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Article

Assessing Profitability and Environmental Impact of Cleantech Start-up Business Models: A Monte Carlo Simulation

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Abstract The clean technology (cleantech) industry is an exponentially growing sector aimed at producing sustainable products of services that are good for the environment. While these start-ups are producing cutting-edge research with real-world implications, their path to financial and environmental success is tenuous and heavily dependent on their choice of business model. Due to high uncertainty in parameter values and variables pertinent to decision-making, stimulation analyses need to be performed to discuss such choices. We construct a Monte Carlo simulation to evaluate and compare the financial and environmental outcomes of two competing business models: a Business Owned and Operated (B.O.O.) model and a licensing model. The results showed that while a licensing model consistently delivered more environmental benefit, it was also 10% less profitable than a B.O.O. model at their expected values. The analysis identified three main decision points for cleantech start-ups with varying levels of compromise between financial and environmental outcomes. The simulation model is easily adjustable for future cleantech decision-makers, allowing them to choose the right business model and increase their chances of financial and environmental success.

Keywords recycling; cleantech; business model; sustainable operations; simulation

1. Introduction

1.1. Background

The clean technology (cleantech) industry is relatively young and has been emerging since the mid-1990s. It is a subcategory of the "deep technology" industry where innovation is produced with the purpose of helping the environment in some way. As the threat of climate change became more widely recognized by governments, corporations, and consumers globally, the cleantech industry gained more traction and attracted an increasing level of investment spurring advances in technology during the mid-2000s [1,2]. Cleantech generally refers to four broad sectors: materials, water, transportation, and energy. A cleantech company's product or service aims to deliver the same value that the incumbent technologies do—but in a manner that is significantly more environmentally sustainable and affordable [3]. A simple example is a newly developed electric vehicle (EV) that provides the same transport function a traditional internal combustion engine vehicle does. However, an EV has the ability to use clean energy and not emit greenhouse gases (GHG), whereas a traditional car burns fossil fuels which releases copious amounts of GHG emissions. A more recent example is the low carbon recovery of metals from electronic waste which are returned into the circular economy.

A large proportion of cleantech companies focus on developing facilities that either provide a "clean service" or product within the four sectors mentioned earlier. An energy example would be the company Orsted, the largest renewable energy producer in the world [4]. Orsted produces wind, solar, and hydrogen energy through their energy farms to compete with the conventional fossil fuel energy market and provide a low-carbon source of electricity to cities. Similarly, companies such as Lanzatech compete in the fuels, fabrics, and packaging market by converting waste carbon dioxide gas from steel mills into ethylene through engineering specialized biocatalysts. These companies operate by building facilities that carry out their developed processes and establish them across the globe. Given the relatively nascent stage of the industry and the low R&D risk appetite of big corporations, cutting-edge but risky sustainable technology is generally developed by start-ups who attempt to commercialize these facilities across the world.

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1.2. Positive Environmental Impact

The term "environmental impact" has been used with negative connotations over several decades. Therefore, it is important to explicitly state that this study is measuring the "positive" environmental impact delivered by each facility that the start-up produces. Environmental impact, whether it's positive or negative, can take different forms and therefore is difficult to compare fairly across cleantech sectors. However, the common downstream effect of all cleantech activities is the mitigation of GHG. CO_2 as the headline indicator—with regard to climate change indicators, the Intergovernmental Panel on Climate Change (IPCC) declared anthropogenic CO_2 in the atmosphere provides the largest warming effect of all the GHG [5]. While other GHG have more potent heat-trapping ability per molecule when compared to CO_2 (e.g., methane) they are present in the atmosphere at significantly lower levels. Furthermore, there has been extensive analysis of industrial processes with regard to their individual CO_2 emissions and these are databased and offered to companies in order to assist them in calculating their own CO_2 impact, set reduced targets, and work on any CO_2-intensive activities. This makes atmospheric CO_2 an optimal comparator for this study and what is referred to when stating "GHG emissions mitigated". It is this unit of measurement in tonnages that will be used so that the model generated can be applied to any branch of cleantech.

1.3. The Cleantech Trade-off

Unlike the incumbents, these facilities can be profitable while also producing a positive environmental impact. However, the ratio between these two desired outcomes is highly dependent on the type of business model a cleantech company utilizes. There are many models available to cleantech companies such as a build, own and operate (B.O.O.) model, a franchising model, a joint venture, or a licensing model. While business models have overlapping functions and capabilities, the B.O.O. model and licensing model can be considered to be diametrically opposing each other, providing a company with different sets of strategy, competitive edge, or growth forecast. As such, an analysis of the profitability and positive environmental impact of these two models is paramount given the state of the climate, the robust nature of the cleantech industry, and the tenuous commercialization journey of a cleantech start-up.

1.4. Research Question and Purpose

To fairly assess the financial and environmental implications a business model choice can make on a cleantech start-up, this study analyzes the effect of business model choice on profitability and the environmental impact of a clean-technology start-up. Start-ups across industries have a difficult commercialization journey, and many cleantech start-ups fail due to not achieving their primary outcomes: financial growth, and a positive environmental impact [6]. Bumpus et al. [6] highlight that many of these start-ups are pre-revenue until they reach commercial scale, and as such they are capital-restricted causing profitability to be a critical success factor for them. This capital restriction, and the company's purpose of benefiting the environment, become core decision-making factors when choosing which business model to employ. The model chosen will potentially pose a trade-off between these two desired outcomes and will likely dictate the company's fate until they reach a scale where they can afford to make mistakes. Naturally, such a decision will pose many uncertain variables that are difficult or almost impossible to account for all at once. A common solution to this issue is a Monte Carlo Simulation (MCS) which allows a decision-maker to capture every pertinent variable and simulate their respective variability at once. This is commonly used in a variety of contexts from natural sciences to election result predictions as it is able to include multiple simultaneous changes in variables simulating real life as opposed to changes in a single variable at a time from a standard sensitivity analysis [7]. Such an approach can be used to calculate the Net Present Value (NPV) of projects and take into account important aspects such as operating cost (OPEX) and capital expenses (CAPEX) [8]. The statistical model produced will allow future readers to apply and easily adjust the equations produced towards their specific cleantech industry and uncertainties. By doing so, a decision-maker can make informed choices on which business model to employ and increase the start-up's chances of survival and environmental success. There is a plethora of statistical analyses done on cleantech firms regarding factors affecting their financial performance or environmental performance. However, they do not assess the potential compromise in the same context and therefore would have to be compared against each other with a set of bold assumptions. This is a gap that this study aims to bridge and provide a widely usable tool for future cleantech start-ups. The model and the spreadsheet-based simulation in this study are developed to be modular, where a user can use values of any of the parameters included, such as CAPEX or OPEX, that are respective to their specific industry. The model also allows adding or subtracting further parameters for a higher level or more granular simulation. By doing so, managers can compare the financial and environmental impacts of alternative business models available to them for any given cleantech start-up and any industry.

