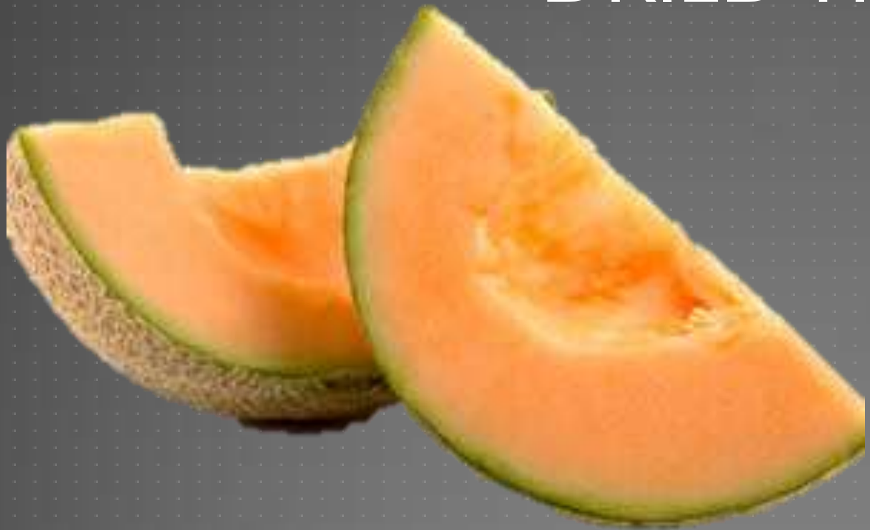
# DESIGNING A MACHINE TO PRODUCE AND PACK DRIED TROPICAL FRUITS



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This project aims to contribute to an association of small farmers that want to export dried cantaloupe to North America, Europe and Asia.



Clarification of the Task

To achieve this goal, the farmers plan to begin with processing 1 ton per day, and potentially increasing with success over time.


Clarification of the Task

In order to design a process that will greatly benefit these lower class Colombian farmers, several specifications need to be identified.


Non-toxic environment


Easy to install

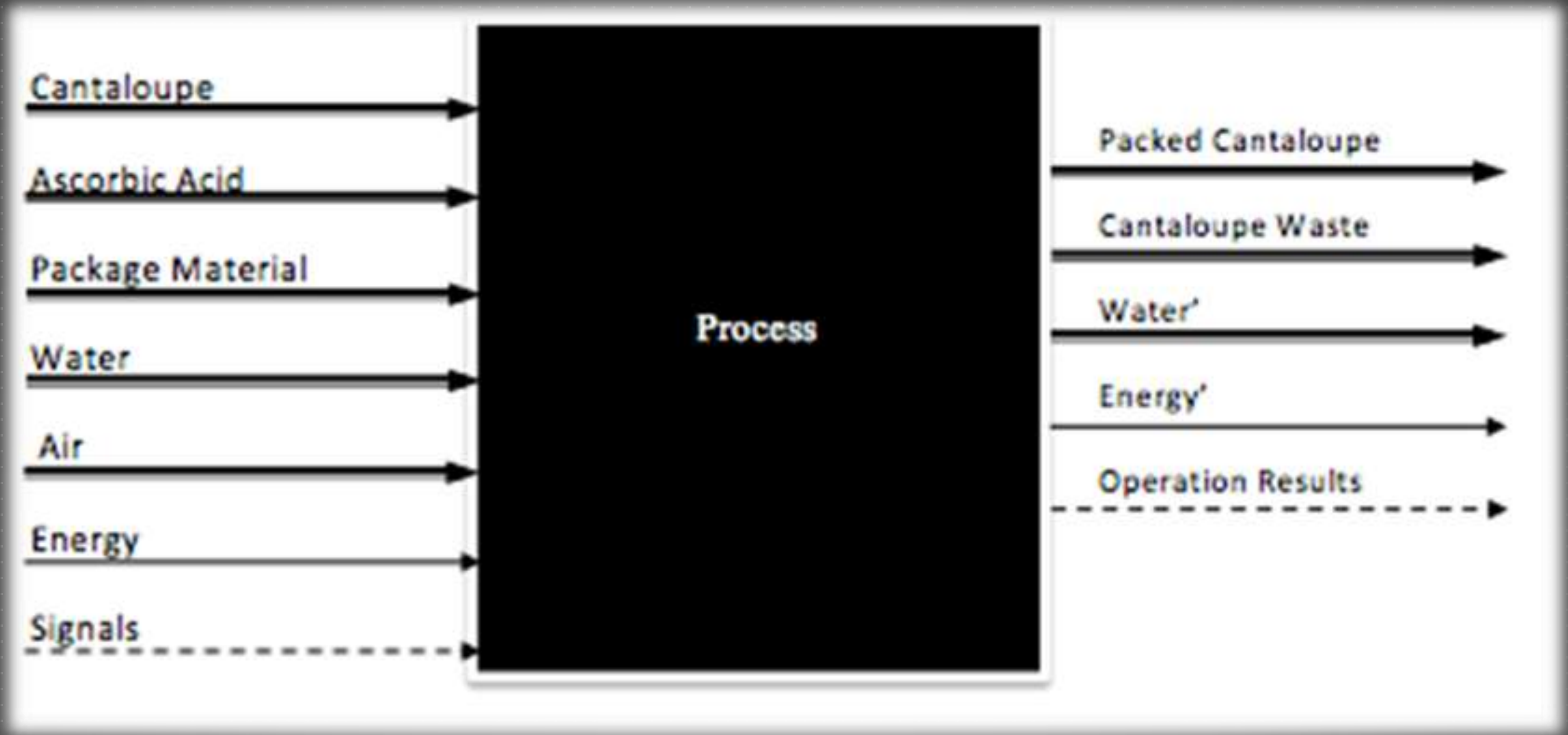
Easy to maintain

Economical

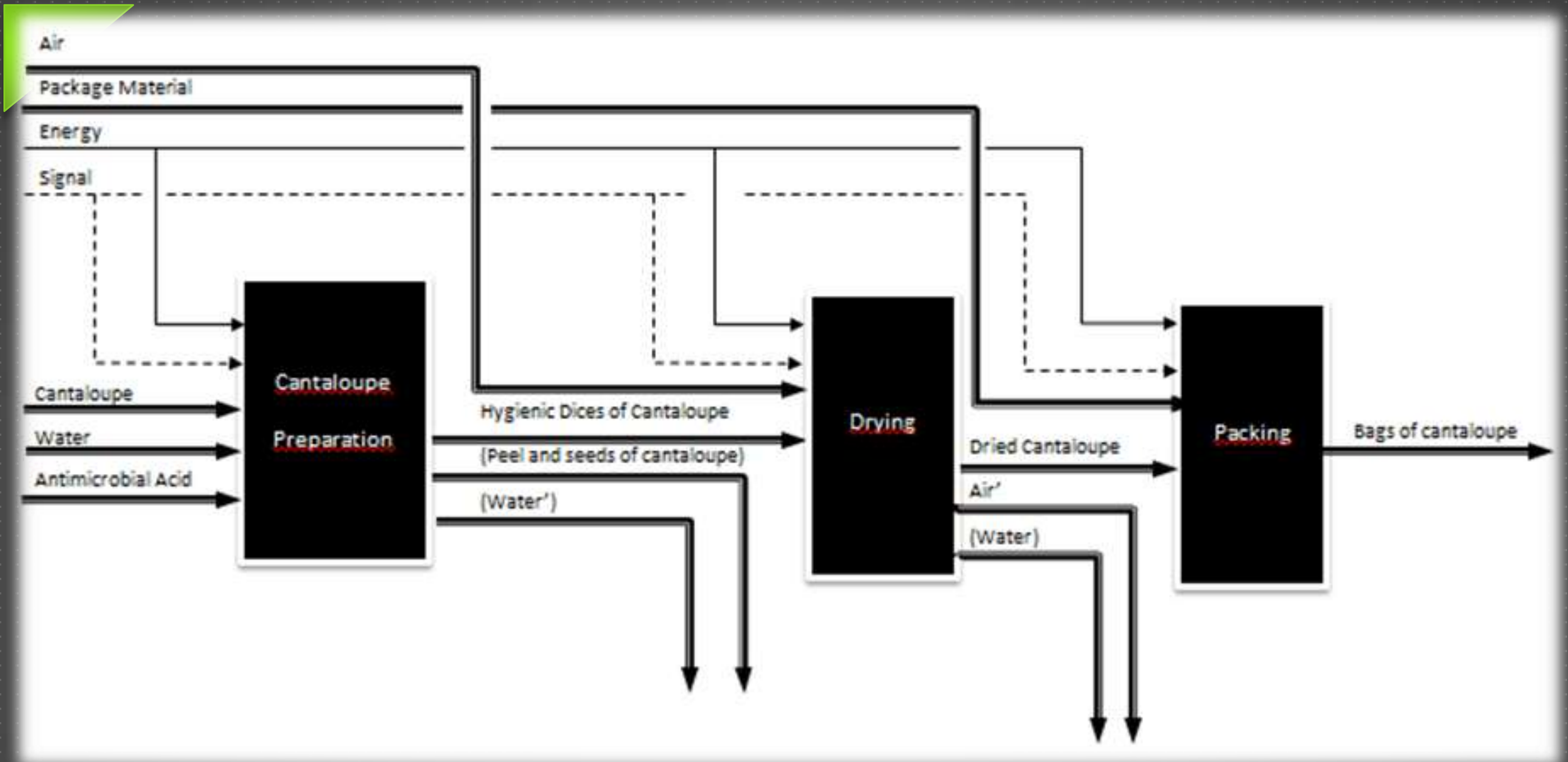

Consistent 250 g packages

Clarification of the Task

To summarize these inputs for the entire process, we can create a single diagram to represent the whole.



