Project II

Cold storage without external power

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Declaration

I declare that this written submission represents my ideas in my own words, and where other's ideas or words have been included, I have adequately cited and referenced the original source. I also declare that I have adhered to all principles of academic honesty and integrity and have not falsified, misinterpreted or fabricated any idea/data/facts/sources in my submission. I have understand that any violation of the above will be cause for disciplinary action by the institute and can invoke penal action from the sources from which proper permission has not been taken, or improperly cited.

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Date: 13.01.14

Place: Mumbai

Approval sheet

This Industrial design project report entitled 'Cold storage without electricity' is approved in partial fulfillment of the requirements for Master of Design degree in Industrial Design.

Project Guide:

Project Co-Guide: Aug 5, 2014

Chair Person: 13 Jan, 2014

Internal Examiner:

External Examiner:

Date: 13-01-14

Place: Mumbai

Acknowledgment

I'm really thankful to Prof. Chakravarthy & Prof. Dipankar for their guidance and for their support in involving me in this project. The knowledge they passed on to me and the learnings throughout the project is one of the finest I have got. The experience of working on a live project in itself was great.
Thanks to India's rich history and intellectual pros, we were able to address one such value of her which was long forgotten.
Thanks to TreeLabs for giving me such an opportunity to think and take responsibility of a project like this which has the potential to change the livelihood of people.
I'm also thankful to my teachers, whose suggestions and comments had opened up mind to new ideas. I hope the project will engage me productively towards the success of this and more such collaborative projects in the future.

I would also like to thank my friends in IDC, TreeLabs and Electrical department, my family and the Almighty for their continuous support and guidance throughout the project.

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Abstract

In a tropical country like India, with about 70% of population of India is engaged in agriculture, the importance of refrigeration can hardly be over-emphasized. Nearly 30 per cent of the country's fruits and vegetables perish due to lack of cold-storage facilities.
The estimation of growing need for household refrigeration products reflects upon the scope of the market of the product.
But the fact that the refrigeration is the highest consumer of power only next to lighting, leads to the selection of natural ways of cooling and refrigeration.
In the past around 4000 years from now, people in India and Egypt are known to produce ice by keeping water in the porous pots outside the home during the night period by radiative cooling or nocturnal cooling technique.

On a clear night the water would lose heat by radiation upwards. Provided the air was calm and not too far above freezing, heat gain from the surrounding air by convection would be low enough to allow the water to freeze by dawn.

Night sky radiant cooling has in modern times been forgotten due to widespread use of modern mechanical cooling systems and refrigerants. However, this type of cooling has roots in many ancient civilizations across the globe.

The idea is to use the ancient technique to solve the current day problem of cold storage and without external power which will satisfy the need of the rural household and enhance their lively hood.

Inference for the design is taken from the experiments conducted with the prototypes made for testing. The usability is given prime importance in the design. The device is designed with double walls with insulator inside to avoid conduction and mouth wide opened to increase radiation. Handling, locking mechanism, manufacturing were given importance considering the context and affordance of the home products.

Device can be used for ice making regularly with the suitable atmosphere and storage of food. This enables the storage of freshly grown vegetables to last much longer than usual in a hot climate.
Some enterprise can also use this as a business opportunity and make ice and sell. It is also great for using at a picnic or outdoor trekking where there is no electricity outside, but food or drinks need to be kept cool
The disadvantage is the process of ice making is highly dependent on the atmospheric weather and need for a person to religiously engage in the process of ice making from keeping it in a proper place to taking it back at the right time.

Introduction

How the project started

Problem Finding:
The journey of Project 2 started with the problem identification for the project topic with the constrain, as design for emerging market or rural market.

My understanding of the Emerging Markets:

Markets which showing signs of becoming the dominant social or business markets in terms of growth, industrialization and consumption.
The trending needs of the people based on the regional or culture aspects is also a sign of an emerging market

Hence based on the understanding, internet research and the books by UNICEF on Design for rural world, the prospects of the design for rural population of the world are targeting their needs on the sectors of cooking, solar lights, sanitation, energy, Natal needs, sustainable transportation, water issue, refrigeration, health care needs, tools redesign, etc.

Also Prof. Dipankar from TreeLabs suggested the topic of 'Cold storage without electricity'.

The scope of the project in terms of its understanding in science, giving shape to ancient technology, social cause and its scope of designing for rural population attracted me to take that as my Project II.
Hence choosing Cold Storage without power as the topic, I started the primary research to understand the concept of refrigeration and natural cooling.

Also the 7c's of Innovation By Prof. Chakravarthy helped me in co relating and arriving to the final design.

Brief history of refrigeration

In the past around 4000 years from now, people in India and Egypt are known to produce ice by keeping water in the porous pots outside the home during the night period by radiative cooling technique. There are a few accounts in China about the use of ice around 1000 BC for cooling the beverages.
In 4th century A.D., East Indians were producing ice by dissolving salt in water.
Because of the very small amount of production, the aforesaid methods were not feasible for commercial applications.

Natural ice is limited to certain regions, therefore, the absence of good quality insulation systems in those days forced the man to develop methods to produce ice artificially. Out of many pioneers' work on refrigeration side, a few are presented here.
In 1790 the first British Patent was obtained by Thomas Hariss and John Long.
In 1834 Jacob Perkins developed a hand operated refrigeration system using ether as the working fluid

In the 19th century, there was remarkable development of refrigeration systems to replace natural ice by artificial ice producing machines.
In 1915, the first two-stage modern compressor was developed.
Until about 1920s the development in refrigeration system was restricted to the refinement in the cold-air machines and vapor-compression systems.
After 1920s, there has been extensive diversification in the growth of refrigeration systems leading to new developments such as vortex tube, thermoelectric, pulse-tube, steam-jet, centrifugal compression systems, etc.

The most important development can be the invention of new refrigerants which were chlorfluor hydrocarbons. This development occurred in 1930 in GE Corporation of USA.The chlorfluor carbons offered the advantages of best refrigerants and were a non-toxic substances in comparison with NH_3 and SO_2
Other developments took place due to special requirements to utilize waste heat or low grade energy or materials of specific properties for thermoelectric effect.

