Concurrent Engineering in Aerospace Systems

MECH 6941

Winter - 2022

Project proposal:

Design and Development of Solar Dryer

Submitted to

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Abstract

The use of solar energy has been significantly increased during past few decades but still there are many aspects of it which are still not utilize or explore one such application of solar energy is to use for food preservation in formalize manner. The goal here is to eliminate the moisture from vegetable, crops, and fruits. The solar dryer is a machine which can be used to harness the solar radiation to reduce the moisture content from the food items and agriculture product this method is cost effective and time saving then conventional method such as refrigerator. In this machine, a portion of the incident sun energy on the glass cover is reflected into the atmosphere, while the rest is delivered to the inside cabinet drier. Furthermore, a portion of the transmitted energy is reflected off the product's surface. The remaining portion is absorbed by the material's surface. The temperature of the product rises because of solar light absorption. As a result, the temperature of the product inside the chamber rises. Finally, the product is dried and can be preserved. Solar dryer is rarely used in domestic as well as industrial application. So, we are targeting this sector by introducing solar dryer as a new method because awareness about the use of renewable energy is exponentially increased and use and application of it and main targeted audition of this product is agriculture industry.

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1 Introduction

The global population is projected to be 9 billion in the year 2050, which will lead to increase the food production by 70% as per the Food And Agriculture Organization report, 2009. To overcome the high demand of food requirement, the production rate must be increased. Not only the high production rate but also reducing the food lost is a key to overcome the necessary food demand in future. According to FAO 2011, every year around 1.3 billion tons of agricultural products is lost because of lack of storage, post-harvest food lost and improper supply chain.

Though, there are several methods to store the food produce such as cold storage, open air drying, gas heater etc. but majority of these techniques uses fossil fuels. Drying is often considered as a one of the economic methods to improve the storability and the life of the farm products. In drying process simultaneous transfer of heat and mass take place and moisture near the surfaces of the product is evaporated through various mechanisms such as diffusion, capillary and gravity flows and flow caused by shrinkage and pressure gradients. A reduction of the moisture content prevents the risk of microorganism growth, minimizes many of the moisture-intermediated, deteriorative reactions such as enzymatic reactions, non-enzymatic browning, and oxidation of lipids and pigments, and substantially reduces weight and volume

For smaller farmers in rural areas of tropical countries open air drying is most preferable method du to the affordability and financial point of view but the method is very much dependent on the ambient condition and more likely to be affected by the dust, rain, pests, bugs, birds and rodents which at the end lead to production lost. (El Hage et al., 2018; Singh et al., 2018)

1.1 Working Principle

The working principle of solar drying is to absorb solar radiation and evaporate the moisture from the material. The rays of solar radiation falls on the material some part of it absorbed by the material based on the colour of it, some part is reflected and remaining portion is lost in atmosphere as shown in figure 1.

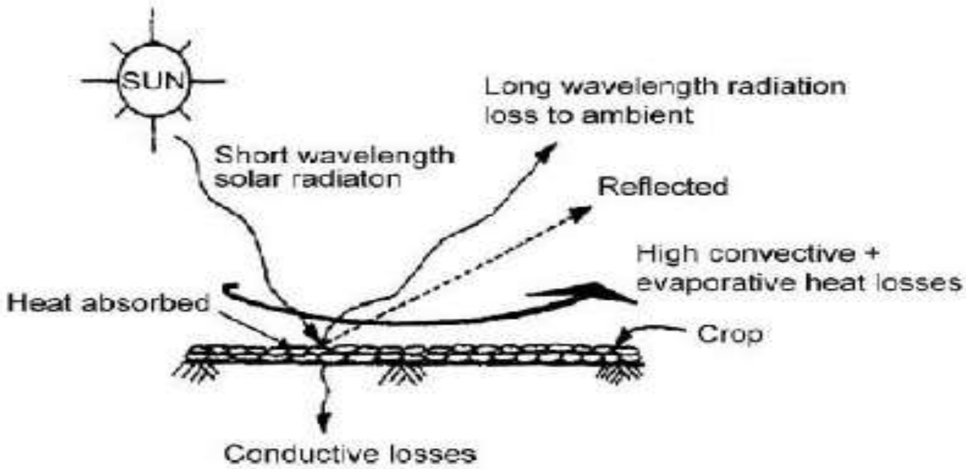


Figure 1 working principle od solar dryer

1.2 Classification of Solar dryer

Solar dryer is a developing technology during last decade various types of solar dryer has been developed to reduce post-harvest loss and increased the product quality. Solar dryer for agriculture can be classified based on size, shape, method of air movement and types of solar radiation absorption method. Generally, solar dryer can be classified in mainly two types direct type solar dryer and indirect solar dryer.

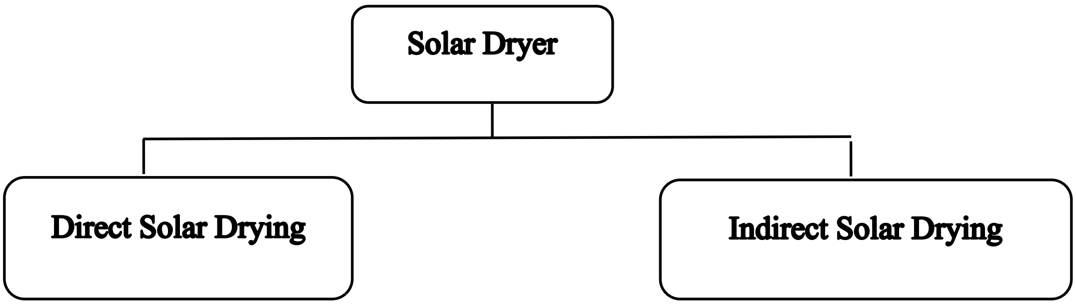


Figure 2 Classification of solar dryer

1.2.1 Direct type solar dryer

The working of direct solar drying is same as green house, in which corps are placed in a glass covered box. The solar radiation falls on the top of the glass as shown in the figure 3. The air is entered from the bottom of the box and leaves from the top of the box which creates natural flow of air due to the temperature difference. In the cabinet dryer, of the total solar radiation impinging on the glass cover, a part is reflected to atmosphere and the remaining is transmitted inside the cabinet. A part of the transmitted radiation is then reflected from the crop surface and the rest is absorbed by the surface of the crop which causes its temperature to increase and thereby emit long wavelength radiations which are not allowed to escape to atmosphere due to the glass cover.

1.2.2 Indirect solar drying

In the indirect solar drying radiation is absorbed in a collector which increases the temperature in collector box due to increased temperature the air moves in the upper part of the solar dryer,

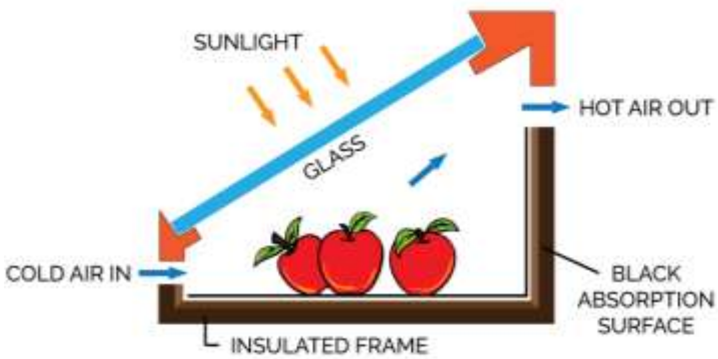


Figure 3 Direct type solar dryer[2]

where corps are placed as shown in the figure 4. This hot air removes the moisture from the corps. This type of solar dryer is useful for the products such as flowers, fruits, vegetables which will dry completely when come into contact with direct sunrays.

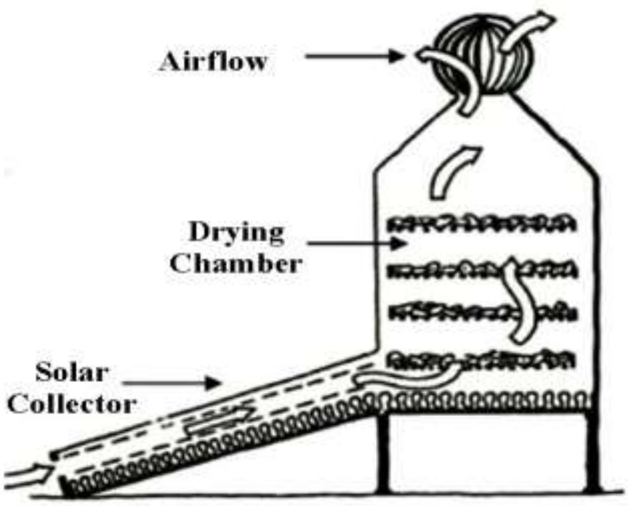


Figure 4 Indirect type solar dryer[3]

1.3 Functional Analysis

Based on customer survey we have decided the deliverables to the customers to fulfil the customer satisfaction. These deliverables are described in the following functional analysis diagram. The functional analysis is classified in five main topic design, operation, safety, durability, market survey and each topic is further divided in various sub-topic which shows merits of the solar dryer design.

