Financial Risk System Dynamics Modeling for Investment Decision in Solar Thermal Technologies for Malaysia's Industries

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Abstract— **The objective of this study is to analyze the impact of financial risk as part of the investment risk for solar thermal heating installation in Malaysia. The solar thermal installation is focusing on small medium enterprises (SME) industries. In this work, the Net Present Value (NPV) of the projects is investigated over existing condition where no specific policy and financial mechanism available for solar thermal heating installation in Malaysia as a base case, and with various government's supports as case studies. The financial risk is measured through a model developed using System Dynamics simulation technique. Monte Carlo simulation using Excel software is used for solar thermal heating energy demand by Malaysian industries for the next 20 years. Meanwhile, Monte Carlo simulation technique by Vensim software is used for the financial risk behavior validation. The results reveal that the government support and financial funding mechanism has great influence on the investment decision which lead to the increase of solar thermal install capacity by Malaysian SME industries. The policy maker can benefit from the result obtained in tailoring the better policy for solar thermal heating in SME industries.**

***Index Terms*—Solar Thermal, Financial Risk, System Dynamic, Monte Carlo.**

I. INTRODUCTION

MALAYSIA final energy demand in 2015 by industrial sector was 13,989 ktoe, which is equal to 162,692,070 MWh. This amount contributes to 27% of the National final energy demand. From the total energy consumed by each industry, two third of the usage is used for heating purposes and 50% of it is utilized for low to medium heating temperature [1-[2].

A significance potential of energy savings from fossil fuel can be obtained if the heating consumption can be supplied from renewable technologies. A solar thermal heating technology has the capability for supplying renewable heat especially in food and beverages industries. Current statistic in Malaysia shows 40% of industrial primary energy consumption is supplied by natural gas and 41% by petroleum [1]. Renewable energy technologies in Malaysia is rapidly expanding in order to have continuous sustainable energy [3] &[4]. Although renewable energy technology has good potential in replacing fossil fuels, its high investment cost and uncertain energy production are the main concern of investor. According to economist intelligence unit survey in 2011, the top three ranking of investment risks for renewable energy are financial, political and regulatory. The financial risk to investors, policy or regulatory changes may results in delay for implementing the project. Furthermore, getting funding from private sector and government is also the main challenge.

In 2014, Malaysia has established a National Solar Thermal Roadmap for Malaysian Industry under Global Environment Facility (GEF) and United Nation Development Organization (UNIDO) project. In this project, Malaysia has set an installation capacity goal of 2,000MW by 2025 for industries which use low and medium heating temperature in their process activities such as drying, washing, pasteurizing, boiling and sterilizing [5]. In meeting the goal, Malaysia requires a proper action plan for policy and support programs in order to help boosting solar thermal development in the country [6].

Extensive researches on renewable energy have been reported for Malaysia as shown in TABLE 1 above. It is seen that 39% of the studies is on power generation, 22% is on Feed-in Tariff (FiT) (electricity), 17% is on agricultural and marine products, 6% is related on financing for PV and heating for building, 5% is on solar energy utilization, and 5% is on solar irradiance analysis. Although a number of studies has been conducted on solar heating for drying, there is no study focus on investment risk of solar thermal application specifically for SME industries in Malaysia. Therefore, there is a need for an investment risk evaluation for solar thermal in industry that can be modeled using System Dynamics simulation. This study offers some important insights on financial investment in solar thermal technology. This study is based on existing situation where limited support mechanism or policies exist that favors solar thermal installation in SME industries.

From the literature, solar thermal application for industrial heat process in Malaysia can be considered new [25-[26]. However, the technology has been widely implemented in

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TABLE I
PREVIOUS RESEARCH IN MALAYSIA