Img 01

Food wastage -India

Nearly 30 per cent of the country's fruits and vegetables perish due to lack of cold-storage facilities

Despite millions of Indians going to bed on a hungry stomach, the country is letting food worth a whopping Rs 44,000 crores being wasted, While the wasted fruits and vegetables alone was estimated at Rs 13,300 crores.

In a tropical country like India, with about 70% of population of India is engaged in agriculture, the importance of refrigeration can hardly be over-emphasized. India is the 2nd largest producer of fruits and vegetables in the world. The wastage in fruit and vegetables is estimated to be worth about Rs.330 billion. India, therefore, has tremendous growth potential with respect to rural-based food processing.

Effect

• This is not just a matter of crores of rupees, it is wastage of water used in agriculture, manpower and electricity lost in food processing industries.
• Also contributes to so much of deforestation.

Facts about Refrigeration

To Understand the need and scope of refrigeration in developing Countries like India.

From the Documentation and data of 'RESIDENTIAL CONSUMPTION OF ELECTRICITY IN INDIA'-A Draft by The World Bank on India: Strategies for Low Carbon Growth July 2008 gives us insight about the growing trends in the refrigeration sector in Urban and Rural India.

The fact that the refrigeration is the highest consumer of power only next to lighting.
And it is the only device which runs 24x7 and having the highest operating time, rings the alarm bell of serious attention needed in that field.

Also the estimation of growing need for household refrigeration products reflects upon the scope of the market of our product.

Table 40: Total Power Consumed by Kitchen Appliances

White Appliances			2006	2011	2016	2021	2026	2031
Refrigerator	Operating	GWh/yr	23.490	32.706	43.472	57.349	70,844	84,244
Washing machines	Operating	GWh/yr	312	672	1,433	2,742	4,439	6,328
Electric Oven	Operating	GWh/yr	509	909	1,564	2,484	3,553	4,687
Toaster	Operating	GWh/yr	261	646	1,359	2,404	3,583	4,742
Microwave	Operating	GWh/yr	320	495	761	1,138	1,582	2,063
	Standby	GWh/yr	297	408	562	787	1,062	1,372
	Total	GWh/yr	617	903	1,323	1,925	2,644	3,434

Table 33: Parc Average Per Unit Power consumed by Lighting

Lighting			2006	2011	2016	2021	2026	2031
	Operating	kWh/yr	33.7	35.2	35.0	35.1	35.2	35.0

Table 35: Parc Average Per Unit Power consumed by Kitchen Appliances

White Appliances			2006	2011	2016	2021	2026	2031
Refrigerator	Operating	kWh/yr	704.6	567.7	472.7	431.1	417.4	418.4
	Standby		0.0	0.0	0.0	0.0	0.0	0.0
	Total		704.6	567.7	472.7	431.1	417.4	418.4
Washing machines	Operating	kWh/yr	36.6	40.7	47.5	54.1	59.3	63.5
	Standby		0.0	0.0	0.0	0.0	0.0	0.0
	Total		36.6	40.7	47.5	54.1	59.3	63.5
Electric Oven	Operating	kWh/yr	87.6	99.3	108.9	113.9	116.0	116.7
	Standby		0.0	0.0	0.0	0.0	0.0	0.0
	Total		87.6	99.3	108.9	113.9	116.0	116.7
Toaster	Operating	kWh/yr	73.0	94.1	107.9	113.7	115.9	116.6
	Standby		0.0	0.0	0.0	0.0	0.0	0.0
	Total		73.0	94.1	107.9	113.7	115.9	116.6
Microwave	Operating	kWh/yr	39.4	39.4	39.4	39.4	39.4	39.4
	Standby	kWh/yr	36.6	32.5	29.1	27.3	26.5	26.2
	Total	kWh/yr	76.1	72.0	68.5	66.7	65.9	65.6

Figure 58: Annual Sales of Microwaves and Fridges

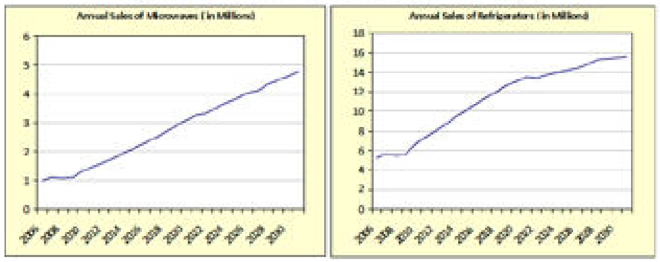
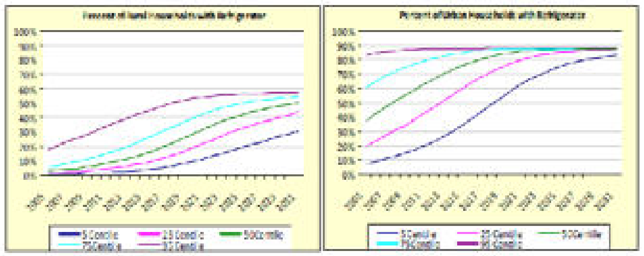


Figure 46: Projection of Ownership of Fridges in Selected Centiles - Rural and Urban



The refrigeration is classified in to Natural and Artificial methods of cooling based on the technique employed for cooling. Few of the known methods are listed below.

&

Natural Cooling

1. Transported from colder regions, (Ancient)
2. Harvested in winter and stored in ice houses for summer use or, (Ancient)
3. Art of ice making by nocturnal cooling / Radiative cooling from stratosphere
4. Evaporative cooling,
5. Cooling by salt solution,
6. Draft fridge
7. Solar refrigerator

Artificial Cooling

1. Domestic refrigeration system / Ice box (Ancient)
2. Vapour compression systems,
3. Vapour absorption systems,
4. Gas cycle systems etc.
5. Solar energy based refrigeration systems
6. Air cycle refrigeration systems
7. Steam and vapour jet refrigeration systems
8. Thermoelectric refrigeration systems and
9. Vortex tubes

&

Hybrid Techniques
Solar powered refrigeration


Img 02

From the research I understood that less is been done in the field of natural cooling techniques because of the advent of the industrial era and the fast phased life which demands quick results.

And sticking to the idea of cold storage without power, I decided to explore on few methods in natural cooling technique from innovation and design point of view.