The overall process can be broken into sub-process which can be defined by their input and output to create a Black Box Diagram.



The overall process our team has designed is made up of several subcomponents.

During the initial planning stages, all possible solutions to the problem were considered in order to find the best possible solution.

1) Peeling (P) - removal of the skin/outer peel;
2) Slicing (S) - cutting the cantaloupe into small pieces;
3) Cleaning (C) - removal of seeds and ensuring fruit is clean.

To obtain the seed removal we have to add another step:

4) Half Cutting (H) – cutting the cantaloupe into two large halves.

These can be combined in several different ways. The following figure outlines all the possible sequences we can use:

| | | | |
|---|---|---|---|
| H → P → C → S | P → H → C → S | C → P → S → H | S → P → H → C |
| H → P → S → C | P → H → S → C | C → P → H → S | S → P → C → H |
| H → C → P → S | P → S → H → C | C → H → P → S | S → H → P → C |
| H → C → S → P | P → S → C → H | C → H → S → P | S → H → C → P |
| H → S → P → C | P → C → H → S | C → S → H → P | S → C → P → H |
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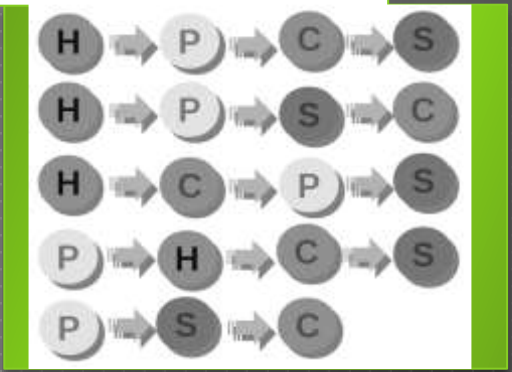


Each possible sub-function was analytically considered with respect to advantages and disadvantages.

| AUTOMATIC | |
|---|---|
| ADVANTAGES | DISADVANTAGES |
| High | |
| Oper | |

| MANUAL | |
|---|---|
| ADVANTAGES | DISADVANTAGES |
| Cost | |
| Main | |

| SEMI-AUTOMATIC | |
|---|---|
| **ADVANTAGES** | **DISADVANTAGES** |
| Cost Manufacturing | Operation Simplicity |
| Maintenance Cost and Simplicity | (Human) Energy Cost |
| High Peeling Rate | |

***Table 3.3- Advantages and Disadvantages of Semi-Automatic Peeling***

Another method to select the best option for each sub-function is to assign weights to different factors by importance, and grading each.

| | Manufacturing Costs | Energy Costs | Maintenance Costs | Slicing Rate | Operation Simplicity | Installation Simplicity | Repair Simplicity | Waste Product | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| Manual | 3 | 1 | 3 | 1 | 1 | 3 | 3 | 1 | 2.3 |
| Automatic | 1 | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 2.5 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 |

| | Manufacturing Costs | Energy Costs | Maintenance Costs | Cleaning Rate | Operation Simplicity | Installation Simplicity | Repair Simplicity | TOTAL |
|---|---|---|---|---|---|---|---|---|
| Filter | 2 | 3 | 2 | 1 | 3 | 1 | 2 | 2.1 |
| Manual | 3 | 1 | 3 | 1 | 1 | 3 | 3 | 2.2 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.3 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2.5 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 3.0 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 |

| | Manufacturing Costs | Energy Costs | Maintenance Costs | Peeling Rate | Operation Simplicity | Installation Simplicity | Repair Simplicity | TOTAL |
|---|---|---|---|---|---|---|---|---|
| Automatic | 1 | 1 | 1 | 3 | 3 | 2 | 1 | 1.5 |
| Manual | 3 | 1 | 3 | 1 | 1 | 3 | 3 | 2.2 |
| Semi- | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 2.3 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 |

| | Manufacturing Costs | Energy Costs | Maintenance Costs | Cutting Rate | Operation Simplicity | Installation Simplicity | Repair Simplicity | TOTAL |
|---|---|---|---|---|---|---|---|---|
| Automatic | 3 | 1 | 3 | 1 | 1 | 3 | 3 | 2.2 |
| Manual | 1 | 2 | 2 | 3 | 3 | 2 | 2 | 2.0 |
| WEIGHT | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 1 |

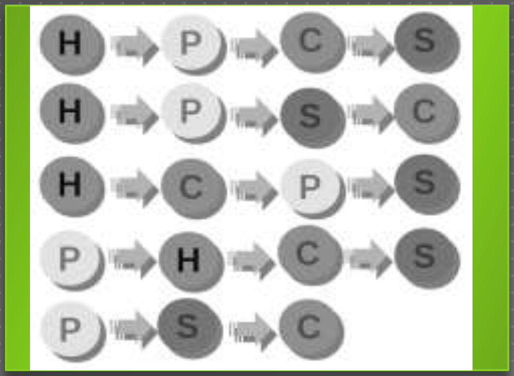
*Table 4.1-Comparison of all available half cutting options*

Using these tools, we were able to select the best options for each sub-function to accomplish the greater goal of processing cantaloupe.

| Methods<br>Steps | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Peeling | Automatic  | Manual  | Semi-automatic  | | |
| Slicing | Manual  | Automatic  | | | |
| Cleaning | Filter  | Manual  | Vaccum  | Conveyor  | Peeler Combined  |
| Half Cutting | Automatic  | Manual  | | | |

*Table 4.5-Best solutions*

From the original sequences considered, the best sequence was selected to create the most efficient process.





Conceptual Design

The dryer was considered as a separate entity because of its grave importance to the project; it is worth 60% of the overall process.

| | Manufacturing Costs | Energy Costs | Maintenance Costs | Drying Rate | Operation Simplicity | Installation Simplicity | Repair Simplicity | TOTAL |
|---|---|---|---|---|---|---|---|---|
| Convection | 3 | 2 | 2 | 2 | 2 | 1 | 2 | 2.1 |
| Solar | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 2.8 |
| Freezing | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1.2 |
| Microwave | 2 | 1 | 2 | 3 | 2 | 2 | 1 | 1.8 |
| Infrared | 2 | 1 | 2 | 3 | 2 | 2 | 1 | 1.8 |
| Ultrasound | 1 | 2 | 2 | 3 | 2 | 1 | 1 | 1.7 |
| Desiccant | 3 | 3 | 1 | 1 | 3 | 3 | 3 | 2.4 |
| WEIGHT | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 1 |

*Table 5.1-Comparison of all available drying options*

- Low manufacturing, energy and maintenance cots
- Has to process one tons per day
- Constant drying rate
- Inlet air temperature = 75°
- Inlet air relative humidity = 30%
- Inlet air velocity = 1.8 m/s
- Easy installation, operation

| ADVANTAGES | DISADVANTAGES |
|---|---|
| High Drying Rate | Energy Cost |
| Flexible | Operation and Installation Simplicity |
| | Exhaust Produced |
| | Unburned |

An Analytical Hierarchy Process algorithm was used to compare different dryer types and combinations, producing matrices for each.

Characteristics matrix =

| | Manu. | Energ. | Mante. | Dryin. | Oper. | Inst. | Rep. |
|---|---|---|---|---|---|---|---|
| Manu. | $\frac{1}{1}$ | $\frac{3}{4}$ | $\frac{4}{3}$ | $\frac{3}{2}$ | $\frac{2}{1}$ | $\frac{4}{1}$ | $\frac{3}{1}$ |
| Energ. | $\frac{4}{3}$ | $\frac{1}{1}$ | $\frac{4}{2}$ | $\frac{3}{2}$ | $\frac{2}{1}$ | $\frac{4}{1}$ | $\frac{3}{1}$ |
| Mante. | $\frac{3}{4}$ | $\frac{2}{4}$ | $\frac{1}{1}$ | $\frac{3}{2}$ | $\frac{2}{1}$ | $\frac{4}{1}$ | $\frac{3}{1}$ |
| Dryin. | $\frac{2}{3}$ | $\frac{2}{3}$ | $\frac{2}{3}$ | $\frac{1}{1}$ | $\frac{2}{1}$ | $\frac{3}{1}$ | $\frac{3}{1}$ |
| Oper. | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{1}$ | $\frac{4}{3}$ | $\frac{4}{3}$ |
| Inst. | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{1}{3}$ | $\frac{3}{4}$ | $\frac{1}{1}$ | $\frac{3}{4}$ |
| Rep. | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{3}{4}$ | $\frac{4}{3}$ | $\frac{1}{1}$ |

***Matrix 5.1-Comparison of all characteristic***

| Drying technology | Ranking |
|---|---|
| Convective | 14.20 |
| Solar | 21.94 |
| Microwave | 12.17 |
| Infrared | 11.56 |
| Ultrasound | 12.31 |
| Desiccant | 18.57 |
| Freezing | 9.25 |

***Table 5.3-Ranking calculated with the AHP algorithm***

A potential hybrid solution combining the benefits of the top three solutions proved to be the best option.