AUTHOR	Type of Renewable Energy (Renewable Energy)	Application [a]	AUTHOR	Type of Renewable Energy (Renewable Energy)	Application [a]
[7]	Biomass	Electricity Generation	[8]	Solar Photovoltaic	Fit- incentive policy
[9]	PV + fuel cell and battery	Co-generation system	[10]	Solar energy	Utilization of solar energy
[11]	Solar Energy (PV)	Fit Scheme for residential houses	[12]	Building integrated photovoltaic (BIPV)	Heating or drying for Building and construction industries
[13]	Photovoltaic and solar thermal collector	Solar drying system and space heating	[14]	Solar drying system- air based solar heating	Agricultural and marine products
[15]	Hydrogen production from thermochemical process	Drying process	[16]	Solar energy- Malaysia building integrated photovoltaic (MBIPV)	Feed-in tariff
[17]	Photovoltaic	Analyze solar irradiance received in Perlis	[18]	Solar photovoltaic	Financing option: for companies and for individual home
[19]	Marine renewable energy	Feed –in tariff system	[20]	Solar Photovoltaic	Energy generation
[21]	Ocean renewable energy	Electricity generation	[22]	Growing energy demand in end-use sectors	Energy usage
[23]	Biomass and Biogas	Power generation system	[24]	Solar Energy	Electrical power generation

China, India and European countries for number of years [27]. From a survey, it is found that, financial risk is the main factor hampering solar thermal investment for industry in Malaysia [6], hence is chosen as the main investment risk in this study.

In this study, System Dynamics financial risk model based on current business as usual scenario is first developed in evaluating the net present value (NPV) of a solar thermal investment. Then, various government supports are used as agent factors that influence the financial risk of solar thermal in Malaysia for industrial heat process especially by small and medium enterprises (SME). At present, Malaysia has a limited support mechanism to assist development of solar thermal in industry. Therefore, the developed model can be used to evaluate the financial risk of investor and to study the effectiveness of various policies that could help boosting the growth of solar heating application in Malaysia industry.

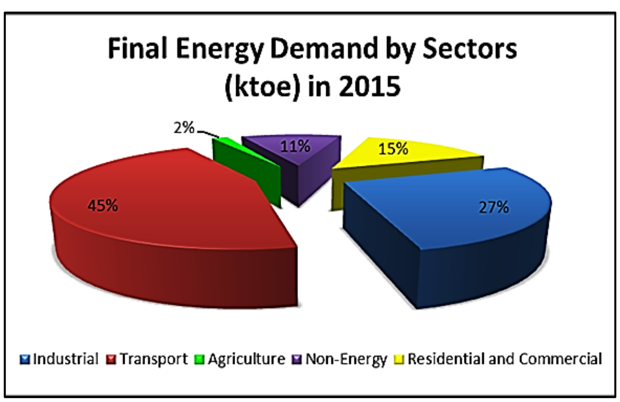

Fig 1. Malaysia final energy demand by sectors in kilotonne of oil equivalent for the year 2015.

II. INVESTOR RISK

Renewable energy investment is higher than the conservative ways of producing energy. In such case, the investor needs upfront capital and policy support for implementing the technology [28]. Many SMEs industries have perception that investing in Renewable Energy technology is just too risky. In order to properly justify the investment, the investor needs to comprehensively evaluate the investment risks before making investment decision. The investment risk may exist in three stages of the renewable technology implementation; i.e. planning, construction, and operation.

Malaysia can be considered as new player in Solar Thermal Technology, therefore, the investment risk of the project is mainly appeared in the planning stage. At this stage, the risk involves is related to country risk such as political steadiness, economic growth, degree of corruption and exchange rate instability social acceptance risk, administrative risk, financing risk, grid access risk and sudden policy change risk. [29].

According to author in [30], among the risks listed above, financial risk is the major one, hence becomes the main focus in this study. This finding was supported by the survey done by Economist Intelligence Unit in 2011. Recently, a study to reduce the financial risk has been conducted by author[31]. He has studied on incentives effectiveness which available in India for industrial process heating.

III. SYSTEM DYNAMICS

In this research System Dynamics simulation has been used to model the investment financial risk. System Dynamics has the ability to manage complex feedback where the simulation of the current event may influence the other event in the future. It gives the qualitative predictions and insights of a problem that evolve over time. It is done by having stocks and flows internal feedback loop, table function, and time delay. [32]. The author [33], has used system dynamics in his study on Colombia biodiesel policy. Recently, the author [34], had coupled Bayesian Network together with System Dynamics modelling method to study the relationship between financial instruments function and Australian public building retrofitting rate. Meanwhile, Saavedra M., [35] has investigated the effects of System Dynamics method on the renewable energy supply chain. System Dynamics modelling also been used in solar themal installation capacity projection [36],. solar thermal acceptance [37] and techno-economic influence on process heating industries in Malaysia [38].