Considering the scope and chances of proving the technique and the possibility of design inputs I choose

Evaporative cooling and
Radiant cooling (which is suggested by TreeLabs)

Evaporative Cooling

Evaporation is vaporization of the liquid [Img 02]to gaseous state. Nature's most efficient means of cooling is through the evaporation of water and most common example is perspiration and sweat.

When water evaporates it draws energy from its surroundings which in terms produces a considerable cooling effect in the liquid.

Evaporative cooling occurs in a closed container with the food kept inside, when air, that is not too humid, passes over a wet surface(the faster the rate of evaporation the greater the cooling.) evaporates the water ,the water in terms take the heat from the interior of the container and keeps it cool.
There are different types of evaporative cooling based food refrigeration which differs by the medium or structure it is made.

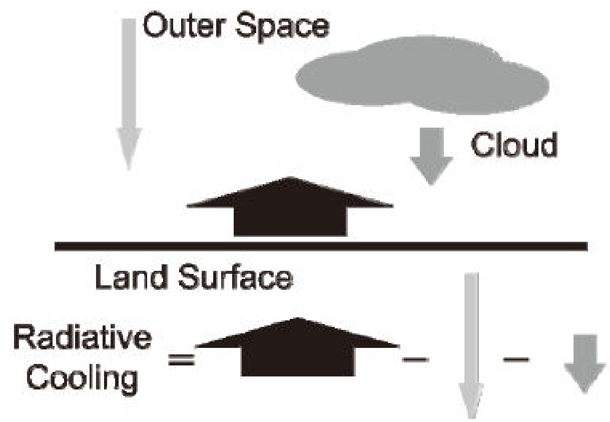
Few of the famous ones are listed below.

Clay based cooling

Bamboo refrigerator

Charcoal fridge

Coolgardie safe



Radiant cooling

A radiant cooling system refers to a temperature-controlled surface that cools indoor temperatures by removing sensible heat and where more than half of heat transfer occurs through thermal radiation

Ice making with Radiative cooling:

The evaporation of water in almost cool dry air and radiative heat transfer between the water and the deep sky that is at a very low temperature (much below the freezing point of ice) caused the formation of ice even though the surrounding air was at a higher temperature than the freezing point of water.

Night sky radiant cooling has in modern times is been forgotten due to widespread use of modern mechanical cooling systems and refrigerants.

Ancient techniques:
Egyptians and Iranians made ice from night sky and from doomed roof fridge

From the British archives it is understood that the Indians made ice from the clear night sky during summer in the northern and eastern part of India.
Night sky - Invisible Freezer
Night sky radiant cooling is a natural process that helps the earth maintain thermal equilibrium in the planet and it is the only way earth can lose heat.

Heat lost from the surface of the earth at night is comparable to the heat gained by the sun.

A layer of frost will form on rooftops and on automobiles (moisture condenses out of the air) even though the outdoor air temperature is well above freezing is an obvious example of radiant cooling.

Secondary Research

Few Terminologies:

The meaning of few terminologies used throughout the project is given aside, for better understanding.

Radiation:

Thermal radiation is electromagnetic radiation generated by the thermal motion of charged particles in matter. All matter with a temperature greater than absolute zero emits thermal radiation.

Conduction :

Conduction (or heat conduction) is the transfer of heat energy by microscopic diffusion and collisions of particles or quasi-particles within a body due to a temperature gradient and heat spontaneously flows from a body at a higher temperature to a body at a lower temperature

Convection:

Circulatory motion in liquid or gas: circulatory movement in a liquid or gas, resulting from regions of different temperatures and different densities rising and falling in response to gravity

Thermal insulation :

It is the reduction of heat transfer (the transfer of thermal energy between objects of differing temperature) between objects in thermal contact or in range of radiative influence.

Infrared thermometer:
The device used to measure temperature during experiments)

It measures heat (infrared) radiation from hot objects using semiconductor-based, light-sensitive photocells (similar to tiny solar cells, but designed to respond to both visible and infrared radiation).

An infrared thermometer is a thermometer which infers temperature from a portion of the thermal radiation sometimes called blackbody radiation emitted by the object being measured. By knowing the amount of infrared energy emitted by the object and its emissivity, the object's temperature can often be determined. Infrared thermometers are a subset of devices known as "thermal radiation thermometers".

Evaporative Cooling:

The basic principle relies on cooling by evaporation. When water evaporates it draws energy from its surroundings which produces a considerable cooling effect.
Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling. The efficiency of an evaporative cooler depends on the humidity of the surrounding air. Very dry air can absorb a lot of moisture so greater cooling occurs. In the extreme case of air that is totally saturated with water, no evaporation can take place and no cooling occurs.

Generally, an evaporative cooler is made of a porous material that is fed with water. Hot dry air is drawn over the material. The water evaporates into the air raising its humidity and at the same time reducing the temperature of the air. There are many different styles of evaporative coolers. The design will depend on the materials available and the users requirements. Some examples of evaporative cooling designs are described below.

Market Study:

Mitti Cool

Mitticool is a natural refrigerator made entirely from clay to store vegetables, fruits and also for cooling water. It provides natural coolness to the stored material without requiring any electricity or any other artificial form of energy.

Fruits, vegetables and milk can be stored fresh without deteriorating their quality for 2 to 3 days retaining their original taste. It works on the principle of evaporation. Water from the upper chambers drips down the side, and gets evaporated taking away heat from the inside, leaving the chambers cool. The top upper chamber is used to store water. A small lid made from clay is provided on top. A small faucet tap is also provided at the front lower end of chamber to tap out the water for drinking use. In the lower chamber, two shelves are provided to store vegetables, fruits and milk etc.

It will take about 12 hrs to get cooling effect when using first time. It is durable in nature and need not to be replaced after using some period (like MATKA).

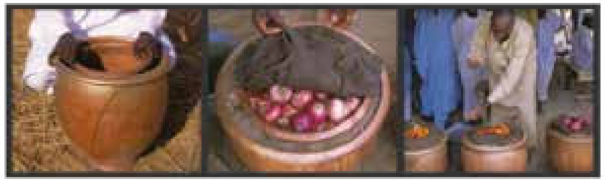
About 20 liters of water, 5 kg of vegetables, fruits and 5 litres milk or any liquid material can be kept inside the refrigerator and it cost around Rs. 3440/- .

I tried testing the mitti cool which is been used by Prof. Ganesh's(CSE dept) in his house.