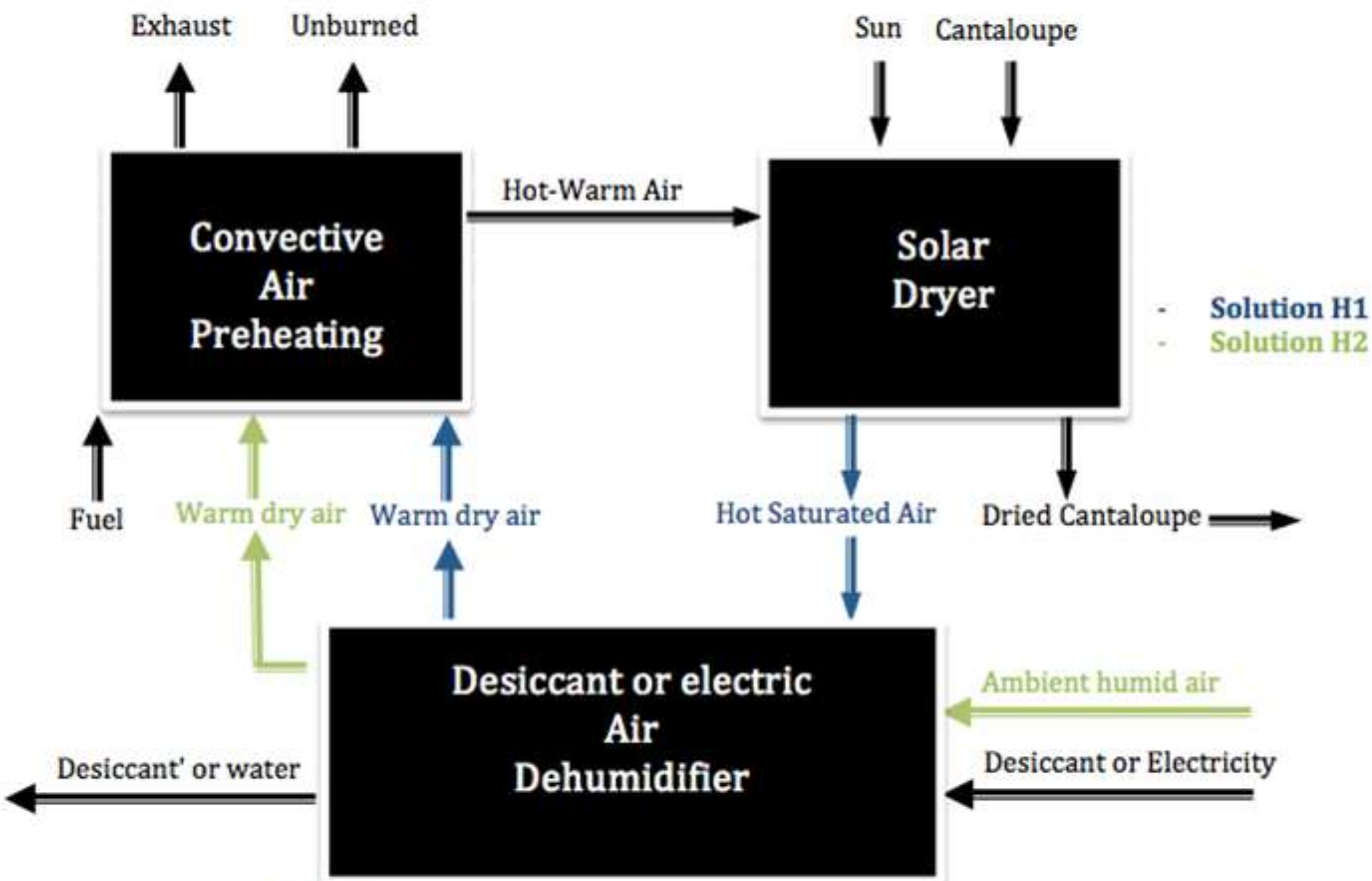
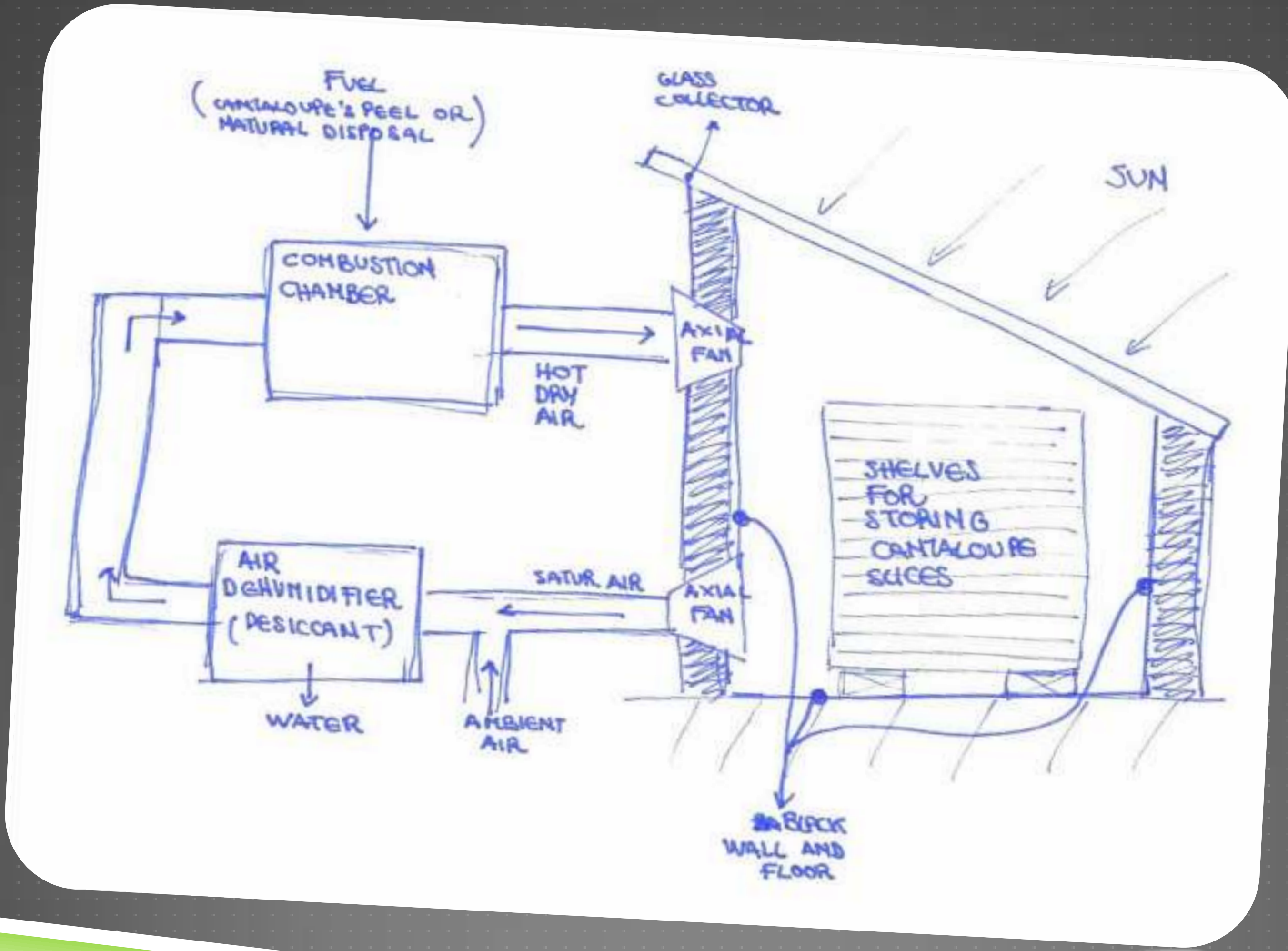



*Figure 5.6-Black Box Diagram for Hybrid solution of All 3 Optimal Technologies*

Thus, a hybrid solution was chosen that combines the three best drying methods into one powerful, economic choice.



The dryer is the only sub-function that uses full, non-human energy sources, so power options had to be considered.