2. Method

Constructing a MCS requires a set of equations to be built—these must be able to estimate the profitability and positive environmental impact achieved by both the B.O.O. model and the licensing model. Calculating the net present value of both models is a viable method to assess the profitability of both models. To produce a fair analysis, both will be discounted at the same rate and have the same time period. An approach taken by the Finnish government evaluating the regulatory and environmental hurdles to the deep tech industry is an appropriate precedent for this [9]. Similarly, the positive environmental impact will be calculated through the tonnes of greenhouse gases mitigated by each model. This equation does not have any discount factor; however, the expected value of GHG emissions mitigated will be different for each model as will their respective level of uncertainty. Using these equations to perform a Monte Carlo Simulation on Microsoft Excel will produce NPVs and inform the tonnes of GHG emissions mitigated for each model while accounting for the uncertainties prescribed to every variable considered for each equation. The four sets of results will then be graphed so that each model's merits and limitations can be analyzed visually. If there is a compromise, then the graph will illustrate which model is more profitable and at what environmental cost (or vice versa). If instead one of the models mitigates more GHG emissions and also results in a higher NPV—this will be visually clear on the final graph.

2.1. Equations

There are two primary outcomes to calculate: profitability and positive environmental impact. These are to be calculated under two different scenarios, one where the company chooses a purely B.O.O. model, and the other where it chooses a purely licensing model. Each of these outcomes requires its own equation, variables with an expected value, and a level of uncertainty prescribed as a standard deviation.

2.1.1. B.O.O. Model: Profitability

The build, own, and operate model incurs a minimum of two costs to the company—the CAPEX and OPEX of a facility. Naturally, the CAPEX would be a relatively large cost while OPEX is a lower but recurring cost. The revenue is deducted from these two primary costs resulting in the profit produced by a single facility. We assume the maximum number of facilities the cleantech start-up can afford to build is limited, that is, they cannot build as many facilities as they want. This is a reasonable assumption as most start-ups are limited in budget.

We assume the capital cost of building cleantech facilities is uncertain and we assume normal distribution to capture this uncertainty, which is common in MCS. Hence, the costs of the CAPEX, denoted by C is $C \sim N(\mu, \sigma)$.

To illustrate the MCS, we create a numerical example by generating parameter values. Parameter values are adjusted based on one of the authors' experience from working in a cleantech start-up. Hence, although the numerical values are not precise figures for any specific start-up, they are adjusted w.r.t. proportional relations between parameter values for cleantech start-ups. Therefore, although on an arbitrary scale, our numerical example could be a proper proxy for the Simulation of cleantech start-ups. In the case of CAPEX, we have assigned it a value of USD 15,000,000. As such, we acknowledge that real parameter values could be different for different industries. To account for this, a future user of this simulation could change this value to reflect the CAPEX of building a nuclear power plant or building a simple waste collection bin. Similarly, numerical examples for standard deviation are created to reflect the level of uncertainty attached to each parameter. In the case of CAPEX, a standard deviation value of USD 300,000 was chosen to reflect a low-risk level of ±2%.

$$C \sim N(\mu, \sigma) \rightarrow C \sim N(\$15\text{M}, \$300\text{K}) \quad (1)$$

We acknowledge that the standard deviation value could differ between industries, parameters, and how conservative or optimistic a user wishes to produce the simulations. One can increase or decrease the standard deviation to produce more conservative or optimistic (respectively) results based on their circumstances. Table 1 summarizes the numerical examples chosen to run the simulation.

For OPEX, as Table 1 shows, we choose a figure of USD 600,000 per annum to represent the operational cost of cleantech facilities. The level of uncertainty prescribed to the OPEX is USD 100,000. Unlike CAPEX, this high level of uncertainty cannot be mitigated in a B.O.O. model, even though the fiscally lean start-up is directly operating it. When building the equation, the OPEX will be denoted by O, its value as \$600K, its standard deviation as \$100K and it will be normally distributed.

$$O \sim N(\mu, \sigma) \rightarrow O \sim N(\$600\text{K}, \$100\text{K}) \quad (2)$$

For this study, a revenue figure of USD 6,000,000 per annum is used. The level of uncertainty prescribed to the revenue is USD 600,000. Similar to OPEX, this uncertainty is primarily dictated by external factors and cannot be mitigated in the B.O.O. model, even though the facility is operated by expert staff. When building the equation, the revenue will be denoted by R, its value as \$6M, its standard deviation as \$600K and it will be normally distributed.

$$R \sim N(\mu, \sigma) \rightarrow R \sim N(\$6\text{M}, \$600\text{K}) \quad (3)$$

For this study, the expected number of facilities built by the start-up is 10 facilities. The level of uncertainty prescribed to this variable is three facilities. When building the equation, the "number of facilities" variable will be denoted by F, its value as 10, its standard deviation as 3 and it will be normally distributed.

$$F \sim N(\mu, \sigma) \rightarrow F \sim N(10{,}3) \quad (4)$$

Naturally, this figure will vary depending on the branch of cleantech innovation; however, it presents a reasonable level of uncertainty which can be applied to any cleantech context.

This NPV figure must be deducted from the initial capital investment (Equation (1)) to result in the mean simulated profits of a single facility. This is done outside of the NPV calculation as shown in Equation (5):

$$\text{NPV} = \sum_{t=1}^{10} \frac{R_t - O_t}{(1+0.1)^t} - C \quad (5)$$

where $R_t \sim N(\$6\text{M}, \$600\text{K})$, $O_t \sim N(\$600\text{K}, \$100\text{K})$ and $C \sim N(\$15\text{M}, \$300\text{K})$. We assume a discount factor of 10% for discounting future payoffs. The rate we adopt is based on those calculated for the local economy (New Zealand) based on the Capital Asset Pricing Model (CAPM) and Weighted Average Cost of Capital (WACC) methods [10], which we round up to 10%. It is worth noting that this rate could be different for start-ups in other economies [11]. Furthermore, depending on the economy, the discount factor could be uncertain as well. However, in the interest of simplicity and keeping the focus on the comparison of cleantech business models in a stable economy, we do not assume uncertainty for the discount factor. As Equation (5) applies to every single facility individually—this entire equation can simply be multiplied by the number of facilities simulated ($F \sim N(10{,}3)$)—which results in the Mean Simulated Profits (MSP) for the B.O.O. model:

$$\text{MSP}_{\text{BOO}} = \left[\sum_{t=1}^{10} \frac{R_t - O_t}{(1+0.1)^t} - C\right] \times F \quad (6)$$

where $R_t \sim N(\$6\text{M}, \$600\text{K})$, $O_t \sim N(\$600\text{K}, \$100\text{K})$, $C \sim N(\$15\text{M}, \$300\text{K})$ and $F \sim N(10{,}3)$. This equation can be applied in a MCS using Excel. In this study, it will be simulated 500 times and averaged resulting in the mean simulated profits.