The output was little lower than the ambient cooling, and it is been never tried with milk products.


Img 03

ZEER pot
(An African technique using two pots one inside the other and wet sand layer in between to absorb the heat)




Img 04

Pot in Pot Refrigeration

These are simple designs of evaporative coolers that can be used in the home. The basic design consists of a storage pot placed inside a bigger pot that holds water. The inner pot stores food that is kept cool.
Mohammed Bah Abba a teacher in Nigeria, developed a small-scale storage “pot-in-pot” system that uses two pots of slightly different size. The smaller pot is placed inside the larger pot and the gap between the two pots is filled with sand.

An idea revived by Muhammed Bah Abba, this refrigerator is now being used by many farmers in warm climates who need to preserve their food for a longer time and keep the insects away.
Keeping the sand moist all the time enables evaporation to cool the produce kept inside the inner pot. This enables the storage of freshly grown vegetables to last much longer than usual in a hot climate. It is also great for using at a picnic or outdoor meal where there is no electricity outside but food or drinks need to be kept cool.

A bamboo cooler

The base of the cooler is made from a large diameter tray that contains water. Bricks are placed within this tray and an open weave cylinder of bamboo or similar material is placed on top of the bricks. Hessian cloth is wrapped around the bamboo frame, ensuring that the cloth is dipping into the water to allow water to be drawn up the cylinder’s wall. Food is kept in the cylinder with a lid placed on the top.

Img 05

Img 06

A charcoal cooler

The charcoal cooler is made from an open timber frame of approximately 50mm x 25mm (2" x 1") in section. The door is made by simply hinging one side of the frame. The wooden frame is covered in mesh, inside and out, leaving a 25mm (1") cavity which is filled with pieces of charcoal. The charcoal is sprayed with water, and when wet provides evaporative cooling. The framework is mounted outside the house on a pole with a metal cone to deter rats and a good coating of grease to prevent ants getting to the food. The top is usually solid and thatched, with an overhang to deter flying insects (Not shown in Figure 2). All cooling chambers should be placed in ashady position, and exposure to the wind will help the cooling effect.

The Coolgardie Safe

The Coolgardie Safe was made of wire mesh, hessian, a wooden frame and had a galvanized iron tray on top. The galvanised iron tray was filled with water. The hessian bag was hung over the side with one of the ends in the tray to soak up the water.
Gradually the hessian bag would get wet. When a breeze came it would go through the wet bag and evaporate the water. This would cool the air inside the safe, and in turn cool the food stored in the safe. This cooling is due to the water in the hessian needing energy to change state and evaporate. This energy is taken from the interior of the safe (metal mesh), thus making the interior cooler. There is a metal tray below the safe to catch excess water from the hessian.

User Study

Place: **Farm Fresh Organic Garden**
Hiranandhani.

I choose this Organic shop assuming that people who go for organic food stuffs are more conscious about the environment and their health. And I wanted to place my product as an urban lifestyle alternative for refrigeration.

The customers of the shop where asked about their opinion on eco friendly, power less refrigeration, after explaining about the environmental and health benefits of it. And their opinions are recorded as below.

Person 1: Ranjani Govil,
Profession: Teacher
Number of family members: 02
She is environment conscious and she will go for such an option if available. But not sure whether it can replace the conventional refrigeration.

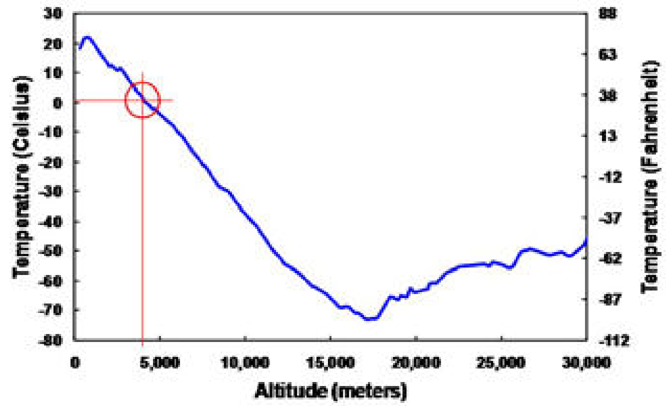
Person 2: Nilesh
Profession: IT Employee
Family Members: 4
He will use eco facility, if they can provide extra health benefits, He even thought about it once about refrigeration using clay
He never mind about the cost.

Person 3: Name Unknown
Profession: Retired employee
Age: 75
Having lever problem, but had a opinion that people don't care about buying stuffs like this unless it is providing more features.

Person 4: Ragav
Profession: Government employee
Family members: 3 person family
He is conscious about health and convenience,
If your product provides additional features he can consider.

Insights:
•People don't really care about going for eco responsible design unless it adds to their convenience.
•The cooler cant be a alternative for refrigerator, but can reduce the usage of fridge and electricity.

Radiant Cooling



Img 07

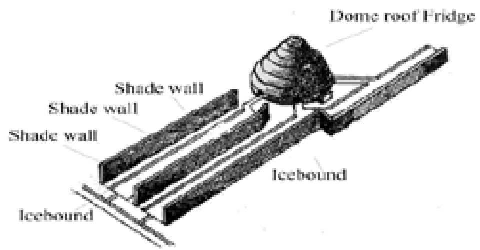
Radiative cooling is commonly experienced on cloudless nights, when heat is radiated into space from the surface of the Earth, or from the skin of a human observer, outer space radiates at about a temperature of 3 kelvins (-270 degrees Celsius or -450 degrees Fahrenheit), The effect is blunted somewhat by Earth's surrounding atmosphere which also traps heat.

In the same way that thermal radiation travels from the sun to the surface of the earth, across the vacuum of space, the heat from the earth also radiates back into space.

Night sky radiant cooling is a natural process that helps the earth maintain thermal equilibrium. A layer of frost will form on rooftops and on automobiles even though the outdoor air temperature is well above freezing. This frozen condensation is proof that the rooftops were losing heat by radiation to the night sky faster than the surrounding warmer air could replace that heat by natural convection. The radiant cooling occurs at a slower rate on partly cloudy nights, but can still provide reliable cooling. Only when the night sky is completely cloudy, does the radiant cooling effect stop completely

History of Night Sky Radiant Cooling

Yakchal



Img 08

Small earthen pots filled with water were placed in an open field with sugarcane husks strewed around, and in the morning the coating of ice formed in the cold temperature of the night was collected and stored in ice-pits.

