Economic and Financial Evaluation of a Low-Cost Portable Solar Dryer for Maturing and Drying of Dates

Business for Development (B4D) Report

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Key messages

What are the main findings?

- The Construction of a low-cost dryer that operates with solar power is in favour of small holding date palm farmers in the GCC countries;
- Drying different products (dates, fruits, vegetables, etc.) on our prototypes prove to be similar and cheaper compared to an electric /fuel commercial dryer;
- The drying process is completed in the most hygienic and eco-friendly way;
- The dates dried in the solar mobile dryer are reported to be of higher quality than those dried in the sun.

What is the implication of the main findings?

- Solar dehydration of dates (vegetables and fruits) over-production greatly reduces wasted product and the costs of final product (i.e., dates) since dehydration is considered as a key technology to preserve fresh dates (vegetables and fruits) in rural areas and thereby reduce food waste and post-harvest losses;
- The hot environment within the dryer enables the artificial maturing of fruits, particularly in dates that have the ability to fall down before reaching the maturing stage;
- The use of solar drying for agricultural products (vegetables and fruits) has a large potential from the technical and energy-saving point of view in the GCC region;
- The solar dryer, an affordable and low-cost technology, can reduce production costs, energy consumption, and waste (using dates outside the quality standard for fresh consumption) and is an alternative for small and medium producers.

Key words: Solar energy; mobile dryer; dates; return of investment; GCC.

Introduction

One of the challenges affecting small scale date palm producers in the Cooperation Council for the Arab States of the Gulf (GCC) countries is the destination of the goods that they cannot consume or sell. This is especially exacerbated when harvesting periods are very short and products have high rates of deterioration (*ie.,* some date palm varieties). In the practice, freezing process is usually the first solution, but it causes storage and handling difficulties and does not prevent the degradation of nutrients and organoleptic properties in addition to the high energy cost used for this process.

Yet solar energy is well developed to be involved in different sectors including agriculture. Solar radiation is utilized in heat and electricity generation. Both energies are key factors in food processing. The electricity is used in driving mechanical power and controlling processes, whereas heat is utilized in maturing, concentrating, drying and sterilizing of food in different processes. Sun drying is traditionally used in several regions in the world to dry various fruits like grapes, figs, etc. To this end, the aim of the drying process is to preserve fruits and vegetables, enhance quality and hygiene of dried products, and reduce post-harvest losses.

Figure 1: Solar mobile dryer designed by ICARDA in the UAE

Although there are many dryers for drying agriculture products, a low-cost indigenous design is not available for drying dates, vegetables, and fruits. Hence, a portable drying unit for dates has been designed, fabricated, and evaluated for its drying efficacy for the usage of small-scale date palm producers in the GCC countries. The solar dryer is based on the principle of flat plate solar collector and greenhouse effect.

This technology is considered to be one of the most attractive and promising applications of solar energy systems in the GCC countries. The aim is to improve the quality of dried dates, accelerate their drying process, and obtain cleaner fruits that are free from dust. This technology reduces the cost of energy, labor and time required while improving the quality of the fruits. This report focuses on the technical and economical assessment of the technology in the GCC region while presenting a rigorous economic analysis of the return on investment in the technology.

The device: A technical overview

Drying tables

The mobile solar drier consists of tables with covers that form a tunnel, where the product is placed inside. The walls and the fruits will be placed on a mesh so that an airflow below the product is also assured for enhanced drying. The cover consists of polycarbonate sheets that are fixed in a metal frame.

