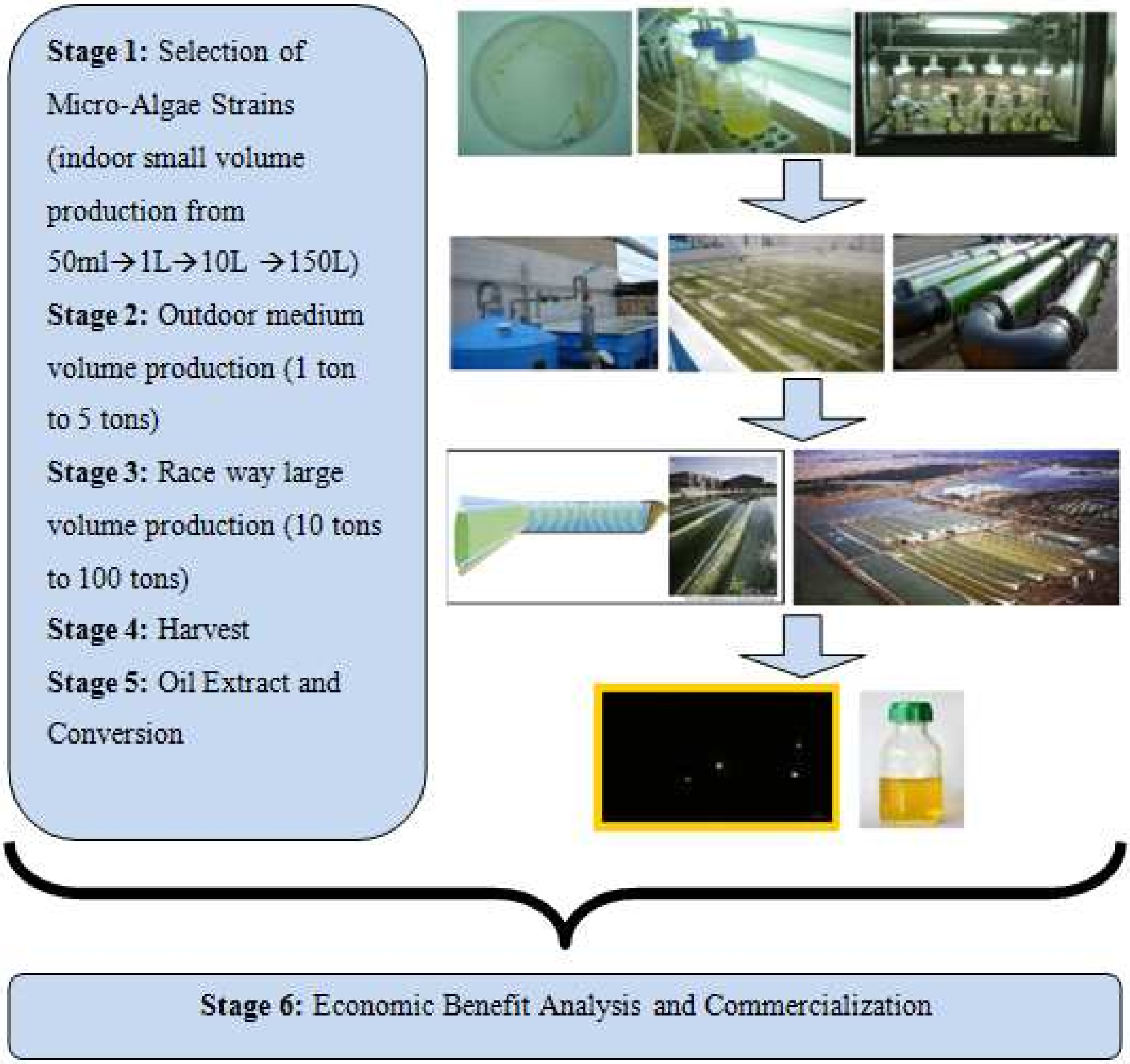
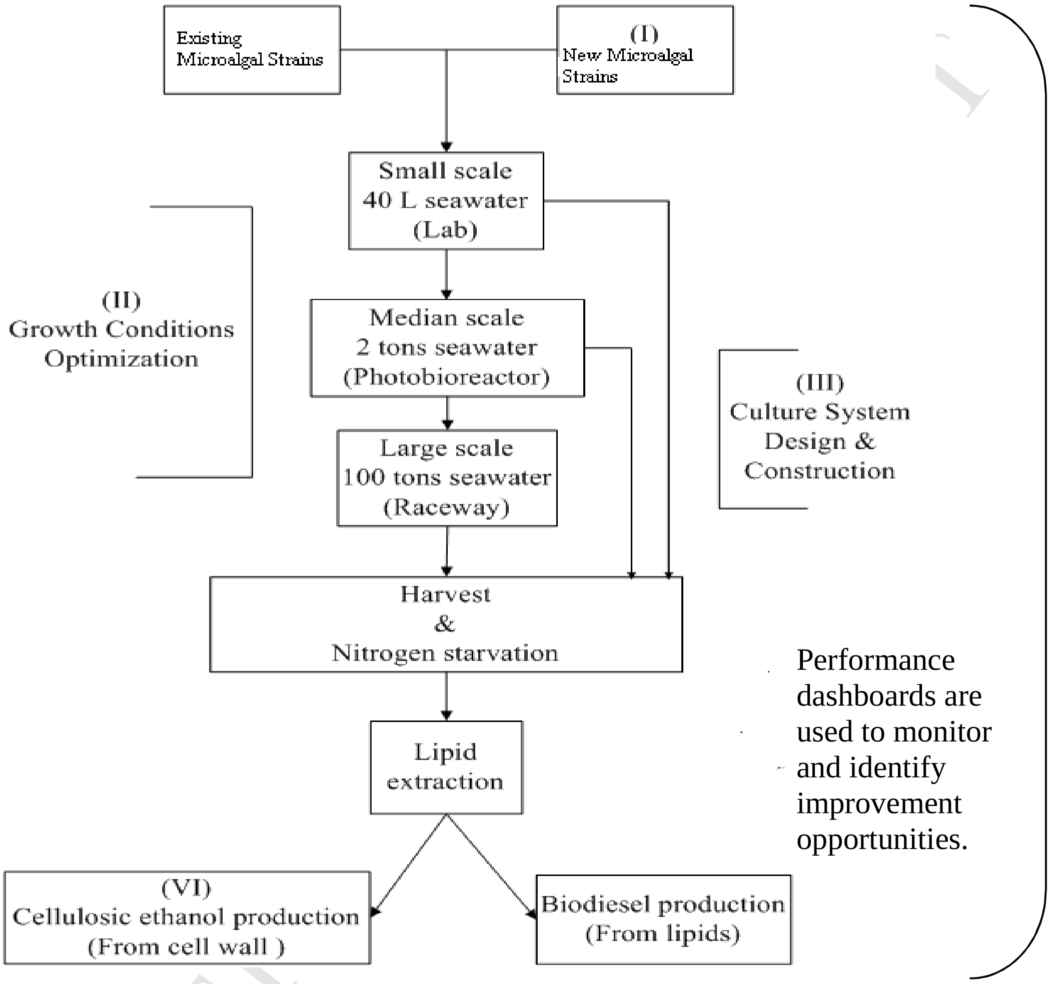


Figure 2. Biofuel Production and Harvest Stages in the Case Organization

Figure 3. Microalgae Culture Process in Case Organization (Data Source: Huang, C. C., Chen, C. N., and Lee, T. M. (2010) Microalgae Biodiesel Development Team, National Sun Yat-sen University, Taiwan)



Performance dashboards are used to monitor and identify improvement opportunities.

3.2 Data Collection and Modeling

The availability of data is important for a Performance Management and Monitoring system (Lea, 2011). During the KPI identification process, the research team verified that the data for the KPIs was either already available or feasible to collect. Experimental factors and data recorded during various experiments were used along with some simulated data for prototype development due to time constraints. The simulated data was generated based on input from the collaborating biofuel research lab. After experimenting with biofuel production processes in varying conditions, a list of relevant KPIs was developed for the dashboards and BSC-based visualization prototypes. Both visualization prototypes were then implemented using software tools provided by SAP Inc. Each prototype has a front-end tool which presents the data to the users and a back-end tool which stores the data in the required form. The dashboard was implemented using the SAP Business Objects Dashboards and the SAP BI platform. The visualization prototype validation was done through a survey which was aimed at gaining insight into the effectiveness, efficiency, and usability of the proposed prototypes. The survey contained three sections: the demographic section, the dashboard prototype section, and the scorecard prototype section. The questions in the demographic section were intended for gaining insight into the background of the survey respondents. The dashboard and scorecard sections started with video presentations explaining the various features of the prototype, followed by questions to measure effectiveness, efficiency, and usability. The survey respondents were selected by the team of biofuel researchers. The survey respondents were primarily researchers and scientists involved in the R&D of biofuels. Video presentations describing various aspects of the prototypes were embedded within the appropriate sections of the survey questionnaire.

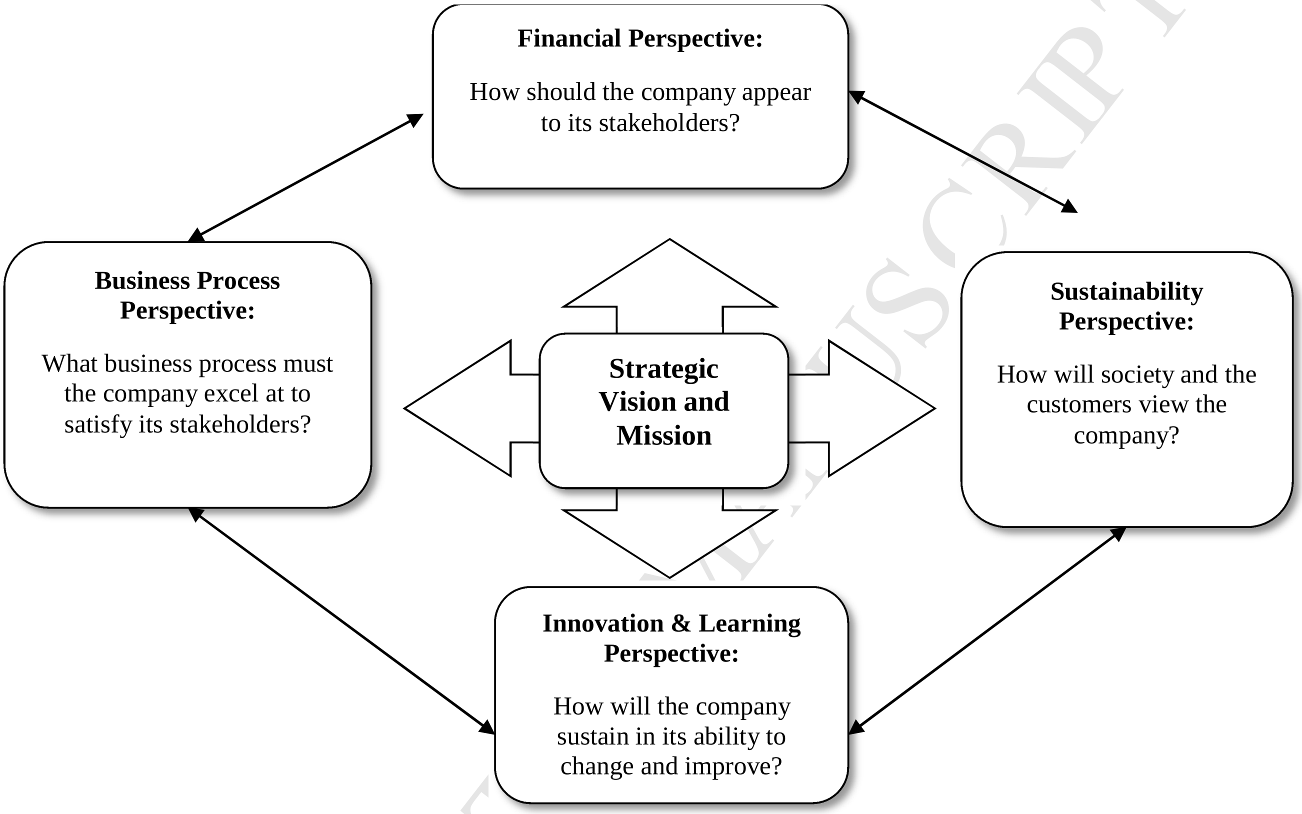
4. Results and Visualization Prototypes

4.1 Development of Key Performance Indicators (KPIs) and the Balanced Scorecard Framework

Some researchers suggested a dedicated performance perspective (van der Woerd & van den Brink, 2004; Hansen & Schaltegger, 2016) while the others (Figge, et al., 2002; Möller & Schaltegger, 2005) were in favor of modifying Kaplan and Norton’s four BSC perspectives to extend the host sustainability aspects. To better reflect the biofuel commercialization assessment found in literature while maintaining the manageability of a comprehensive BSC implementation, a modified BSC perspectives framework was proposed, as shown in Figure 4. The financial perspective reflects the stakeholders’ points of view regarding the profitability of biofuel production and commercialization. The business processes perspective is aimed at monitoring and achieving short term biofuel production targets. The sustainability perspective measures the progress toward achieving cleaner environments and resource conservation. The innovation and learning perspective will prepare the organization for the future with continuous research and development (R&D) efforts for more efficient biofuel production.