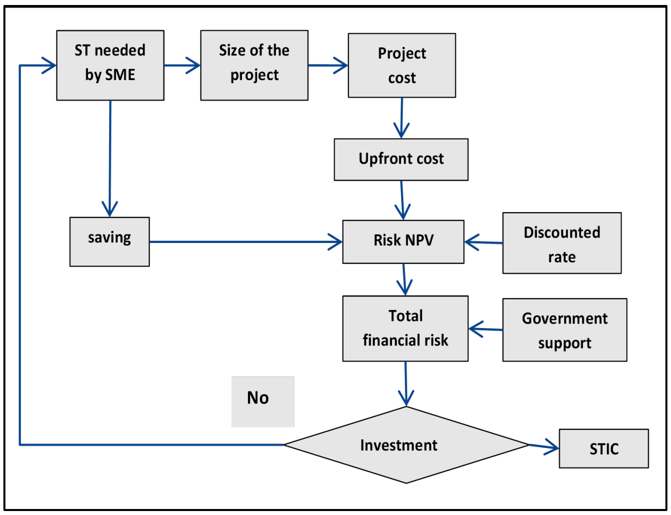

Fig. 2. The framework of the system dynamic for the investment risk model

Fig 2. represents the System Dynamic investment risk work flow. STIC is an abbreviation for Solar Thermal Installation Capacity in Malaysia.

Solar thermal energy required by the SME was obtained from the National Energy Balance. The data (1978 -2015) is gathered from Malaysia Energy Information Hub. The projection (2016-2037) of the energy use (low to medium temperature heating) is performed using Monte Carlo simulation (Microsoft Excel). [25,[1] & [39].

The projection data for the project size is given as below;

$$\text{Project size} = \frac{\text{SME industries use ST kWh needed}}{\text{Annual expected energy generation}} \quad (1)$$

Annual expected energy generation is in per meter square. [25-[26]. The expected energy generated is calculated using 4.5kW/m^2 capacity of the solar thermal system. The assumption used in [26] is based on the industrial practice with 270 working days in a year. Malaysia mostly received 4 hours of sun radiation daily and the efficiency of the solar thermal system is assumed 80% [33].

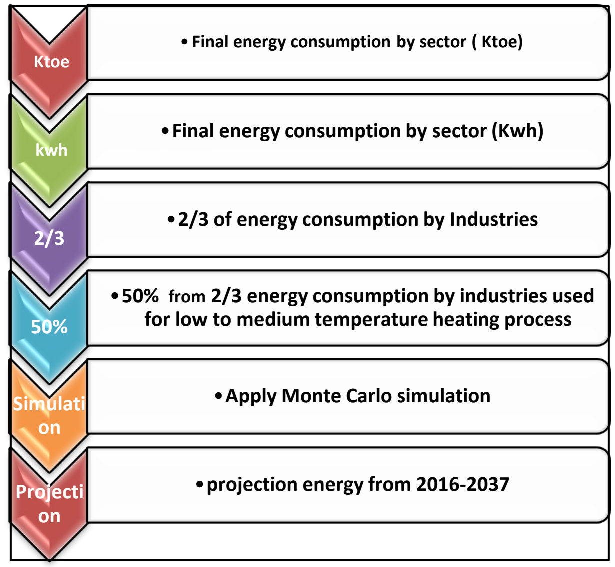

Fig 3. Energy consumption projection for Malaysian industries using Monte Carlo uniform distribution (Excel).

Saving is calculated based on how much electricity consumption can be saved based on the current tariff for small and medium industries. The investment is solely based on project cost. The initial price use is adopted from the investment cost implemented by Vietnam in 2012 [1]. The initial price is set at RM 433.024 (1 EUR = MYR 4.75870 as per date 21/3/2017). The collector used for the solar thermal process heat is evacuated tube collectors (ETC). The system can provide temperature up to 1,200 C and the technology is mature and able to produce higher temperature with proper design technique such as placing the ETC on the tracker and integrating compound parabolic concentrator (CPC) behind the ETC.

The present value of a project in the System Dynamics is calculated using the Net Present Value (NPV).

