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Solar Thermal Heating Acceptance Among Malaysian Industries Using System Dynamics

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Abstract

A solar thermal heating technology has a great potential in industries application. This paper presents a prediction of Malaysian industries acceptance on the solar thermal heating system for replacing the current heating technologies. In Malaysia, most of the heating technologies are using fossil fuel as a heating source due to the low price of the source. The solar thermal is another type of sustainable renewable energy. The objective of this research is to produce a Malaysian industries acceptance model in order to study the willingness of the Malaysian industries to migrate and use the new renewable energy technologies in their heating process. System dynamic simulation has been used to develop the novel solar thermal heating acceptance model by using the survey data collected from process industries in Malaysia. The focus of the research is in low and medium temperature categories of the solar thermal system since most of the process industries in Malaysia are involving with low and medium temperature in the heating process. The System Dynamic model was designed to predict the investment decision taken by the industries based on investment decision rules. The results with current support from the government show that the Malaysian industries acceptance towards solar thermal heating technologies is low. To enhance the willingness among the industries, a new policy on solar thermal energy application for industries properly need to be tailored.

Keywords: *Solar thermal technologies, System dynamics, Investment risk, Industrial process, NPV*

1. Introduction

More recently, solar thermal heating technology has been accepted by 61 countries. By the end of 2015, the total of 435GWth was reported in operation worldwide [1]. Over the past few years, the solar thermal heating system has attracted increasing attention and being considered for application such as industry heating process [2], heating energy supply for building [3] and space heating [4]. Globally, solar thermal heating has great potential in the industrial process. More than 66% of energy consumption in industry is used for heating process and about half out of heating demand in the industry is consumed by small and medium sized enterprises [5]. Common temperature range for an industrial process is between 300C to 2500C. The process operations applications involve are drying, washing, pasteurizing, boiling, sterilizing, bleaching and others [6]

In January 2017, Malaysian Industrial production index has grown by 3.5%. The manufacturing industry has contributed 4.6% which given by 3 major subsectors, 1. electrical and electronics, 2. petroleum, chemical rubber and plastic, and 3. food beverages and tobacco. Each sector percentage is 6.9%, 2.3% and 6.8% respectively [7]. Most of the industries mentioned use heat in their daily process and were produce from fossil fuel combustion. Currently, the price of the fuel is fluctuating.It gives an impact to the cost of the industrial production. Therefore as an alternative to a heat source, solar thermal can be used in the process industries. The solar thermal collectors have the ability to provide a wide range of temperature needed by the industries such as flat-plate collectors (<1000C^0) and evacuated-tube collectors (1000C^0-4000C^0) [2].

However, in Malaysia solar thermal technologies are not wellknown compared to solar photovoltaic[8]. In author [2] review paper, Malaysian Industries is lack of awareness in solar

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thermal technologies benefits towards industrial process heat. The author [9] also mentions malaysian industries' low awareness towards solar thermal heating technologies. Due to that, this paper presents the Malaysian industries acceptance of solar thermal heating technologies. The objective of this research is to produce a Malaysian industries acceptance model with motivation to study the long term impact of the industries decision towards solar thermal heating technologies investment using System Dynamics simulation.

2. Methodology

In Renewable energy studies (RES), matlab simulation is the most popular method used. For example, the author [10] and [11] used matlab simulation for solar photovoltaic studies. The particle swarm optimazation (PSO) used by [12] and artificial neural network (ANN) by [13] are among the well known method in RES. In this study, System dynamics simulation is used due to its capability in solving complex problems [14].

Malaysian industries acceptance model representation was done by construct the causality driving changes through causal loop diagrams as shown in Figure 1.