Img 09

Night Sky Radiant Cooling is not a new technology. This phenomenon has been utilized by many indigenous cultures throughout the world.

The Iranians used ice making walls that incorporated Night Sky Radiant Cooling and adobe storage buildings for ice over 1,000 years ago.

Night sky radiant cooling has in modern times all but been forgotten due to widespread use of modern mechanical cooling systems and refrigerants. However, this type of cooling has roots in many ancient civilizations across the globe. By constructing large ditches filled with water and surrounded by tall mud walls to the south east and west that blocked the sun when it was low on the horizon, the ancient Iranians used night sky radiation to create ice when ambient temperatures were well above freezing. This ice was then moved to a large domed structure called a Yakhchal where the ice was stored through summer months.

In India before the invention of artificial refrigeration technology, ice making by nocturnal cooling was common. The apparatus consisted of a shallow ceramic tray with a thin layer of water, placed outdoors with a clear exposure to the night sky. The bottom and sides were insulated with a thick layer of hay. On a clear night the water would lose heat by radiation upwards. Provided the air was calm and not too far above freezing, heat gain from the surrounding air by convection would be low enough to allow the water to freeze by dawn.

The same radiative cooling mechanism can sometimes cause frost or black ice to form on surfaces exposed to the clear night sky, even when the ambient temperature does not fall below freezing









Market Research:

The proposed Ice maker using Radiant cooling is going to be a new market, the nearest comparable product to this will be Chotu cool, Mitti cool and their variants,

Vision of Chotucool is to endow a brighter future to the millions of households in rural India by enhancing,
Living Standard
Livelihood
Lifestyle

User Research:

Street Vendors:

Tried to understand the ice usage by street vendors and its implications.

Person 1: Kulfi Vendor
Place: Near Dadar station
He is buying ice blocks from the whole sale shop in Dadar for Rs.8/Kg. He is happy to have a device which can make ice for his business daily and that too if it can increase his income.

Person 2: Malai vendor
Place: opposite IIT B gate
He buys ice form the Powai market, and he is having problem of ice getting melted very quickly though he sells it in the night.
He doesn't have a ice box as such.

Person 3: Nimbu Panni vendor
Place: CST, Mumbai
The person buys 5-10 kg's of ice daily to satisfy his business needs. He is not up to try and make ice of his own.!

Person 4:
Place: opposite IIT B gate
This whole sale vendor shop, sells around 500Kg of ice per day at the rate of Rs.7per Kg. He is getting it bulk from Thane or Vashi.

House Hold:

Tried to understand the need for refrigeration in rural households and their way of preserving food when they don't have a refrigerator.

• Their way of using and buying perishable food differs when they don't have a fridge.

• They face problem in storing fast spoiling item like milk, fish and few vegetables which need low temperature.

• Also in summer season they prefer to have cold water using Matka or its kinds.

Insights:

• We need to educate people about possibility of ice making.

• And it has to be cheap enough to compete with the industrial ice production in semi rural areas.

• The people has to be educated about the use of ice and proper storage of food for their health and convenience without them being fallen in to the illusion about cold storage.

• Chances of people looking at an ice maker as cold storage device is high, we should consider that.

• More than making ice, the device should have affordance and satisfy users in terms of reliability.

Technique Evaluation:

To prove the aforesaid technique of radiant cooling though it is been employed in ancient India, with the deeper understanding of science and technology, it is approached in our possible context.

With the help from Treelabs in the technical specification, I build the alpha prototype for testing.

The making of prototype based on calculations alone wont produce results. To get the desired result, there are few environmental parameters which play a key role, like

- Humidity (Ideally below 25-35%)
- Clear night sky (with less haze and pollution)
- Wind (speed close to none)
- Insulation of the box (thick enough to make sure to stop heat transfer due to convection and conduction.

The following theory and calculation will give a rough idea of what is been done in making ice and what is possible.

Making of Alpha Prototypes:
Thus a Prototype is made with bubble sheet wrapped around circular fashion to accommodate a steel thali.

Around the bubble sheet, for strength, styrene sheet was used, which is wrapped around the with aluminium foil to reflect the unwanted radiation from the ground.

Polystyrene is used inside, for strength and support. Overall the testing prototype is made weight less for easy of transportation during testing.

Experiments:

Insights:
The experiment in Anantha rooftop gave the insight about the wind disturbance and the need to find for a proper IR transparent sheet which will reduce the convection.

In order to validate the prototype and technique, experiments were conducted in different places to test for suitable condition. The insights from the different experiments are listed below as follows.

The temperature is measured using IR pyrometer and the humidity and ambient temperature is measured using Hygrometer.

Date:	06.11.13			
Location:	Anantha roof top(16 floors), IIT B,			
Ambient Temp.	26.4 C			
Humidity	65% aprox.			
Wind	5-7 kmph (Approx.)			
Experiment Table				
Time(PM)	**Ground Temp.(C)**	**Sky Temp.(C)**	**Plate Temp.(C)**	**Note**
10.4	23.4	-9.5	23.4	
10.45	23	-9.9	18.9	
10.52	23	-9.6	19.2	
11.01	24	-9.5	18.7	
11.17	23.4	-9.4	19.2	
11.29	23	-9	19.5	
11.41	23	-9.4	22	(with the plastic sheet covered)
Note:				
The sky is not clear and the experiment is done without water.				

This above images are taken from shirdi, where the temperature reached zero°c

Insights:

Its decided to do the experiment far from the humid shores of Arabian sea, hence Shridi is been chosen, which is the nearest (250 Km)dry place from Mumbai. Though faced difficulties from local villagers and the police , we started the experiment very late in the night and was able to attain 0°c,
which raised the spirit to continue the experiment the next day also.

Date:	14.11.13		
Location:	Shirdi,(3 km towards pimpalwadi)		
Ambient Temp.	21.3	(at the time of starting the exp.)	
Humidity	59%		
Wind	almost no wind		
Experiment Table			
Time(AM)	**Ground Temp.(C)**	**Sky Temp.(C)**	**Plate Temp.(C)**
2.53	9.8	-22.8	11
3.04	9.5	-23.2	5.3
3.17	9.5	-23	6.7
3.56	9.5	-21.3	
4.42	8.4	-22.7	1.8
5.22	8.5	-22.6	0.6
5.55	8.2	-23.4	0.4

The above images are from Aman nagar where the minimum sky and water temperature recorded.