Table 1. Numerical examples and Standard Deviation of each parameter.

Parameter	Unit of Measurement	Numerical Example	Standard Deviation Example
CAPEX	USD	15,000,000.00	300,000.00
OPEX	USD	600,000.00	100,00.00
B.O.O Revenue	USD	6,000,00.00	600,00.00
B.O.O Number of Facilities	-	10	3
Licensing Revenue	USD	900,000.00	45,000.00
Licensing Number of Facilities	-	30	5
B.O.O Positive Environmental Impact	Tonnes of Greenhouse Gasses mitigated	100	5
Licensing Positive Environmental Impact	Tonnes of Greenhouse Gasses mitigated	50	15

2.1.2. Licensing Model: Profitability

Unlike the B.O.O. model, the licensing model incurs no costs as none of the facilities are built or operated at the start-up's expense. However, the facilities themselves are not owned by the start-up and therefore neither are the profits—which are instead owned by the licensing company. Instead, start-up receives royalties from the licensee for letting them use their Intellectual Property (IP). Where the B.O.O. model was contingent on the number of facilities being built—the licensing model relies on the number of license deals formed (D) and we assume that *Revenue = Profits*.

For this study, royalty payments of USD 900,000 are used—this is 15% of the expected revenue of a facility (USD 6 million—rationale outlined in Section 2.1.1). The uncertainty prescribed to this is USD 45,000 or 5%. This is half of the prescribed uncertainty rate in the B.O.O. model. This revenue stream is not affected by any internal factors. When building the equation, the royalty revenue will be denoted by RR, its value as 900K, its standard deviation as 45K and it will be normally distributed.

$$RR \sim N(\mu, \sigma) \rightarrow RR \sim N(\$900\text{K}, \$45\text{K}) \tag{7}$$

While the number of deals figure would vary based on these and many more factors, in this study it is assumed the likely maximum number of deals the start-up can create is 30 and the level of uncertainty is 5—which is one-sixth of the total deals created. This uncertainty takes into account the strong market demand for cleantech, but also the poor economic climate that licensees are currently experiencing. When building the equation, the number of deals will be denoted by D, its value as 30, its standard deviation as 5, and will be normally distributed.

$$D \sim N(\mu, \sigma) \rightarrow D \sim N(30{,}5) \tag{8}$$

This representative figure was also determined through the author's experience working in a cleantech start-up. As the start-up incurs no costs in this model—the cashflow variable will simply be the revenue variable:

$$RR = \sum_{t=1}^{10} \frac{RR_t}{(1+0.1)^t} \tag{9}$$

where $RR_t \sim N(\$900\text{K}, \$45\text{K})$ and t is 10 years. This NPV figure now calculates the profits generated by a single license deal over 10 years, with the same discount rate of 10%. This figure now needs to be multiplied by the number of license deals D to result in the mean simulated profits for the licensing model:

$$\text{MSP}_\text{L} = \left[\sum_{t=1}^{10} \frac{RR_t}{(1+0.1)^t}\right] \times D \tag{10}$$

where $RR_t \sim N(\$900\text{K}, \$45\text{K})$ and $D \sim N(30, 5)$. Equation (10) can be applied in a MCS using Excel. In this study, it will be simulated 500 times and averaged resulting in the mean simulated profits.

2.1.3. B.O.O. Model: Positive Environmental Impact

While the use of "tonnes of GHG emissions mitigated" as a metric can be defended, the volumes assigned to the B.O.O. model and licensing model are not intuitively justifiable as different types of clean technology will mitigate vastly different quantities of GHG emissions. However, this study is not exploring the exact quantities of GHG emissions mitigated by the B.O.O. model or licensing model, but rather the difference in effectiveness between the two as a result of the quantity of facilities and correct/incorrect use of technology. As such, it will be assumed that the B.O.O. model represents 100% (or 100 tonnes in absolute terms) of GHG mitigated, while the licensing model will mitigate a lower percentage. The level of uncertainty prescribed to this metric is set at ±5% or ±5 tonnes of GHG emissions mitigated. When building the equation, the level of positive environmental impact will be denoted as BE, its value as 100, its standard deviation as 5, and it will be normally distributed.

$$X \cdot N(\mu, \sigma) \rightarrow BE \cdot N(100{,}5) \tag{11}$$

This figure was also determined through the author's experience working in a cleantech start-up and presents a reasonable level of uncertainty to what this study considers is "maximum output". As discussed, the number of facilities built by the start-up is assumed at a maximum level of 10 facilities. The level of uncertainty prescribed to this variable is three facilities. When building the equation, the "number of facilities" variable will be denoted F, its value as 10, its standard deviation as 3, and it will be normally distributed.

$$X \cdot N(\mu, \sigma) \rightarrow F \cdot N(10{,}3) \tag{12}$$

This figure was also determined through the author's experience working in a cleantech start-up. Naturally, this figure will vary depending on the branch of cleantech innovation; however, it presents a reasonable level of uncertainty which can be applied to any cleantech context. When multiplied by the total number of facilities, the total equation for the Mean Simulated Positive Environmental Impact (MSPEI) is the following:

$$\text{MPSEI}_{\text{BOO}} = BE \times F \tag{13}$$

where $BE \sim (100{,}5)$ and $F \sim N(10{,}3)$. This equation can be applied in a MCS using Excel. In this study, it will be simulated 500 times and averaged resulting in the MSPEI.

2.1.4. Licensing Model: Positive Environmental Impact

This study assumes that the licensing model will only produce a fraction of the positive environmental impact that a B.O.O. model can, being 50%, or in absolute terms 50 tonnes of GHG emissions mitigated. This is a heavily discounted figure compared to the B.O.O. environmental figure. Similar to the rationale outlined when discussing profitability in a licensing context, the facility will be built and operated by non-experts who did not develop or own the IP. As such, it is fair to assume that they cannot maximize output from the facility the same way the cleantech's internal staff would be able to.

Additionally, in today's commercial climate, with corporations adopting Environmental Social Governance practices and leaving behind the "triple bottom line" requirements, their commitments to more sustainable practices or investments are far more susceptible to greenwashing than before. As such, it is entirely plausible that large companies that have made public statements about their commitments to sustainability would license the start-up's technology for greenwashing. By licensing the clean technology, companies can show in audits that they are in fact investing portions of their capital into sustainability; however, this does not necessarily imply that they are applying this technology to their practices or supply chains.