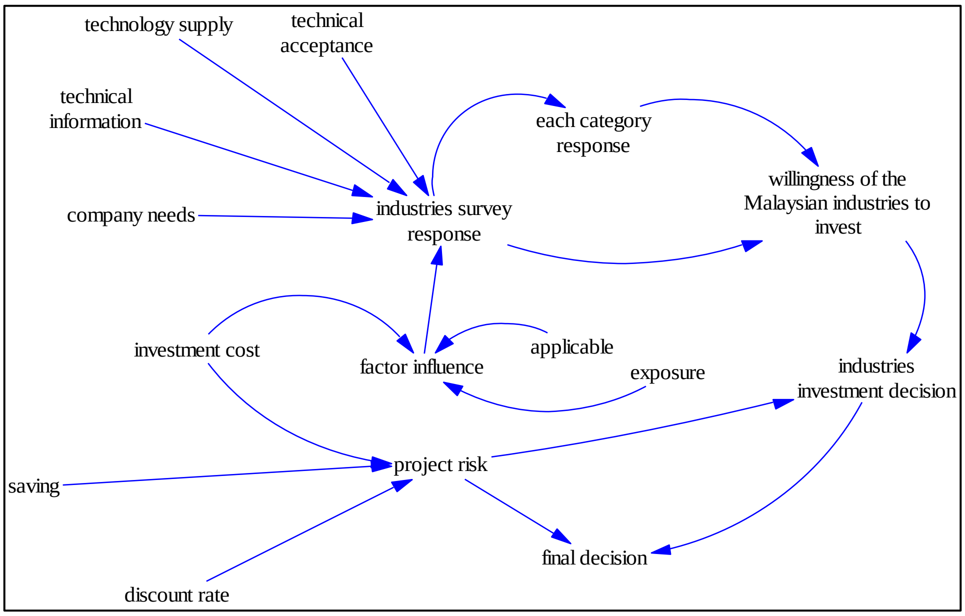

Figure 1. Causal loop diagram (CLD)

The processes of developing the model were done based on 4 steps. Step 1: conceptualization of the model by identifying the purpose of the model, the boundaries, and the variables were identified. Step 2: formulation. In order to convert the information obtained from the cause loop diagram for values estimating and selecting parameters. Step 3: testing the model and observed the output. Finally, the last step, the result obtained was translated into more comprehensive form.

The inputs and the output of the model are shown in Figure 2. The inputs have been categorized into 2 categories, project risk and industries willingness to install the solar thermal system. For the first categories, the combination of 2 methods, internal rate of return (IRR) and net present value (NPV) was used for a decision on economic aspects.

The data for the cost of the system was obtained from the installation done by Vietnam [6] in 2012 which is equivalent to RM 433.041 (as per conversion on 21 March 2017).

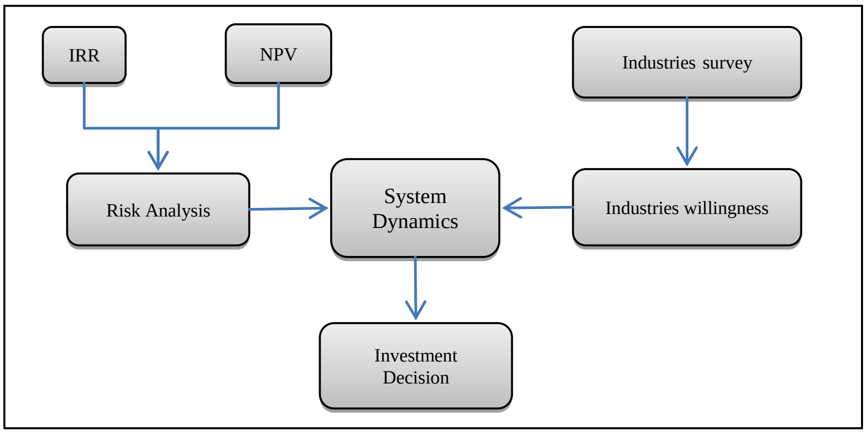

Figure 2. Inputs and output of the acceptance model

Meanwhile, information on saving is based on electricity used for a heating process which is equivalent to Kwh per year [8] multiply with the tariff (cent per Kwh). Finally, the investment cost is depending on the area of collector installed as in Figure 3.

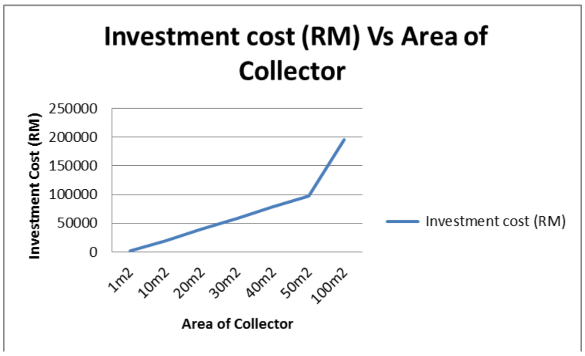

Figure 3 Projected installation Investment cost for size (m2)