After understanding algae-based biofuel production processes from the case organization and literature research, the research team worked with the biofuel research lab to develop a list of relevant KPIs to be used by both the dashboard approach and the BSC approach for monitoring, managing, and analyzing purposes.

Figure 4. Proposed Four Perspectives of the Balanced Scorecard



Through discussion with the field experts from the collaborating biofuel research lab, literature research, and field observations, the main objective of the visualization prototypes was set to "Provide a Sustainable Fuel Alternative" and was operationalized through the following three business strategies: *Production Improvement*, *Profitability Improvement*, and *Providing Environmentally Friendly Products*. In addition to the profitability improvement strategy, which is critical to the commercialization success of algae-based biofuel production, the *Production Improvement* strategy addresses factors related to algae-based biofuel production (Borowitzka, 1992; Ma & Hanna, 1999; Pienkos & Darzins, 2009; Holma, et. al., 2013). The *Providing Environmentally Friendly Products* strategy addresses clean and renewable energy factors

(Figge, et al., 2002; van der Woerd & van den Brink, 2004; Möller & Schaltegger, 2005; Hahn & Figge, 2016; Hansen & Schaltegger, 2016; Xia, et al., 2017). Objectives and KPIs were then derived for each of the four BSC perspectives using the same process. The KPIs proposed in this study balance outcome measures (lagging indicators), performance drivers (leading indicators), and diagnostic indicators. Lagging indicators measure the output of past activities to confirm what has recently happened and to establish a trend. Leading indicators offer future performance indications and are often input oriented and measure activities in their current state or in a future state to achieve an organization's goals. The following sections provide detailed BSC development for each of the four perspectives governed by the three business strategies.

4.1.1 Financial Perspective

The financial perspective aims to answer the question of "How should the company appear to its stakeholders?" The target users include external users such as investors, creditors, biofuel researchers, and the general public as well internal users. For the *Production Improvement* strategy under the Financial Perspective, the objective "Decrease Production Cost" is introduced. As production cost can be affected by the volume of the biofuel (e.g., economies of scale) (Borowitzka, 1992; Ma & Hanna, 1999; Chisti, 2007; Courchesne, et al., 2009) and the cost of setting up the plant, "Yield Volume" and "Setup Cost" were introduced as KPIs.

For the *Profitability Improvement* strategy, "Increase Profit", "Increase Sales Revenue", and "Increase Market Share" are the three derived objectives. Revenue can be generated by the sale of biofuel and its byproducts (Crooks, 2007; Chisti, 2007; Li, et al., 2008; Yang, et al., 2013). As such, these two were selected as the KPIs for evaluating the status of this objective. The objective "Increase Profit" reflects the progress toward biofuel commercialization. To ensure adoptability, generalization, and comparability across different companies and industries, it was measured by commonly accepted KPIs such as "Return on Investment (ROI)", "Return on Equity (ROE)", "Profit Margin", "Gross Margin", and "Economic Value Added (EVA)". The "Increase Market Share" objective was measured by the number of customers and number of sales channels. The eco-friendliness of biofuels should be recognized and promoted by both the general public and the government to justify a premium price (Zografakis, et. al, 2010; Ku & Yoo, 2010; Zorić & Hrovatin, 2012). Therefore, the objectives "Increase Public Awareness" and

"Capitalize Government Incentives" were introduced. Public awareness can be measured by a public survey. Table 2 summarizes the various objectives and their KPIs, and Table 1 in the Appendix provides a sample data dictionary for the KPIs used in this study. Although the KPIs are adoptable in various environments, the target values provided in Table 1 in the Appendix are specific to this research and should be adjusted based on the adoption environment.

Table 2. Financial perspective: Governing Strategy, Objectives, and KPIs

Governing Strategy	Objectives	KPIs / Measures
Production Improvement	Decrease Production Cost	Yield Volume
		Setup Cost
Profitability Improvement	Increase Profit	Economic Value Added (EVA)
		Profit margin
		Return on Equity (ROE)
		Return ion Investment (ROI)
		Gross Margin
	Increase Sales Revenue	Byproduct Revenue
		Biofuel Revenue
	Increase Market Share	Number of Customers
		Number of Sales Channels
Provide Environmentally Friendly Products	Increase Public Biofuel Acceptance Rate	Public Acceptance Rate
	Capitalize Government Incentives	Total Financial Incentives Recieved

4.1.2 Business Process Perspective

The business process perspective aims to answer the question of "What business process must the company excel at to satisfy its stakeholders?" and monitors the internal business processes that are required to generate revenue for the target users such as internal management teams and algae-based biofuel researchers. As stated in the literature review section, the entire biofuel production process consists of three sub-processes: algae cultivation, algae harvesting and fuel production (Pienkos & Darzins, 2009). Each of these processes involves many steps which need to be carefully executed because their efficiency affects the next process. For example, if, after harvesting, the algae culture contains less than 0.5% of water, the biofuel production process will be difficult to execute because of soap formation. It will require more effort to remove the soap which will make biofuel production more expensive (Ma & Hanna, 1999; Li, et al., 2008). Thus, it is important to ensure that every sub-process is executed efficiently. The efficiency of the harvest process hinges on the speed at which the algae is harvested and the number of algae cells that are successfully harvested. Similarly, the biofuel production process is affected by its speed and efficiency as well as the oil extraction rate (Borowitzka, 1992; Ma & Hanna, 1999; Chisti, 2007; Courchesne, et al., 2009).

The oil extraction rate, fuel production cycle time, and potential containment rate can vary significantly by the type of microalgae (Escalera et al., 2008; Pienkos & Darzins, 2009). As such, these factors need to be compared based on the selected algae types for production. Additionally, since microalgae is sunlight-driven (a quality describing cells that convert carbon dioxide to potential biofuels and high-value byproducts as observed by Crooks (2007), Chisti (2007), Li, et al., (2008), and Yang, et al. (2013)), the reduction rate of CO, CO_2, and SO_2 should be monitored as they can be used to promote public awareness and acceptance of biofuel (Ku & Yoo, 2010; Zografakis, et. al, 2010; Zorić & Hrovatin, 2012). After reviewing factors identified from the literature, field observations, and consultations with the biofuel researcher team, the objectives and KPIs pertinent to the business process perspective governed by the overall strategies have been summarized in Table 3, and the KPI data dictionary is provided in Table 2 in the Appendix.

Table 3. Business Processes Perspective: Governing Strategy, Objectives, and KPIs

Strategy	Objectives	KPIs/ Measures
Production Improvement	Improve harvest process efficiency	Harvest efficiency
		Harvest rate
	Improve the cultivation process	Cultivation efficiency
	Reduce contamination rate	Contamination Rate
	Improve the fuel production process	Production efficiency
		Biofuel cycle time
		Oil extraction rate
	Select suitable algae strains	No. of algae strains tested
Profitability Improvement	Improve external growth environment	Profit margin – external
		Capacity utilization of outdoor algae growth equipment
		Anual growth period
	Improve internal growth environment	Capacity utilization of indoor algae growth equipment
		Anual growth period
	Creative marketing process	Marketing efficiency ratio
Provide Environmentally Friendly Products	Improve water quality	Volume of water cleaned
	Reduce environmental pollution	CO_2 reduction rate
		SO_2 reduction rate

4.1.3 Sustainability Perspective

The sustainability perspective intends to answer the question “How will society and the customers view the company?”. It also focuses on assessing sustainable fuel impacts from the perspectives of internal employees and external users such as the general public, regularity agencies, and biofuel researchers. Although the biofuel production process is fairly mature for crops like corn and soybeans, it cannot realistically satisfy even a small fraction of the existing fuel demand. Microalgae, on the other hand, offers various advantages as a raw material for fuel production. Biodiesel produced from soybeans has been found to have an energy-out to energy-in ratio of 1.78 as compared to 1.42 in the case of Ethanol produced from corn. However, congruent with the studies conducted by Escalera et al. (2008), Chisti (2007), and Pienkos & Darzins (2009), even low producing species of microalgae offer a higher yield than soybeans, as summarized in Table 4, and require very little to no cultivable land as summarized in Table 5.

Table 4. Productivity comparisons for soybeans and algae (Source: Pienkos & Darzins, 2009)

Productivity	Soybeans	Algae (Low Productivity)	Algae (Medium Productivity)	Algae (High Productivity)
		10 g/m2/day	25 g/m2/day	50 g/m2/day
		15% TAG	25% TAG	50% TAG
gal/acre	48	633	2637	10,549
Total acres	63.6 million	63.6 million	25 million	6.26 million
gal/year	3 billion	40 billion	66 billion	66 billion
% Petrodiesel	4.5%	61%	100%	100%

Table 5. Comparison of different biodiesel sources (Chisti, 2007)

Crop	Oil Yield (L/ha)	Land area needed (M ha)[a]	Percent of existing US cropping area [a]
Corn	172	1540	846
Soybean	446	594	326
Canola	1190	223	122
Jatropha	1892	140	77
Coconut	2689	99	54
Oil palm	5950	45	24
Microalgae [b]	136,900	2	1.1
Microalgae [c]	58,700	4.5	2.5
a. to meet 50% of all transport fuel needs of the United States b. 70% oil (by wt) in biomass c. 30% oil (by wt) in biomass			

The sustainability perspective mainly focuses on evaluating the intangible benefits such as the goodwill of an organization in a society. The objectives in this perspective affect either the business process perspective or the financial perspective. For example, automobile owners (the end users) will be less interested in switching to biofuel if this fuel reduces the lifespan of an automobile engine. The "Improving Engine and Biofuel Compatibility" objective may not directly generate revenue, but it is likely to boost sales which will lead to a profit increase. As such, this was considered to be an important objective. Similarly, the "Improving Public Awareness" objective and the "Contribution to Green Earth Efforts" objective will increase the goodwill and future revenue as documented by prior literature (Zografakis, et. al, 2010; Ku & Yoo, 2010; Zorić & Hrovatin, 2012). Table 6 summarizes the various objectives and KPIs from the sustainability perspective, and Table 3 in the Appendix provides the KPI data dictionary.

Table 6. Sustainability Perspective: Governing Strategy, Objectives, and KPIs

Governing Strategy	Objectives	KPIs / Measures
Profitability Improvement	Consider opportunity cost	Total opportunity cost
	Improve engine and fuel compatibility	Engine life
Provide Environmentally Friendly Products	Improve public awareness	Public awareness rate
	Contribution to green earth efforts	Gain in Green House Gases (GHG)
		Improve Cloro Floro Carbon (CFC) emission

4.1.4 Innovation and Learning Perspective.

The innovation and learning perspective strives to answer the question "How will the company sustain in its ability to change and improve?". This perspective helps an organization achieve its long-term strategic goals. As a result, internal users and researchers are the target users for the innovation and learning perspective. For the production improvement strategy, the objective "Hone Employee Skills" measures the level of employee skills and training for continuously improving biofuel production efficiency. For the profitability improvement strategy, the objective "Improve Research and Development (R&D)" focuses on increasing the applicability of the existing products to expand the company's customer base and market share. For the providing environmentally friendly products strategy, the objective "Increase Biofuel Acceptance Rate from Internal Stakeholders" is measured by the employees' biofuel purchase rate. Table 7 recapitulates the various objectives and KPIs from the Innovation Perspective, and Table 4 in the Appendix provides the KPI data dictionary.