Collectively, these plausible scenarios limit the level of positive environmental impact that a licensed facility can deliver which is why this study assumes there is little to no scope for it ever producing more than a B.O.O. facility. As the B.O.O. model is a benchmark at 100% environmental output—the relative efficiency or a licensing model will be set at 50% which equates to 50 tonnes of GHG emissions mitigated per annum for a single facility. Furthermore, given the possible combinations of these negative factors (and inverse), the level of uncertainty prescribed to this will be 15 tonnes which is 30%. When building the equations, the level of positive environmental impact will be denoted by LE, its value as 50, its standard deviation as 15, and it will be normally distributed.

$$LE\sim N(\mu,\sigma) \to LE\sim N(50{,}15) \tag{14}$$

This figure was also determined through the author's experience working in a cleantech start-up and presents a reasonable discount to the maximum output that a B.O.O. model can produce. As discussed, the number of license deals produced is set at 30 deals. When building the equation, the number of deals will be denoted by D, its value as 30, its standard deviation as 5, and will be normally distributed.

$$D\sim N(\mu,\sigma) \to D\sim N(30{,}5) \tag{15}$$

This representative figure was also determined through the author's experience working in a cleantech start-up. As before, the mean simulated positive environmental impact is a multiplication of Equation (14) by the number of deals formed:

$$\mathrm{MSPEI_L} = LE \times D \tag{16}$$

where $LE\sim N(50{,}15)$ and $D\sim N(30{,}5)$. This equation can be applied in a MCS using Excel. In this study, it will be simulated 500 times and averaged resulting in the mean simulated positive environmental impact.

2.2. Constructing Monte Carlo Simulations

The developed equations outlined in the method section so far need to be translated into an Excel Simulation Spreadsheet to run a MCS. One could use subscription-based simulation software, such as Crystal Ball or Analytics Solver, to run the MCS. Nonetheless, we develop an Excel Simulation Spreadsheet as it is easily accessible to many although developing Simulation Spreadsheets may take time.

First, an individual simulation with the expected value, its prescribed standard deviation, and their relationship needed to be defined and run with a normal distribution first. Once the variable's expected value was populated in their respective cells, their respective standard deviations were set in a corresponding cell and a randomized number based on those two factors was programmed in another cell below them. The first simulation was then programmed based on those randomized numbers and the respective equation in a results cell. Using the "what if" analysis function under the data tab, the simulation was programmed to repeat 500 times as its own distinct trial. The collective data is bundled and identified by Excel with a name respective to its interval (one out of the seven intervals) and its equation. The average of the 500 trials was taken and considered either the mean simulated profits or the mean simulated positive environmental impact for both the B.O.O. model and the licensing model.

2.3. Collective Assessment of B.O.O. and Licensing Model

The MCS was run seven times (once for every interval) with 500 trials each with the same expected values—the mean results of these seven runs were then plotted on a graph to observe potential changes in either profit or positive environmental impact. The seven intervals were used to assess the changes in a single variable—the number of facilities (when assessing the B.O.O. model) or the number of deals (when assessing the Licensing model). The seven runs were instead seven intervals when changing the expected value of facilities of deals formed. This was to map the changes in profit or positive environmental impact when the volumes of facilities change as opposed to their input and/or output. When assessing the B.O.O. model, the intervals were 7, 8, 9, 10, 11, 12, and 13 facilities built by the start-up with 10 being the original expected value. When assessing the licensing model, the intervals were 21, 24, 27, 30, 33, 36, and 39 license deals made by the start-up with 30 being the original expected value. However, when being compared against each other, the B.O.O. model is kept consistently at its expected value—10 facilities. This is because the requirements for scaling up a B.O.O. model to more facilities are far more difficult to achieve (such as a new round of capital raising, or debt financing) than that of a licensing model (which would require more business development or loosening of stringent contract terms to attract licensees). By comparing these contrasting graphs, the point of intersection will show which model will more easily achieve the same level of profits and/or positive environmental impact.

3. Analysis and Results

3.1. Individual Comparisons

Once the equations were formed for the following points:

- B.O.O. Model: Profitability;
- Licensing Model: Profitability;
- B.O.O. Model: Positive environmental impact;
- Licensing Model: Positive environmental impact.

To compare the two models, one must remain consistent while the other varies. In the context of these two models, the B.O.O. model must remain consistent compared with the licensing model as the process of scaling up a licensing model is far more feasible and achievable than a B.O.O. model for a start-up. This is due to a variety of factors, the key factor being the lack of capital to build more facilities than the expected value. To scale up the number of facilities built and consider the B.O.O. model on a varying scale such as the licensing model, the start-up would be required to acquire more capital through means such as a capital raise, government grants, or debt financing. None of these options are as easy as the requirements placed on scaling up a licensing model, nor are they certain and often would cost the start-up heavily in the form of compromising equity to an investor or heavy interest payments to a debt financer. As such, the primary comparisons will be made with a consistent B.O.O. model at its expected value (10 facilities) against a varying number of licensing facilities (21 to 39 with intervals of three facilities). By comparing these contrasting graphs, the point of intersection will show which model will more easily achieve the same level of profits and/or positive environmental impact.

3.2. Profitability

Figure 1 depicts the change in mean simulated profits as the number of deals achieved in a licensing model changes, overlayed with the mean simulated profits produced by 10 facilities in a B.O.O. model repeated seven times.