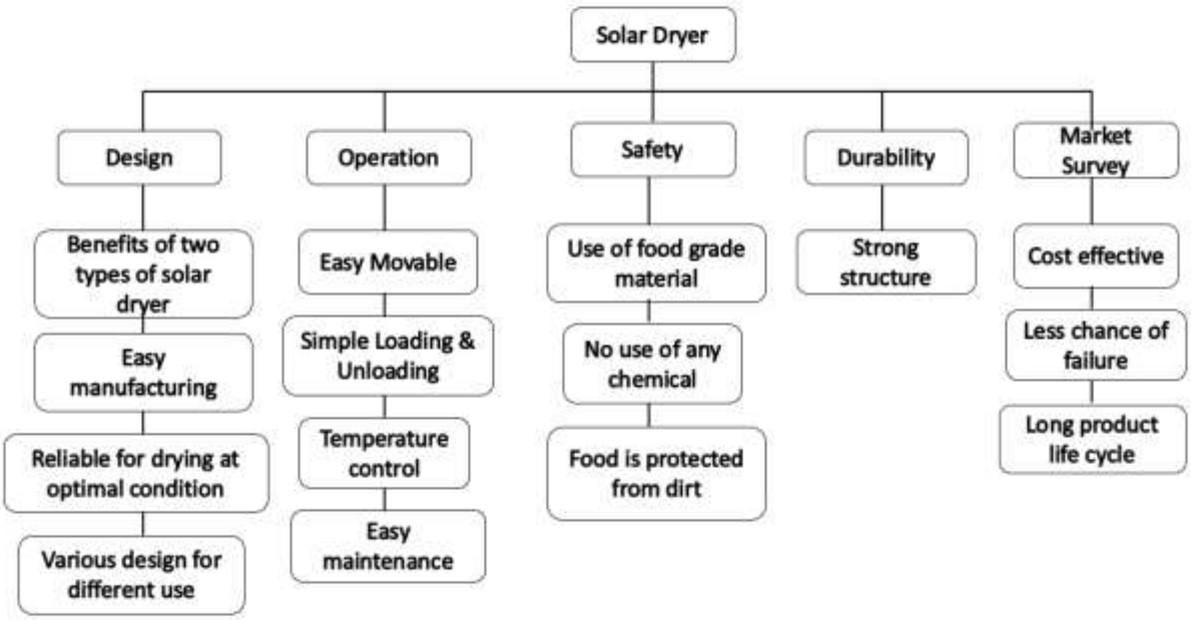


Figure 5 Functional analysis diagram

2 Product Planning

2.1 Competitive Strategy

We aim to achieve competitiveness by utilizing two strategies: Cost Focus strategy, for a family of products, and Differentiation strategy for another family of products. With the cost focus strategy, we aim to offer the lowest price for the family of solar dryers on the market. With this strategy, we can achieve high demand for the products in countries with elevated levels of low-income earners and generally, with value-oriented buyers. Its objectives are an efficient supply chain and low operational cost implementation. With the differentiation strategy, we aim to create high end solar dryers to serve similar needs.

2.2 Product Plan

We aim to launch the solar dryer into the market in September, 2022 utilizing the more basic solar drying technologies and then introduce more advanced models in time. Figure 1.0 shows the product plan map.

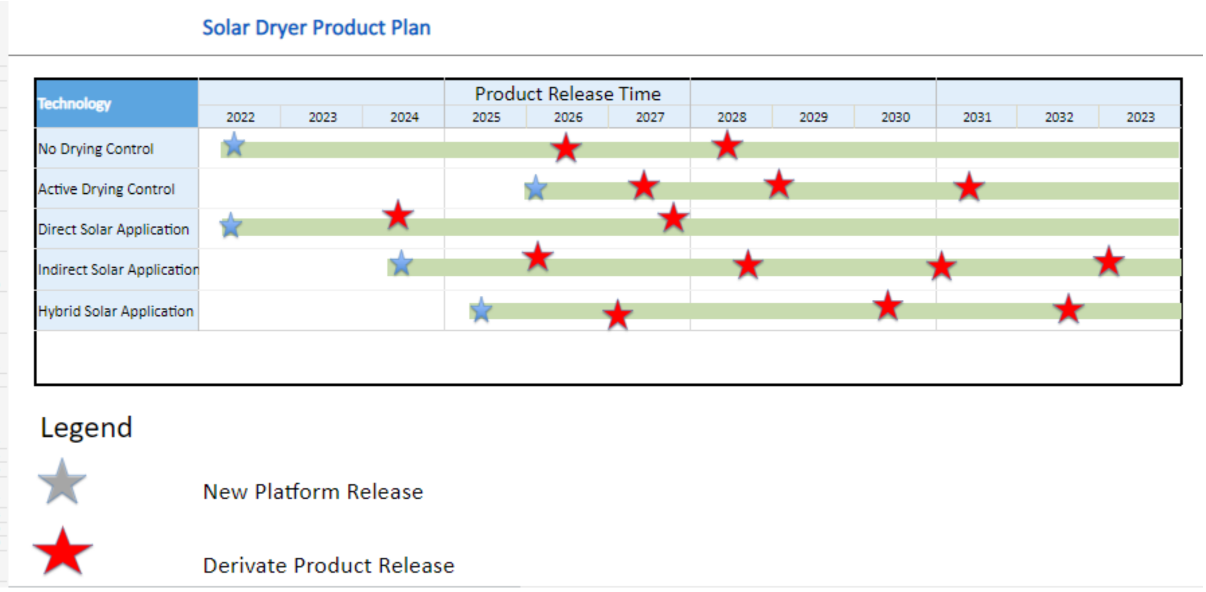


Figure 6 Product Plan Map

2.3 Market Segmentation

Two market segments for the solar dryer are to be explored: Domestic Application, Industrial Application. The product will be launched into the domestic application segment and will later be introduced in the industrial segment. Figure 1.1 shows the market segment map for the two market segments and their introduction times. The products are introduced with the cost focus strategy which make them less costly than existing products. The existing products' prices used for comparison are the mean prices for similar solar dryers in India.

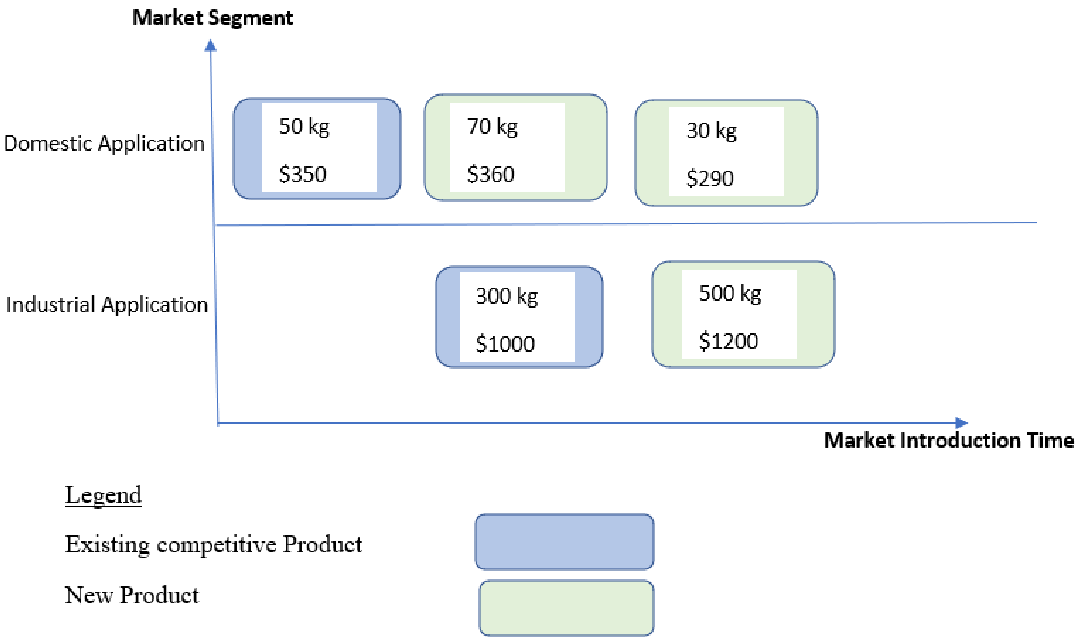


Figure 7 Market Segment Map

2.4 Product Platform Planning

The product platforms are: High Performance Requirement and Basic Performance Requirement. Figure 1.2 shows the product platform planning map for the Solar Dryer. The solar dryer is introduced into the market in the basic performance requirement platform, and its derivative products are released simultaneously based on more specific applications of the product. In the High-Performance Requirement platform, the derivative products are distinguished by performance capabilities based on the technology used