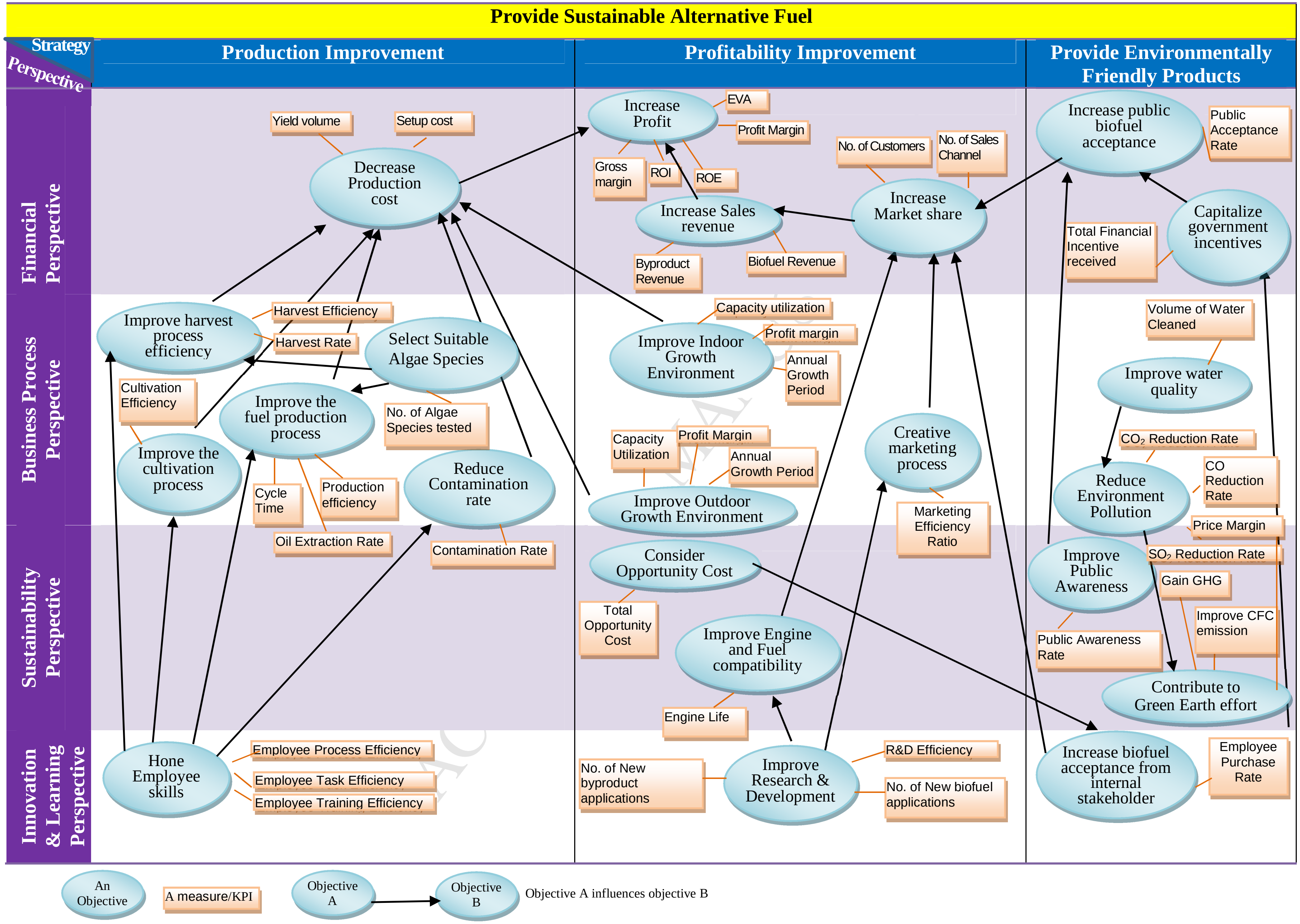
Table 7. Innovation and Learning Perspective: Governing Strategy, Objectives, and KPIs

Strategy	Objectives	KPIs / Measures
Production Improvement	Hone employee skills	Employee process efficiency
		Employee Task efficiency
		Training efficiency
Profitability Improvement	Improve R&D	Number of new applications of byproducts
		R&D efficiency
		Number of new biofuel applications
Provide Environmentally Friendly Products	Increase biofuel acceptance rate from internal stakeholders	Employees' purchase rate

4.1.5 Strategy Map

A strategy map is a diagram that shows the organization's strategy on a single page (Kaplan & Norton, 2004) and plays an important role in creating a coherent performance measurement framework in BSC modeling. It is useful for helping everyone in the organization to clearly understand its primary strategic goals by communicating big-picture objectives in simple terms. As the strategy map presents the hierarchical structure of BSC on how all business activities are linked, it ensures that everyone in the organization understands the business strategy and can aid in successfully implementing the organization's long-term goals. Through literature review and a series of discussions with the biofuel research team, a strategy map that integrates all four perspectives of biofuel production and commercialization is displayed in Figure 5.

Figure 5. Proposed Balanced Scorecard Strategy Map for Sustainable Alternative Fuel



4.2 Dashboard-based Visualization Modeling

To create a user-friendly and intuitive interface that provides users with easy access to information and services while considering their different requirements, the following design principles were utilized:

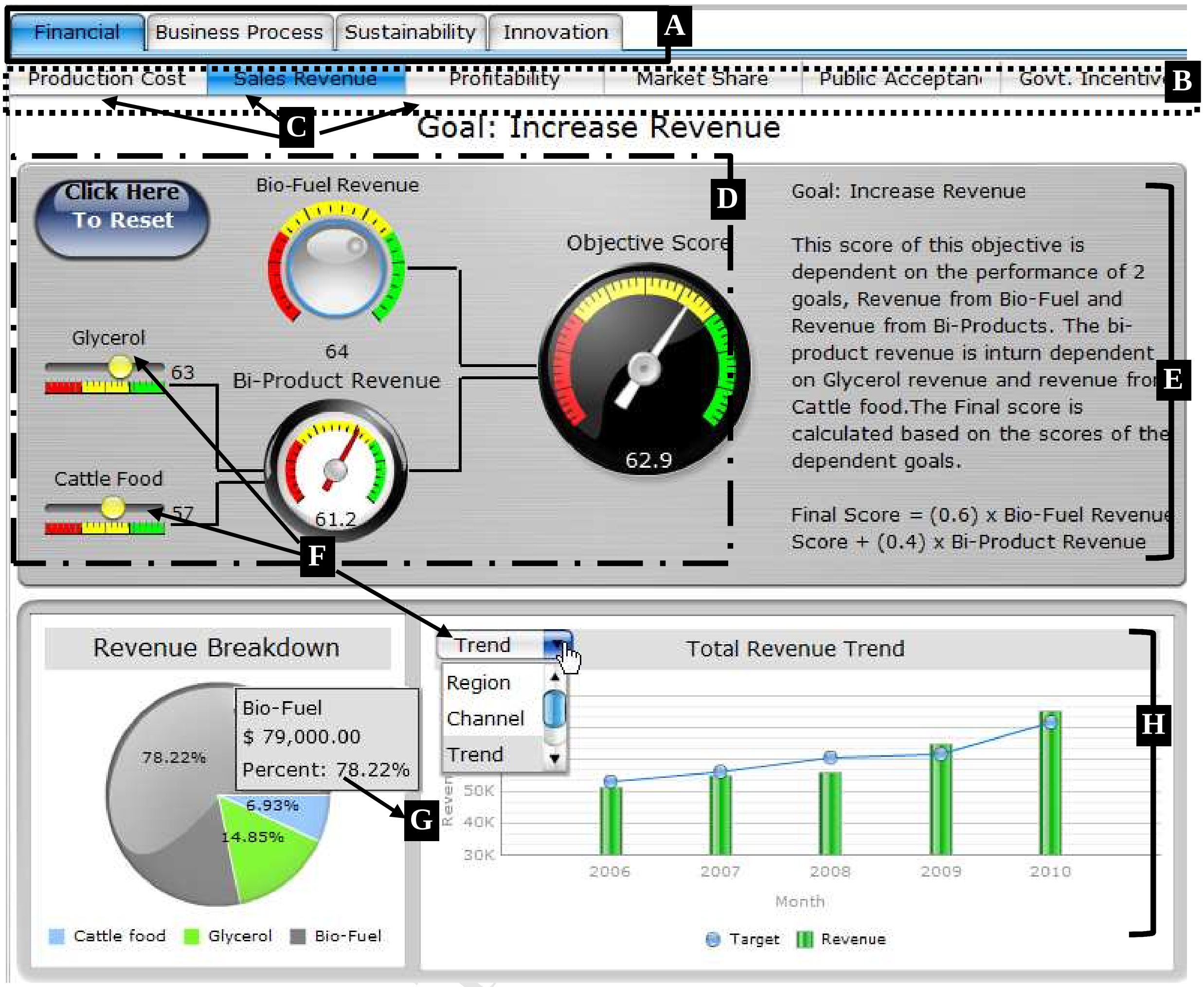
- Utilization of the pre-attentive attributes and visual perception: To utilize the iconic memory (or visual sensory register) that allows for more effective information dissemination, pre-attentive attributes (e.g., color, form, spatial position, and motion) and visual perception principles (proximity, closure, similarity, continuity, enclosure, and connection) were utilized throughout the visualization model's development.
- Information categorization: The information was broken down into different tabs, which were then organized into a meaningful order and hierarchy. In general, four BSC perspectives, strategies, and objectives were used as a navigation guide on top of a dashboard screen, denoted as A and B in Figures 6 and 7.
- Utilization of charts, diagrams, and gauges that are easy to understand without technical knowledge: Users can follow the dashboard with the aid of graphs and dials, clickable charts, a geographic map, and clearly labeled sections, as in the examples shown in Figures 6 and 7.
- Utilization of the familiar selector such as a radio button set, drop-down menu, or a slider: This selector helps the decision maker choose a desired object or take a specific action, as in the examples shown in part F of Figures 6 and 7.
- Dynamic information tip: Placing the cursor over a chart or an object gives details for that chart/object, as illustrated in the example labeled G in Figures 6 and 7.

A dashboard screen typically provides the navigation structure (A and B), performance overview (D), and detailed drill-down or ad-hoc analysis (F, G, H), as illustrated in Figures 6 and 7. The four BSC perspectives presented as natural and logical information groups and were used as the top level navigation menu tabs, denoted as A in Figures 6 and 7. The objectives of a perspective were used and visualized as the second level navigation menu tabs. For example, the objectives denoted as 1 in Table 2 were visualized with navigation tabs “Production Cost”, “Revenue”, Profitability”, “Market Share”, “Public Acceptance”, and “Govt. Incentives” and were labeled as B and C in Figures 6 and 7.

Underneath the navigation structure, the dashboard screen was divided into two parts. The upper part contains a summary of the various KPIs (performance overview), and the lower half provides the guided drill-down or ad-hoc analysis. The performance overview section provides KPI scores and trends, as illustrated in part D of Figure 6. Simulation capabilities were also incorporated in the performance overview section where cause-and-effect relationships are visualized to conduct what-if analyses for changing tasks and action plans throughout the decision-making process (see part D in Figure 7).