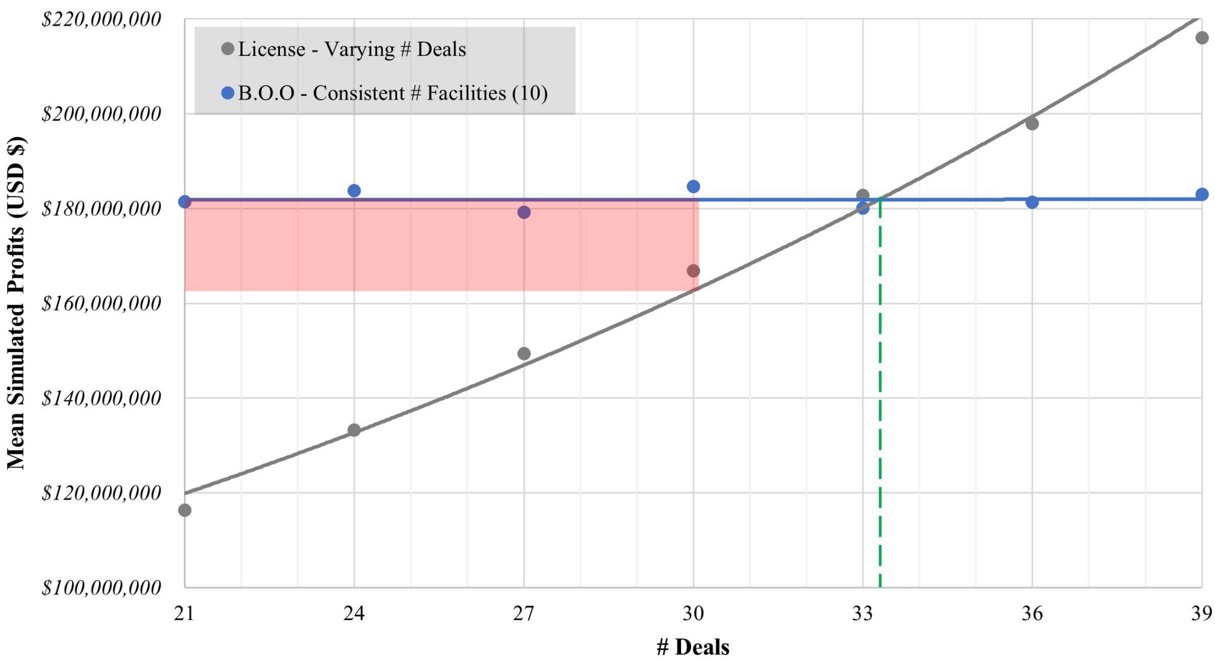

Figure 1. MSPs of B.O.O. Facilities versus MSPs of Varying Numbers of License Deals.

The purpose of choosing this combination to graph together is to assess the effectiveness of the licensing model against the consistent B.O.O. model results. The blue line (B.O.O.—consistent # facilities (10)) is almost completely flat (R-squared = 9×10^{-5}) which means we can confidently say that MSPs are ~$180,000,000 with every simulation while accounting for the inherent uncertainties. If both the models were equally effective at producing profits, one factor noticeable on the graph would be the intersection of the two lines being at 30 deals—which is the expected value for the licensing model. Instead, the graph shows the intersection to be at just past 33 license deals (33.3 which must be rounded up to 34). This implies that the number of deals necessary to achieve the same MSPs as 10 B.O.O. facilities is higher than the expected number of license deals. To simplify, ~13% more license deals than expected are equal to the expected number of B.O.O. facilities suggesting that it is not as profitable a model at their respective expected values. At the expected value of the number of deals formed (30), it is shown by the red box that there is a significant difference in MSPs between 10 B.O.O. facilities and 30 license deals. Calculating the difference in MSP between 10 B.O.O. facilities and 30 licensed facilities, it appears that the B.O.O. model is 9.5% more profitable than the licensing model at their respective expected values.

3.3. Positive Environmental Impact

Using the same comparison approach taken for profitability, the positive environmental impact will be first assessed by comparing the MSPEIs of the consistent expected value of the number of facilities (10) versus a varying number of licensing deals. Without doing any calculations, one can immediately infer from Figure 2 that the expected value of B.O.O. facilities does not produce as much of a positive environmental impact as the licensing model does—with any number of license deals. Even at the lowest number of deals considered (21), the licensing model still mitigates 1053 tonnes of GHG emissions whereas the 10 B.O.O. facilities only mitigate 1006 tonnes. This clear difference suggests that the licensing model is very clearly the better choice for achieving maximum environmental impact—despite the multiple layers of added uncertainties and discount factors associated with it compared to a B.O.O. facility. To understand the exact level of inefficiency, the two equations were used to calculate the intersection points, indicating how many license deals will produce the same MSPEI as 10 B.O.O. facilities. Using the equations: $y = 531.37e^{0.0339x}$ and $y = 1001.5e^{-1E-04x}$, the point of interception was calculated to be 18.641059. This implies that the 18.6 license deals can produce the same level of positive environmental impact as the MSPEI of the expected value of the number of B.O.O. facilities. This cannot be graphically shown as the point of interception is lower than the lowest number of license deals even considered—further highlighting the difference in efficiency.

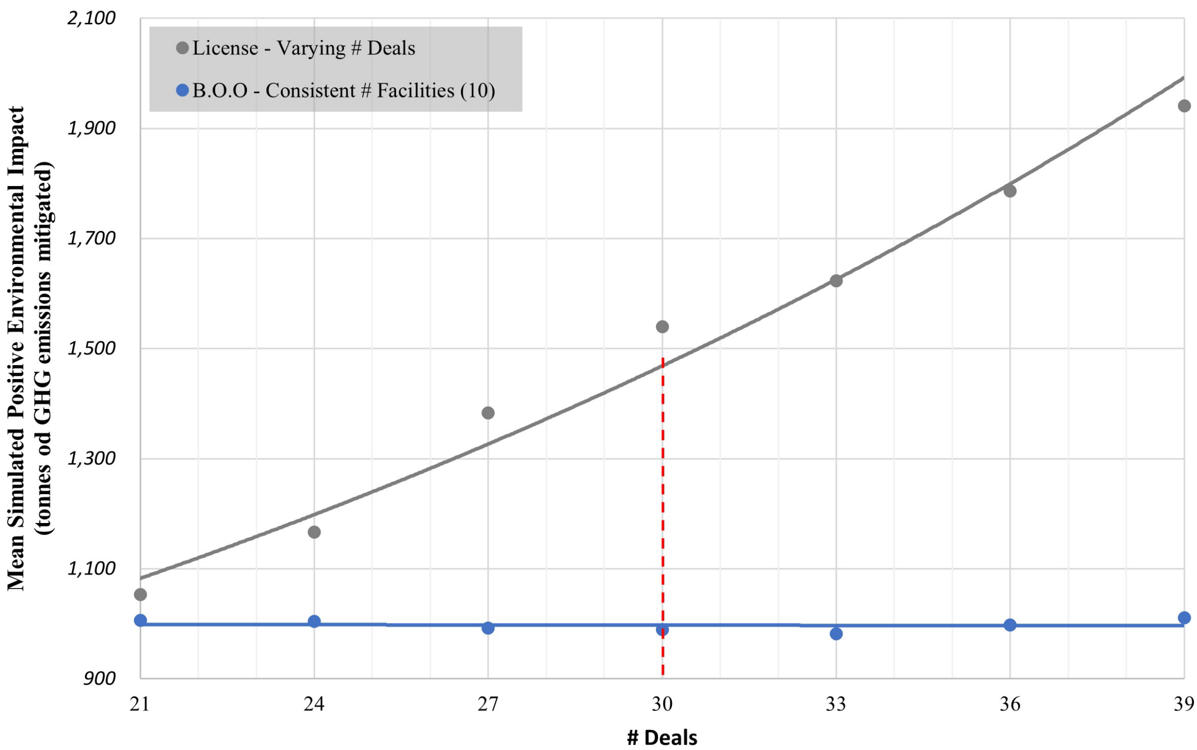

Figure 2. MSPEIs of 10 B.O.O. Facilities versus Varying Numbers of License Deals.