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} \quad (2)$$

where C_n is cash flows over n years, r is discounted rate. N is 20 years of holding period and the discount rate, r is set at 4 %.

I. FACTOR INFLUENCE FINANCIAL RISK

In planning stage, financial risk has taken a big influence in investing in solar thermal. It requires equity and financing support from government or private financing body such as a bank.

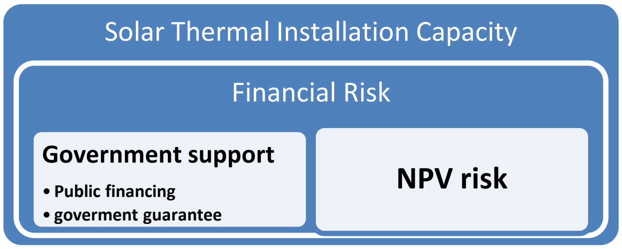

Fig. 4.Criteria for financial risk investment model

In this study, the influential factors considered in the model development (Fig. 4) are based on current situation in Malaysia. At the moment, the policies and support programs are mainly available for electricity or power generation. Government has offered a soft loan mechanism for user or developer of a green technology project under Green Technology Financing Scheme (GTFS). The allocation for user of the green technology project is RM 10 million per company [40]. However, the soft loan granted by financial institution is usually in favors of renewable energy projects such as solar photovoltaic, hydro, biomass, and biogas.

For this study the soft loan variable is set to a low rate of 20%. This is the case with the fact that financing institution has limited knowledge on solar thermal application. The loan guarantee is set to 60%.

The guarantee is set based on the offer from Credit Guarantee Corporation Malaysia Berhad (CGC) of 60% on the granted financing amount.

II. FINANCIAL RISK MODEL

The financial risk model is developed by using System Dynamics. The model is developed based on the relationship shown in Fig. 5 below. The figure shows the stock and flow diagram of the financial risk investment model for Malaysia industries.

The stock and flow diagram help the system to react towards feedback and causal loop. In other words, the stock and flow diagram represents the structural of the system with detail information. The stock in the system is working as a generator of the system behavior. It accumulates the output changes over the time. Meanwhile, the flow is acting as an agent that influences the stock to change. There are four types of variables used in the system development i.e. level, rate, constant and auxiliary. The 'auxiliary' is a variable that has no memory. Its current value does not relate to values from the previous time (*t-1*). The 'constant' variable is free from any changes with time. On the other hand, the 'level' variable changes over time and the value taken at time *t* is dependent on value from other variables at prevous time (*t-1*).