Figure 6. Dashboard –Decrease Production Cost Objective in Financial Perspective

Figure 7. Dashboard –Increase Sales Revenue Objective in Financial Perspective



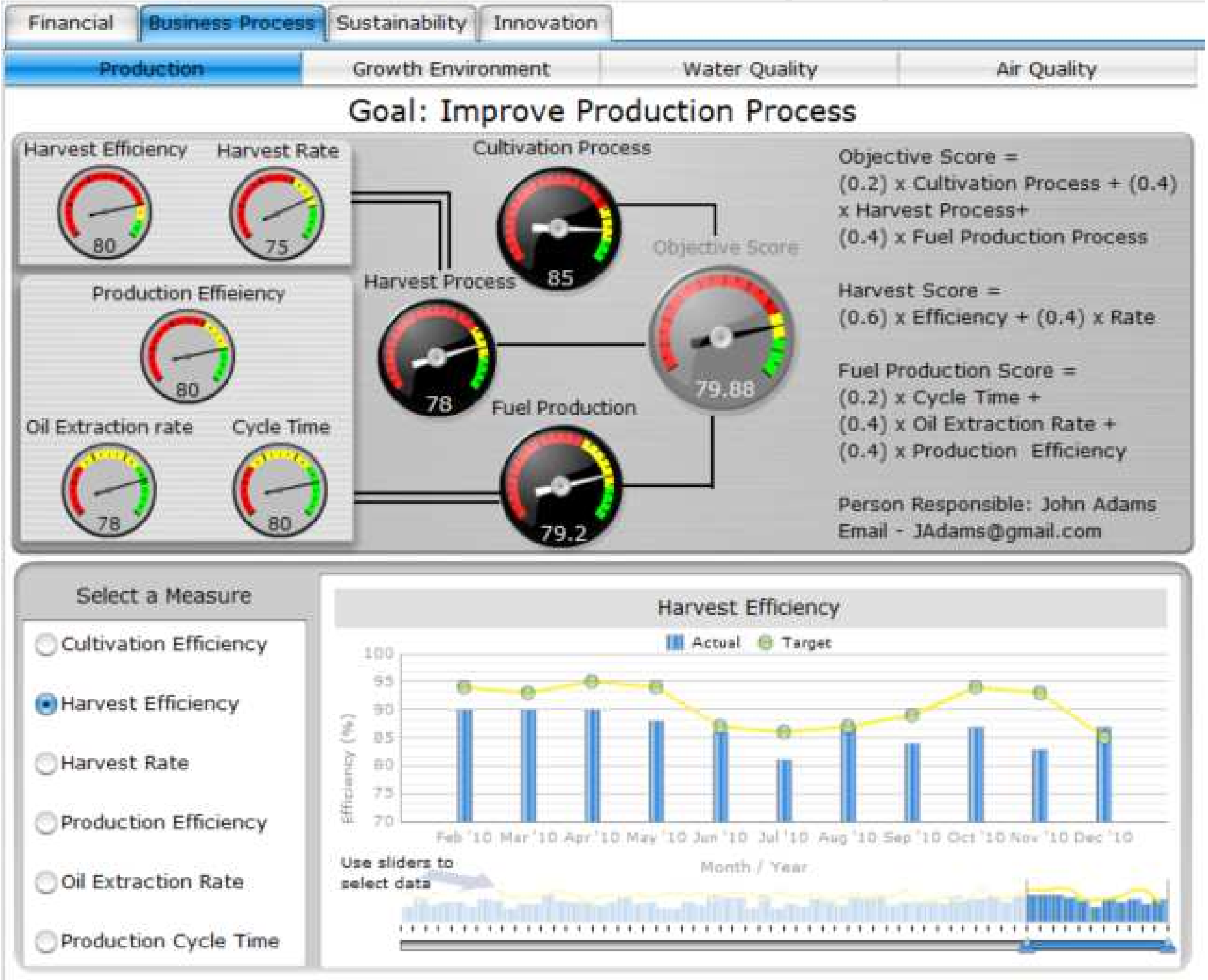
Goal: Increase Revenue

This score of this objective is dependent on the performance of 2 goals, Revenue from Bio-Fuel and Revenue from Bi-Products. The bi-product revenue is inturn dependent on Glycerol revenue and revenue fro Cattle food.The Final score is calculated based on the scores of the dependent goals.

Final Score = (0.6) x Bio-Fuel Revenu Score + (0.4) x Bi-Product Revenue

To improve usability, explanations, formulas, and notes for the objective score calculation were presented in the overview section wherever it was deemed necessary, as illustrated in part E of Figures 6 and 7. For example, the “Decrease Cost” objective score of 47.4 is computed as the sum of 0.4 × Setup Cost Score and 0.6 × Yield Volume Score (i.e., 0.4 × 45 + 0.6 × 49), as shown in part E of Figure 6. Furthermore, the KPIs summarized in Table 2 were visualized in the form of charts and gauges in a detailed drilldown and ad-hoc analysis section underneath the performance overview section. For example, the “Yield Volume” and “Setup Cost” KPIs selected for the objective “Decrease Production Costs” were visualized through interactive charts shown in parts F, G, and H of Figure 6. The cost information included the total cost and the breakdown of each sub-cost by country. Furthermore, the historical data of all the countries was provided for trend analysis. The “Byproduct Revenue” and “Biofuel Revenue” KPIs were selected to measure the objective “Increase Sales Revenue”. They were implemented with OLAP features to supply detailed information about the revenue, such as the contributions of different sources, performance over multiple years, and contributions from various channels and regions, as shown in parts F, G, and H of Figure 7. The amount of data and the level of detail varied depending on each objective and organization’s requirement. Figures 8 and 9 show the two other objectives from different perspectives. Detailed information about all the dependent parameters was provided in the bottom half. The user could adjust the sliders on the chart to change the data, if required for the analysis.

Figure 8. Dashboard –Improve Production Process Objective in the Internal Business Process Perspective



Objective Score = (0.2) x Cultivation Process + (0.4) x Harvest Process+ (0.4) x Fuel Production Process

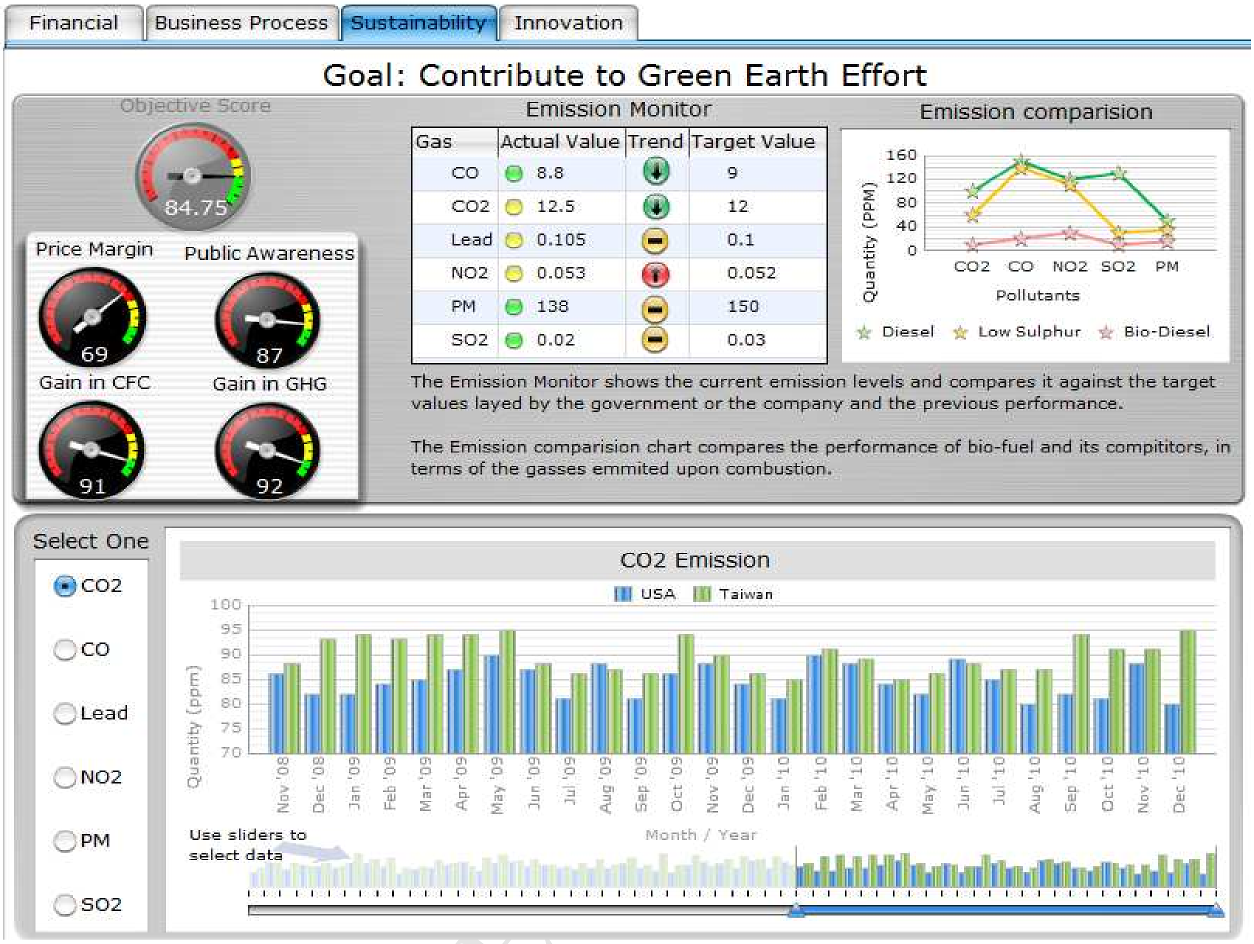
Harvest Score = (0.6) x Efficiency + (0.4) x Rate

Fuel Production Score = (0.2) x Cycle Time + (0.4) x Oil Extraction Rate + (0.4) x Production Efficiency

Person Responsible: John Adams
Email - JAdams@gmail.com

○ Cultivation Efficiency
● Harvest Efficiency
○ Harvest Rate
○ Production Efficiency
○ Oil Extraction Rate
○ Production Cycle Time

Figure 9. Dashboard – Contribute to Green Earth Effort in Sustainability Perspective



Gas	Actual Value	Trend	Target Value
CO	● 8.8	↓	9
CO2	● 12.5	↓	12
Lead	● 0.105	–	0.1
NO2	● 0.053	↑	0.052
PM	● 138	–	150
SO2	● 0.02	–	0.03

The Emission Monitor shows the current emission levels and compares it against the target values layed by the government or the company and the previous performance.

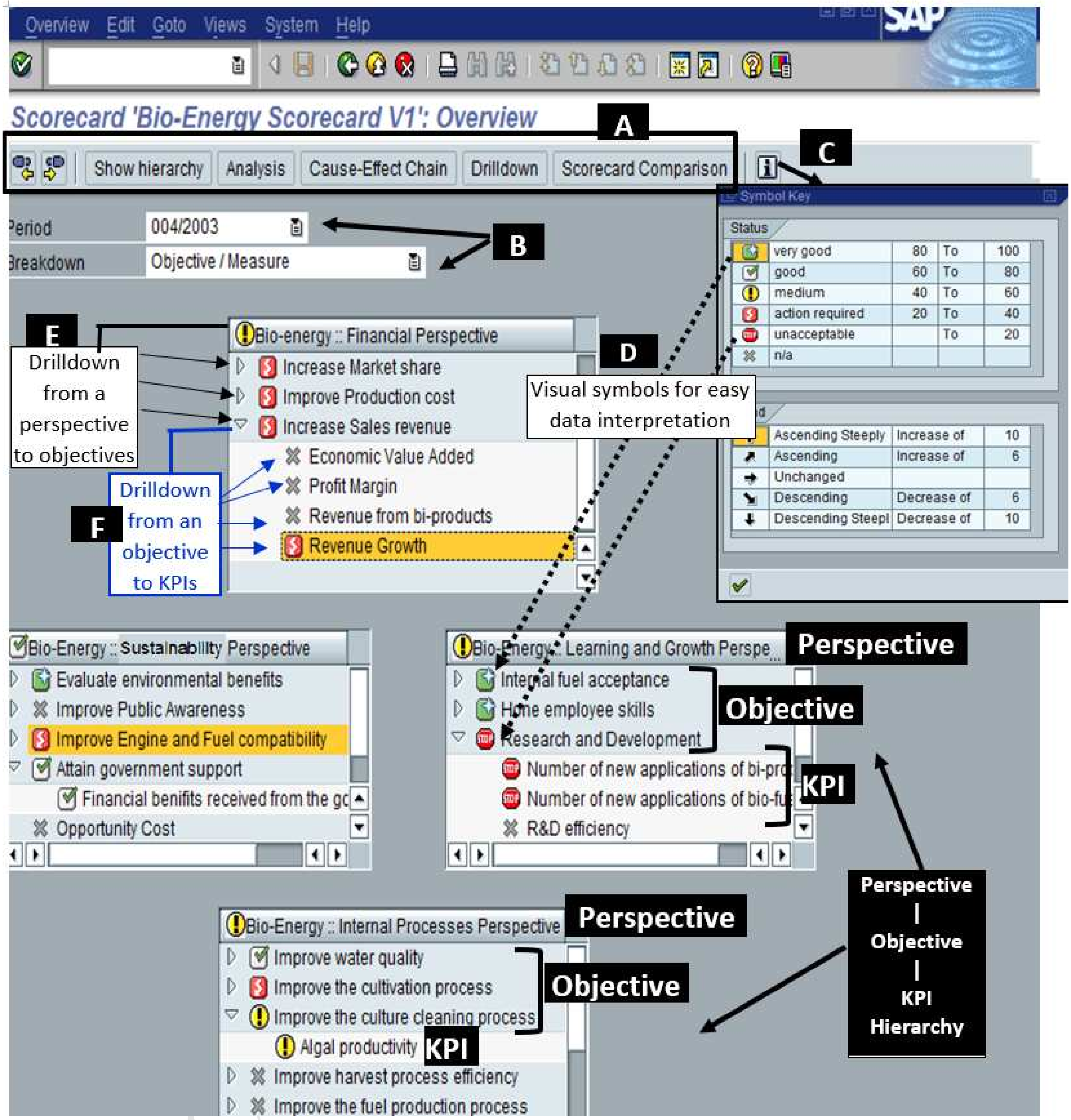
The Emission comparision chart compares the performance of bio-fuel and its compititors, in terms of the gasses emmited upon combustion.