Flow of warm air requested→ 0,4 $\left[\frac{m^3}{s}\right]$

Density of air at 1,01325 bar → 1,2 $\left[\frac{Kg}{m^3}\right]$

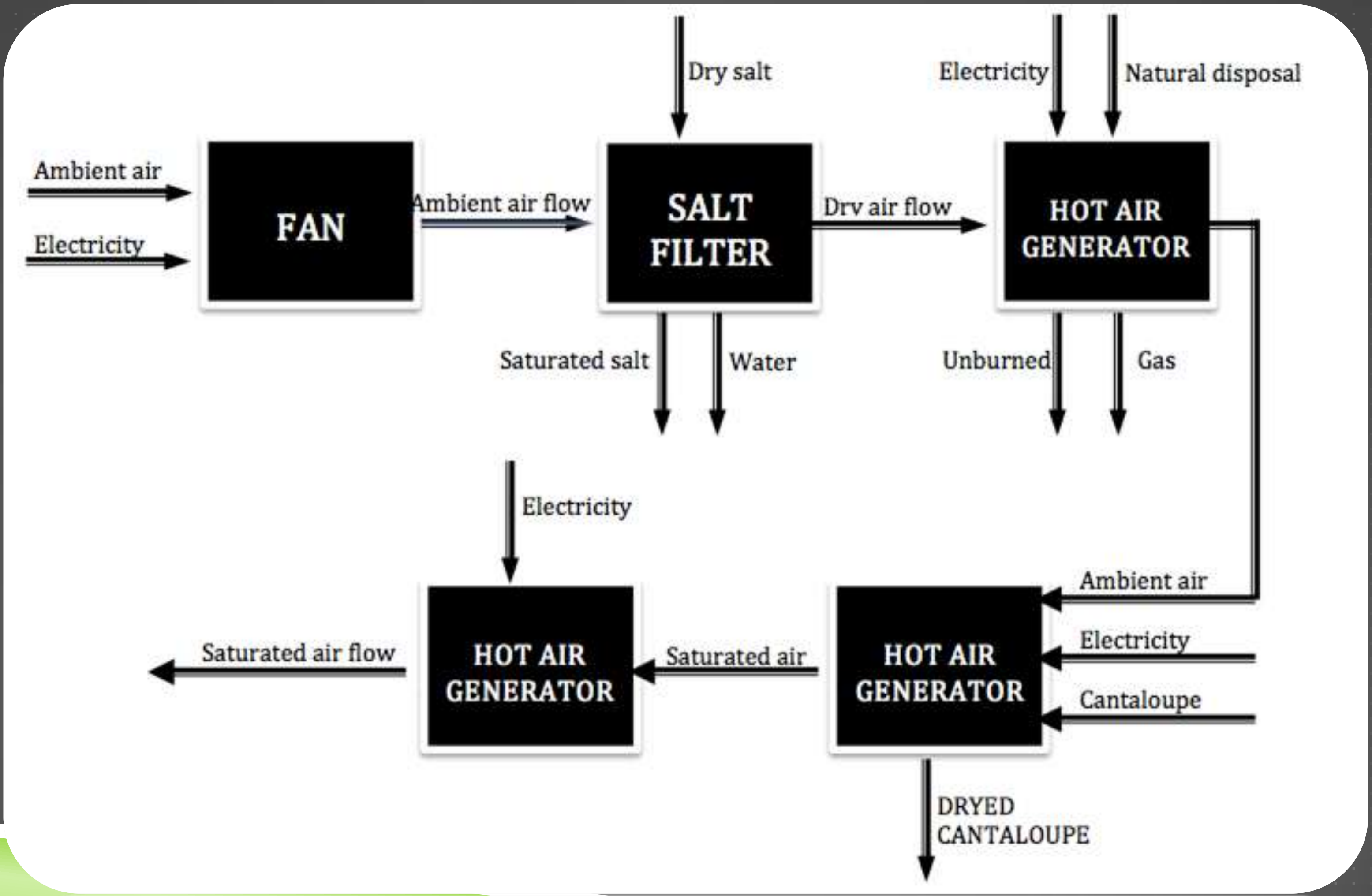
Assumed inlet air temperature→ 20$[°C]$

Air temperature required for drying → 75$[°C]$

Specific heat of air at constant temperature → 1,005 $\left[\frac{Kj}{Kg \cdot °K}\right]$

| Type | Manufacturing Cost ($) | Power (Kw) | Hour cost ($/h) | "Matching" hour | "Matching" day |
|---|---|---|---|---|---|
| Gasoil | 1000 | 20 (minimum) | 3.25 | 1846 | 83 |
| Gasoil | 1000 | 35 (maximum) | 5.51 | 1089 | 50 |
| PLG | 600 | 20 (minimum) | 2.45 | 2612 | 118 |
| PLG | 600 | 35 (maximum) | 6.09 | 428 | 22 |
| Electric | 300 | 20 (minimum) | 3.9 | 1718 | 78 |
| Electric | 300 | 35 (maximum) | 6.8 | 985 | 44 |
| Biomasses | 7000 | | | | |

Conclusively, the hybrid dryer utilizes a solar dryer, biomass generators, salt filters, and fans to dry 1 ton of cantaloupe in 11 hours.




## Conceptual Design

# With respect to packaging, a Quality Function Deployment methodology was used to determine the principle requirements

- Ease of handling
- Low weight
- Easy to translate
- Amount of cantaloupe in every pack to consistently be 250grms
- High work speed
- High durability.
- Easy to print an image onto the pack
- No technical skills needed in order to operate the machine
- Low electricity consumption
- Fast machine departure and delivery
- Exported directly to Colombia
- No delivery charges

| Factors | Importance | % |
|---|---|---|
| Cantaloupe packed | 26,3 | 35,74 |
| Electricity consumption | 21 | 28,53 |
| Machine cost | 26,3 | 35,73 |

| Factors | M1 | M2 | M3 | M4 | M5 | Unit |
|---|---|---|---|---|---|---|
| Cantaloupe packed | 250 | 250 | 250 | 250 | 250 | gr |
| Electricity consumption | 150 | 114 | 145 | 185 | 118 | € |
| Machine cost | 5480 | 5500 | 5490 | 5430 | 5500 | € |

| Importance | Factors | M1 | M2 | M3 | M4 | M5 | Unit |
|---|---|---|---|---|---|---|---|
| 0,3574 | Cantaloupe packed | 0,35733696 | 0,35733696 | 0,35733696 | 0,35733696 | 0,35733696 | gr |
| 0,2853 | Electricity consumption | 0,37542906 | 0,28532609 | 0,36291476 | 0,46302918 | 0,29533753 | € |
| 0,3573 | Machine cost | 0,36062735 | 0,36194351 | 0,36128543 | 0,35733696 | 0,36194351 | € |
| | Total | 1,09339337 | 1,00460655 | 1,08153715 | 1,17770309 | 1,014618 | |
| | | 1,08837969 | 1 | 1,07657783 | 1,17230281 | 1,00996553 | |