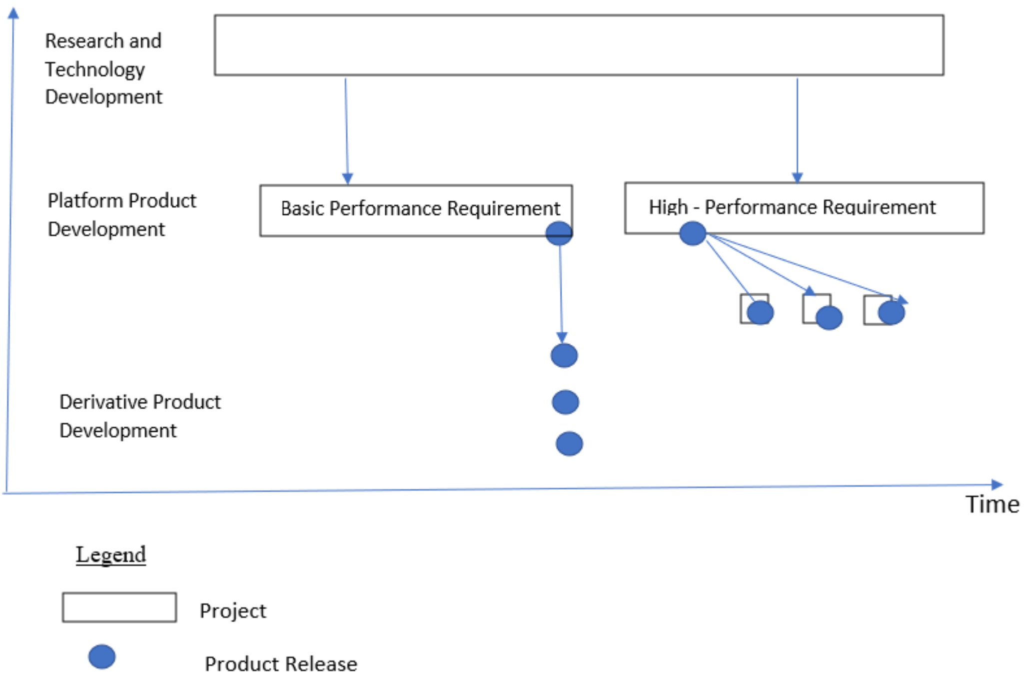


Figure 8 Product Platform Planning Map

2.4.1 Technology Road Map

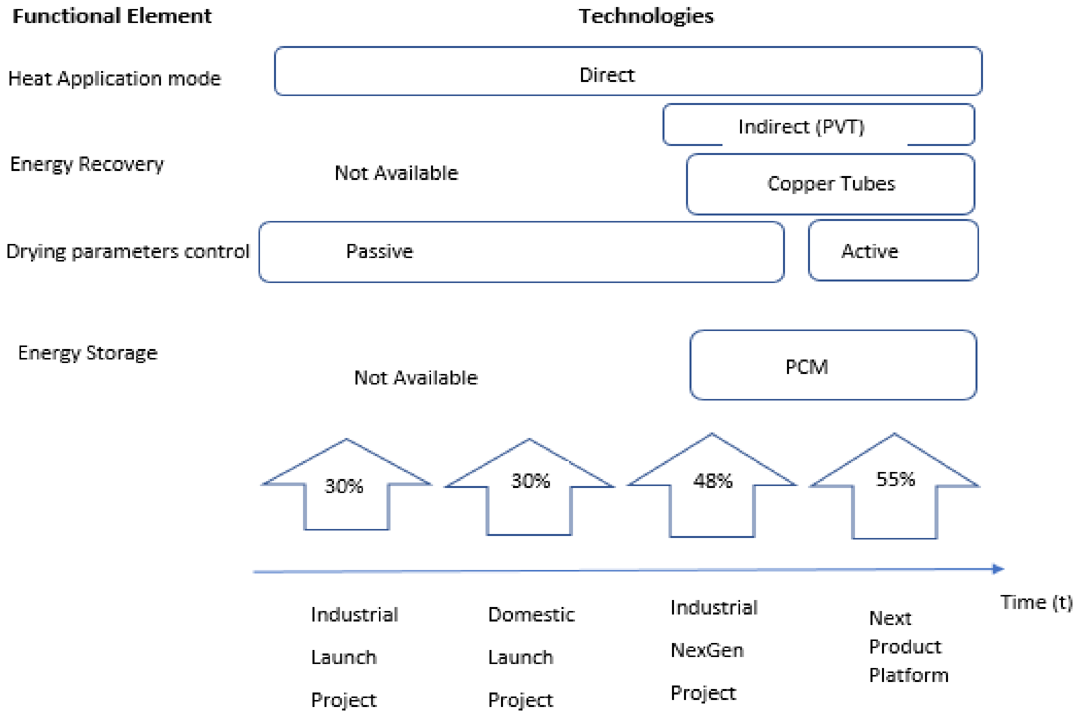


Figure 9 Solar Dryer Technology Road Map

2.5 Mission Statement

Product Description: Direct solar dryer for domestic application	
Benefit Propositions:	Higher drying efficiency than open air drying
	Low maintenance
	Better output quality than open air drying
Key Business Goals:	Launch in September 2022
	Cost focus competitive strategy allowing reaching of target sale volume and margins.
	Consistent 5-star customer reviews
	Grow market share and penetrate into the industrial application segment.
Primary Market:	Households in regions that experience high amount of yearly sunlight.
Assumptions and Constraints:	1. Wheels for ease of mobility
	2. Glass inclined at 22 degrees
	3. Use of food grade materials
Stakeholders:	1. Major retailers
	2. New customers
	3. Marketing & Sales
	4. Manufacturing supply chain

2.6 Results & Conclusions of Product Planning

- This opportunity funnel presents diverse and exciting opportunities.
- The product plan aligns with the competitive strategy.
- The product plan addresses the most important current opportunities.
- Multiple product platforms and partnership with suppliers were used to leverage the business' resources.
- The core team accepts the challenges of the mission statement.
- The elements of the mission statement are consistent.
- The project is not over constrained, and the team has the freedom to develop the best possible product.
- We can improve the process by reducing supply chain costs.

3 Concept Generation

After identifying the customer needs and developing the functional planning various concepts are selected for the design of the solar dryer. For concept generation two approach are selected industrial or agriculture purpose and domestic purpose.