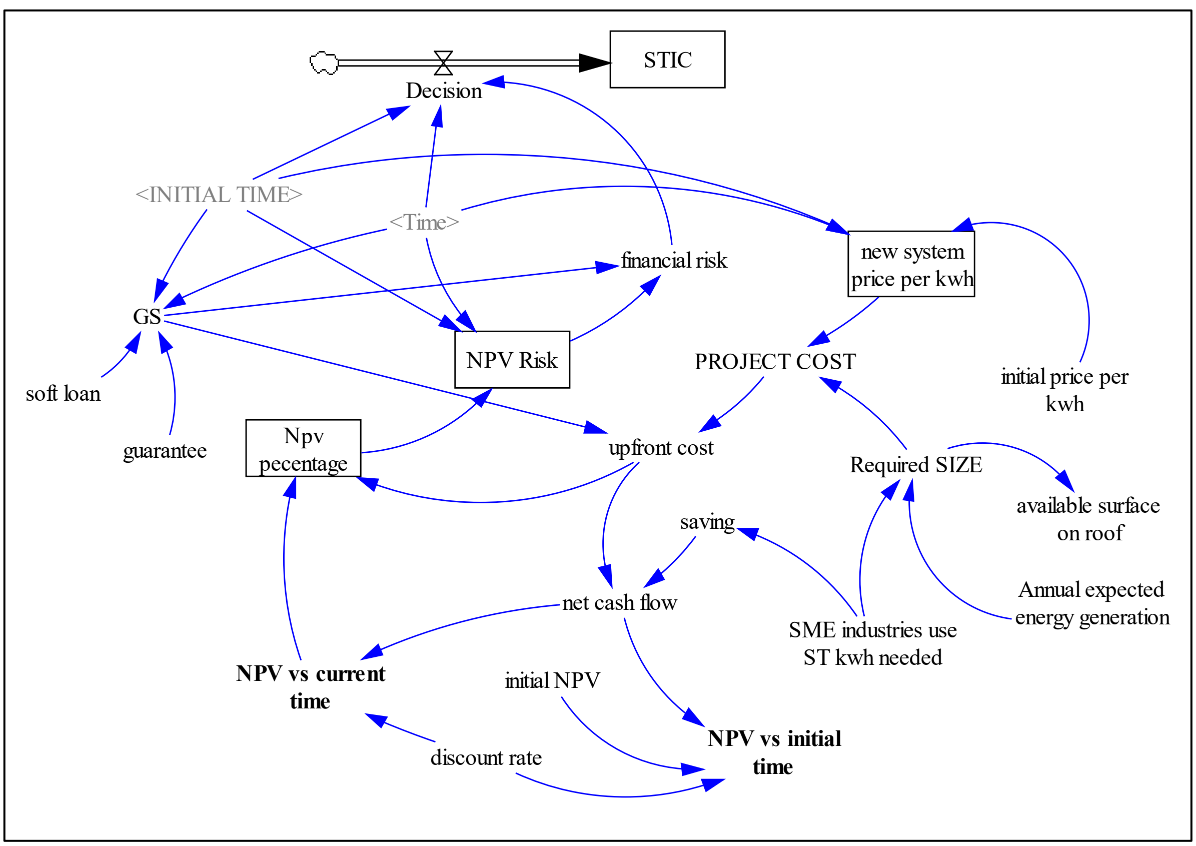

Fig. 5. System Dynamics Model for Financial Risk Investment Model

The decision in the model is a 'rate' where it directly changes the level. It is an auxiliary variable and it is depending on the financial risk. It works contradictory from the financial risk. Solar thermal installation is depending on the investor's decision. The equation of the solar thermal installation is shown in equation 2 based on the stock and flow diagram in Fig. 6.

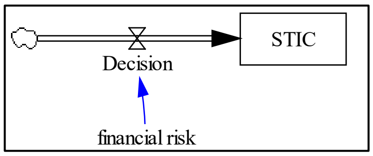

Fig 6. Basic STIC stock and flow diagram

The solar thermal installation capacity (STIC) is a level type of variable. The value presented by STIC is a cumulative value. The STIC is presented by mathematical formulation (3) as shown below. Meanwhile, the decision formula is represented by (4).

$$STIC = \int_{0}^{20} \left(\sum STIC_{t-1}\right) + Decision_t \; dt \quad (3)$$

$$Decision_t = (100 - financial\,risk) * e^{(0.1)*(Time-Initial\,time))/100} \quad (4)$$

The simulation was carried based on business as usual (BAU) scenario. At current scenario in Malaysia, no specific policy exists for solar thermal heating, no other grant available other than the GTFS, the awareness on the solar thermal heating is very low based on survey conducted by SIRIM [25]. Due these, financial institutions may have less confident on financing the solar thermal installation project. As a result, getting funding from privates' sector, such banks, is low. The assumption that was made, it takes 10% increment of awareness each year starting from 2017.

TABLE 2
ASSUMPTION OF EACH VARIABLE

Variable	Explanation
Soft loan - constant	Assumption: 1. With current condition where no policy on solar thermal the percentage of the financing institution will approve the project up to 20% of the total cost
Guarantee (60%)	Assumption: 2. Under 11th Malaysia Planning, the solar thermal project can be considered as a new Renewable Technology which it can help reduce the dependence on imported sources of fuel.

Solar Thermal installation capacity is cumulative. The total number of capacities is based on the table below.

TABLE 3
INSTALLATION CAPACITY

Decision condition	Capacity Decided in kW
Decision =0	0
0< Decision<=10	10
10< Decision<=15	20
15< Decision<=20	30
20< Decision<=25	40
25< Decision<=30	50
30< Decision<=35	60
35< Decision<=40	70
40< Decision<=45	80
45< Decision<=50	90
50< Decision<=55	100
55< Decision<=60	200
60< Decision<=65	300
65< Decision<=70	400
70< Decision<=75	500
75< Decision<=80	600
80< Decision<=85	700
85< Decision<=90	800
90< Decision<=95	900
95< Decision	1000

Saving variable is based on how much of electricity bill being saved.