Figure 2: Solar mobile dryer developed by ICARDA in Jordan

The Innovation

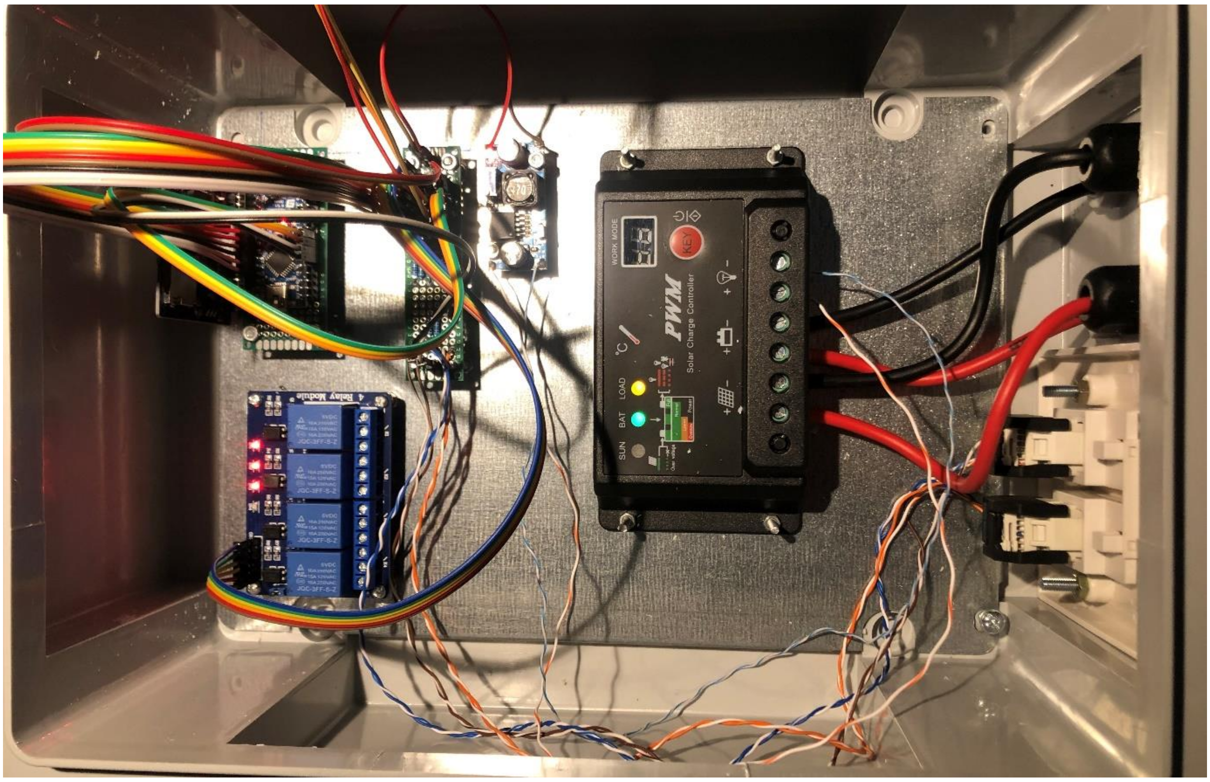
The dryer consists of tables that could be put together to form up to a 12 m tunnel. The solar mobile drier is equipped with a DC fan 12V 40 W, which is installed on a separated part with the control unit. The system is designed to have an autonomy of 6 hours working period during day and 2 hours during night. The dryer is controlled by temperature and humidity sensors. The solar system consists of one panel, one battery and a control unit.

Control unit

The control unit is controlling the fan’s speed and operation through a microprocessor based on temperature and the difference in humidity between the inside and outside the tunnel.

The power source is a solar panel and a battery that can ensure the operation during day and night (figure 3).

Figure 3: Control unit developed by ICARDA



Advantages and constraints of using solar mobile dryer (SMD)

The first assessment of the solar mobile dryer reveals the following advantages and constraints:

Advantages

- Improves the quality of the fruits, especially in humid areas. The agricultural products dried in greenhouses are reported to be of a higher quality than those dried in the sun;
- Avoids the contamination of dates by insects, birds, dust and rain;
- The technology saves energy and drying time, improves product quality as well as increases process efficiency. Solar drying systems have low operation and maintenance costs;
- Reduces the waste and loss rate;
- The technology reduces the amount of air pollution and greenhouse gases that result from the use of fossil fuels for heating or generating the electricity;
- Could be used for other purposes (e.g.: drying other products such as fruits, vegetables, medicinal and aromatic plants, etc. Figure 4).