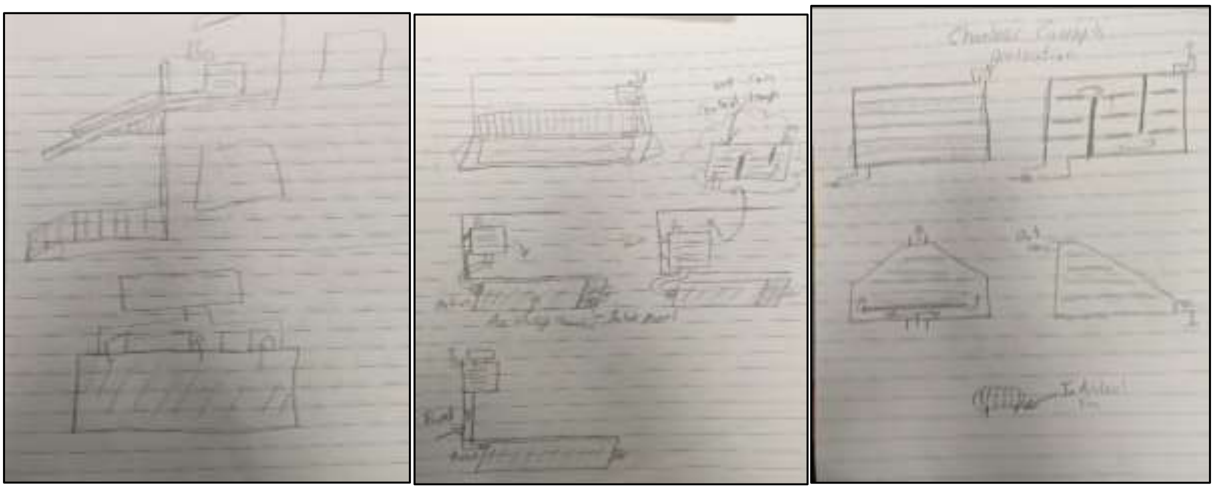


Figure 10 Concept development for agriculture purpose

3.1 Concept Designs

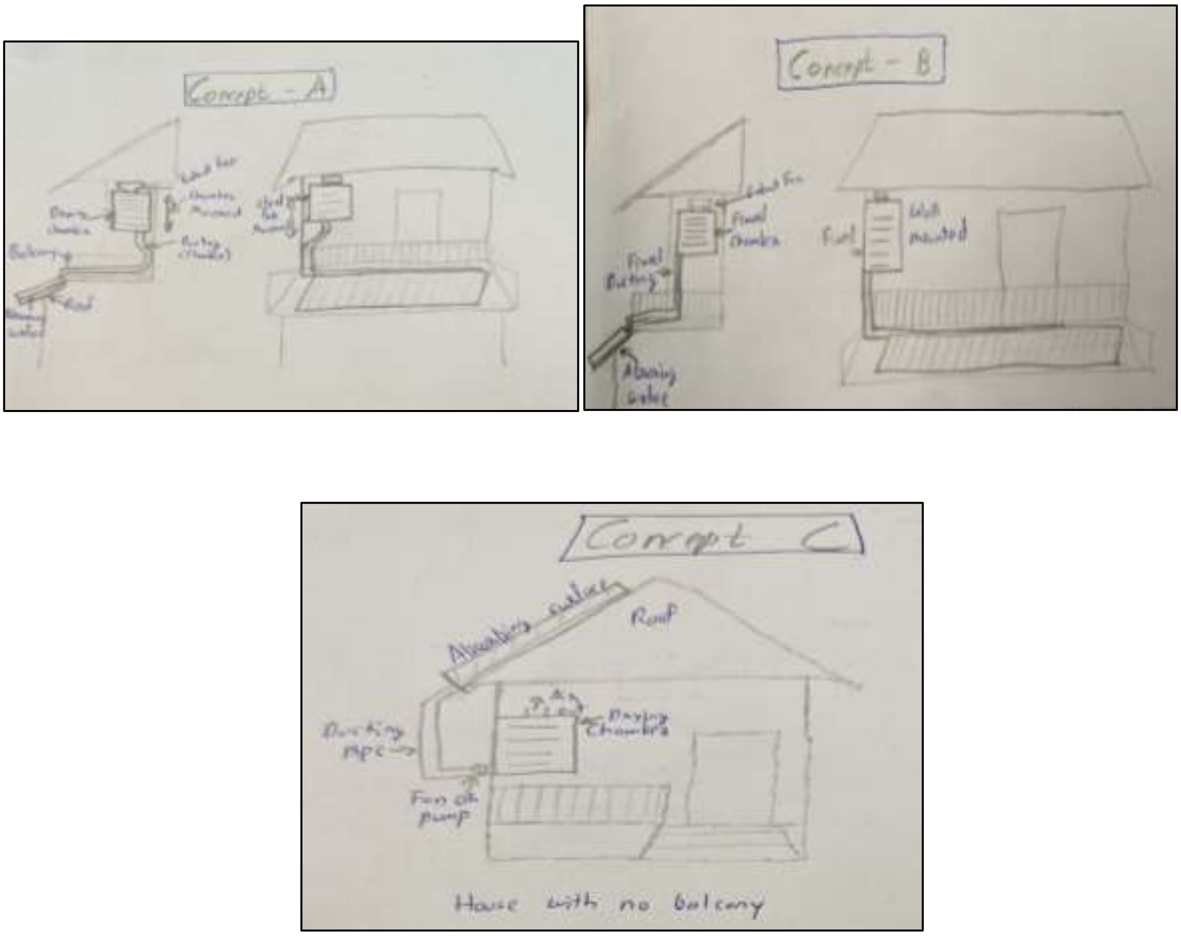


Figure 11 Various concept for solar dryer for domestic purpose

3.2 Concept Selection

Table 1 concept selecction matrix

Evaluation Criteria		Wt.	Concept A		Concept B		Concept C		Existing Model (Reference)	
			Val 1	Wt.*Val1	Val 2	Wt.*Val2	Val 3	Wt.*Val3	Val 1	Wt.*Val 1
1	Easy to build	0.2	2	0.4	3	0.6	2	0.4	3	0.6
2	Cost	0.25	2	0.5	2	0.5	1	0.25	3	0.75
3	Efficiency	0.05	3	0.15	4	0.2	2	0.15	3	0.15
4	Reliable / Robust	0.05	3	0.15	3	0.15	2	0.1	3	0.15
5	Easy to insert and replace Crops	0.15	4	0.6	2	0.3	2	0.3	3	0.45
6	Area Occupy	0.2	5	1.0	5	1.0	5	1.0	3	0.6
7	Elegance	0.1	4	0.4	5	0.5	4	0.4	3	0.3
	Total	1.0	3.2		3.25		2.6		3	
	Rank		2		1		3		-	
	Continue?		Consider		Develop		No		-	

3.2.1 Explanation for weightage distribution

Table 2 weighted distribution

Evaluation Criteria	Weight (%)	Justification
Easy to Build	20%	Manufacturing cost majorly depends on the complexity of the product.
Cost	25%	Customer willingness to buy the product and outstand in the competitive market determines by cost, so it has primary focus.
Efficiency	5%	It is kept at least by 5% because time to dry is not concerning factor for customer unless is add money on it.
Insert and Replace Crops	15%	Convenience to load and unload is concerning factor as it is wall mounted.
Reliability/Robust	5%	Product is do not have more moving parts and not in harsh working condition, thus it is assigned 5%
Area Occupy	20%	Space occupy by the product is main drawback on existing product, so this factor is kept at 20%.

Elegance and Sophistication	10%	The target market initially is urban area, where appearance is in trend, which can change customer willingness to buy.

3.3 Rating

Table 3 Rating for concepts

Rating Criteria	**Rating**
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

3.3.1 Reasoning of rating (Compared with reference)

Easy to build

This term tries say that we can do several processes like casting, moulding, machining, joining, forming, etc. with high manufacturability.

- *Concept A (Rating-2):* - It has specific flexible ducting to transfer heat and hybrid system in solar radiation absorbing panel, which addon some extra parts and assembling process.
- *Concept B (Rating-3):* - In this, hybrid system adds some assembling process, but it can be balance with reference as stand is eliminated in this concept.
- *Concept C (Rating-2):* - It has fan or pump to circulated dry air from up to downside, thus add extra parts and assembly process to manufacture.

Cost: -

This term refers to the total manufacturing cost of product, along with considering development, marketing, other miscellaneous cost.

- *Concept A (Rating-2):* - It has specific flexible ducting to transfer heat and hybrid system in solar radiation absorbing panel, thus it increases overall cost of the product.
- *Concept B (Rating-2):* - In this, it has hybrid system and have ducting with insulated, which at the end adds some overall cost in the product.
- *Concept C (Rating-1):* - In this extra cost of fan or pump and has larger heat absorbing panel, which makes it little bit costlier compared with the reference.

Efficiency

- *Concept A (Rating-3):* - It has long ducting to transfer the dry air, which make heat lose, but it is compensate by hybrid system.
- *Concept B (Rating-4):* - It has fixed ducting, so it improves dry air transferring system and has hybrid system makes more efficient than the reference.

- *Concept C (Rating-1):* - In this concept dry air pushed by the fan or the pump, where back pressure lose decreases the efficiency.

Easy to insert and replace corps
As the term says, it denotes how easily or single headedly you can put or take out the crops or species and from inside the home itself.

- *Concept A (Rating-4):* - It has same kind of loading process but because of a convenience location from inside the home it rated by 4.
- *Concept B (Rating-3):* - This concept does not have moving stand to load and unload crops, but convenience to access from home make its rating same as reference.
- *Concept C (Rating-2):* - The concept C have the same design is terms of the accessibility to the chamber, but normally at ground floor height may increases, which can be not ergonomically good.

Reliable/Robust operation
We can say that if a piece has a long life without less need of maintenance or overhaul, it is robust and reliable. Like a Nokia 3310 mobile phone.

- *Concept A (Rating-2):* - In this concept it has moving stand, which can become loose or malfunction after certain numbers of cycles.
- *Concept B (Rating-3):* - It has aluminum and stainless-steel body which do not get effected by environment as same as reference, so it rated by 3.
- *Concept C (Rating-2):* - It has moving parts like fan or the pump which can be malfunction after longer period of use as compared to reference.

Note - None of the design is weatherproof or can be used outdoors as compared to our reference model.

Area Occupy
Product total surface area occupy after the installation.

- *Concept A (Rating-5):* - It has wall mounted chamber, and the heat absorbing panel is placed on the roof, thus place occupy is very less compared to the reference.
- *Concept B (Rating-5):* - In this concept also same advantage as mentioned in the concept A, compared with reference.
- *Concept C (Rating-5):* - It has also the almost same design as the concept A and B, thus it is rated by 5.

Elegance and Sophistication: -
This term denotes how much modern and integrated it looks after installation.