Comparing the expected values of both models (shown by the red dashed line in Figure 2), a difference greater than 450 tonnes is clearly visible. Using the numbers produced by the simulation, the level of positive environmental impact produced by 30 license deals is 54% higher than what 10 B.O.O. facilities can achieve.

3.4. Comparative Results

Figure 3 illustrates the compromise between MSP or MSPEI when choosing the B.O.O. model or the licensing model. Comparing the profitability of both models clearly shows the B.O.O. model to be more profitable—highlighted by the vertical red arrow labeled L-30. At their respective expected values, the B.O.O. model is 9.5% more profitable than the licensing model. Furthermore, the intersection between the two models' profitability lines (highlighted by the dashed orange vertical line) shows that 33.3 (rounded up to 34 deals as 0.3 deals is not possible) license deals are necessary to achieve the same MSP as the B.O.O. model at its expected value indicating that the start-up will need to overperform the licensing model by 13% if they wish to achieve the same MSP.

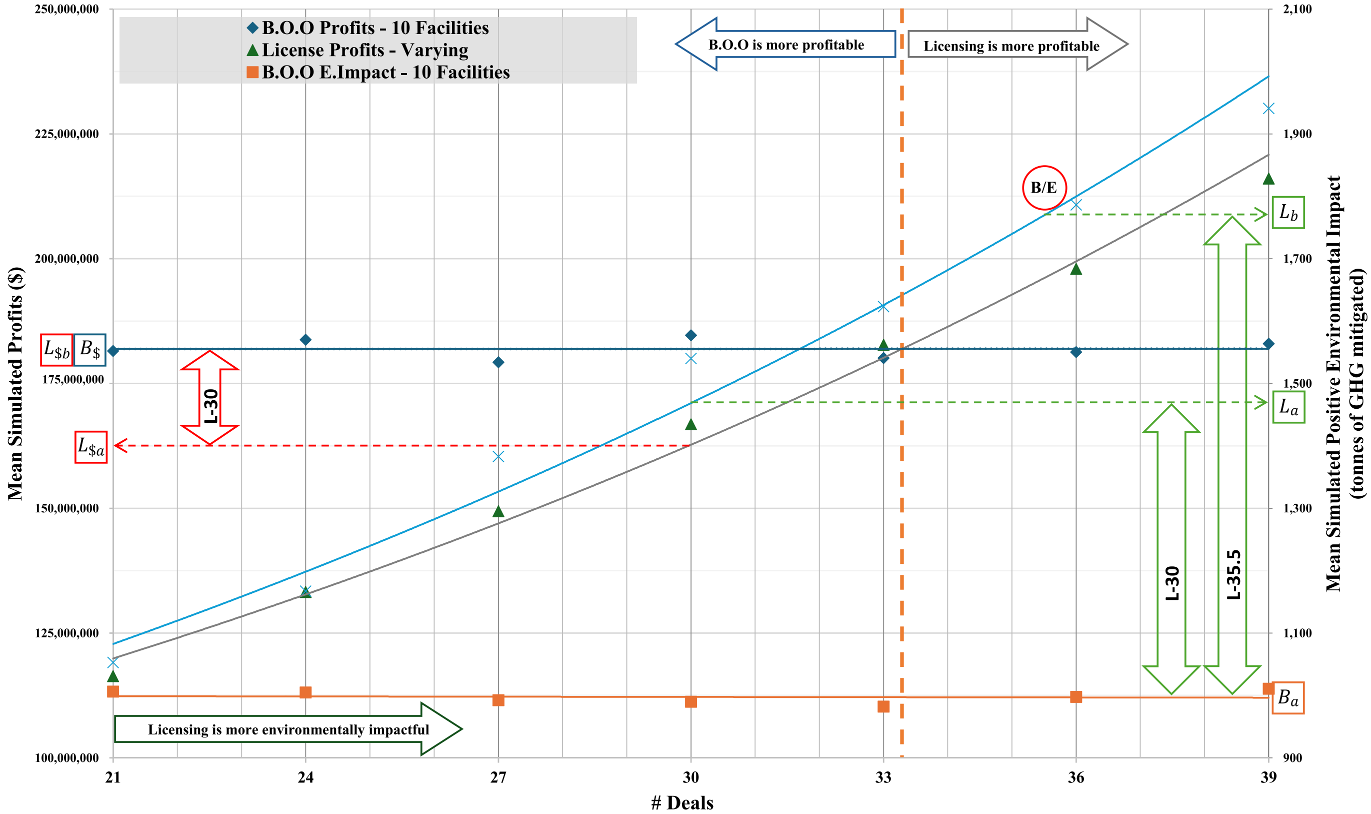

Figure 3. Graph plotting MSPs and MSPEIs of 10 B.O.O. facilities (consistent) against those of a varying number of license deals (21 to 39).

Comparing the MSPEI on the other hand, the trendlines do not intersect within the graph parameters at all—indicating that the licensing model achieves a higher MSPEI than the B.O.O. model at every level of deals or facilities formed. By choosing the B.O.O. model, the start-up would be compromising on MSPEI (highlighted by the vertical green arrow labeled L-30). If the start-up chooses to attempt achieving 33.3 license deals, to diminish the compromise on MSP, the difference between MSPEI will be even larger—highlighted by the vertical green arrow labeled L-33.3. As such, Figure 3 identifies three options for a start-up to choose from, each with its own risks and compromises. Firstly, choosing the B.O.O. model at its expected value—defined by the horizontal blue and orange lines marked $B_\$$ and B_a. The second option is to choose the licensing model at its expected value which is 30—the results from this are shown through the dashed horizontal red and green lines marked $L_{\$a}$ and L_a (respectively). The third option is to choose a licensing model at the intersection points for MSP which was 33.3 license deals indicated by the vertical dashed orange line and the breakeven mark.

4. Discussion

4.1. Decision Points

Table 2 summarizes the benefits and compromises of choosing either licensing option (expected value or 33.3 deals) against the MSP and MSPEIs of 10 B.O.O. facilities.

Table 2. Financial and environmental outcomes and achievability of the EV-L and 33.3L against EV B.O.O. option.

	Expected Value Licensing Model (EV-L)	Expected Value B.O.O. Model	33.3 deals Licensing Model (33.3-L)
Profitability	−10%	N/A	0%
Positive Environmental Impact	+35%	N/A	+40%
Achievability	100%	100%	87%

4.1.1. EV B.O.O. versus EV-L

The results present a clear compromise between the two primary outcomes for the start-up. They can choose the EV-L option to mitigate 35% more GHG emissions but at a 10% cost in profits. If the importance of these two outcomes is assumed to be equal, then the decision-makers should very clearly elect the EV-L option as there is a net benefit of 25%. Given that the value of these outcomes is subjective, and the prioritization dependent on what financial stage the start-up is in, If the company is able to forego high levels of initial positive environmental impact, then the EV B.O.O. model may prove to be a better decision than EV-L in the long run.