Figure 4: Drying red pepper and Rosemary Jordan valley, Jordan

Constraints

- Drying can be performed only during sunny days unless the system is integrated with a conventional energy-based system. The drying in absence of sunshine is limited to the difference in environment humidity between inside and outside the drying chamber;
- Due to limitations in solar energy collection, the solar drying process is slow in comparison with dryers that use conventional fuels or electricity;
- Solar drying requires large land areas and long drying times, in addition to being subject to fluctuations in solar radiation, ambient temperature particularly in normal sun drying in open areas;
- Farmers lack knowledge for the maintenance of the system.

Performance analysis and economic evaluation of solar mobile dryer

Data collection

The dryer unit was fabricated by ICARDA APRP team. The structure is consisting of a metal frame that is enclosed and covered with semi-transparent white polycarbonate material as a thermal collector to concentrate solar energy, thus combining greenhouse heating and concentrated thermal collection for drying. The dryer has been later tested for several agricultural products such as dates (Majhool and Lulu), okra, tomatoes, pepper, thyme, rosemary. Information on the costs and prices has been collected from the existing values during the experimental trials conducted in Jordan (figure 5).

Figure 5: Drying Tomato at a cooperative Jordan valley, Jordan

Methodological framework

An economic analysis of the solar mobile dryer can be performed using three methods, namely annualized cost, lifecycle saving, and payback period (PBP) (Nayak et al., 2012). The annualized cost
method allows comparison of the cost of drying per unit weight of the product using solar energy. The annualized drying cost of a solar dryer remains almost constant over the entire life of the system. The lifecycle savings method determines the savings made in the future years to determine whether the present investment is worth the annual savings over the life of the system. The payback period method gives the investment's return period. This last indicator helps to determine the acceptability of the technology.

Given that the objective of the project is to enhance the adoption of such technology, the PBP was used in this report. The main disadvantage of using the PBP as an investment assessment technique is overlooking the overall profitability of the investment. Taken into account is the cumulative net cash flows only up to the point where they become positive. Any net cash flows after that point are ignored. For this reason, in this analysis we use PBP in conjunction with the net present value (NPV) and the internal rate of return (IRR). The aim is to provide a clear picture for the end user (farmer, private sector, government, etc.) for the expected investment period for this drying house, and hence, its acceptability by the smallholder date palm farmers.

Empirical results

1- Descriptive statistics results

A preliminary simple economic analysis was conducted on different products to evaluate the drying efficiency and performance. The results are presented in the below table.

Table 1: Descriptive statistics and economic indicators for key dried agricultural products

Item	Unit	Tomato	Ocra	Majhool	Lulu
Quantity	kg	100	150	60	66
Device area	m^2	6	9	3	3
Times of drying to cover the quantity		7	7	2	1
Time of drying	h	36	24	72	48
Dried quantity	kg	20	26	45	54
Row material cost	USD	0.21	2.82	2.12	
Product selling	USD	14.12	21.19	6.36	
Device capacity	kg/batch	28.57	100	240	264
Drying rate	%	20	17.33	75	81.82
Device capacity	kg/m^2	2.381	8.333	20	22
Capacity per day	kg/m^2	1.587	8.333	6.667	11
Product per day	kg/m^2	0.317	1.444	5	9
Material cost	USD	21.19	423.73	127.12	-
Salt	USD	0.21			
Packaging	USD	2.82	1.41		
Dried price	USD	282.49	550.85	286.02	-
Total cost	USD	24.22	425.14	127.12	-
Total income	USD	282.49	550.85	286.02	-
Net income	USD/kg (fresh)	2.58	0.83	2.66	-

Source: Own elaboration based on experimental data.