● CO2
○ CO
○ Lead
○ NO2
○ PM
○ SO2

4.3. Balanced Scorecard-based Visualization Modeling

The same design principles were used to develop the balanced scorecard (BSC) visualization prototype. The perspectives, strategies, objectives, and KPIs are similar to those used in the dashboards but there are well-defined cause and effect relationships between them, as defined in the strategy map shown in Figure 5. On the scorecard's starting screen, as shown in Figure 6, the navigation structure was provided on the top (see part A of Figure 10). The prototype provided the user with a quick glimpse of the organization's performance through graphical indicators. Users could make changes in the time period of evaluation and the format of the data breakdown (see part B of Figure 10). The starting screen also allowed the user to view the meaning of the graphical indicators which remain the same throughout the BSC visualization prototype (see parts C and D of Figure 10).

Figure 10. Balanced Scorecard Visualization Prototype Overview Screen



Period 004/2003

Breakdown Objective / Measure

Symbol Key

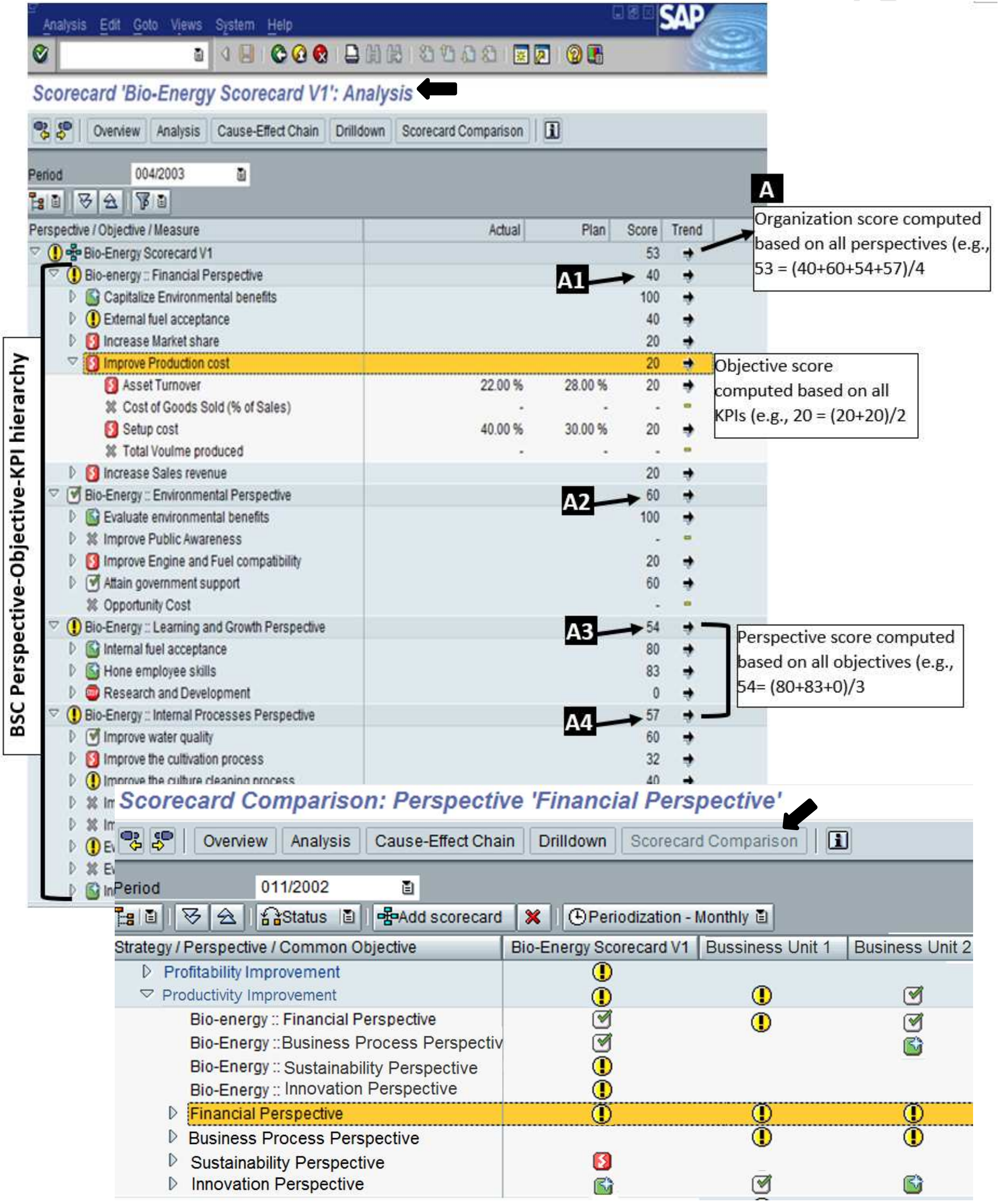
Status

very good	80	To	100
good	60	To	80
medium	40	To	60
action required	20	To	40
unacceptable		To	20
n/a			

Ascending Steeply	Increase of	10
Ascending	Increase of	6
Unchanged		
Descending	Decrease of	6
Descending Steepl	Decrease of	10

The balanced scorecard approach is a comprehensive framework that translates a firm's vision and strategy into a coherent and linked hierarchy of perspectives, objectives, performance measures, and KPIs. The perspectives, objectives, and KPIs hierarchy was implemented in the BSC visualization model, as shown in Figure 10. Users could identify the relationships between the perspectives, objectives, and KPIs for monitoring and analyzing management activities as illustrated in parts E and F of Figure 10. An example of the drilling down from the perspective to the objectives was shown in part E of Figure 10. An example of the drilling down from an objective to the KPIs was shown in part F of Figure 10. The perspective-objective-measures (KPI) hierarchy was maintained wherever deemed appropriate, as illustrated in the Analysis view and the Scorecard Comparison view sections of Figure 11.

Figure 11. Perspective-Objective-Measures (KPI) Hierarchy Examples



Scorecard 'Bio-Energy Scorecard V1': Analysis

Period 004/2003

Perspective / Objective / Measure	Actual	Plan	Score	Trend
Bio-Energy Scorecard V1			53	→
Bio-energy :: Financial Perspective			40	→
Capitalize Environmental benefits			100	→
External fuel acceptance			40	→
Increase Market share			20	→
Improve Production cost			20	→
Asset Turnover	22.00 %	28.00 %	20	→
Cost of Goods Sold (% of Sales)	-	-	-	-
Setup cost	40.00 %	30.00 %	20	→
Total Voulme produced	-	-	-	-
Increase Sales revenue			20	→
Bio-Energy :: Environmental Perspective			60	→
Evaluate environmental benefits			100	→
Improve Public Awareness			-	-
Improve Engine and Fuel compatibility			20	→
Attain government support			60	→
Opportunity Cost			-	-
Bio-Energy :: Learning and Growth Perspective			54	→
Internal fuel acceptance			80	→
Hone employee skills			83	→
Research and Development			0	→
Bio-Energy :: Internal Processes Perspective			57	→
Improve water quality			60	→
Improve the cultivation process			32	→
Improve the culture cleaning process			40	→

Organization score computed based on all perspectives (e.g., 53 = (40+60+54+57)/4

Objective score computed based on all KPIs (e.g., 20 = (20+20)/2

Perspective score computed based on all objectives (e.g., 54= (80+83+0)/3

Scorecard Comparison: Perspective 'Financial Perspective'

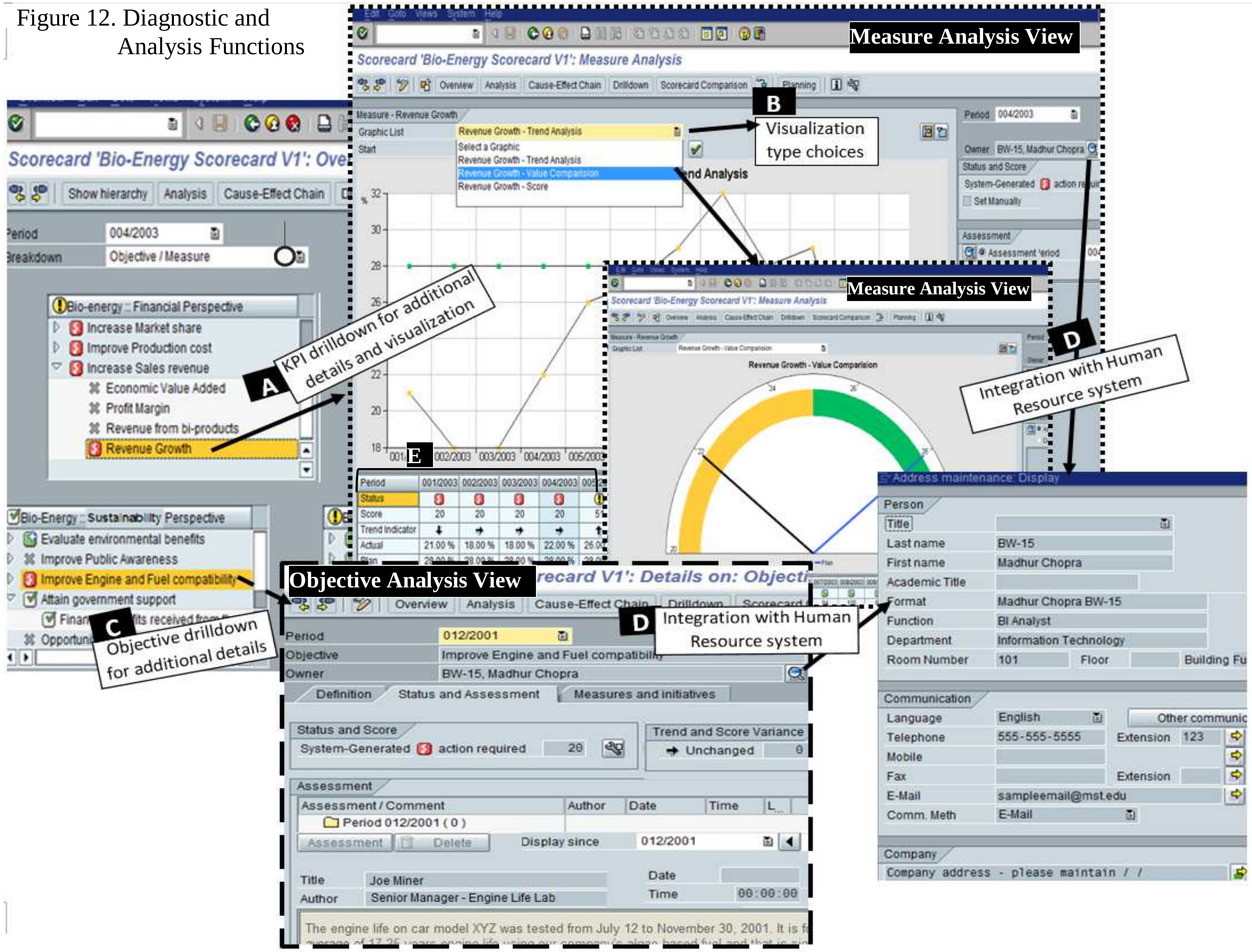
Period 011/2002

Strategy / Perspective / Common Objective	Bio-Energy Scorecard V1	Bussiness Unit 1	Business Unit 2
Profitability Improvement	!		
Productivity Improvement	!	!	✓
Bio-energy :: Financial Perspective	✓	!	✓
Bio-Energy ::Business Process Perspectiv	✓		★
Bio-Energy :: Sustainability Perspective	!		
Bio-Energy :: Innovation Perspective	!		
Financial Perspective	!	!	!
Business Process Perspective		!	!
Sustainability Perspective	✗		
Innovation Perspective	★	✓	★

Another implementation example of the interconnectivity of a BSC model and its ability to improve cause-and-effect diagnosis and analysis was shown in the Analysis view in Figure 11. A performance comparison between the actual values and the planned values was provided in addition to the scores and trends to support additional analysis. The process of determining the scores and trends followed a similar BSC hierarchical structure. For example, the perspective score was determined by all of its objective scores, and the objective score was determined by all of its KPIs through a predefined weighting schema. The examples shown in Figure 11 assumed the simple average for illustration purposes. Such information helped guide the organization to achieve its organizational goals through dashboard-based visualization.