4.1.2. EV-L versus 33.3-L

An initial assessment would suggest that 33.3 deals is the ideal option as it produces more environmental benefit than both the other options without compromising on profits. However, compared to the EV-L option, it is only 5% more environmentally beneficial and is 13% less likely to be achieved. Attempting to achieve an additional 13% licensing success could be easily justified if it resulted in either 13% more profits or 13% more environmental benefits. However, it only achieves a 10% higher MSP and a 5% higher MSPEI resulting in a collective net benefit of 15%—meaning the benefits very narrowly outweigh the risks by 2% (1.5% rounded up). A 2% difference may not justify an immediate decision to elect the 33.3-L option and would require further analysis.

4.1.3. EV B.O.O. versus 33.3-L

Assessing the 33.3-L option against the EV B.O.O. option presents a similar judgment call. If financial and environmental gains are once again assumed to be equally important, then the cost-to-benefit analysis sways in favor of 33.3-L as the overall net benefit is 40%. Similarly, the risk analysis is a net gain as the 13% decrease in achievability is offset by the 40% environmental gain. Such an evaluation would immediately paint the 33.3-L option as a clear winner. However, if the start-up is not able to achieve a minimum of 34 deals (33.3 license deals rounded up), then not only is the 40% increase in an environmental benefit not achieved, but the 0% increase in financial gains enters the negative and poses a loss to the company, compounding the net loss at a rate of $5.5M per license deal. With every extra required deal not met, the narrowly positive risk-to-benefit situation quickly becomes negative as both the 10% MSP increase and the 5% MSPEI increase is lowered.

4.1.4. Model Options Summary

The compromises between profitability and positive environmental impact are made clear in Table 2. The net gain or loss however is dependent on the subjective value placed on financial or environmental gains—as such, the numbers in Table 2 must be adjusted to the ratio that a decision-maker chooses. However, in any case, it can be inferred that the 33.3-L option presents a risk-to-benefit analysis that is too close for a confident decision to be made. External market factors and internal company factors such as strategy and financial position may influence a decision-maker's choice between *EV-L* or *EV B.O.O.* This is however a holistic evaluation of the results and can influence a start-up's decision differently based on their immediate and long-term goals and strategy to achieve them. A company's ability to switch between models in response to their environment may also result in them electing the EV-L option initially and then adopting the EV B.O.O. option when ideal (or vice versa).

4.2. Mutual Exclusivity of Licensing Models

So far, the two licensing options discussed have been considered as separate options, and choosing either would incur an opportunity cost. Outside the context of the results produced by this MCS, the licensing option requiring a minimum of 34 deals means it is essentially an ambitious version of the expected value licensing option. The 33.3-L option functions under the key assumption that the start-up would lose value if they were not able to achieve the required number of deals. However, it can be also argued that this option poses no risk or potential value loss as the alternative EV-L option is essentially an achievable backup plan. As they both require the same strategy to achieve, even if a start-up committed to the 33.3-L goal falls short of three deals—they will still be achieving the same, or a higher MSP and MSPEI than a strictly EV-L approach would. This logic implies that if the start-up is comfortable with the MSP and MSPEI that the EV-L model achieves and that a licensing model aligns with their overarching strategy and goals–they should commit to a 33.3-L model regardless.

This optimism however will be faced with several barriers potentially preventing a decision-maker from choosing it. The caveat is that a decision-maker must be comfortable with settling at EV-L over EV B.O.O, in the event that they are not able to achieve 33.3-L. This is a situation that many executive-level managements would not be willing to risk. Furthermore, any start-up would have a board of directors and a number of shareholders who may or may not be as risk-averse as the decision-maker arguing the merits of reaching for the 33.3-L option. Stakeholder exit strategies may not align with the decision-maker's licensing outlook and may argue that it is better to safely settle for 10% increased profits from the EV B.O.O. option than to assume a 33.3-L option is possible and risk achieving only the same amount of profits.

This approach to evaluating a licensing model cannot be repeated for a B.O.O. model. The primary barrier to this is the difference in restrictions placed on the scaling up of these models from their expected values to an increased level as discussed in Section 3.1. As such, one cannot evaluate the B.O.O. model at the expected value, and at an increased level—reflected in Figures 1–3 by the B.O.O. option being shown only as consistent and not varying.

4.3. Limitations and Future Research

Equation (10) was built to calculate the profitability of the licensing model. While as a skeleton equation it is valid, it is heavily simplified with regard to the revenue streams and was built under the assumption that there are no costs (CAPEX or OPEX) as the facilities are being built and operated at the licensee's cost. Omitting these is potentially risky as the CAPEX and OPEX of a facility are not the only costs placed on a business. The simple act of conducting business will incur labor and other OPEX costs that are irrespective of a business model—the only difference is that they are likely to be marginal compared to the facility's OPEX. These costs were omitted from the equations because they are impossible to account for uniformly as they depend on any number of factors such as research and development investment, overheads, jurisdiction, or tax. Furthermore, these costs are likely to be the same between the two models and as such can be safely omitted from the equation while keeping the comparison consistent. If the analysis was being considered for a specific company, where this information is available then they can and should be accounted for in the equation; however, due to the holistic scope of this project, it is not possible or necessary.

A single licensed facility was assigned an expected value of positive environmental impact as 50 tonnes of GHG emissions were mitigated. This is a 50% discount of the figure assigned to a single B.O.O. facility which was 100 tonnes of GHG emissions mitigated. Given that the environmental impact delivered by a licensed facility is being considered as a percentage of what a B.O.O. facility can achieve—it can be argued that a 50% discount is too heavy a penalty.

From the author's experience working in a cleantech start-up, a 30% discount for environmental impact is also a valid approach. A licensee, despite their lack of involvement in developing the IP or tacit knowledge, would still have access to support from the parent company as part of the licensing agreement terms. Furthermore, if a licensed facility was not performing well due to operator error or mismanagement, it is a mutual concern as it will reflect poorly on the cleantech start-up despite it not being any fault of their own. As such, it is in the start-up's own interests to make sure that this discount rate is minimized as much as possible—the benefits and costs of which are intangible but an added liability to the licensing model.

The use of such a large penalty in this MCS was justified by the points outlined in Section 2.1.4. Given that this MCS covers the entirety of the cleantech industry, a larger 50% penalty is an ideal rate to encompass all the possibilities of why a licensee may not achieve the same level of positive environmental impact that a B.O.O. model might out of a single facility. As discussed, these reasons can range from a lack of capability or knowledge to less mitigate issues such as greenwashing or leadership's "white whale" attitude.