Note:

- *Experimental design and trials have been conducted in Jordan and UAE.*
- *The analysis is based on fresh product used.*

From the displayed findings, it is clear how the drying can contribute to increase the net income for the different products analysed. For the dates, such income could be increased by almost 2.66 USD/Kg. This indicates that a small date palm farmer (with 100 trees producing 70 kg/tree) with a production capacity of 75%, an income could be generated by almost 13965 USD.

2- Approach, analytical framework, and results

Analytical framework

As mentioned in the previous section, three indicators were used to evaluate the profitability of the solar mobile dryer: NPV, IRR, and PBP. These are explained in more detail below. Net present value (NPV) Net present value is simply the sum of the annual discounted net cash surpluses and deficits throughout the life of the project (solar mobile dryer). If the NPV is positive (i.e., NPV is greater than zero), the investment is normally considered profitable. Internal rate of return (IRR) Internal rate of return is the discount rate at which the NPV equals zero. Payback period (PBP) Payback period is the minimum time required for the investment to break even. It is the minimum number of years required for the undiscounted cumulative net cash flow to become positive.

Key assumptions

Costs and returns are presented in "real" and not "nominal" values. Inflation was not considered. That is, all costs were converted to USD in all years are considered to have the same purchasing power and be directly comparable. Given that our data is based on the information provided at the experimental level, for the cost items, we considered the following assumptions for the calculation of economic and financial indicators:

- Will consider the use of a period of 4 months for the device. Thus, for Majhool variety, the total quantity to be dried is around 16000 Kg and for Lulu is about 24000 Kg.
- The device is used only for drying dates.
- The effective drying capacity is about 75%. The final potential dried quantity of Majhool is 12000 Kg and for Lulu 18000 Kg.
- Product net weight (kg/kg of fresh date) is considered 75% for Majhool variety and around 80% for Lulu variety.
- Dried quality of dates (75% good quality and higher selling price and 25% as moderate quality with lower selling price).
- The investment cost of the solar mobile dryer is around 1000 USD.
- The lifecycle of the device is estimated to be 10 years.
- The estimated maintenance cost is about 25% of the capital investment cost.
- The variable costs (labour, transportation, etc.) is estimated at 500 USD/person/month.

Economic/Financial indicators

The major cost of the polycarbonate dryer is the construction, including the drying trays. The parameters required for financial analysis include discount rate, inflation rate, and project lifetime. As indicated above, the cost-benefit analysis was performed assuming prevailing market prices for both fresh and the dried dates in Jordan. This is an analysis of the sum of all costs and benefits in a period derived as annualized cost, benefit-cost ratio, and simplified PBP.

The performance of an investment in a polycarbonate drying house can be studied from the production level. Profit/returns is defined as the difference between sales (PP) with all types of costs. Profit can be written as:

$$PR = PP - CC - PC \tag{1}$$

Where:

- PR: Profit (in USD)
- CC: Capital costs/investment (in USD)
- PC: Production costs (in USD)

Production cost includes the costs of fresh material, labour, electricity, maintenance, and insurance.

Return of capital (ROC) is also called the profit from the investment. This indicator is influenced by time of the investment and the life of the system and can be expressed using the following formula:

$$ROC = PR/CC \quad (2)$$

The PBP indicator is defined as the investment cost per average annual net income. This is calculated using the following formula (expressed in years):

$$PBP = CC/PR$$

Net present value, defined as a popular measure of profitability used in corporate budgeting to assess a given project's potential return on investment, was used to calculate the present value of excess cash flow during the project period. This is calculated as the total for each year of the net cash flow minus capital costs, according to the following formula:

$$NPV = \sum_{n=1}^{N} P_n(1+i)^n - CC \quad (3)$$

Where:

$$P_n = S(1+i)^n \quad (4)$$

P is the discounted present value (*S*) to be invested in *n* years. The NPV decision criteria state that an investment is usually acceptable if the NPV is greater than zero.