A useful feature of the BSC-based dashboard was the scorecard comparison feature, which allowed the organization to compare the performances of different organizational units/teams working toward the same strategic goals, as shown in Figure 12. It could also visualize the performance of different plant locations in a country or the performances of multiple organizations spread across multiple countries. However, scorecard comparison could only be made for business units when the organizations had comparable strategies, perspectives, objectives, and KPIs. Figure 12 illustrates the scorecard comparison screen where three scorecards were used to compare three different business units which shared common strategies, perspectives, objectives, or KPIs. For example, the strategy “Productivity Improvement” was a common strategy for all three business units, while the “Profitability Improvement” strategy was only applicable to the Bioenergy Scorecard-V1 unit. For a common strategy, each unit might have either shared or unique perspectives, objectives, along with KPIs applicable for its operations. For example, within the common strategy “Productivity Improvement,” the sustainability perspective was unique for the Bioenergy Scorecard V1 unit; thus, a comparison with other units was not available. On the other hand, the financial perspective was common and thus three units were compared for their performances. Since OLAP functions comprised of filtering, drilldown/drill across, and aggregation were essential for performance analysis and diagnosis, they were embedded in the BSC visualization prototype. This prototype allowed the user to further drilldown to any level of detail for analysis whenever he/she might desire by double clicking on a perspective, objective, or KPI menu as shown in Figure 12.

Figure 12. Diagnostic and Analysis Functions



Scorecard 'Bio-Energy Scorecard V1': Ove

Period: 004/2003
Breakdown: Objective / Measure

Bio-energy :: Financial Perspective
- Increase Market share
- Improve Production cost
- Increase Sales revenue
  - Economic Value Added
  - Profit Margin
  - Revenue from bi-products
  - Revenue Growth

Bio-Energy :: Sustainability Perspective
- Evaluate environmental benefits
- Improve Public Awareness
- Improve Engine and Fuel compatibility
- Attain government support
  - Finan… …fits received from th…
- Opportuni…

Scorecard 'Bio-Energy Scorecard V1': Measure Analysis

Measure - Revenue Growth
Graphic List: Revenue Growth - Trend Analysis
- Select a Graphic
- Revenue Growth - Trend Analysis
- Revenue Growth - Value Comparison
- Revenue Growth - Score

Start
…end Analysis

Period: 004/2003
Owner: BW-15, Madhur Chopra
Status and Score
System-Generated: action requi…
☐ Set Manually
Assessment
Assessment Period

Period	001/2003	002/2003	003/2003	004/2003	005/2…
Status	S	S	S	S	!
Score	20	20	20	20	51
Trend Indicator	↓	→	→	→	↑
Actual	21.00 %	18.00 %	18.00 %	22.00 %	26.0…
Plan	28.00 %	28.00 %	28.00 %	28.00 %	28.0…

…recard V1': Details on: Objecti…

Period: 012/2001
Objective: Improve Engine and Fuel compatibility
Owner: BW-15, Madhur Chopra

Definition | Status and Assessment | Measures and initiatives

Status and Score
System-Generated: action required 20

Trend and Score Variance
→ Unchanged 0

Assessment

Assessment / Comment	Author	Date	Time	L…
Period 012/2001 (0)				

Display since: 012/2001

Title: Joe Miner
Author: Senior Manager - Engine Life Lab
Date:
Time: 00:00:00

The engine life on car model XYZ was tested from July 12 to November 30, 2001. It is f…

Address maintenance: Display

Person
Title:
Last name: BW-15
First name: Madhur Chopra
Academic Title:
Format: Madhur Chopra BW-15
Function: BI Analyst
Department: Information Technology
Room Number: 101 Floor: Building Fu…

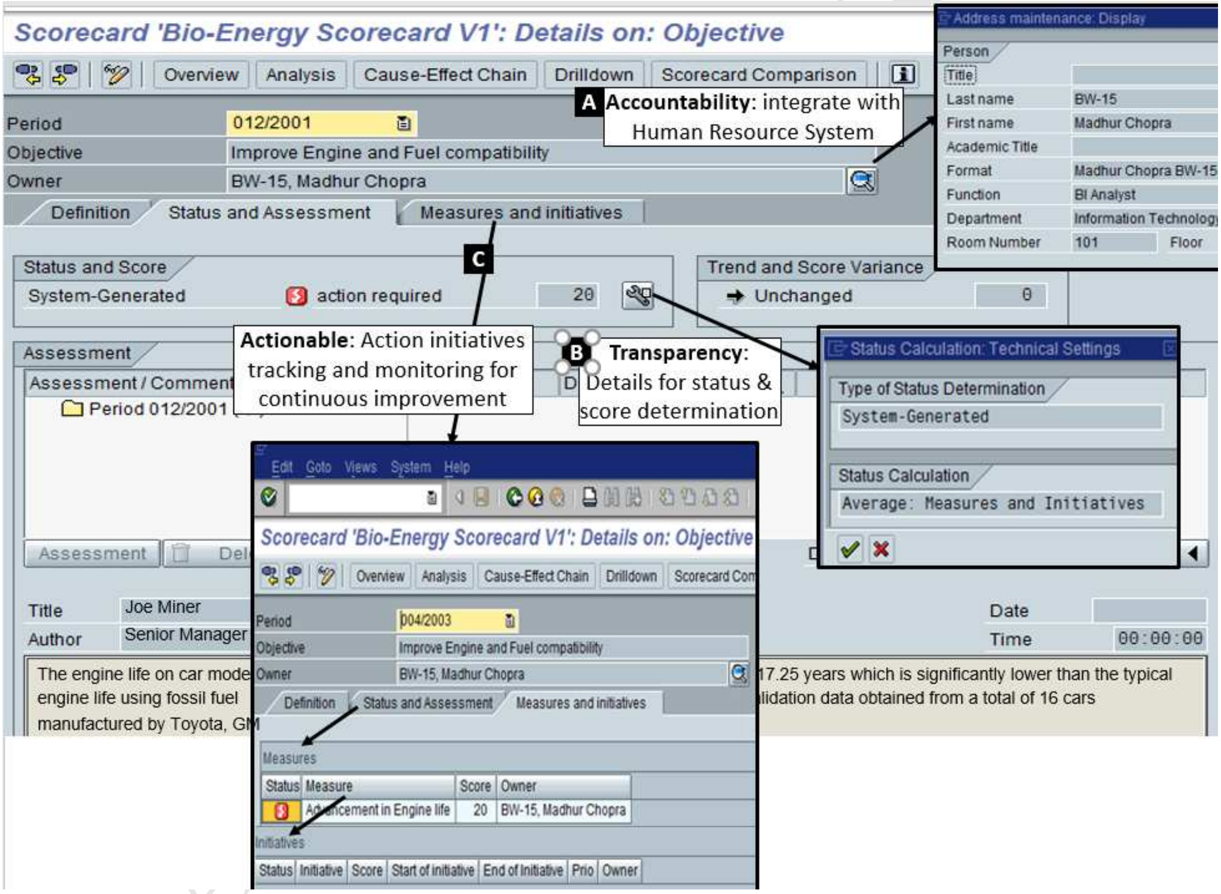
Communication
Language: English
Telephone: 555-555-5555 Extension: 123
Mobile:
Fax: Extension:
E-Mail: sampleemail@mst.edu
Comm. Meth: E-Mail

Company
Company address - please maintain / /

The Objective Analysis view depicted in part C of Figure 12 provided further details regarding information pertinent to an objective. Details for the definition, assessment, initiative (action plan), owner, and assessment manager of an objective were provided for further analysis and for crafting proactive action plans. The Measure (KPI) Analysis view in the scorecard provided the most detailed level of information. The BSC prototype provided additional details such as the owner, assessment, and definition of a KPI at the measured level. Furthermore, the BSC visualization prototype allowed the user to view the same data in a number of different ways depending on the varying preferences of different users. Labeled as B in Figure 10, the Revenue Growth KPI was displayed as a line graph for trend analysis, a dial gauge for value comparison, and other graphic types appropriate for a specific type of analysis. Trend analysis was performed for the KPI score, status, target value, and planned values as shown in part D of Figure 12. The BSC visualization prototype was further integrated into the HR database as illustrated in part D of Figure 12. The prototype retrieved the contact information of the KPI owner from the organization’s Human Resource (HR) system. As such, the manager could communicate with the KPI owner for additional information or action plans. The integration was modeled to provide a single version of truth that retrieves the same information from different access points (i.e., from the Measured Analysis view or from the Objective Analysis view in this example).

As discussed above, the BSC provided the users with a guided analysis without getting lost in an information jungle. Each level provided a different extent of detail. For example, as shown in Figure 13 at the objective level, the user was presented with information detailing the owner of the objective, a score of the objective, and the formula used to calculate the score. The score of the objective was calculated based on the underlying measures (KPIs) and initiatives, as shown in Figure 13. The user could also check the underlying dependent objectives and measures for further analysis. Another important feature of the proposed BSC-based dashboard was its ability to create accountability, transparency, and actionable features in the interconnected BSC hierarchical structure. For example, accountability was realized through integration with the Human Resource (HR) system as shown in part A of Figure 13. Transparency was implemented through the predefined formula, as shown in parts A and B of Figure 11 and Figure 13, respectively. The measured status of the corrective action plans (initiatives) was shown in part C of Figure 13. The interconnectivity of the BSC model to the cause-and-effect diagnosis and analysis was illustrated in the Analysis view in Figure 11. The performance comparison between the actual values and the planned values was provided along with scores and trends to support additional analysis. The process for calculating the scores and analyzing the trends followed a similar BSC hierarchical structure. For example, the perspective score was determined from all of its objective scores, and the objective score was calculated from all of its KPIs through predefined weighting schemes. The examples shown in Figure 11 assumed the simple average for illustrative purposes. This information helped the organization achieve its organizational goals.

Figure 13. Accountability, Transparency, and Actionable Features



Scorecard 'Bio-Energy Scorecard V1': Details on: Objective

Period: 012/2001
Objective: Improve Engine and Fuel compatibility
Owner: BW-15, Madhur Chopra

A **Accountability**: integrate with Human Resource System

Address maintenance: Display
Person
Title:
Last name: BW-15
First name: Madhur Chopra
Academic Title:
Format: Madhur Chopra BW-15
Function: BI Analyst
Department: Information Technolog
Room Number: 101 Floor

Status and Score
System-Generated: action required 20

Trend and Score Variance
Unchanged 0

C

Actionable: Action initiatives tracking and monitoring for continuous improvement

B **Transparency**: Details for status & score determination

Status Calculation: Technical Settings
Type of Status Determination: System-Generated
Status Calculation: Average: Measures and Initiatives

Assessment
Assessment / Comment
Period 012/2001

Title: Joe Miner
Author: Senior Manager
Date:
Time: 00:00:00

The engine life on car mode … 17.25 years which is significantly lower than the typical engine life using fossil fuel … lidation data obtained from a total of 16 cars manufactured by Toyota, GM

Scorecard 'Bio-Energy Scorecard V1': Details on: Objective
Period: 004/2003
Objective: Improve Engine and Fuel compatibility
Owner: BW-15, Madhur Chopra

Measures

Status	Measure	Score	Owner
🟥	Advancement in Engine life	20	BW-15, Madhur Chopra

Initiatives

Status	Initiative	Score	Start of initiative	End of Initiative	Prio	Owner

5. Concluding Remarks and Future Research Directions

The cost and volume of algae-based biofuel is significant, since they can dictate the success of biofuel commercialization. Such success often hinges on various influential factors such as temperature, light intensity, and algae strain. Since each step of biofuel production poses unique challenges, performance monitoring systems are needed. As such, this paper proposed both dashboards and BSC as a way of systematically monitoring and evaluating the biofuel production process. Additionally, the strategy map was developed to visualize the biofuel production and commercialization strategy from different perspectives under varying environmental factors. To verify the usefulness and practicality of the proposed data visualization tools (i.e., dashboards, BSC, and the strategy map), this paper developed their prototypes using the SAP software.