*Table 6.3-Machine comparison*

Initial Cleaning

Half Cutting

Peeling and Pitting

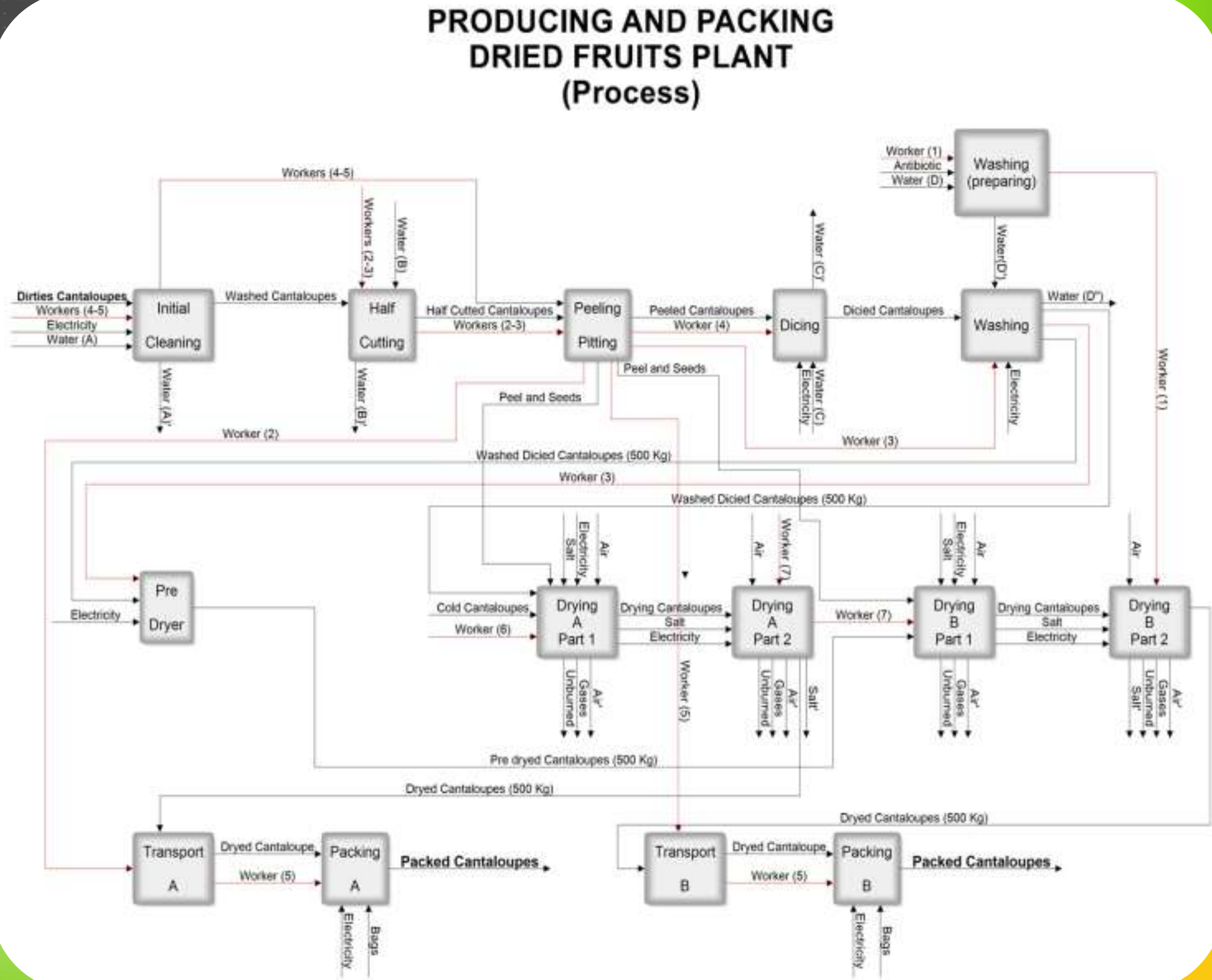
Slicing

Drying

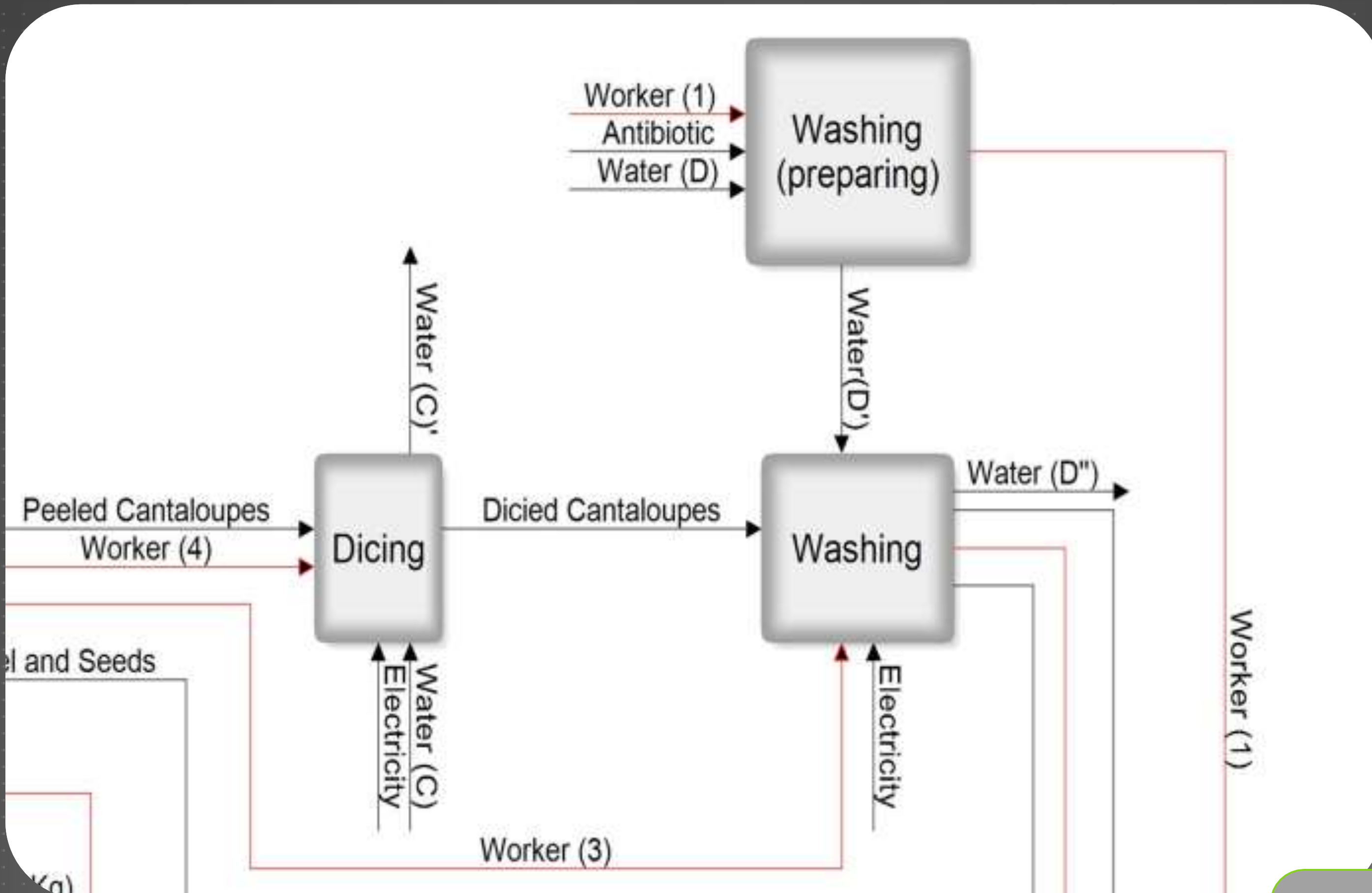
Packaging

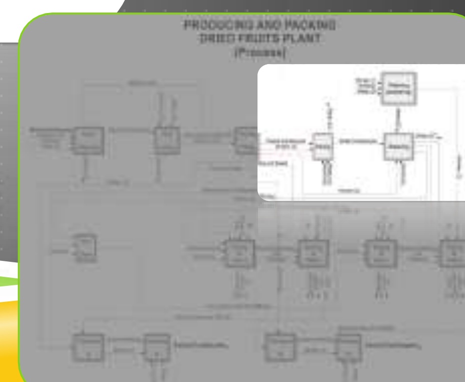

Conceptual Design

Combining all of the selected best methods, we have created an in depth diagram describing the entire plant process.



# Zooming in on each section to better see the diagram…



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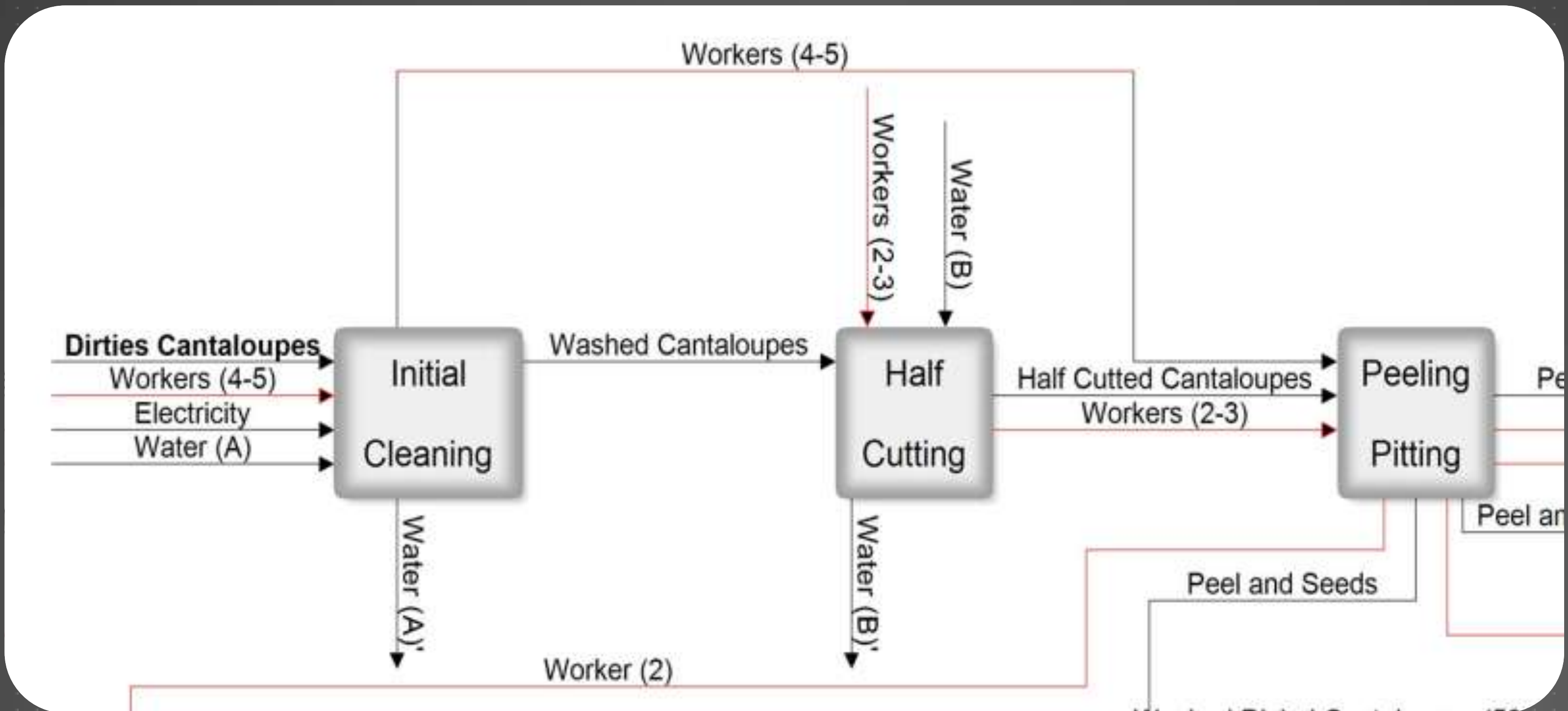