This large environmental penalty also provides a clear distinction between the B.O.O. and licensing model in terms of the capabilities and external pressures an IP owner and licensee have. Given the limited global reach any cleantech start-up has, it is unlikely that they would elect to, or be able to build a facility in more remote or difficult-to-access markets. A licensing option allows IP owners to access all parts of the world, including areas where a business presence is ideal, but not necessarily self-funded business operations. If the start-up were to license its tech to such a jurisdiction, it is fair to assume that the plant cannot and will not be run at maximum capacity simply due to the environment it is being run in. Issues such as maintenance cost avoidance, sub-standard health and safety measures and limited or ineffective marketing are all hurdles that are more common in such types of license arrangements. Thus, they are also accounted for with the large environmental penalty—a difference that is simultaneously highlighted.

4.4. Binary Scope of Potential Business Models

The context of this study only considers the opposites of the business model spectrum: 100% "business owned and operated" or the 100% licensing model. While the methodology and equations built are appropriate to consider the profitability and positive environmental impact of these models against each other, it is important to note that there is a plethora of models available to any business besides these two as mentioned in the introduction. The most popular of these models often sit between the B.O.O. and licensing models on the spectrum.

One intuitive model would be a blended approach, where a start-up can commit half of its resources to a B.O.O. approach, and the other half to maximizing license deals. While this will present its own set of hurdles, such as the possibility of licensing arrangements cannibalizing immediate and future B.O.O. options—it is an option entirely valid in the short run. By doing so, the start-up can assess the benefits and drawbacks of each model in real-time. The results of this parallel assessment can inform adjustments to the ratio of B.O.O. to licensing—either a shift from 50:50 to 25:75 (or vice versa). Immediate adjustments may be difficult due to the CAPEX-intensive nature of B.O.O. and term period agreements of a license deal. Nevertheless, it is an available option and will be easier or more difficult for different start-ups depending on their IP and specific industry. The model built in this study can be a starting point for decision-makers who may find a middle-ground result to be desirable and worth exploring.

A franchise model appears similar to a licensing model, whereby the revenue stream is a form of royalty payments. However, the primary difference is that a franchise model operates from a complete business system, utilizing assets such as trademarks, and operating manuals, and provides a higher degree of support to the other party. This support can take many forms such as training programs, on-call support, real-time operational analysis, and even potentially expensive litigation support. The relationship between the licensee and IP owner is more transactional and less intimate than one between a franchise owner and the franchisee party [12].

With this stronger level of support provided by the cleantech start-up, they would also retain a higher degree of control over the IP and business operations of the facility built. In the context of a recycled metals sector, the IP owner could influence the offtake of these green metals ensuring that they are redirected towards electronics manufacturing instead of jewelry or an industry that doesn't contribute to circular economies. Furthermore, a franchisee will typically share higher quantities of its revenue or higher fees, including an increased level of initial investment compared to a standard licensing arrangement. As such, a franchise model would provide a cleantech start-up with stronger confidence in the franchisee's ability to produce a positive environmental impact, and therefore the environmental penalty can be lower than the 50% figure used in this study—this assumption is made due to author's experience working commercially in a cleantech start-up. While the franchising market may be more limited than a licensing market—the higher revenue stream and confidence in the environmental impact produced may warrant consideration. Naturally, a statistical analysis such as this study will require a set of equations and a Monte Carlo simulation for a franchise model as well and then compared to the licensing results in a similar fashion. However, the stark similarity between licensing and franchising will allow a future decision-maker to use the model produced in this study with minimal adjustments and can compare a B.O.O., licensing, or franchise model with confidence.

A popular business model for many start-ups is a Joint Venture (JV) model, whereby two or more companies pool their resources and expertise to achieve a shared goal. In the case of a cleantech start-up, it is likely they would partner with a more established company to access their financial resources, consult their management experience, and leverage their larger presence in the market. The minimum contribution from the start-up would be their IP as they and the partner company join forces to establish facilities—this however can extend to any level of contribution including financial. Depending on the level of contribution from both (or all) parties, they would share the profits and take proportional credits for the positive environmental impact they achieve. Given the likely cash infusion from the partner company, it is likely that the partners will choose to build facilities at their own expense rather than license. This can be considered a B.O.O. model, however, both the financial and environmental gains are shared, and therefore must be evaluated as such. This would require a model based on this one with many extra layers of uncertainties accounted for. These could include unsupportive terms, diverging goals and values between the parties, and decision-making power dynamics. While these are variables with high degrees of uncertainties that cannot be ignored, a start-up considering a JV can use the B.O.O. facet of this model as a starting point and skeleton for their analysis. It is possible to easily adjust this MCS to evaluate the MSP and MSPEI of a B.O.O. model against a JV model, allowing decision-makers to extrapolate the results to inform strategy and potentially important terms if entering a JV.

5. Concluding Remarks

This study sought to uncover this potential compromise and discuss the financial and environmental pros and cons of a “build, own and operate” business model, or a licensing business model. The results showed the EV-L option to be an environmentally beneficial choice to make, at a small compromise in profits. On the other hand, the ambitious decision to license 34 deals presents little increased benefit, while requiring 13% more licensing effort. These results very clearly highlight the level of compromise between the desired outcomes and can inform a decision-maker what is the prudent call to make based on the company’s financial and strategic position, and the value they place on profits versus positive environmental impact.

By including only the key variables in each equation and prescribing the positive environmental impact figures to a B.O.O. facility and licensed facility as the ideal and penalized versions (respectively), the MCS was kept at a holistic level so that it could be applied to every cleantech sector and easily adjustable for future decision-makers. Having such a malleable statistical model, future cleantech decision-makers of start-ups can better understand the compromises business model choices present to them. The start-up will be able to make informed decisions that align with its short-term goals and long-term strategies.

Our study has clear implications for cleantech start-ups. Extensive literature has studied the importance of identifying and implementing an appropriate business model that balances the financial reality of the start-up with the environmental goals of their ventures. This study has created a modular tool that managers can use to compare business models available to them and assess the profitability and environmental impact they can achieve. Furthermore, managers can input values appropriate to their cleantech sector and project by choosing replaceable numerical examples in the model and the spreadsheet-based Monte Carlo Simulation. This will allow any cleantech user to effectively dictate their business decisions based on their priorities.

Immediate extensions to this study would include more pertinent variables such as identifying the differing OPEX between a B.O.O. and a licensing model. Further expansions could include comparing three models instead of two, such as a franchising model, licensing model, and joint venture model against each other. Using the equations built as a foundation, a blended model, such as a balance between B.O.O. and licensing models to understand if a ratio between them would suit a particular strategy better.

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Data Availability

The simulation data are available from the corresponding author on request.

Author Contributions

Conceptualization: N.G., & M.M.; Formal analysis: N.G.; Methodology: N.G., & M.M.; Writing–original draft: N.G.; Writing–review & editing: M.M.

Conflicts of Interest

The authors have no conflict of interest to declare.

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