5.1 Main Contributions

One of the main contributions of this research is the development of a comprehensive list of financial and non-financial key performance indicators with an actionable data dictionary relevant to the success of algae-based biofuel commercialization that can be easily adopted with little to no modifications. Specifically, this research is one of the first to develop specific performance metrics and data visualization techniques for gauging the commercialization potential of biofuel alternatives based on algae nurturing. Contrary to the traditional performance evaluation, the proposed metrics, based on both dashboards and BSC, shed light on four different perspectives (i.e., financial, internal process, innovation, and sustainability) of biofuel creation.

Another contribution of this research is the inclusion of both lagging indicators (outcome measures) and leading indicators (future performance predictors) that made it feasible to translate the intangible environmental benefits (e.g., low air pollution) of alternative fuel into tangible financial figures to assess the financial implications (affordability) of biofuel creation. For example, the low carbon footprint, a leading indicator, resulting from biofuel consumption may not directly contribute to the immediate growth of a company that produces biofuel, but it can foster a positive image of the company. That positive image will eventually help attract more customers and subsequently increase the sales revenue and profit, not to mention improve its social capital. Additionally, this paper developed an integrated strategy map that provides a cause-and-effect hierarchical mapping of the proposed perspectives, objectives, and KPIs. Although some elements may be specific to the case organization studied, the underlining concepts, strategies, key perspectives, objectives, KPIs and their inter-relationship can easily be adopted and modified for different business settings. Thus, the design principles, visualization designs, and data dictionary implemented using a dashboard approach and a BSC approach provide examples and templates that can easily be adopted by any organization.

Furthermore, this paper is unique because it is dashboard-based, and the balanced scorecard driven visualization tools present a new way of identifying data patterns and presenting them in a user-friendly manner. Both visualization prototypes are useful for ad hoc analysis and were built on a business intelligence platform utilizing OLAP functions. The graphical displays (via the strategy map) of the proposed data visualization techniques allow the decision-maker (top management) to fully understand the managerial implications of biofuel production, even with limited technical knowledge, and thus help him/her make a wise strategic decision regarding biofuel commercialization. Also, it should be noted that the proposed data visualization techniques can be exploited to assess the commercialization potentials of other alternative fuels such as thermal and wind-powered energy with minor modifications.

5.2 Future Research Directions

Although this research is the point of departure for exploring the commercialization potentials of various alternative fuels, it is still confined to the particular biofuel production process that is available from today’s technology. As biofuel technology continues to evolve and advance, a number of factors that are believed to affect the efficiency of biofuel production may change, and their impacts may either diminish or increase. For instance, the sub-production processes such as oil extraction and bio-diesel production may be improved over time with advances in biotechnology, and thus its impact on cost and/or volume may change. Therefore, the subsequent KPIs and strategy map should be updated frequently. Additionally, a comparison of different alternative fuel commercialization potentials is another line of research that is worth pursuing. A study that could assess decision support quality through dashboard-based and BSC-based visualization would be invaluable as well.

References

Aitken, D., Bulboa, C., Godoy-Faundez, A., Turrion-Gomez, J. L., & Antizar-Ladislao, B. (2014). Life cycle assessment of macroalgae cultivation and processing for biofuel production. *Journal of Cleaner Production*, 75, 45-56.

Andonov-Acev, D., Buckovska, A., Blagojevic, Z., & Kraljevski, V. (2008, June). Enterprise performance monitoring. In *Information Technology Interfaces, 2008. ITI 2008. 30th International Conference on* (pp. 185-190). IEEE.

Andrienko, N., & Andrienko, G. (2013). Visual analytics of movement: An overview of methods, tools and procedures. *Information Visualization*, 12(1), 3-24.

Borowitzka, M. A. (1992). Algal biotechnology products and processes—matching science and economics. *Journal of applied phycology*, 4(3), 267-279.

ChartsBin (2017). Historical crude oil prices, 1861 to Present. http://chartsbin.com/view/oau, retrieved on April 15, 2017.

Cheng, H., Lu, Y. C., & Sheu, C. (2009). An ontology-based business intelligence application in a financial knowledge management system. *Expert Systems with Applications*, 36(2), 3614-3622.

Chisti, Y. (2007). Biodiesel from microalgae. *Biotechnology advances*, 25(3), 294-306.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (1999). New product portfolio management: practices and performance. *Journal of product innovation management*, 16(4), 333-351.

Courchesne, N. M. D., Parisien, A., Wang, B., & Lan, C. Q. (2009). Enhancement of lipid production using biochemical, genetic and transcription factor engineering approaches. *Journal of biotechnology*, 141(1), 31-41.

Crooks, A. (2007). Evolving technology may generate profit from biodiesel glycerin glut. *Rural cooperatives*, 31.

DeBusk, G. K., Brown, R. M., & Killough, L. N. (2003). Components and relative weights in utilization of dashboard measurement systems like the Balanced Scorecard. *The British Accounting Review*, 35(3), 215-231.

EIA (2016) World energy demand and economic outlook. Unpublished International Energy Outlook 2016 Report, DOE/EIA Report #0484, Washington DC: US Energy Information Administration.

Escalera, E., Lee, J., Parsons, J., & Rusangiza, I. (2008, April). Biofuel production system analysis. In *Systems and Information Engineering Design Symposium, 2008. SIEDS 2008*. IEEE (pp. 301-305). IEEE.

Falle, S., Rauter, R., Engert, S., & Baumgartner, R. J. (2016). Sustainability management with the sustainability balanced scorecard in SMEs: Findings from an Austrian case study. *Sustainability*, 8(6), 545-561.

Few, S. (2013). *Information Dashboard Design: Displaying data for at-a-glance monitoring*. Analytics Press.

Figge, F., Hahn, T., Schaltegger, S., & Wagner, M. (2002). The sustainability balanced scorecard–linking sustainability management to business strategy. *Business strategy and the Environment*, 11(5), 269-284.

Figge, F. Hahn, T., & Figge, F. (2016). Why architecture does not matter: On the fallacy of sustainability balanced scorecards. *Journal of Business Ethics*, 1-17.

Hansen, E. G., & Schaltegger, S. (2016). The sustainability balanced scorecard: A systematic review of architectures. *Journal of Business Ethics*, 133(2), 193-221.

Holma, A., Koponen, K., Antikainen, R., Lardon, L., Leskinen, P., & Roux, P. (2013). Current limits of life cycle assessment framework in evaluating environmental sustainability–case of two evolving biofuel technologies. *Journal of Cleaner Production*, 54, 215-228.

Kaplan, R. S; Norton, D. P. (1992). The Balanced Scorecard – Measures That Drive Performance. *Harvard Business Review* (January–February), 71–79.

Kaplan, R. S., & Norton, D. P. (2004). *Strategy maps: Converting intangible assets into tangible outcomes*. Harvard Business Press.

Kerzner, H. (2017). *Project Management Metrics, KPIs, and Dashboards: A Guide to Measuring and Monitoring Project Performance*. Hoboken, NJ: John Wiley & Sons.

Keller, P. R., Keller, M. M., Markel, S., Mallinckrodt, A. J., & McKay, S. (1994). Visual cues: practical data visualization. *Computers in Physics*, 8(3), 297-298.

Ku, S. J., & Yoo, S. H. (2010). Willingness to pay for renewable energy investment in Korea: A choice experiment study. *Renewable and Sustainable Energy Reviews*, 14(8), 2196-2201.

Lea, B-R, Beyond ERP: Enhancing Decision Making through Performance Dashboards and Scorecards, in *Readings on Enterprise Resource Planning*, ERPsim Lab, HEC Montréal (ISBN: 978-0-9866653-3-2) 2011.

Lea, B. R., & Nah, F. F. H. (2013, July). Usability of performance dashboards, usefulness of operational and tactical support, and quality of strategic support: a research framework. In *Lecture Notes in Computer Science 8017*, Yamamoto S. (editor), Springer-Verlag, 116-123.

Li, L., Chang, Q., & Ni, J. (2009). Data driven bottleneck detection of manufacturing systems. *International Journal of Production Research*, 47(18), 5019-5036.

Li, Y., Horsman, M., Wu, N., Lan, C. Q., & Dubois□Calero, N. (2008). Biofuels from microalgae. *Biotechnology progress*, 24(4), 815-820.

Liew, W. H., Hassim, M. H., & Ng, D. K. (2014). Review of evolution, technology and sustainability assessments of biofuel production. *Journal of Cleaner Production*, 71, 11-29.

Luhn, H. P. (1958). A business intelligence system. *IBM Journal of Research and Development*, 2(4), 314-319.

Ma, F., & Hanna, M. A. (1999). Biodiesel production: a review. *Bioresource Technology*, 70(1), 1-15.

Macrotrends (2017). Crude oil prices - 70 year historical chart. http://www.macrotrends.net/1369/crude-oil-price-history-chart, retrieved on May 15, 2017.

Marcus, A. (2006). Dashboards in your future. *Interactions*, 13(1), 48-60.

Min, H. (2015). *The Essentials of Supply Chain Management: New Business Concepts and Applications*. Upper Saddle River, NJ: Pearson Education.

Möller, A., & Schaltegger, S. (2005). The Sustainability Balanced Scorecard as a Framework for Eco□efficiency Analysis. *Journal of Industrial Ecology*, 9(4), 73-83.

Murray, S. (2017). *Interactive Data Visualization for the Web: An Introduction to Designing with*. Sebastopol, CA: O'Reilly Media, Inc.

Pauwels, K., Ambler, T., Clark, B. H., LaPointe, P., Reibstein, D., Skiera, B., & Wiesel, T. (2009). Dashboards as a service: why, what, how, and what research is needed?. *Journal of Service Research*, 12(2), 175-189.

Pienkos, P. T., & Darzins, A. L. (2009). The promise and challenges of microalgal□derived biofuels. *Biofuels, Bioproducts and Biorefining*, 3(4), 431-440.

Puich, M., & Paz, A. (2004). Simulations improve production capacity. *Biopharm international*, 17(5), 52-58.

Statistica (2017). U.S. motor gasoline and distillate fuel oil consumption by the transportation sector from 1992 to 2016 (in 1,000 barrels per day). Available at https://www.statista.com/statistics/189410/us-gasoline-and-diesel-consumption-for-highway-vehicles-since-1992/

Telea, A. C. (2014). *Data Visualization: Principles and Practice*. CRC Press: Boca Raton, FL.

Tiwari, P., Kumar, R., & Garg, S. (2006). *Transesterification, modeling and simulation of batch kinetics of non-edible vegetable oils for biodiesel production*. San Francisco: American Institute of Chemical Engineers.

U.S. Energy Information Administration (2017). Oil: Crude and petroleum products explained use of oil. Available at https://www.eia.gov/energyexplained/index.cfm?page=oil_use

Van Kasteren, J. M. N., & Nisworo, A. P. (2007). A process model to estimate the cost of industrial scale biodiesel production from waste cooking oil by supercritical transesterification. *Resources, Conservation and Recycling*, 50(4), 442-458.

Van der Woerd, F., & van Den Brink, T. (2004). Feasibility of a responsive business scorecard–a pilot study. *Journal of business ethics*, 55(2), 173-186.

Xia, D., Yu, Q., Gao, Q., & Cheng, G. (2017). Sustainable technology selection decision-making model for enterprise in supply chain: Based on a modified strategic balanced scorecard. *Journal of Cleaner Production*, 141, 1337-1348.

Yang, F., Hanna, M. A., & Sun, R. (2012). Value-added uses for crude glycerol--a byproduct of biodiesel production. *Biotechnology for biofuels*, 5(1), 13.

Yigitbasioglu, O. M., & Velcu, O. (2012). A review of dashboards in performance management: Implications for design and research. *International Journal of Accounting Information Systems*, 13(1), 41-59.

You, Y. D., Shie, J. L., Chang, C. Y., Huang, S. H., Pai, C. Y., Yu, Y. H., & Chang, C. H. (2007). Economic cost analysis of biodiesel production: case in soybean oil. *Energy & Fuels*, 22(1), 182-189.

Zografakis, N., Sifaki, E., Pagalou, M., Nikitaki, G., Psarakis, V., & Tsagarakis, K. P. (2010). Assessment of public acceptance and willingness to pay for renewable energy sources in Crete. *Renewable and Sustainable Energy Reviews*, 14(3), 1088-1095.

Zorić, J., & Hrovatin, N. (2012). Household willingness to pay for green electricity in Slovenia. *Energy Policy*, 47, 180-187.