Insights:
The Amanagar which is 90 km from shirdi, seems to be the right place to continue the experiment (thanks to Avinash and his hospitality), The experiment was continued on the next day and temperature reached -0.3°c though the humidity was not conducive.
But the data clearly shows the possibility of making ice, given the right atmosphere.

Date:	15.11.13			
Location:	Ahmed nagar,(Surya nagar,)			
Ambient Temp.	23.9- 14.4	(at the time of starting the exp.- to its minimum(at 4am)		
Humidity	45%- 67%			
Wind	mild wind throug out the exp.			
Experiment Table				
Time(PM-AM)	**Ground Temp.(C)**	**Sky Temp.(C)**	**Plate Temp.(C)**	**Water temp.(C)**
10.09	14.6	-23.9	15	
10.31	15.3	-23.2	11.5	
11	17	-22.4	12.8	
11.49	15.3	-22.8	11.8	
12.31	14.7	-24.9	9.9	
1.47	13.8	-24.2	8.7	14.5
2.41	10.5	-24		6.5
3.21	10.2	-24		4.9
4.01	10.5	-26.5	2.8	3.1
4.41	9.8	-27.1	2.2	2.9
5.25	8.5	-27.5	2.5	2.5/3
5.45	7.8	-29.8	-0.3	0.8/1


Professor. Dipankar setting up the prototypes for testing in Gote, Igathpuri site.

Insights:
The experiment in gymkhana ground IITB was done to test the IR transparent sheet to control the convection. The results were not very convincing, but the sheet doesn’t trap the temperature as such.

Date:	16.12.13				
Location:	Gym khana ground, IITB				
Ambient Temp.	22-21c	(avg)			
Humidity	50%- 57%				
Wind	very less wind				
Experiment Table					
Time(PM-AM)	**Ground Temp.(C)**	**Sky Temp.(C)**	**Plate Temp.(C)**	**Water temp.(C)**	**Note**
10.35	12	-25.4	12.8		(w/o IR sheet covered)
11.11	11.4	-25.5	3.6		"
11.34	11.3	-24.8	4.5		"
12.05	11.8	24.6	7.3		(with IR sheet covered)
12.35	11.2	-24.9	7.1		"
1	12	-24.7	3.7	14.4	(w/o IR sheet covered)
1.3	10.5	-26.3	4.7	7	"
4.45	8.7	25.1	2.5	2.6	"

Design Brief:

• To design a low cost Ice maker for rural household without using electricity.

• Consideration for storing ice and food.

• Emphasis on ease of use, maintenance and handling.

Technical Brief:

• Highly insulated walls (8-10cm thickness)

• Mouth of the ice maker should be wide angled towards the sky, to increase radiation.

• Provision for IR transparent lid to reduce convection.

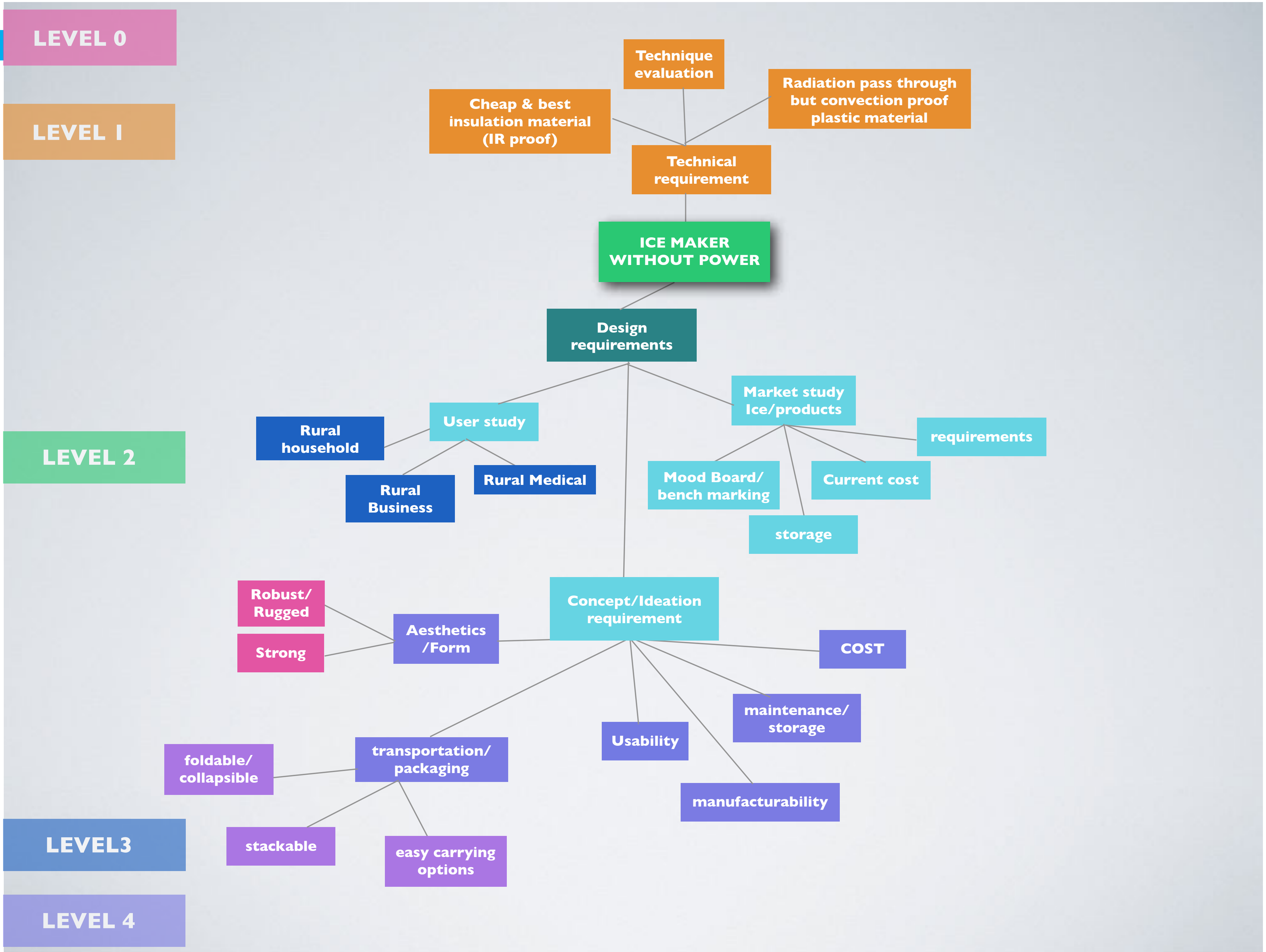
User Brief:

The product should be easily understandable by people of rural household.