For second categories the feedbacks were obtained from the survey conducted by Scientific and Industrial Research Institute of Malaysia (SIRIM). 2 sub models of Solar Thermal heating technologies acceptance model were developed. The sub models are Malaysian Industries investment willingness model which is measured in percentage and solar thermal heating investment risk model also measured in percentage. The acceptance model is depending on the acceptance calculation as Equation 1. The investment risk model is depending on the net present value (NPV) and Internal rate of return (IRR) of the project. The Investment calculation for each component is shown in the Equation 2.Based on the simple calculation of payback period; Equation 3, the payback period for the project takes almost 1.5 years to reach the break-even point of the investment provided the same parameter used in the model is used.

$$A_{\text{Malaysian Industries}} = D_{f\&b} + D_{rubber} + D_{wood} + D_{textile} + D_{others} \quad (1)$$

$$R_{investment} = (R_{NPV} + R_{IRR}) \quad (2)$$

$$P_{ayback}\ P_{eriod} = \text{Initial Investment / Cash Inflow per Period} \quad (3)$$

Where $A_{\text{Malaysian Industries}}$, $D_{f\&b}$, D_{rubber}, D_{wood}, $D_{textile}$ and D_{others} represents acceptance by Malaysian industries, decision by food and beverages based industries, decision by rubber based industries, decision by wood based industries, decision by textile based industries and decision by other sector industries. Meanwhile, the Equation 2, $R_{investment}$, R_{NPV}, R_{IRR} represents investment risk, Npv risk and IRR risk.

The logic formulation is used for NPV decision and IRR decision. Table 1 shows the logical condition set for the simulation.

Table 1. The IRR logical Formulation

	Logical formulation for IRR
1.	If IRR value minus discounted rate is > than 80% then the decision 100%
2	If IRR value minus discounted rate is > than 60% then the decision 70%
3	If IRR value minus discounted rate is > than 50% then the decision 50%
4	If IRR value minus discounted rate is > than 40% then the decision 40%
5	If IRR value minus discounted rate is > than 20% then the decision 20%
6	If IRR value minus discounted rate is > than 10% then the decision 10%

Table 2. The NPV logical Formulation

	Logical formulation for NPV
1	if npv> 75% from investment then accept 100%
2	if npv> 50% from investment then accept 75%
3	if npv> 25% from investment then accept 50%
4	if npv> 10% from investment then accept 25%
5	if npv = 0 % from the investment then accept 10%
6	if npv < 0 from the investment then reject

Table 3. The Risk Decision logical Formulation

	Logical formulation for Risk Decision
1	IRR decision >95% and npv decision >95% the risk free decision = 100%
2	IRR decision >85% and npv decision >85% the risk free decision = 90%
3	IRR decision >75% and npv decision >75% the risk free decision = 80%
4	IRR decision >65% and npv decision >65% the risk free decision = 70%
5	IRR decision >55% and npv decision >55% the risk free decision = 60%
6	IRR decision >45% and npv decision >95% the risk free decision = 50%
7	IRR decision >35% and npv decision >95% the risk free decision = 40%
8	IRR decision >25% and npv decision >95% the risk free decision = 30%
9	IRR decision >20% and npv decision >95% the risk free decision = 20%
10	IRR decision >10% and npv decision >95% the risk free decision = 10%
11	IRR decision less 10% and npv less 10% the risk free decision = IRR decision +NPV decision

Malaysian Industries acceptance model is shown in Figure 4. This model consists of 2 sub models, Malaysian Industries investment willingness model and solar thermal heating investment risk model. The output of the model is measured in percentage. The equation for the output used shows as the Equation (4).