Analytical results
The collected experimental data is displayed in table 2 below.

Table 2: Descriptive statistics and economical indicators for dates palm variety Majhool and Lulu

Item	Unit	Majhool	Lulu
Quantity	kg	60	66
Device area	m2	3	3
Times of drying to cover the quantity		1	1
Time of drying	h	72	48
Dried quantity	kg	45	54
Row material cost	USD	2.12	
Product selling	USD	6.36	
Device capacity	kg/batch	240	264
Drying rate	%	75	81.82
Device capacity	kg/m2	20	22
Capacity per day	kg/m2	6.667	11
Product per day	kg/m2	5	9
Material cost	USD	127.12	-
Salt	USD	-	-
Packaging	USD	-	-
Dried price	USD	286.02	-
Total cost	USD	127.12	-
Total income	USD	286.02	-
Net income	USD/kg (fresh)	2.66	-

Source: Own elaboration based on experimental data (2023).

Note – Practical hypothesis:

- *Economic evaluation will be applied to the two dates palm variety Majhool and Lulu.*
- *Will consider the use of a period of 4 months for the devise. Thus, for Majhool variety, the total quantity to be dried is around 16000 Kg and for Lulu is about 24000 Kg.*
- *The device is used only for drying dates.*
- *The effective drying capacity is about 75%. The final potential dried quantity of Majhool is 12000 Kg and for Lulu 18000 Kg.*
- *Product net weight (kg/kg of fresh date) is considered 75% for Majhool variety and around 80% for Lulu variety.*
- *Dried quality of dates (75% good quality and higher selling price and 25% as moderate quality with lower selling price).*
- *The investment cost of the solar mobile dryer is around 1000 USD.*
- *The lifecycle of the devise is estimated to be 10 years.*
- *The estimated maintenance cost is about 25% of the capital investment cost.*
- *The variable costs (labor, transportation, etc.) is estimated at 500 USD/person/month.*

The empirical findings indicate that, for the Majhool variety, a real discount rate of 7.5%, the NPV is 209546.87 USD (Table 3). Given that the NPV decision criteria state that an investment is usually acceptable if the NPV is greater than zero, then the solar mobile dryer appears very profitable. The IRR for this project supports this. The estimated IRR (+100%) is much higher than current interest rates (7.51%). This shows how profitable the investment in this solar mobile dryer is and its potential affordability by the small holder date palm producers. In addition, there are calculated indicators for non-discounted profitability criteria such as profitability index (PI), known as profit investment ratio (PIR), payback period (PB), return on investment (ROI), and cost-benefit ratio (CBR) of this solar mobile drier technology.

Applied for drying Majhool variety, the PBP is very small, 0.4 years (Table 3 and Figure 4) compared to the expected life of the solar mobile dryer (10 years). This PI rule is a decision-making exercise that helps evaluate whether to proceed with this technology. The rule is that a PI ratio greater than 1 indicates that the project should proceed. A PI ratio below 1 indicates that the project should be abandoned. The PI indicator shows a ratio greater than 1 (i.e., 210) which confirms the profitability of this business project. The PB indicator refers to the amount of time it takes to recover the cost of an investment. Under the 7.5% discount rate scenario, the PB of an investment reaches a break-even point in less than one year (i.e., almost one operating months). Thus, the desirability of an investment is directly related to its PB. In this case study, therefore, shorter paybacks mean more attractive investments. The ROI indicator used to measure the amount of return on a particular investment relative to the investment's costs highlights that higher returns mean more attractive investments. The ROI indicator is not only positive but very high suggesting a gain from this investment in this machine business relative to its costs, and consequently the profitability of this investment. This statement is also confirmed by the discounted profitability indicators of benefit cost ratio (BCR =1.35) and internal rate of return (IRR=2977%). Overall, investing in solar mobile dryer in the GCC date farming systems could save money by reducing post-harvest losses, reduce wastes, reduce production costs, providing evidence for the model's profitability and self-sustainability.