Table 3. Data Dictionary of Financial Perspective's KPIs

Measure	Data Point or Formula	Target/planned values *	KPI Type (Leading / Laging / Diagnostic)	KPI Description & Relevance
Yield Volume	Tons of fuel produced	10% increase from prior period	Lagging	• The quantity of fuel produced. • This measure monitors the production volume over time.
Revenue from biofuel	Revenue from fuel / (Revenue from fuel-last year) × 100	3% increase from prior period	Lagging	• It represents the rate of escalation of the sales revenues from biofuel. • Sales trends over a selected time period will be monitored.
Gross Margin	(Net Sales-Cost of Goods Sold)/ Net Sales	3% increase from prior period	Lagging	• The amount of contribution to the business enterprise after cost of goods sold. • The ratio reflects how much the organization spent to produce and sell products.
Revenue from byproducts	(Revenue from byproducts / Total revenue) × 100	3% increase from prior period	Lagging	• Revenue from selling the byproducts like methane, glycerol, animal feed and so forth, obtained from the production process and expressed as a percentage of the total revenue. • The revenue from byproducts plays an important role in reducing the cost of fuel production. But with a high availability of products the demand tends to decrease and leads to a reduced price.
Profit Margin	Net Income / Net Sales	30% of standard fosil fuel profit margin	Lagging	• The ratio measures income generated from every sales dollar and is calculated as net income divided by revenues, or net profits divided by sales. • Profit margin is useful when comparing organizations with competitors and industries. A higher profit margin indicates a more profitable organization that has better control over its costs compared to its competitors. A low profit margin indicates a low margin of safety. There is a higher risk that a decline in sales will erase profits and result in a net loss.
Return on Investment (ROI)	Total sales revenue / Total Assets	3% increase from prior period	Lagging	• The ratio shows the financial growth for every dollar invested and is a common profitability ratio used worldwide. • The ratio can be filtered by different revenue types and asset types to provide additional ad hoc analysis. For example, if the algae growing equipment cost is used in place of total assets, the ratio can also be used to compare the revenue and cost of the algae growing equipment.
Economic value added (EVA)	EVA = Net Operating Profit After Taxes (NOPAT) - (Capital × Cost of Capital)	5% decrease from prior period average	Diagnostic	• A common financial measure of an organization's financial performance based on the residual wealth measured as the Net Operating Profit After Taxes (or NOPAT) minus the monetary cost of capital.

Table 3. Data Dictionary of Financial Perspective's KPI (continued)

Measure	Data Point or Formula	Target/ planned values	KPI Type (Leading / Laging / Diagnostic)	KPI Description & Relevance
Percent of Setup cost to total cost	(Setup cost / total cost) × 100	5% decrease from prior period average	Diagnostic	• The cost of setting up the plant expressed as a percentage of the total cost. This includes equipment, land, and labor cost (engineers/specialists). • A lower setup cost would encourage an organization to invest or enter this industry. A decrease in this value will also mean that the equipment manufacturers are able to reduce their production costs.
Number of customers	Total number of unique customers	5% increase from prior period	Lagging	• The change in the customer base influences the market share. This measure allows management to focus on the individual fuel consumers and track the growth in the number of direct customers
Number of sales Channels	Total number of sales & distribution channels	2% increase from prior period	Leading	• This measure tracks the number of sales channels (e.g., internet store, brick-and-mortar store, dealership) an organization used to sell its products. • An organization can explore and compare sales and distribution channels with the fossil fuel industry. A more creative use of this measure includes collaboration with the fossil fuel industry, airline carriers, and transportation companies.
Public acceptance rate	Actual survey value	3% increase from prior period	Leading	• This survey measures the degree of public acceptance of biofuel and their degree of willingness to pay a premium price for biofuel.
Total government incentives recieved	Total tax rebate + increase in sales due to new regulations and so forth	5% increase from prior period	Lagging	• This measure evaluates the total financial incentives such as tax rebates as well as favorable regulations that were received from different government agencies and external agencies to finance an organization's operations. • This measure can also provide information for future opportunities in the area.

Table 2. Data Dictionary of Business Process Perspective's KPIs

Measure	Data Point or Formula	Target/planned values	KPI Type (Leading / Laging / Diagnostic)	KPI Description & Relevance
Harvest efficiency	(Number of algal cells after harvest / number of cells before harvest) × 100	3% increase from prior period	Leading	• The percentage of algal cells successfully recovered from the culture. A leading KPI as it will lead to future sales. • The number of cells required for fuel production is important, and a small decrease will have a considerable impact on the final outcome. If the actual value falls below the planned value, immediate action can be taken to correct the process.
Cultivation efficiency	(Actual output quantity / Available capacity) × 100	3% increase from prior period	Leading	• The effectiveness of the cultivation process. A comparison of the available capacity and the actual output. • This measure indicates whether a process needs improvement or action.
Production efficiency	(Actual output quantity / Available production capacity) × 100	3% increase from prior period	Leading	• The effectiveness of the fuel production process. A comparison of the available production capacity and the actual output quantity. • This measure indicates whether a process needs improvement or action.
Harvest rate	(Volume of culture processes) / hour	3% increase from prior period	Leading	• The speed at which the cultivated algae is harvested. • The harvest rate and harvest efficiency are dependent on each other. A higher harvest rate will impact the efficiency. Hence it is important to monitor both of these parameters to arive at an optimum value for both.
Marketing Efficiency Ratio	Sales / marketing cost	20 times	Leading	• The amount of sales generated by every dollar spent on marketing.
Anual growth period	Total number of days the environmental factors were in favor	Within 10% variability of 300 days	Diagnostic	• The number of days in a year when the sunlight and other environmental factors were in favor of algae cultivation. • The cost of fuel is greatly affected by the growth period. A decrease from 300 to 250 days can increase the cost by 33%. By comparing this KPI, the researchers can determine if a location is ideal or if the entire production process needs to be suported by other means.
Moisture Content	The actual moisture content captured at the specified time intervals	Within 20% variability control to not exceed 0.5%	Leading	• The percentage of moisture content in the processed algae before it is fed to the fuel production process as a raw material. • If algae with a moisture content that is greater than 0.5% is used to produce fuel, the processing cost increases greatly due to soap formation. Extremely useful information because the moisture removal is dependent on uncontrollable processes like sunlight and temperature.

Measure	Data Point or Formula	Target	KPI Type (Leading / Laging / Diagnostic)	KPI Description & Relevance
Volume of water cleaned	Total volume of waste water processed	3% increase from prior period	Lagging	• The amount of waste water and residue processed over a year. • This measure shows the amount of waste water treated.
Biofuel cycle time	(Fuel production cycle time / Total production cycle time) × 100	3% decrease from prior period	Lagging	• Biofuel cycle time as a percentage of total cycle time (Algal cultivation & extraction time + fuel production time). • This measure indicates which area needs to be focused in case of expansion and production increase. • If the fuel processing time is considerably less than the algae processing time, an increase in algae cultivation will increase the quantity to be processed and, in turn, utilize the speed.
Oil extraction rate	The mass of oil produced per unit volume of the microalgal broth per day	At leat 80 % by weight	Lagging	• Oil productivity depends on the algal growth rate and the oil content of the biomass, so this measure can be used to compare and select proper algae types for a specific cultivation environment.
Contamination rate	The speed at which the algae cells die due to lack of sunlight and/or other factors	Within 3% of variation	Lagging	• Contamination rate can be used to compare and select proper algae types for a specific cultivation environment.
Number of algae strains tested	Actual number	5% increase from prior period	Leading	• The oil content varies with the algae species so it is important to test various algae strains.
Capacity utilization (indoor & outdoor algae growth equipment)	Total volume produced/Total available production capacity	3% increase from prior period	Lagging	• This measure monitors the utilization capacity of the internal algae growing equipment. • It is conducted to find out if it is worth investing in both external equipment and internal equipment at a given plant location.
CO2 Reduction rate	Xi / Yj i: CO_2, CO, SO_2 j = fossil, corn, soy bean, and so forth.	Industry standards of biofuel from corn, soybeans, and other viable biofuel types.	Leading	• This measure identifies the exact amount of CO2, CO, and SO2 reduction compared to fossil fuels. • These three measures are helpful in comparing and selecting algae strains and in promoting biofuel to the public and the government.
CO Reduction rate				
SO2 Reduction rate				

Table 3. Data Dictionary of Sustainability Perspective’s KPIs

Measure	Formula used in this research	Target	KPI Type (Leading / Laging / Diagnostic)	KPI Description & Relevance
Price margin	[(Bio fuel price – fossil fuel price) / fossil fuel price] × 100	20% (taking into consideration the non-tangible benefits)	Leading	• The difference between the price per gallon for fossil fuel and biofuel, expressed as a percentage of the fossil fuel price. • This leading measure indicates how close the biofuel target is to competing with fossil fuel. This measure takes into consideration the efforts of improving the processes and reducing the cost.
Gain in green house gasses (GHG)	(biofuel GHG emission / Acceptable level of GHG) × 100	Industry standards of biofuel from corn, soybeans, and other viable biofuel types.	Leading	• The emission of GHG from biofuel compared to the emission norms, expressed as a percentage of acceptable level. • This leading measure shows the impact biofuels offer on the global environmental effort.
Gain in CFC emission	(biofuel CFC emission / Acceptable level of CFC) × 100	Industry standards of biofuel from corn, soybeans, and other viable biofuel types.	Leading	• The emission of CFC from biofuel compared to the emission norms, expressed as a percentage of acceptable level. • This leading measure shows impact of biofuels offer on the global environment effort.
Public awareness rate- Actual biofuel sold	(Amount of biofuel sold/ amount of fossil fuel sold) × 100	0.1% improvement from prior period	Leading	• The amount of biofuel sold compared to the sales of fossil fuel. • This measure evaluates the willingness of customers to switch to biofuel. The assumption is that both fuels are sold alongside each other, and the amount of both the fuels are available for comparison.
Engine life	[(Age of the engine when run on fossil fuel – age of the engine when run on biofuel) / (Age of the engine when run on fossil fuel)]× 100	Industry average of engine lifespan running on fossil fuel	Leading	• The gain/loss in engine life due to the use of biofuel expressed as a percentage of engine life when run on fossil fuel. • This leading measure addresses customers who may be concerned about the loss of engine life as a result of using biodiesel. • This measure can also serve as an indicator for biofuel researchers to devote R&D efforts to develop biofuel that makes engine life comparable to the life achieved when using fossil fuel.

Table 11. Data Dictionary of Innovation and Learning Perspective's KPIs

Measure	Formula	Target	Type (Leading / Lagging /Diagnostic)	KPI Description & Relevance
No. of new applications of biofuels	Number of new applications or patents of biofuel	2 per period	Leading	• An organization should constantly look for new ways to use biofuel and the byproducts produced during the biofuel production process as it will result in increased market share which leads to increased revenue.
No. of new applications of byproducts	Number of new byproducts applications	1 per period	Leading	
Employee purchase rate	Number of employees using biofuel / Total employees	2% improvement from prior period	Lagging	• This measure evaluates how employees of an organization react and adopt to the biofuels. Furthermore, word of mouth is one of the best ways of spreading awareness and the employees of the organization provide the best testimonials.
Employee process efficiency	The number of tasks performed by an employee	3% improvement from prior period	Leading	• Number of tasks that can be performed by an employee without assistance. • This measure evaluates the employee efficiency in performing a task with continuous improvement efforts that will result in cost reduction.
Employee task efficiency	Time to complete a task without assistance	3% improvement from prior period	Leading	• The amount of time an employee spent completing a task • This measure evaluates employee task efficiency toward continuous improvement efforts that will result in cost reduction.
Employee training efficiency	Number of new tasks preformed / number of hours of training	5% improvement from prior period	Leading	• As an organization needs to continuously train the employees in order to increase the productivity and stay competitive, this leading KPI measures the impact that one hour of training has on the employees' performance.
R&D efficiency	R&D / Expense Sales	1% improvement from prior period	Leading	• This leading KPI evaluates R&D spending recovered from sales by showing the rise in sales from every dollar spent on R&D.

Data Visualization for Assessing the Biofuel Commercialization Potential within the Business Intelligence Framework

Highlights

- Ways to commercialize renewable energy are proposed.
- We examine how eco-friendly and cost efficient renewable energy is as compared to traditional fossil fuel-based energy.
- We assess the eco- and cost-efficiency of renewable energy such as Algae based bio-fuels using data visualization tools.
- We provide guidelines for renewable energy production decisions.