$$D_t = \int_0^t [D_{t-1} + Willingness_t + Free\ risk_{\ t}] \quad (4)$$

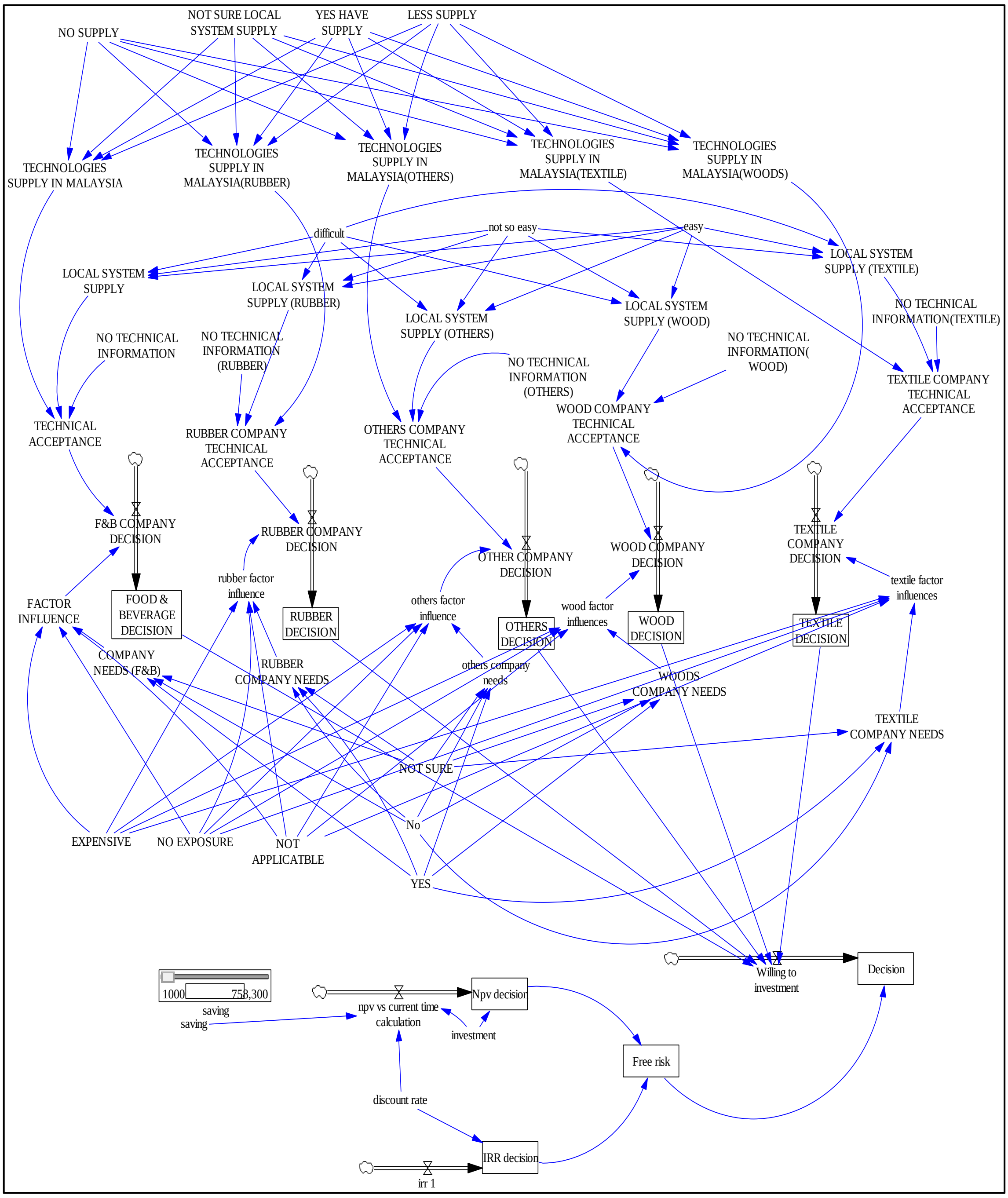

Figure 4. Malaysian industries acceptance model

3. Results and Discussion

The results obtained from the System Dynamics simulation is shown in Figure 5-6. The simulation was run based on the maximum value of a discounted rate (r =12), the highest total investment (RM 194869) and saving achievement in a year basis (RM 151650) for installed collector size of 100m2. Overall each category of company's decision on solar thermal installation is less 0.5% (without the risk free factor) until next 20 years. It is too low. On the other hand, the output of the free risk shows that the installation project of the solar thermal heating system has low investment risk.

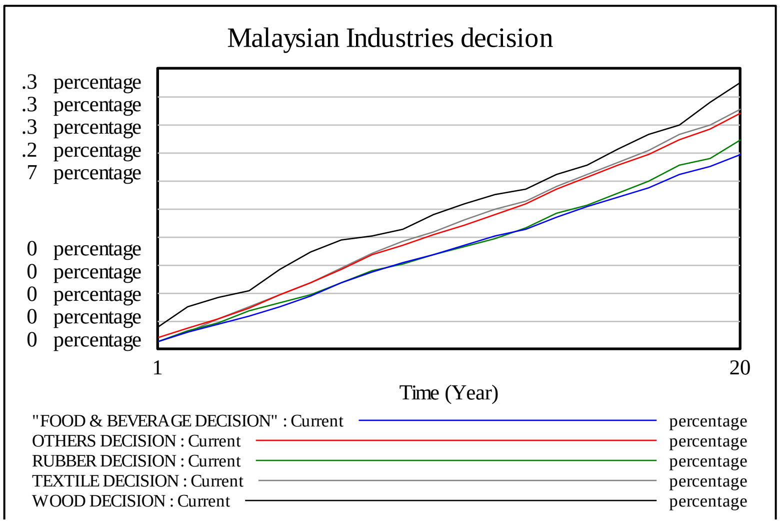

Figure 5. Decision for individual industries in Malaysia

The percentage for the 1st year of the free risk is less than 1%.and it takes almost 8 years to reach 100% for becoming a risk free project. It shows that the installation of the solar thermal heating project can be considered low risk compared to another type of renewable energy technologies.