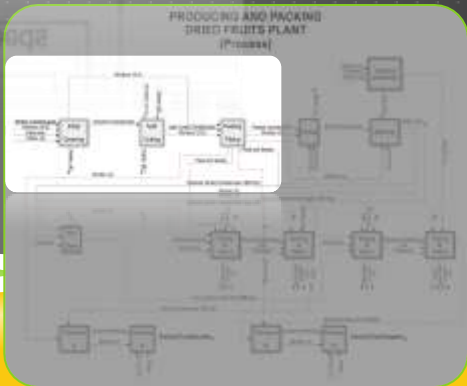

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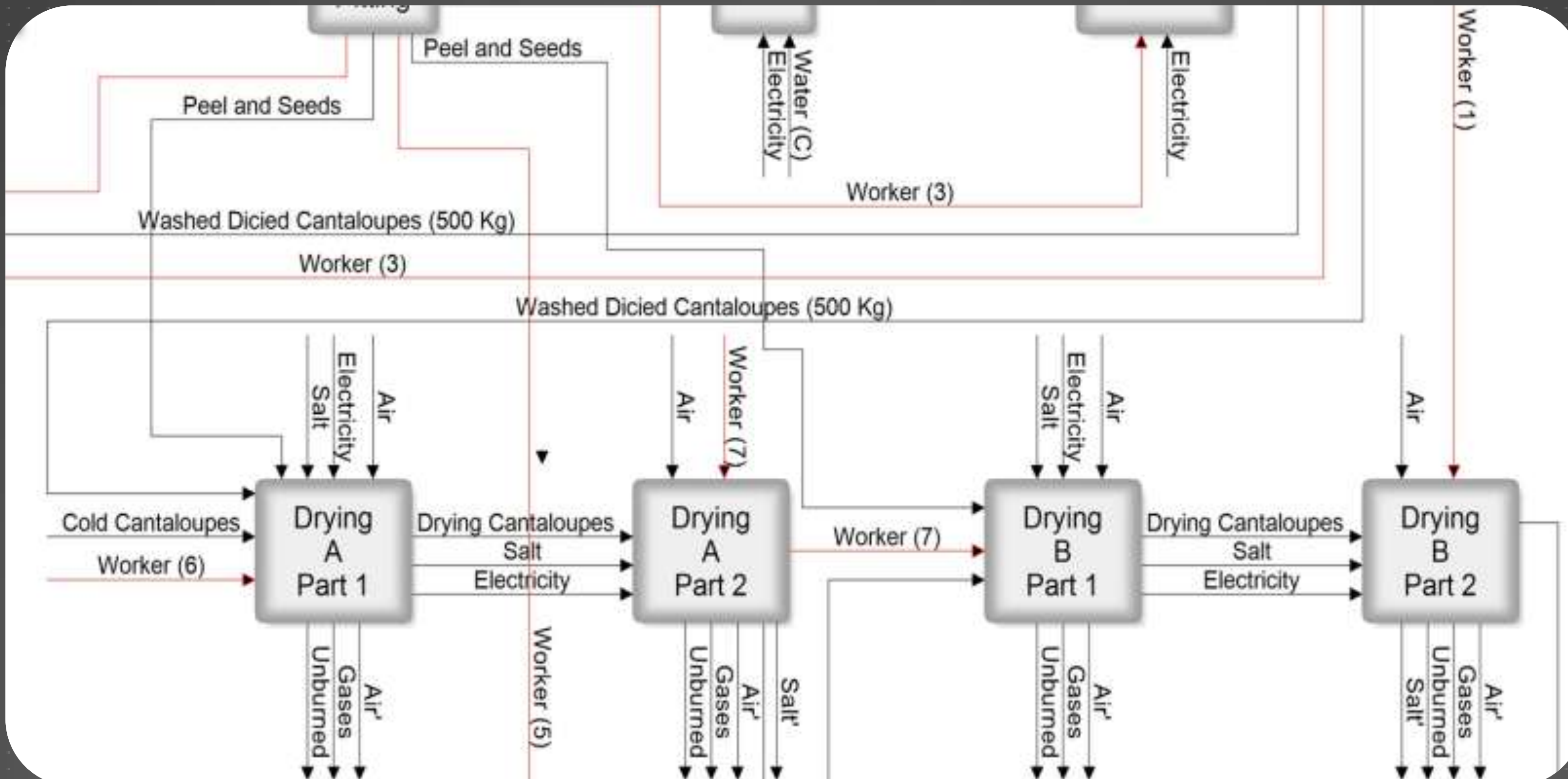


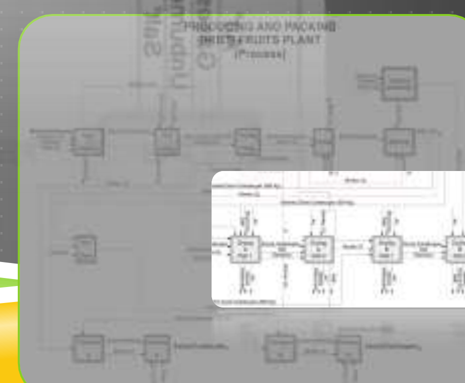

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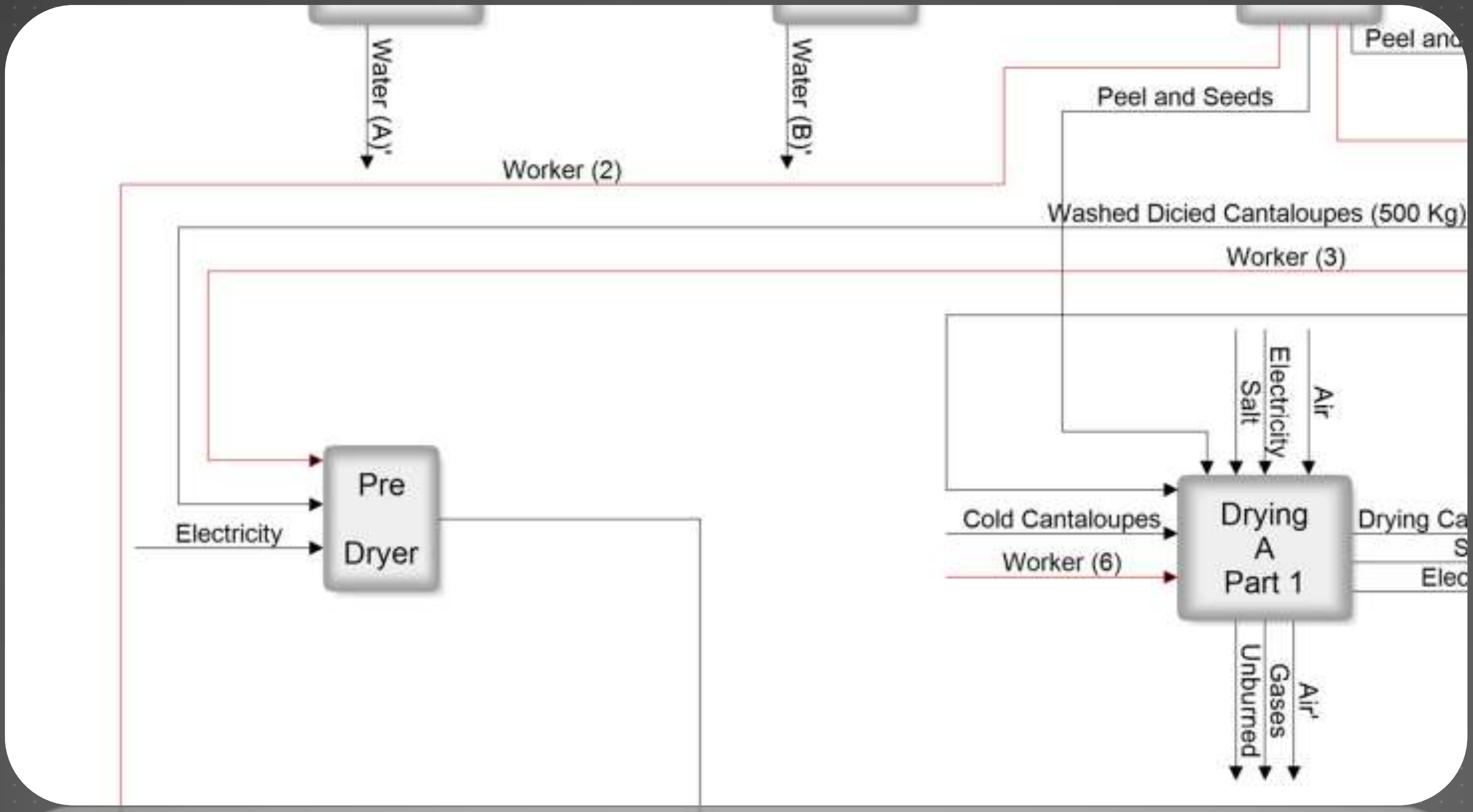