III. MONTE CARLO SIMULATION.

In order to validate the results, sensitivity simulation was carried out by applying Monte Carlo simulation on the developed model. The simulation results are shown in Fig 11 – Fig 12. Financial guarantee, payback period, and soft loan are used as controll parameters.

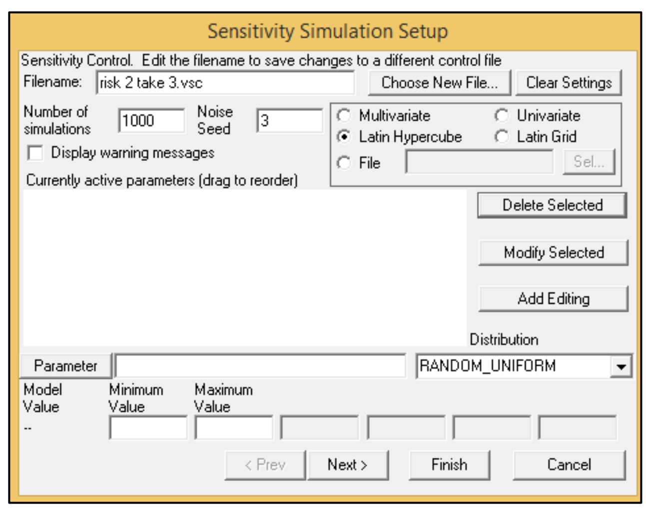

Fig 7. Monte Carlo sensitivity simulation setup.

In this study, number of simulations is set to 1,000 and noise seed is set to 3. Method of sampling, Latin hypercube is used. The Latin hypercube method varies all the parameters simultaneously and stratified along for each dimension.

Confidence interval of 100%, 95%, 75% and 50% are used in the study. Confidence interval is a specific probability of true value of parameter within the range of values (percentage) constructed. For example, 75% confidence interval or bound means that 75% of the time, the true value is within the range and only 25% of the time the true value is outside the range.

IV. SENSITIVITY ANALYSIS

In System Dynamics, the researcher main interest is on the behavior or pattern of the systems. The sensitivity analysis helps to find the important parameter which is has great impact on the system modeled.[41]. According to the author [32], test assessment for dynamic models can be conducted through behavior reproduction

Therefore, in this study, the system modeled has been tested to analyze the possible changes on the system.

V. RESULTS AND DISCUSSION.

In this section, the results are discussed under BAU scenario. The results obtained are based on the 10% of growth and decay rate due to lack of awareness in all sectors such as human, technology, skill, financial and policy

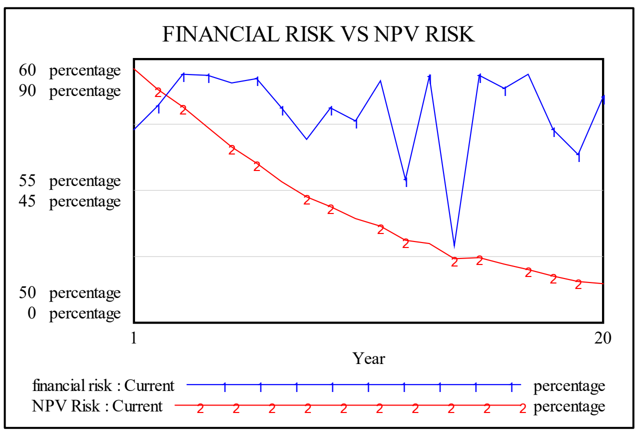

Fig 8. Comparison between financial risk and NPV risk.

In view of the results obtained (Fig 8), the percentage for NPV risk is reducing by year even the financial risk is bouncing (Fig 8). The trend (NPV risk) has shown a good sign of the solar thermal heating potential in Malaysia.

It can be seen that (Fig 9) the percentage of government support (GS) appears to influence the NPV risk. The NPV risk is decreasing. Meanwhile the solar thermal (ST) kWh needed by industries is reflecting the financial risk outcome. The result suggests that government support does play a role in financial risk trend.