- *Concept A (Rating-4):* - It has mostly integrated design into the house roof and wall, which appears as a part of house, just one downside is that it has hanging duct.
- *Concept B (Rating-5):* - This concept rated the highest as it is almost everything concealed into the house and ducting is also fixed, which make it look sophisticated.
- *Concept C (Rating-4):* - This concept is almost same as the concept B, but it is rated by one less because it is for the front entrance, where it may look mismatch as per customer POV.

4 Desigb

4.1 Selection of the mode of solar drying

Solar Drying is just a simple process of removing moisture from an item to obtain the required moisture content to aid longer storage time. In addition to this, the other benefit of drying is that enhances the quality, handling, and further processing. There are two basic requirements for the solar drying, the first one is the heat which is required to vaporize the moisture present in the item and the second one is a medium which removes and carries the water vapor after its extraction from the food item.

The selected solar dryer must be able to provide the following improvements when compared to conventional open air sun drying system:

- Operation at an increased rate
- Improved efficiency
- Safety from environmental contaminations
- Retaining the nutrition values

The project requires two different models for two different customer groups,

1. Agricultural Model: it is targeted towards small scale farmers
2. Domestic Model: it is targeted towards household use

Based on above requirements, there are three types of solar dryer available, each with its own distinct energy collection and conversion method.

4.2 Direct type solar dryers

In the direct type of solar dryer, the solar radiation directly hits the food items. Heat transfer takes place due to radiation which increases its temperature causing them to lose the moisture. Here, the flowing air removes the moisture from cabinet to outside through convection mode of heat transfer.

The advantages of this type of dryer are that they are very easy and cheaper to construct. Based on the type of crop to be used, there are some disadvantages such as poor vapor removal rate, insufficient temperature rise, localized overheating.

4.3 Indirect type solar dryers

The main body of the indirect solar dryer is opaque in nature so there is no direct impartation of solar radiation on the food items. It has a separate chamber to heat the flowing air and in the main body the vapor gets removed due to concentration difference and the here the mode of heat transfer is convection.

The main features of this type of dryer are improved efficiency, quality, and temperature rate as well as better suitability for fragile and photosensitive crops. However, large capital is needed for such dryer as extensive and elaborate construction is needed.

4.4 Hybrid type solar dryers

The hybrid type, both the direct and indirect type of solar dryers work in conjunction which offers better heating temperatures and vapor removal rate. Hence, improving the overall efficiency.

4.5 Selection of the model

For the agricultural model, the direct type of solar dryer is the best suitable for extended operation hours, solar energy utilization and production capacity.

For the domestic model, the hybrid type solar dryer is the best fit for house hold requirements such as ability to dry variety of things which may include photo sensitive items too.

5 Design for Assembly

5.1 2.1 Need of DFA

The components of the solar dryer are fairly easy to manufacture so the design need to be optimized through assembly procedure. Therefore, Design for Assembly (DFA) philosophy is adopted for making the models.

5.2 2.2 Reducing cost of Manufacturing and Assembly

The manufacturing of the various components is to be done in modular fashion to reduce the overall manufacturing lead time and cost. This smoothens out the assembly procedure which in turn reduces the assembly cost and time.

5.3 2.3 Assembly components

The direct type of solar dryer contains the following components:

- Sheet Metal Chamber
- Food Trays
- Glass
- Electronic Fans
- Thermostat
- Stand

The indirect type of solar dryer contains the following components:

- PVC Box
- Wire mesh
- Turbo Ventilation Fan
- Pipe
- Stand

5.4 Design for Environment(DFE):

5.4.1 Goals of DFE

The word “solar” in the term solar dryer is more than enough to describe the type of energy used by the machine and its environmental footprints.

The manufacturing and assembly processes used for making the various components are welding, screwing, adhesion. All of the above-mentioned processes have very little environmental impact.

The solar dryer model literally adheres to all the principals or goals established by DFE practices. Thus, it provides better quality without having any negative consequences on the environment.

5.4.2 Potential Environment Impacts

Although the manufacturing and assembly processes used for making the various components don't have any significant environmental effect as previously mentioned, there are some possibilities of contamination

- Air pollution from emission of gases from welding process.
- Generation of biodegradable waste from processing of food items.

5.4.3 DFE Guidelines

The main two stages in the product development where the DFE guidelines are to be strictly implemented.

- Material Selection: It empathizes on minimal use of toxic and non-biodegradable materials as much as possible.
- Manufacturing and Assembly processes: The process should have low environmental impact
- Distribution: Minimal packaging and using recyclable material.

6 Design Prototypes

The prototypes of the prescribed models are made in the CAD software SolidWorks to have a better understanding of the overall look and working of the model. Additionally, the models can also be used to perform different tests to quantify various attributes such as stress, temperature, strength etc.

6.1 Exploded Assembly View

The Exploded Assembly View for the direct as well as indirect model is shown in the figures below.

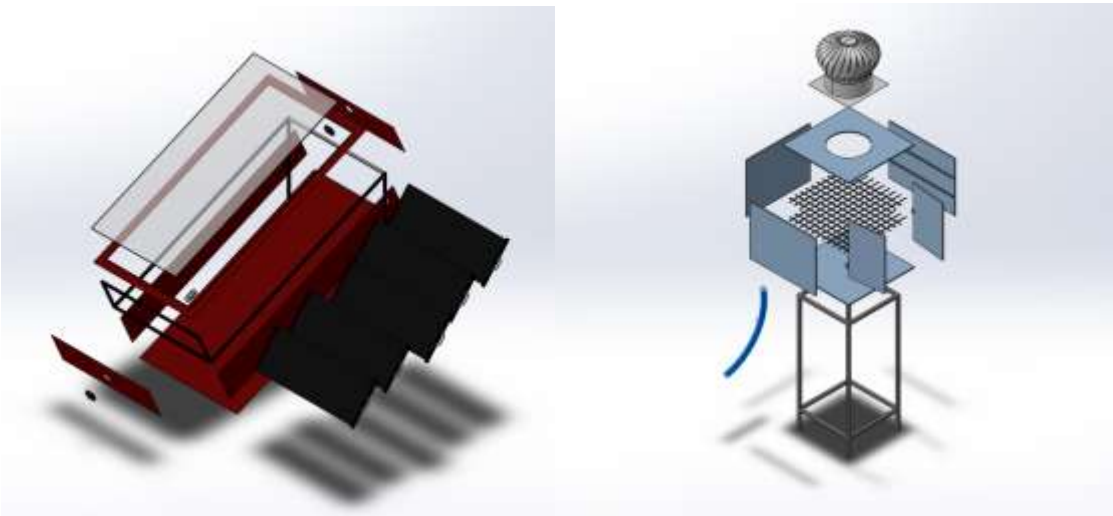


Figure 12 Exploded view of indirect type solar dryer and direct type solar dryer

6.2 Full rendered view

The Full rendered view for the agricultural and domestic model is shown in the figures below.

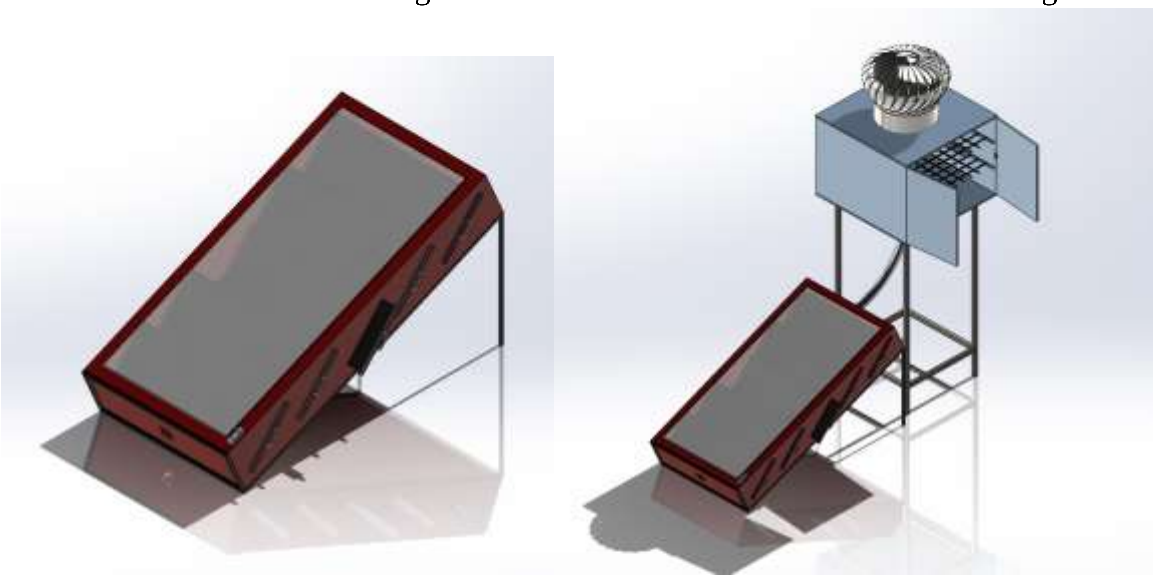


Figure 13 Domestic model and agricultural model

6.3 Design Specifications

6.3.1 Material Selection

Table 4 Material specification

Component	Material and specification
Glass top	Low Iron glass
Chamber Sheet Metal	Mild steel
Tray Sheet Metal	Mild steel
Flexible pipe	Plastic
Indirect drying Box	C-PVC
Wire Mesh	Stainless steel
Frame Channels	Mild Steel
L-Angels Box	Mild Steel
Gasket Ring	Rubber
Handle	Brass
Hinges	Stainless Steel
Silicone Sealant	Sourced directly
Paint	Sourced directly
Ventilation Induced Fan	Sourced directly
Forced Draft Fan	Sourced directly
Thermostat	Sourced directly