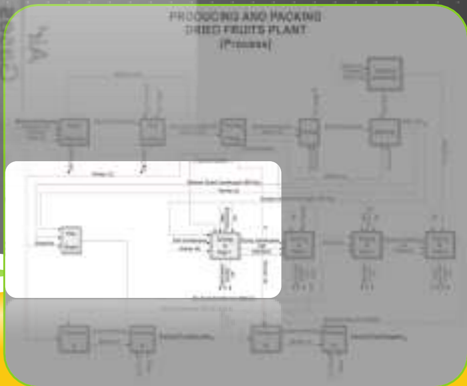

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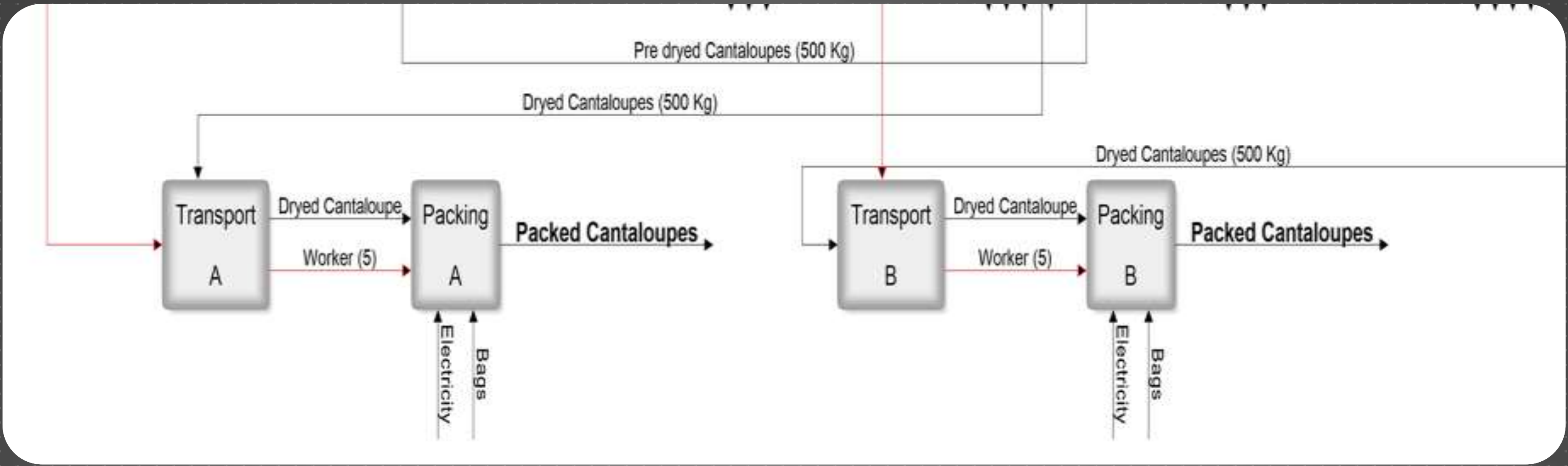
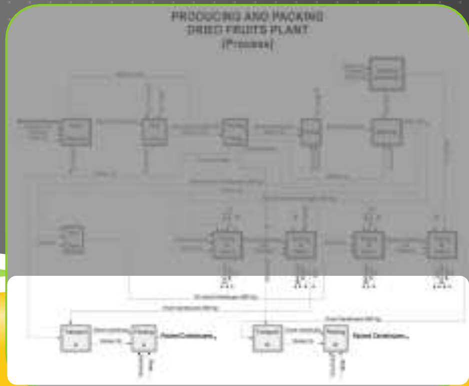
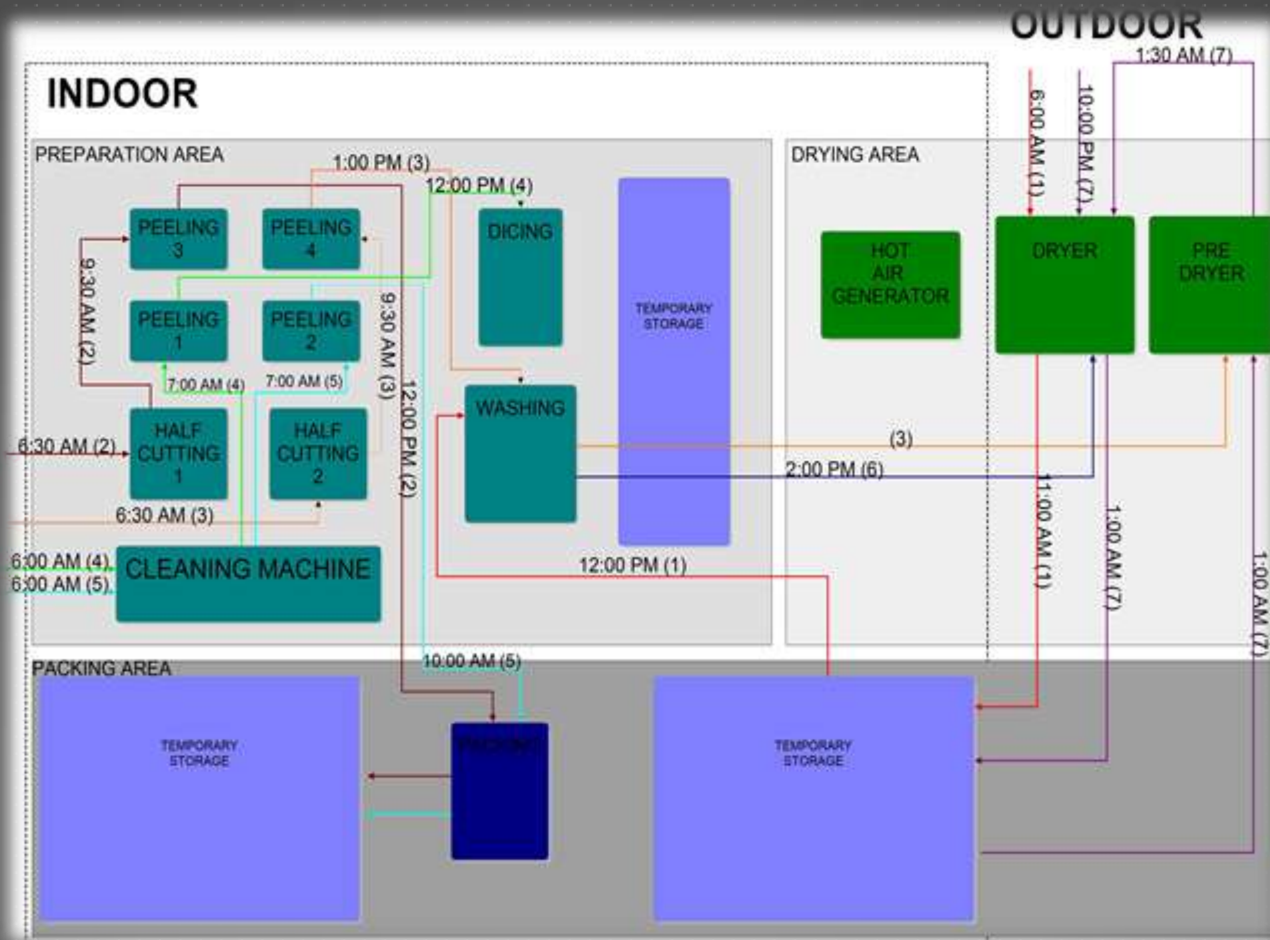
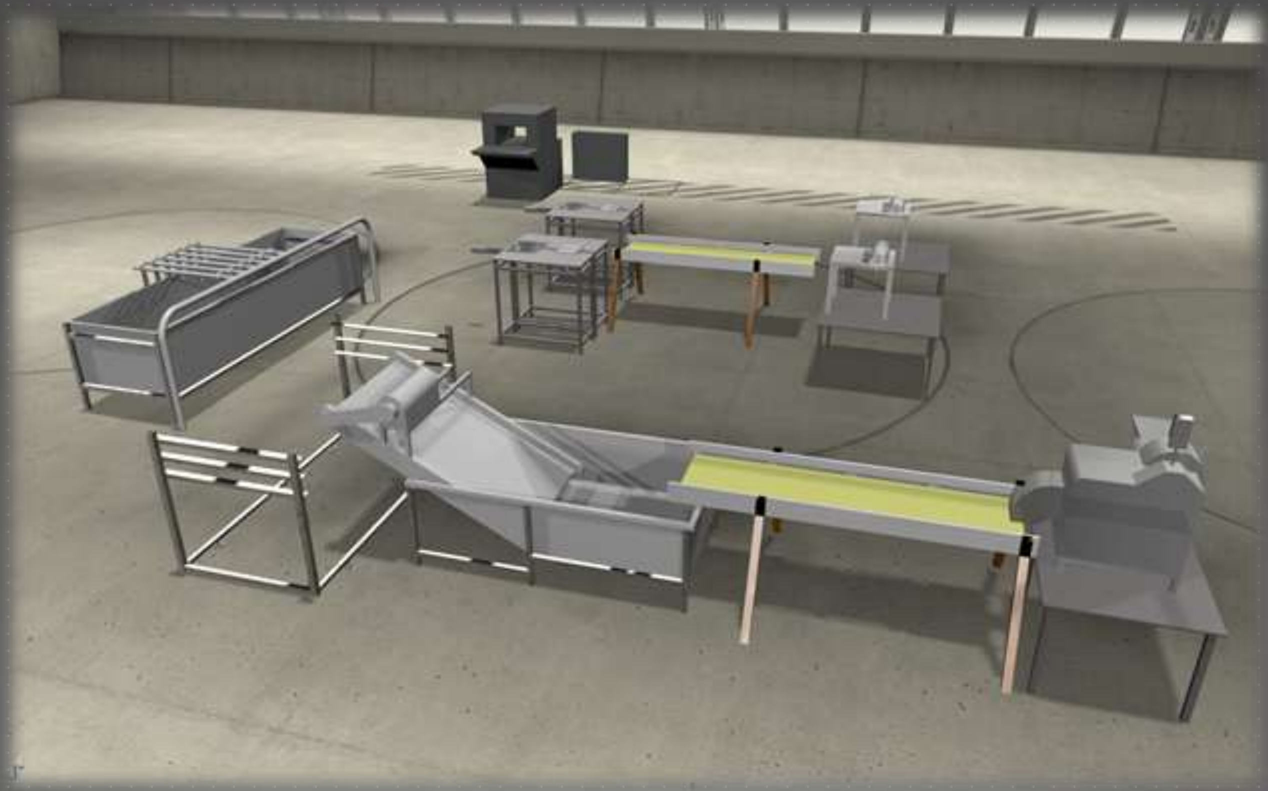