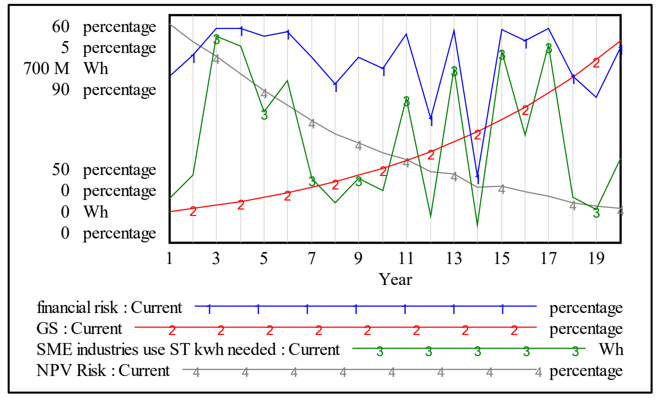

Fig 9. Influence of government support, financial risk, NPV risk and SME industries demand

The trends for influence of new system price per kWh on solar thermal installation when the factors were varied over the different level of government support are shown in fig 10. It shows that for the 1st year, 1,000W of solar thermal capacity are installed. In 10th year the solar thermal installation is 1,0230W and by 20th year the solar thermal installed capacity will have 70.71% of installation growth rate. This shows that the continuity support from the government together with the new price per system will help increase the installed capacity. The upfront cost is depending on the SME industries heating demand projection. The financial risk is within range of 52.92% to 59.41%, is considered as high.

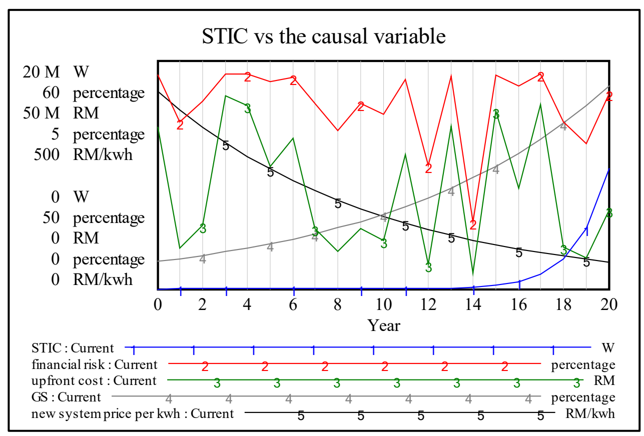

Fig 10. The impact on solar thermal installation capacity from causal variables such as government support (GS), upfront cost, new system price and financial risk.

Fig 11(a) shows the blue lines lied in the range 95% (Fig 11 (b)) of confident interval. The blue color line has shown the same pattern or behavior. The behavior of the model does not change over the whole run. It shows no impact on the modeled system even the parameters such as soft loan, guarantee and payback period were varied from 0.2 - 0.4, 0.6 - 0.7 and 4 - 5 respectively.