6.4 Direct Chamber

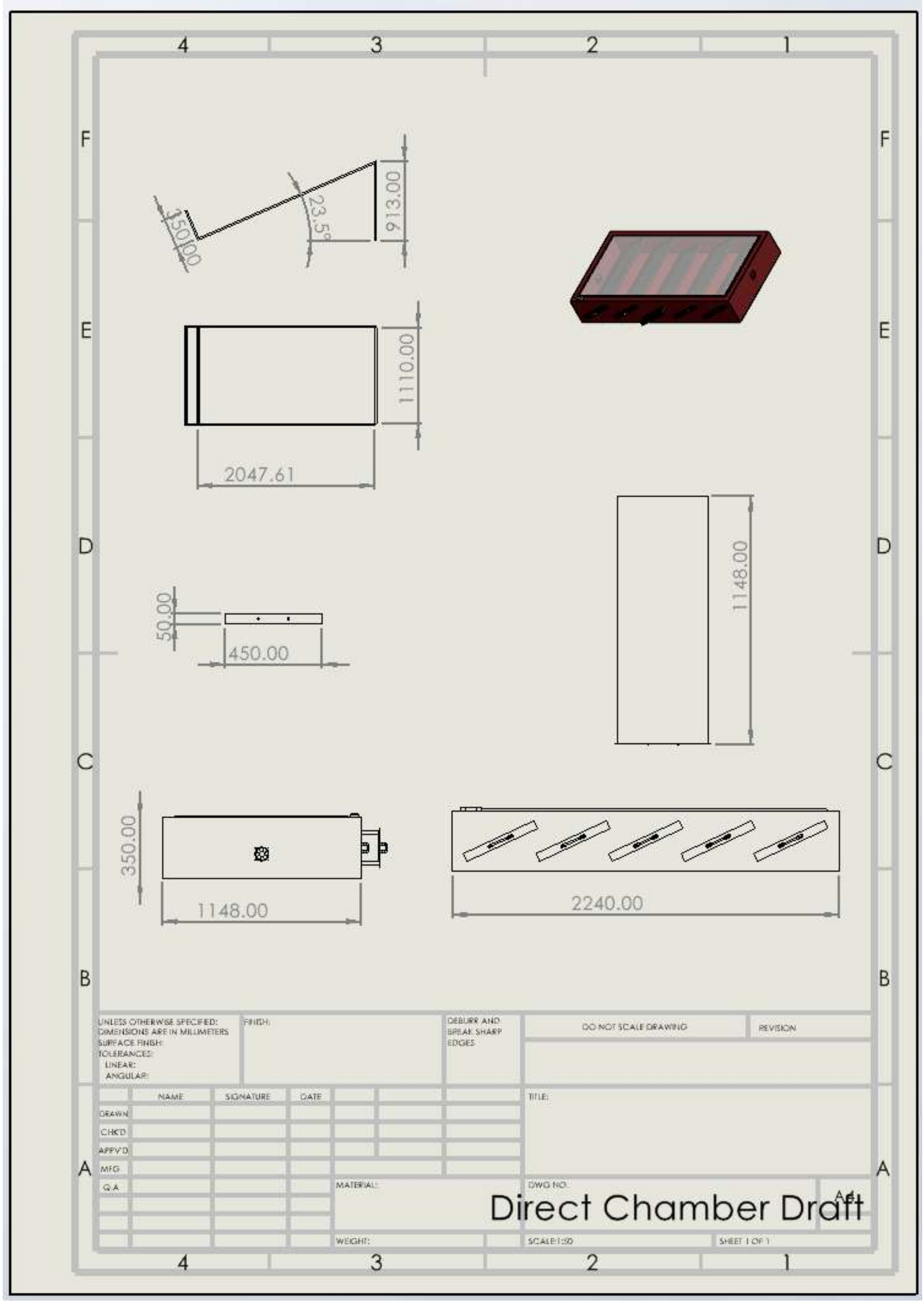


Figure 14 Direct chamber specification

6.5 Domestic Model

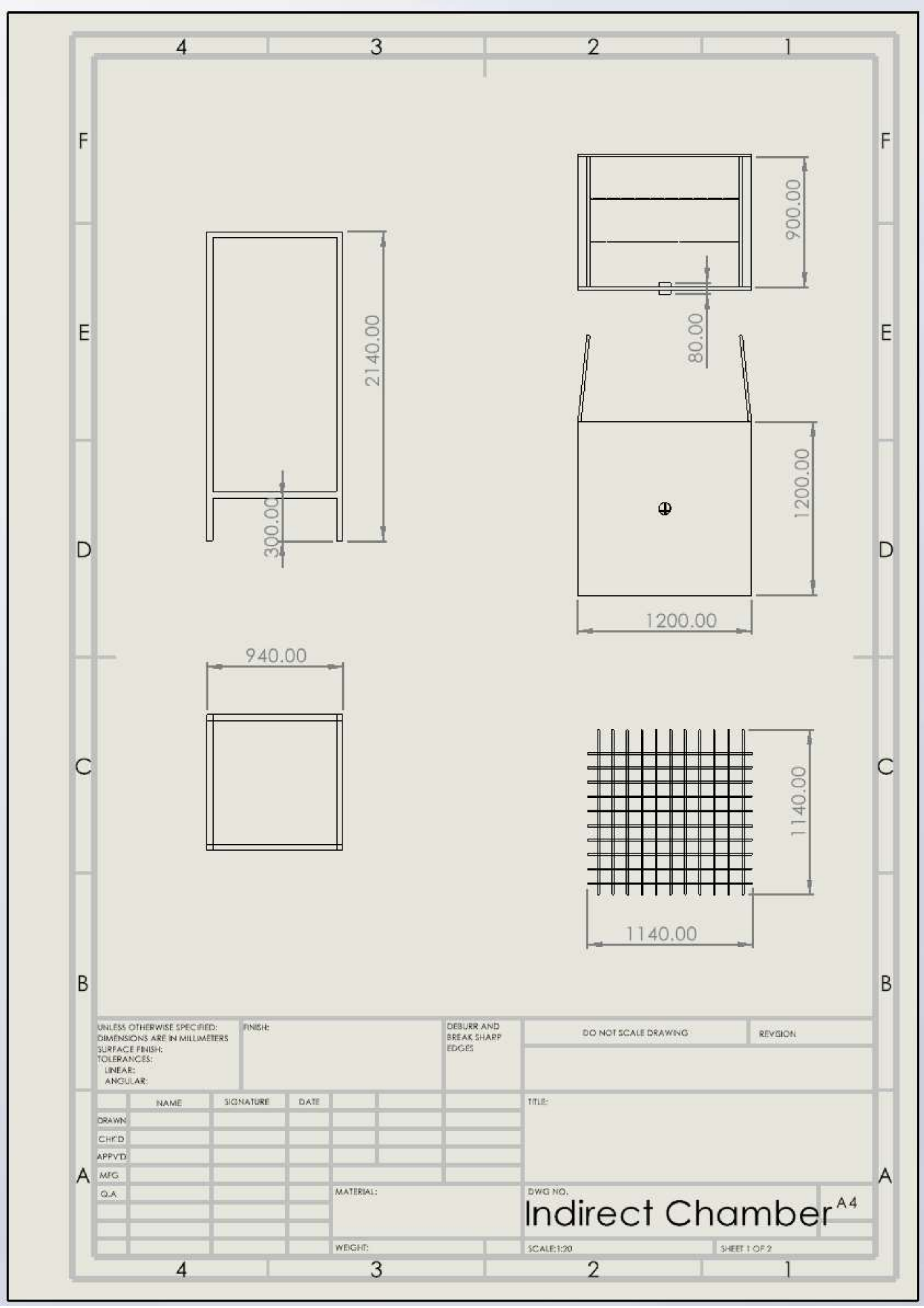


Figure 15 Indirect chamber specification

7 Costing

7.1 Direct material cost

This cost is the summation of the material which is used to manufacture our device.
Note – All the costs below are taken form Alibaba.com and are in USD