It should go with the other kitchen products.

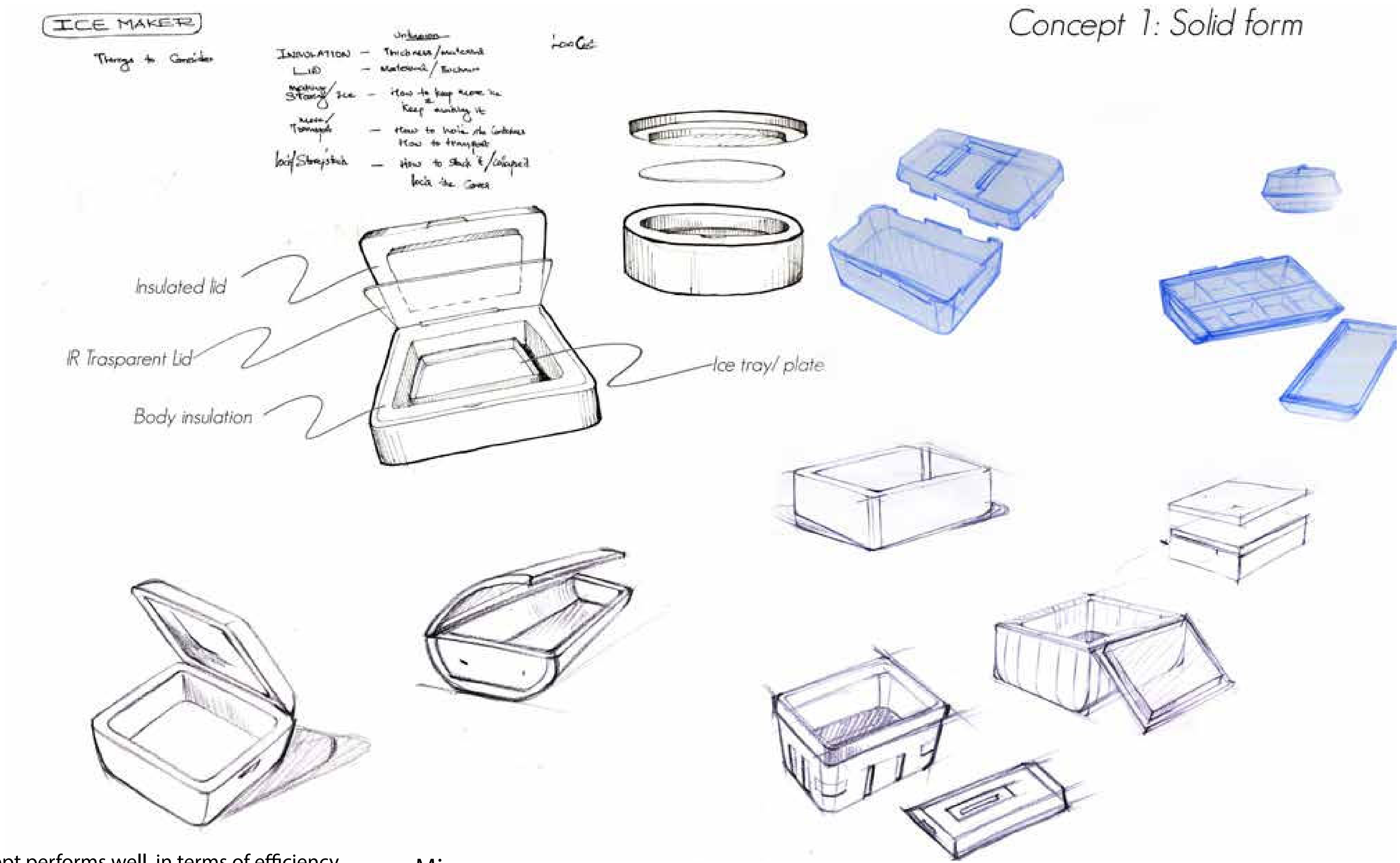
LEVEL 0	Topic finalization and Pre research
LEVEL I	Evaluation of technique, Topic justification, User study (Stage I)
LEVEL 2	Evaluation of technique, Market study, Start ideating,sketch, digital renders (Stage 2)
LEVEL3	Concept finalization, CAD Model, Make test prototypes, Evaluate, (Stage 3+Report)
LEVEL 4	Make final form model/prototype (Jury)
LEVEL 5	Up for manufacturing.!