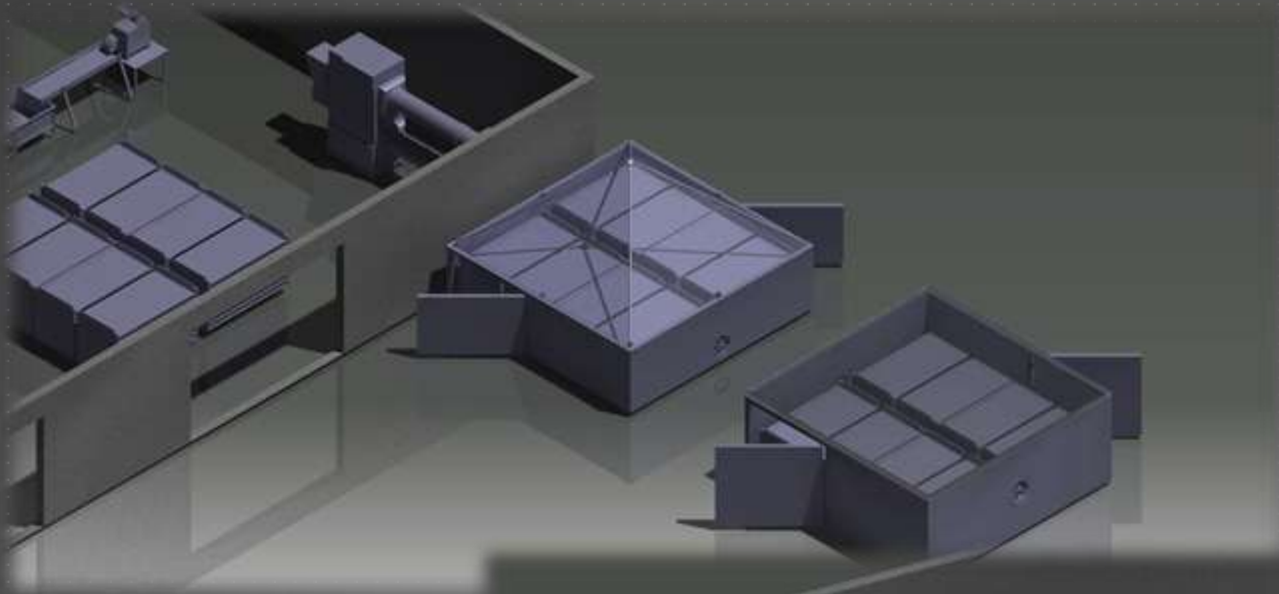
The layout of the plant will include placement of the sub-functions to allow for efficient flow of cantaloupe from place to place

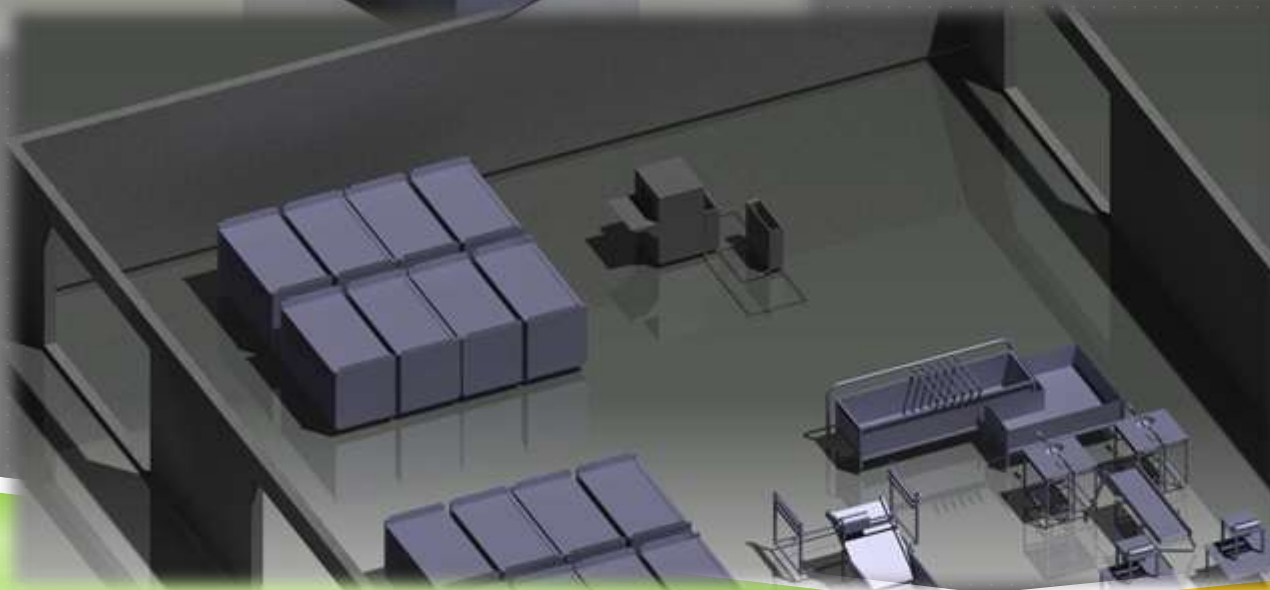


Finally, a 3D visual rendering of the plant was created in order to depict the final product in a realistic manner

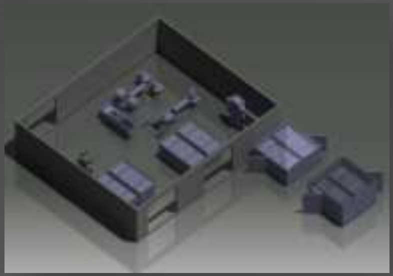


Finally, a 3D visual rendering of the plant was created in order to depict the final product in a realistic manner





In summary, the final specifications show that all of our initial specifications were met, and an efficient product was designed

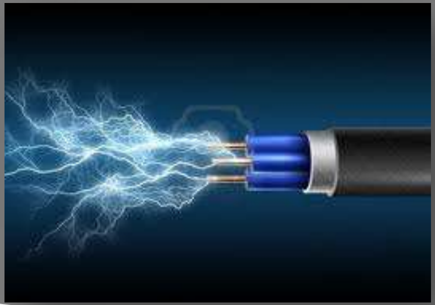


**Total Initial Investment:**

€ 17,203

**Total Daily Labor Cost:**

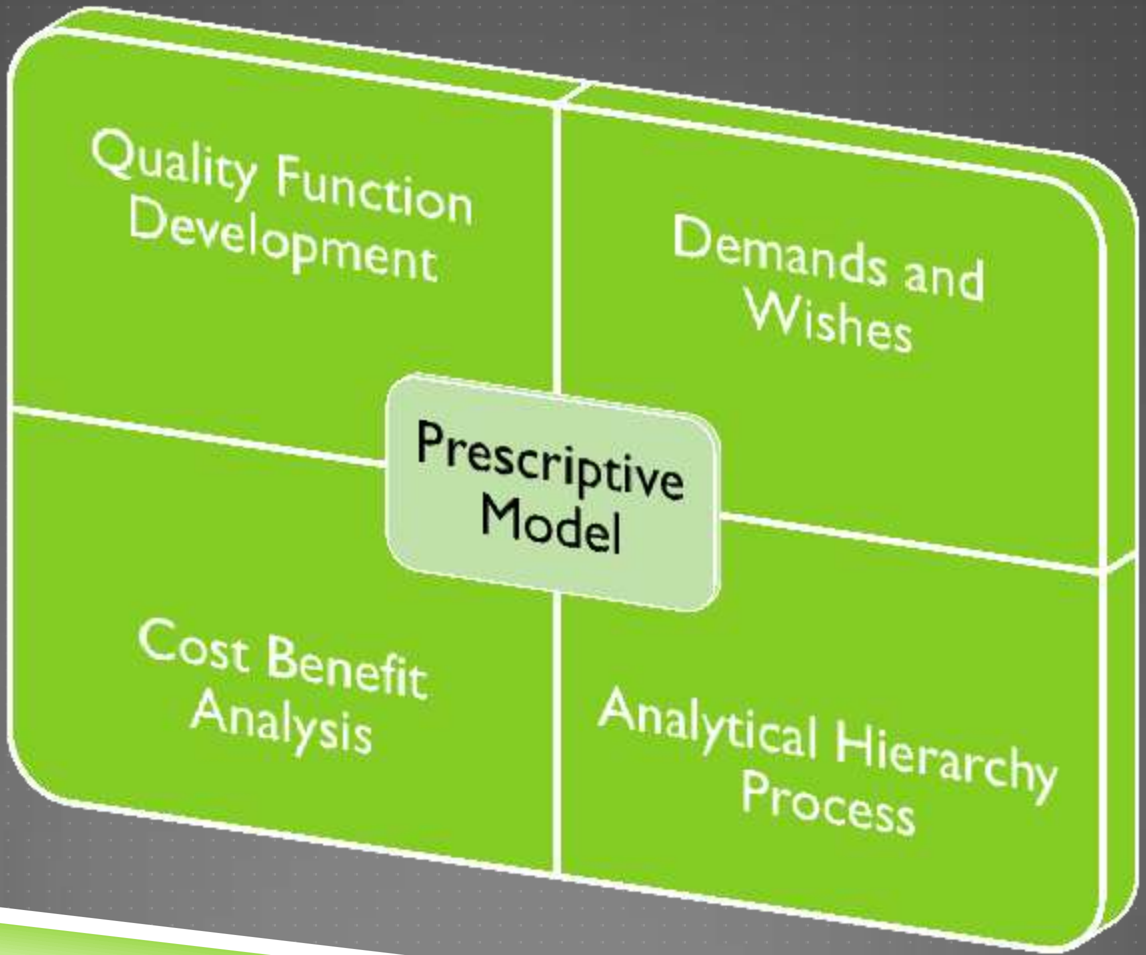
€ 79



**Total Daily Energy and Resource Cost:**

€ 51

The various methods for creating this design allowed for decisions to be made quantitatively and analytically, allowing for the best final options to be proven, not simply found.



## Sources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2. "Fruit and vegetable processing" by Mircea Enachescu Dauthy, Consultant FAO AGRICULTURAL SERVICES BULLETIN No.119 Food and Agriculture Organization of the United Nations, Rome, 1995, M-17, ISBN 92-5-103657-8

3. Business Procedures in Columbia.  Doing Business KFC. The International Bank for Reconstruction and Development. 2012


## Acknowledgements


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