Solar rays capturing glass –

- Specs – Low iron transparent glass of 6.4mm
- Price per sq. meter = 13.16$
- Total cost = 13.16 (Rate per Sq. m.) x 2.05 (Required quantity) = 27.88$

Mild steel plates for body structure –

- Price per ton – 780$ per Ton
- Required quantity = 4.9 m^2 = 38.46 Kg as 1m^2 = 7.85 Kg
- Total cost = 30$

Trays made up of mild steel –

- Required quantity – 0.695m^2
- Thickness of the plate – 2mm
- Weight = 10.911 Kg as 15.7 Kg/m^2
- Total cost = 8.5$ (0.780 $ per Kg)

Handle of the Tray –

- 5 Handle needed, 1 for each tray. 0.10$ per piece = 0.50$

Flexible pipe connecting two boxes –

- Cost – 5$ per meter for 10 cm diameter
- Required quantity = 3 feet = 0.9144 meters
- Total cost = 4.57$

Socket to attach the pipe

- Cost per piece = 1.5$
- Quantity required = 2 Nos.
- Total cost = 3$

Indirect heating box –

- Material – CPVC sheet of 4.5mm thickness
- Required quantity = 7.2 Kg
- Total cost = 10.8$ (1.5$ per Kg)

Steel mesh plates -

- It is used to keep delicate items on it inside the Indirect heater.
- Required quantity = 4.3 m^2
- Rate per m^2 = 10$
- Total cost = 43.2 $

Structural support frame -

- Specification of the **box channel** – 30mmx30mm. Thickness 3mm
- Weight = 2kg/m
- Total length of frame needed = 41.99 m
- Total weight of frame = 83.98 Kg.
- Total cost = 50.3 $ (600$/Ton)

Specification of the **L - Angel channel**

- Required quantity – 5 Meters = 5 Kg
- Weight per meter = 1 Kg per meter
- Total cost = 3$ (600$/Ton)

Some ready to use/assemble products

- Sealant – 1 $
- Paint = 1$
- Ventilation Induced draft fan = 18$
- Ventilation Forced draft fan = 12$ for 2 Nos.
- Thermostat =20$

Hinges

Used at glass top and doors of indirect CPVC box

- Cost per piece = 0.39$
- Required piece = 7
- Total cost = 2.73$

Total material Cost = **237.93$**

7.1.1 Conclusion and design changes made from direct material cost.

The Indirect heating box was changed to CPVC box as this area's temperature is not too high and easily manageable by CPVC material. This material is cost effective as well it is light weight as compared to Mild steel.

The pipe joining two boxes was changed to plastic as it can be easily sustaining this temperature. It is cheaper than aluminum flexible pipe which was earlier chosen, and it is also a good insulator.

7.2 Operational Cost –

This cost consists of the work and money goes onto the product manufacturing after receiving the material to make the product useable to the end customer.
Note – All the labour charges are taken from job postings from glassdoor.com and LinkIn.com and are in CAD according to Canadian Market.

7.2.1 Cutting Operation =

- Time required = 30 min for a set
- Labour rate per hour = 20$
- Charge per piece = 10$
- Assembling of all the pieces
- Time required = 40 min for a set
- Labour rate per hour = 20$
- Charge per piece = 13.33$

7.2.2 Paint Job -

- Time required = 10 min for a set
- Labour rate per hour = 15$
- Charge per piece = 1.5$

Machinery depreciation cost = 13$ per piece

Electricity cost = 9$ per piece (Considered cutting saw, spot welder, spray painting machine, lights & fans)

Facility rent – 10$ per sq/year (Assumed factory location in Laval outskirts, data from clickspace.ca)

- Factory size = 3000 sq feet needed.
  =30,000 $ per year
  =2500$ per month

Assuming total production of 10 Units per for a 5 day per week working factory.

- Per piece cost comes out to be =2500$/80 pieces a month
  = 12.5 $ a piece.

Miscellaneous cost (10% of direct material cost) = 23$

Total Labour cost = 96.33 $

Total Cost price = 392$ CAD

We are planning to sell the product online with 15% margin.

So, **selling price = 451.68$ CAD**.

Note – This cost will reduce in future as this all calculations is done on the production capacity of 10 units per day. As demand and production ramps up operational cost can cut off by 25% and material cost by 10%.

7.2.3 Conclusion and design changes made from Operational cost analysis,

- The welding process which was earlier SMAW was changed to Spot welding. This process was cost and time effective than the previous one. It is even suitable for plates but it doesn't makes a airtight seal.
- We found a solution but came up with another problem. So, to make the main compartment airtight silicone sealant was applied at the joint. It is also a cheaper version and doesn't lose its properties as it is anti-corrosive.

7.3 Total cost savings by the industrial client base.

- Its saves all the Cryogenics energy goes into freezing and preservation of the food.
- It is a maintenance free machine.
- It savings on electrical energy and cold storage transportation as it products doesn't spoil while on the way.
- Total supply chain cost gets down.

8 Team Structure

It is crucial to select the structure of the team and the team members for success of the protentional product according to their expertise and the experience they carry in the specific industry or the process. Here every team member is connected to the team leader and directly or indirectly connected to the other departments. The department are Concept generation, designing of product, manufacturing, assembly, product planning, market analysis and supply chain. The designing department is continuous in contact with the manufacturing, assembly, supply chain and concept generation department as 80% of product cost can be determine in design stage and the product should be easy to manufacture, assemble and to supply to customer for maximization of the profit and to achieve the goal of customer satisfaction.

Figure 16 Team structure

Team leader perform important role because team leader sets clear goals which are to be achieved by the department, make sure to maximize the communication and transparency between the departments and to handle the expertise (team member).

Individual Objective –

Team Leader Yash Chauhan

- Opportunity Identification: Fenil
- Product Planning: Motunrayo Oluwole
- Identifying Customer Needs: Fenil
- Product Specification: Smit
- Industrial Design: Bhargav, Yash Chauhan
- Design for manufacturing: Bhargav, Yash Chauhan
- No. Of different variation or model: Bhargav

- Design For assemblies: Fenil
- Sales forecasting: Krushil Navadi
- Financials: Krushil Navadi
- Supply Chain Model and cost: Yash Chauhan
- Future Scope: Smit
- Conclusion: smit

8.1 Supply Chain

There is significant important of setting up the supply chain to make sure supplier, manufacture, assembly units, warehouses, and final customers receive their product at the promised time and to implement numerous constrains and decision for minimizing the cost of product and moreover to satisfy the primary material requirement of each department.

8.1.1 Five Layer Supply Chain System.

There are five-layer supplier, manufacturing plants, assembly center, warehouse and customers each layer connected to other layer by satisfying the different constrains to optimize the operations

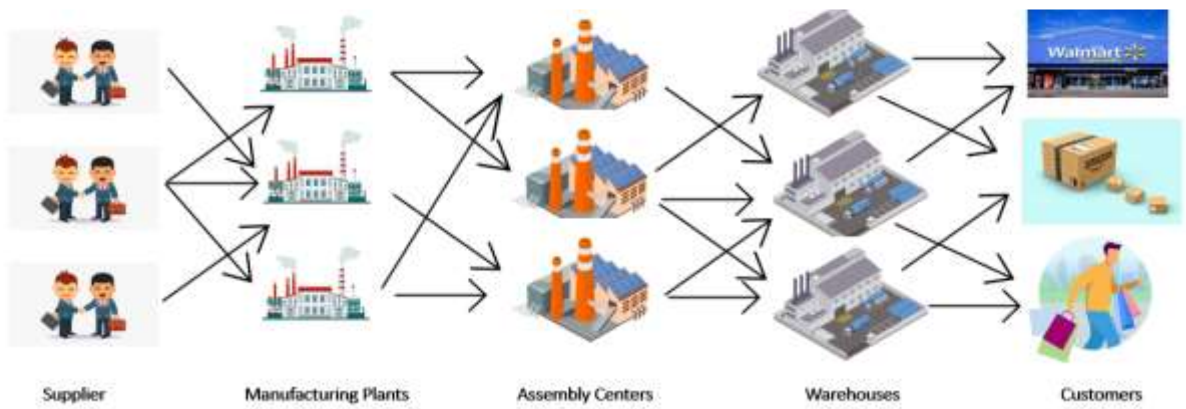


Figure 17 Five layers of supply chain

Decision to make 4th and 5th layers

Which warehouse to open?

Which warehouse serves which customer?