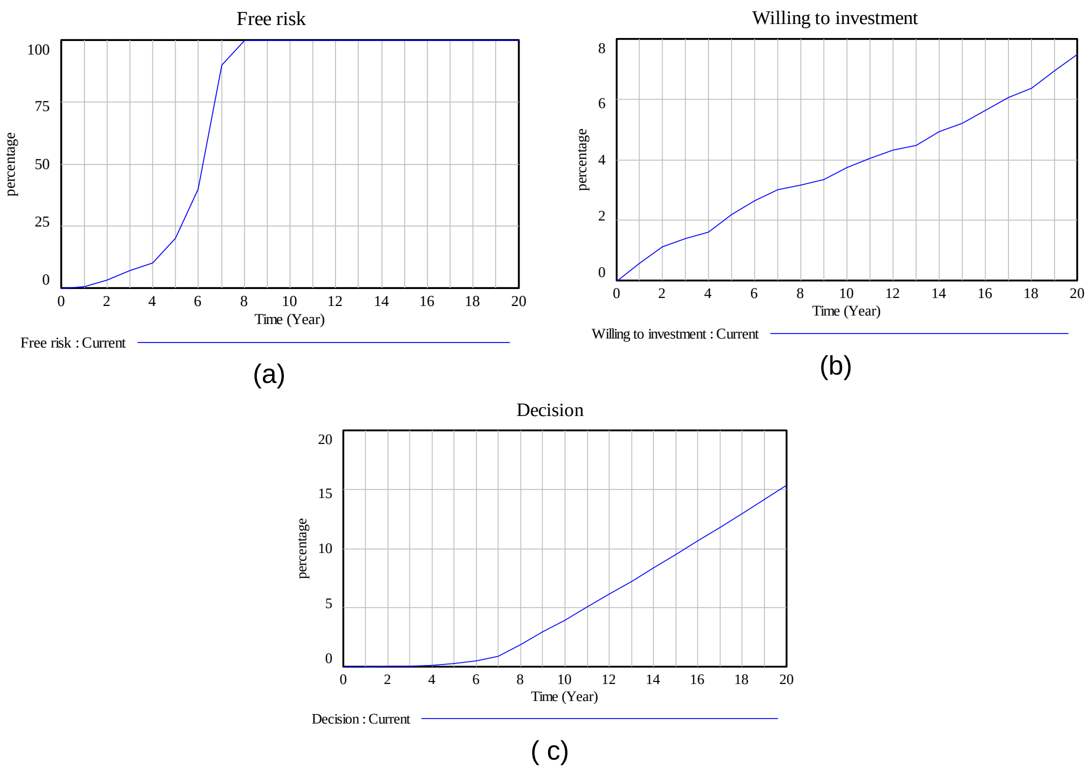

Figure 6. (a) – (c) Comparison between investment decision and industries willingness and risk

In general, the model outcome (Figure 6 (a)-(c)) shows that the industries willingness to invest in solar thermal technologies is very low. The percentage of industries willingness does not reach 50% even for 20 years. It explains that most of the process industries in Malaysia still reluctant to have an extra cost or budget for allocating on new technologies even though the project has low investment risk. This is supported by the result of the simulations, which in 20 years; the industries willingness is still less than 8%. Meanwhile, the investment decision is low (15.4%). It takes time to gain the confident from the industries to invest in the solar thermal technologies.

4. Conclusion

The model developed is to determine the Malaysian industries acceptance towards solar thermal heating technologies. The results from System Dynamics model simulation has found that Malaysian industries have strong resistance towards solar thermal technologies in process operation even though the study has shown that the solar thermal technologies have good potential in terms of investment risk free. It is considered that the model can provide a guideline to the Malaysian government to tackle few issues that influence the industries decision such as the system prices, technical knowledge, and financial support. Therefore for further works, the incentives from the government are suggested to be taken into account to describe in the system dynamics modeling simulation.

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