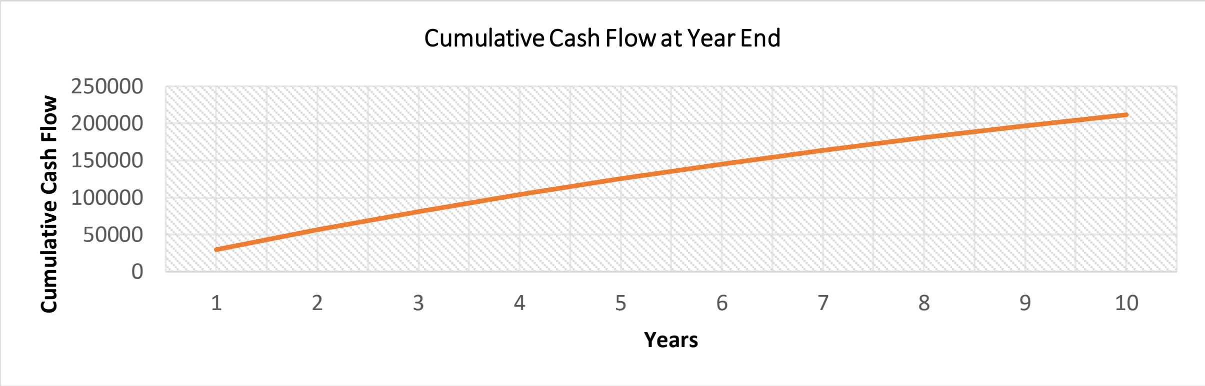
Table 3: Computation of economic indicators and financial indicators (NPV, IRR, and PBP) of the solar mobile dryer

Economic & Financial Indicators – Solar Mobile Dryer (SMD)	***Majhool***	***Lulu***
Net present Value (NPV) USD	209546.87	168362.39
Profitability Index (PI)= (1 + (Net Present value / Initial investment))	210.54	169.36
Payback Period (PBP)-(Years)	1	1
Return on Investment (ROI) - %	306.50	246.50
Benefit Cost Ratio (BCR)	1.35	1.44
IRR (%)	Very high (2977)	Very high (2378)
Accept or Reject SMD investment	Accept	Accept

Source: Own elaboration based on experimental data (2023).

Note: The IRR is very high because the period to recuperate the investment is very low (less than one year) for a life cycle of the device for 10 years

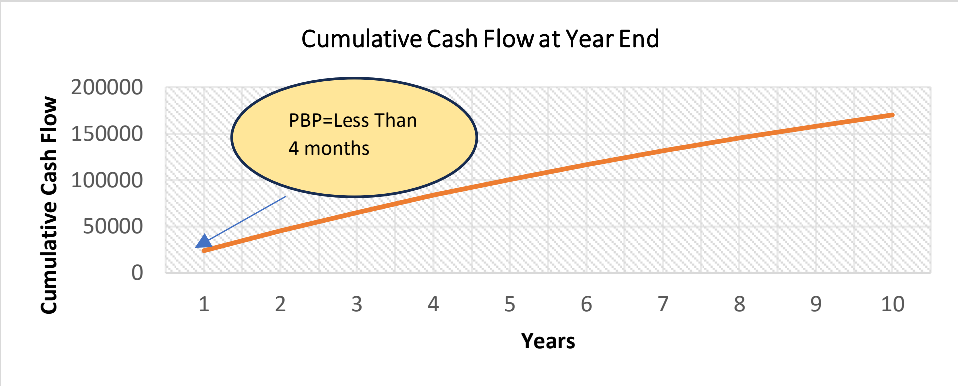
Figure 4: Cumulative cash flow at year end (PBP when the solar mobile dryer used for Majhool variety)



Source: Own elaboration based on experimental data (2023).