Location Decision Variable

Z_i = 1 If a warehouse i is opened, 0 Otherwise

Allocation Decision Variable

X_{ij} = 1If customer j is allocated to the warehouse i,

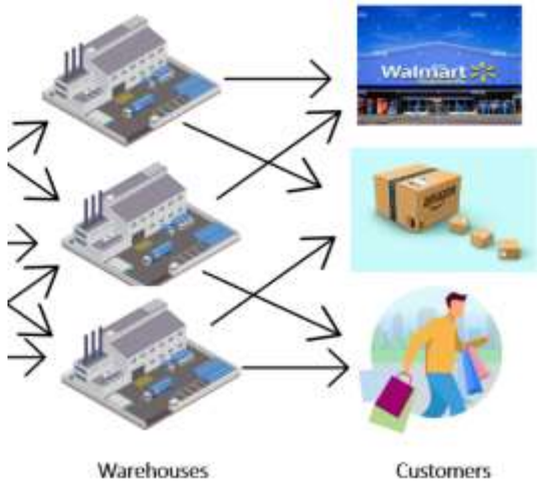


Figure 18 Team structure for 4th and 5th layer

Inputs

J: The set of customers Inputs

I: The set of warehouses

C_{ij}: Per unit transportation cost from the warehouse i and customer j.

dj: Demand of customer j.

fi: Fixed cost of opening warehouse i.

b: The volume of each unit of the product.

Minimizing the total transportation Cost (TC4)= Total transportation cost from warehouses to customers

+Total fixed cost of opening warehouses

$$\sum_{i\in I}\sum_{j\in J} d_j c_{ij} x_{ij} \quad + \sum_{i\in I} f_i z_i$$

Decision to make 3rd and 4th layers

How much product does each assembly center send to each warehouse?

Distribution Decision Variable

Y_{li} = The amount of the product sent from Assembly Center l to warehouse i.

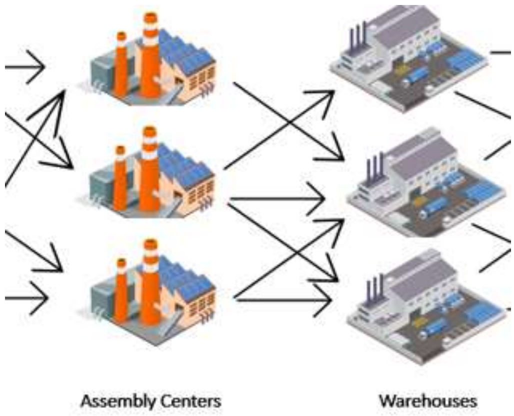


Figure 19 Team structure for 3rd and 4th layer

Other Decision Variable

Wl = 1 if assembly center l is open, 0 otherwise

Xij = 1 if customer j is allocated to warehouse i, 0 otherwise.

Inputs

J: The set of customers Inputs

I: The set of warehouses

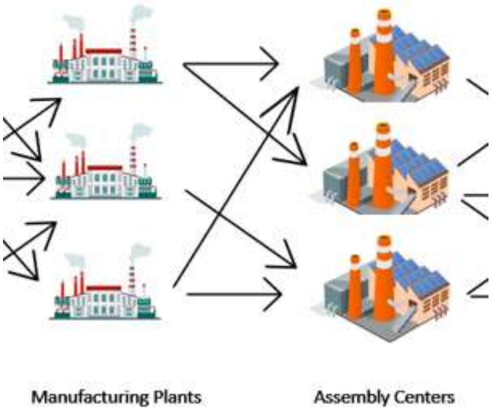
L: The set of assembly centers

Cli ′: Per unit transportation cost from the assembly l to warehouse i.

fl ′: Fixed cost of opening an assembly center l.

Minimizing the total transportation Cost (TC3) = Total transportation cost from assembly centers to warehouse+ Total fixed cost of opening assembly centers.

$$\sum_{l\in L}\sum_{i\in I} c'_{li} y_{li} + \sum_{l\in L} f'_l w_l$$



Decision to make 2nd and 3rd layers

How much product does each assembly center send to each warehouse?

Distribution Decision Variable

Ugkl = The amount of the item type g sent from plant k to assembly center l.

Yli = The number of products sent from assembly center l to warehouse i

Figure 20 Team structure 2nd layer 3rd layer

Inputs

I: The set of warehouses.

L: The set of assembly centers.

K: The set of plants.

G: The set of items

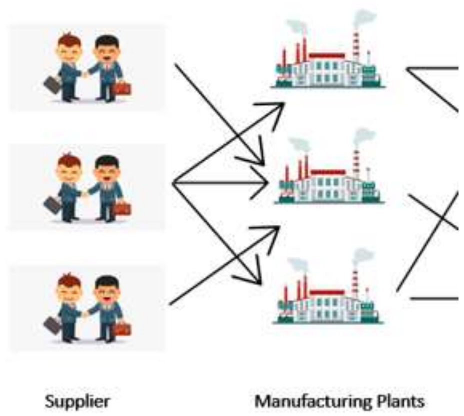
c_{gkl}'': Transportation cost for each unit of item g from plant k to assembly center l

a_g: The number of items g that each final product requires

t_{gk}': Required production capacity for each unit of item g.

Minimizing the total transportation Cost (TC_2) = Total transportation cost from plants to assembly

$$\sum_{g \in G} \sum_{k \in K} \sum_{l \in L} c_{gkl}'' u_{gkl}$$



Decision to make 1st and 2nd layers

How much product does each supplier send to each plant?

Distribution Decision Variable

Vhsk =The amount of material type h sent from supplier s to plant k

Ugkl = The amount of the item type g sent from plant k to assembly center l.

Figure 21 Team structure 1st and 2nd layer

Inputs

L: The set of assembly centers.

K: The set of plants.

S: The set of suppliers.

H: The set of materials

Chsk ''' : Transportation cost for each unit of material type h from supplier s to plant k

ah$g$ ': The amount of material type h required to produce one unit of item g.

Minimizing the total transportation Cost (TC1) = Total transportation cost from suppliers to plants

$$\sum_{h \in H} \sum_{s \in S} \sum_{k \in K} c'''_{hsk} v_{hsk}$$

Total Cost

Minimum total cost= $TC_1 + TC_1 + TC_1 + TC_1$

Subjected To =

$$TC_1 = \sum_{h \in H} \sum_{s \in S} \sum_{k \in K} c'''_{hsk} v_{hsk}$$

$$TC_2 = \sum_{g \in G} \sum_{k \in K} \sum_{l \in L} c''_{gkl} u_{gkl}$$

$$TC_3 = \sum_{l \in L} \sum_{i \in I} c'_{li} y_{li} + \sum_{l \in L} f'_l w_l$$

$$TC_4 = \sum_{i \in I} \sum_{j \in J} d_j c_{ij} x_{ij} + \sum_{i \in I} f_i z_i$$

9 Conclusion (Projection outcome): -

- The modified solar dryer will become market changer as it will improve the lacking area of existing methods in terms of drying time, space utilization and convenience.
- The hybrid system will utilize advantages of both active and passive solar drying system.
- This concept will work as a forced convectional system without using any external electric source.
- New design will make assembly process more flexible by 20-25 % in adding new features, also decreases lead time.

10 Future Scope

- Furnishing parabolic glass on both sides of the collector.
- By replacing the heat-absorbing chamber with a PVT collector.
- In the future by placing PCM based thermal energy storage system in the dryer to maintain the required temperature throughout the 24 hours.
- Placing a dehumidifier between the drying chamber and the ducting for removing moisture in the air to improve the drying rate.
- It is possible to increase efficiency by adding copper tubes to the sidewall of the dryer to recover heat from the sidewalls.
- Adding of TES (Thermal Energy System) unit in it, which aids to reduce the required time for drying.
- Providing photovoltaic which will directly power the thermostat and fan or pump to make the dryer as forced convection.
- Solar dryers will be design based on the local climate with low-cost will be scatter to rural areas targeting micro & small enterprises and households.
- On further development of technical design by increasing collector tilt angle we can raise the temperature of the dryer.

11 Reference

1†) Patchimaporn U., Sebastian R., Steffen S., Busarakorn M., Murat S., Tesfamicheal W., Emmanuel N., Bernard V., Joachim M. "Review of solar dryers for agricultural products in Asia and Africa: An innovation landscape approach" Journal of Environmental Management 2020.

2†) https://sinovoltaics.com/learning-center/technologies/solar-dryer/

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4†) A review on indirect type solar dryers for agricultural crops – Dryer setup, its performance, energy storage and important highlights. "Abhay Bhanudas Lingayata, V.P. Chandra mohana, V.R.K. Rajua, Venkatesh Medab"

5†) Survey on solar dryers for drying offood and wood in Ghana. "Danish technological institute"

6†) Hossein Hashemi Doulabi Mathematical modeling of five layer supply chain system Concordia University

7†) Solar Drying Shed for Cassava in Malawi, McGill University. "Caitlyn Chappell & Sarah Lebel

Form ENCS-SAS (03/04)

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3. Direct quotations make up a very small proportion of the text, i.e., not exceeding 5% of the word count.
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