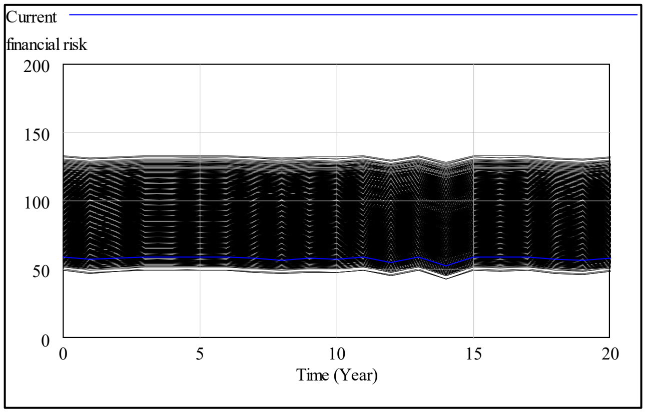

Fig 11 (a) Sensitivity Analysis for Financial Risk using Monte Carlo Simulation

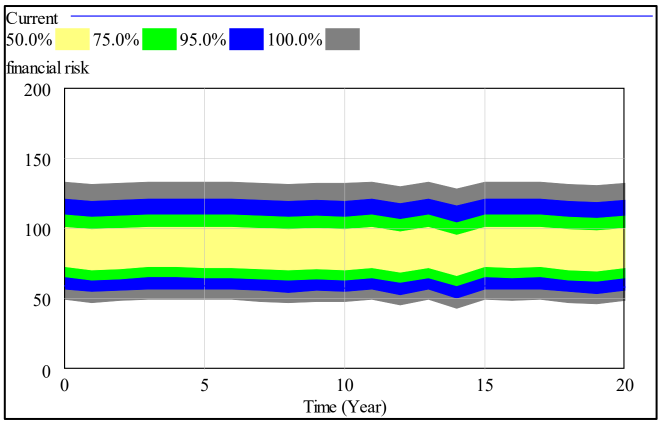

Fig 11(b). The financial risk confidence interval for multi-variate sensitivity analysis.

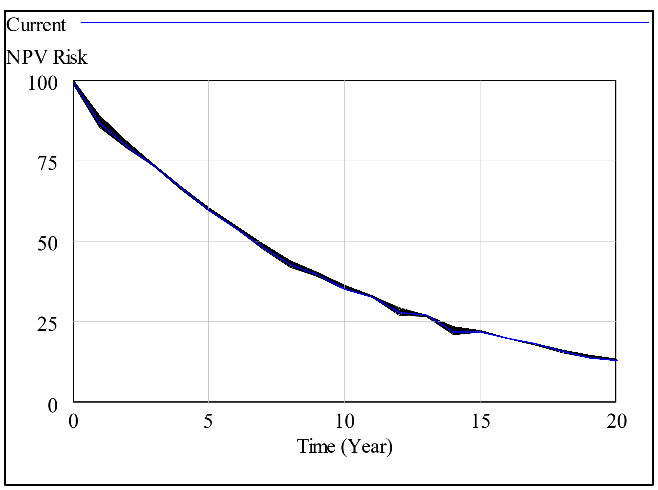

Fig 12 (a). Individual Traces for NPV risk Sensitivity analysis

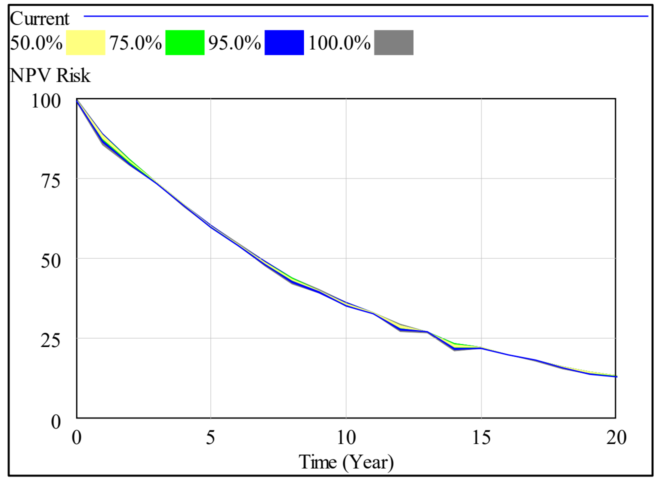

Fig. 12 (b). The confidence interval for the NPV Risk.

Fig 12 shows the main behavior of the financial model is not changed as the testing varying levels of parameter. It reflects that the parameters tested does not create a symptom to the model developed.

VI. Conclusion.

In this work, the financial risk model was developed and validated using System Dynamics and Monte Carlo simulation respectively in order to assess the effect of payback period, government guarantee on financial investment on solar thermal installation.

For the output of the behavior of payback period on financial investment suggested that the optimum period is between 4 to 5 years. Meanwhile, the optimum percentage for guarantee is between 60% to 70%. Lastly the Monte Carlo simulation suggests that the highest percentage for soft loan is 20% to 40%. All percentages and years measured are based on current situation where solar thermal installation in Malaysia is still in infancy stage. Up to date, there is no specific policy on solar thermal heating. There is also no specific rule or guidance for SME industries to invest on solar thermal for their alternative resource for heating process in their process industries.

The government support does help to increase the awareness to invest in solar thermal technology by industry. Policy maker can use the developed model for tailoring proper policy which beneficial Malaysian process industries. Improper policy may contribute risk to other categories such as construction and operation.

For further works, the financial support such as subsidies, grant or training is suggested to be taken into account to describe the financial risk faced by solar thermal installation capacity.

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