For dates palm lulu variety, the analysed data revealed that the internal rate of return (IRR) of investing in the solar mobile dryer system is very high (around 2378%) for a lifecycle of 10 years (Table 3). The IRR indicator is a key element that determines the technology's validity by calculating when it exceeds the opportunity cost of capital. For a lifecycle period of 10 years, IRR exceeds the opportunity cost of capital (which is normally the interest rate on borrowed capital that is available in the economy – at the time of project implementation this was about 7.5% for the GCC region, on average). The analysis also determined that the net present value (NPV) of using SMD for drying Lulu variety at a 7.5% discount (or interest) rate is USD168362.39. The overall benefit cost ratio (BCR) of using this system is 1.44, indicating that the costs could rise by 44% before the BCR would decline to 1. In addition, the empirical findings also shows that the performance of the SMD system, given the high value of the return on investment (ROI) indicator used to measure the amount of return on a particular investment relative to the investment's costs, is acceptable (+240%), suggesting a gain from this investment in this technology relative to its costs. The profitability index (PI), also known as profit investment ratio, is greater than one (1691). A PI below 1 indicates that the investment in this technology should be abandoned. The last measured indicator is the payback period (PBP). The PBP refers to the amount of time it takes to recover the cost of an investment and is defined as the length of time at which an investment reaches a break-even point (Figure 5). Thus, the desirability of an investment in this technology is directly related to its PBP. In our case, therefore, shorter paybacks mean more attractive investments (less than one year). Overall, all economic and financial indicators support investment in this SMD technology for small holder's date palm producers in the GCC countries.

Figure 5: Cumulative cash flow at year end (PBP when the solar mobile dryer used for Lulu variety)



Source: Own elaboration based on experimental data (2023).

Concluding remarks and policy implications

Solar mobile dryer (SMD) is an important ICARDA initiative for the smallholder's date palm growers in the GCC countries for its benefits in energy saving, reducing waste and post-harvest losses, and comprehensive competitiveness of modern agriculture improvement, especially in these high dates production area. An overview and economic assessment of ICARDA progress towards the development of mobile solar dryer is presented in this report.

SMD applied for dates were evaluated economically for two varieties of dates. Empirical findings reveal the high profitability of the SMD. At a real discount rate of 7.51%, the NPV is positive and very high in both cases. Given this, the decision criterion states that an investment is usually acceptable if the NPV is positive (the investment is profitable). This criterion was also supported by both the IRR and the PBP criteria. The estimated IRR was higher than the current interest rate in the GCC region, which could encourage both smallholders date palm growers to invest in this technology. The PBP was found to be less than one year (for only one cropping season) which is relatively short considering the life of the system (10 years). This suggests that investment or action costs in this dryer system are recovered quickly reducing the risk involved in the investment. The results from the present research study suggest the following:

- First, given the SMD meet the technical, economical and socioeconomical requirements, there is a need for a greater political and institutional input into larger SMD's projects (targeting high production areas). There is a need to design and develop alternative policy instruments and institutions for extension, technical assistance, training, and credit services that will facilitate the adoption of this technology.

- Second, the benefits of this technology must be clearly perceived by all farmers categories (Small scale farmers, small and medium enterprises-SME's, community-based organisations- CBO's, etc.) operating in different agro ecological zones (date palm growers, vegetables and fruits growers, medicinal and aromatic plants entrepreneurs – MAPS, etc.), given their own socioeconomic conditions. In GCC areas, increasing farmers' knowledge and perception of the merits of SMD (and their uses for other products) through better access to technical information, extension, and training will help them to develop a positive economic assessment of the technology.

- Last, research on application of this advanced solar technology has been proved effective to promote solar energy utilization in these SMD and provide an insight into their integration prospect. With further improvement in the technical performance, as well as the establishment of supportive policy and incentive mechanism, modern and large SMD in the GCC will have a promising prospect to lead a sustainable development and cope with the climate change threat (reduces the amount of air pollution and greenhouse gases that result from the use of fossil fuels for heating or generating the electricity).

Contacts

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