Mind Map



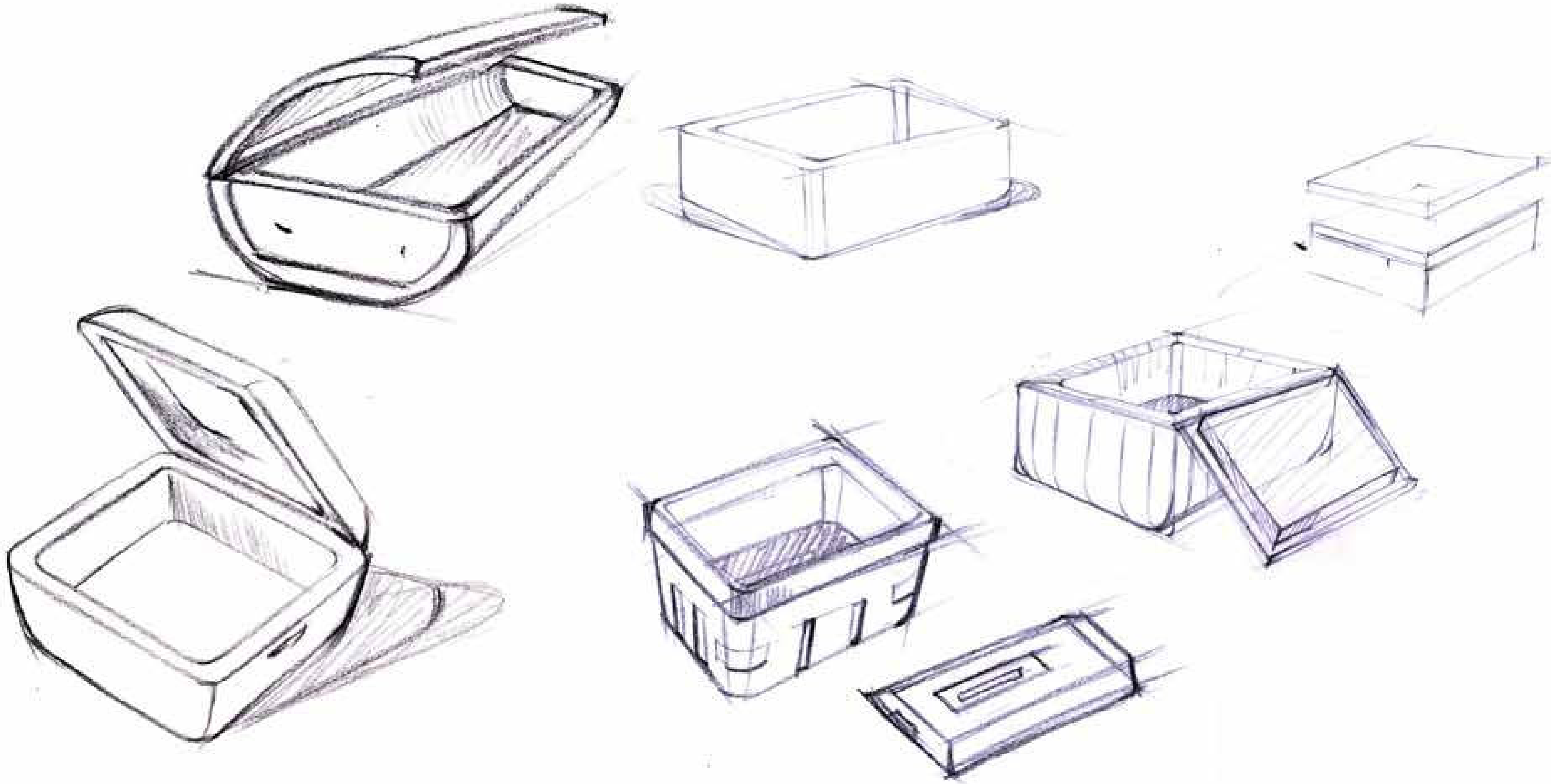
LEVEL 0
LEVEL I
LEVEL 2
LEVEL3
LEVEL 4
Technique evaluation
Cheap & best insulation material (IR proof)
Radiation pass through but convection proof plastic material
Technical requirement
ICE MAKER WITHOUT POWER
Design requirements
User study
Rural household
Rural Business
Rural Medical
Market study Ice/products
requirements
Mood Board/ bench marking
Current cost
storage
Concept/Ideation requirement
Robust/ Rugged
Strong
Aesthetics /Form
COST
maintenance/ storage
Usability
manufacturability
transportation/ packaging
foldable/ collapsible
stackable
easy carrying options

The Conception



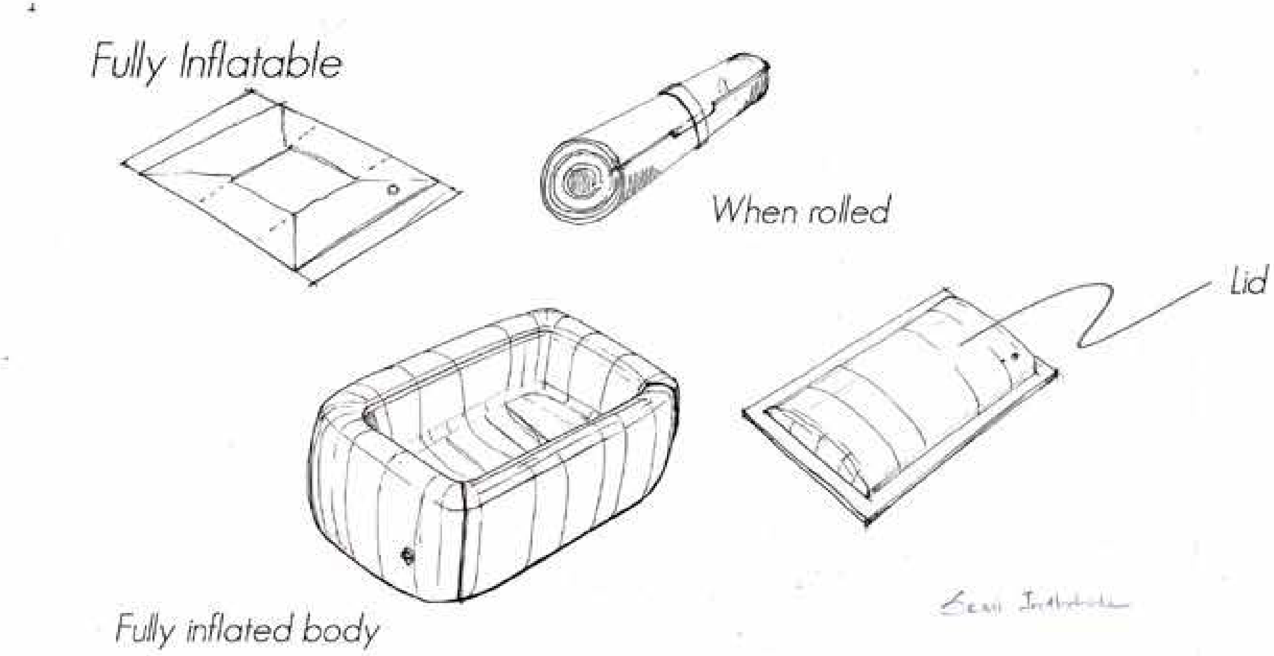
Plus+
This concept performs well, in terms of efficiency and maintenance
It will serve its purpose of ice making helped by the wide angled mouth.

Minus-
But this is not suitable for the storage of food.



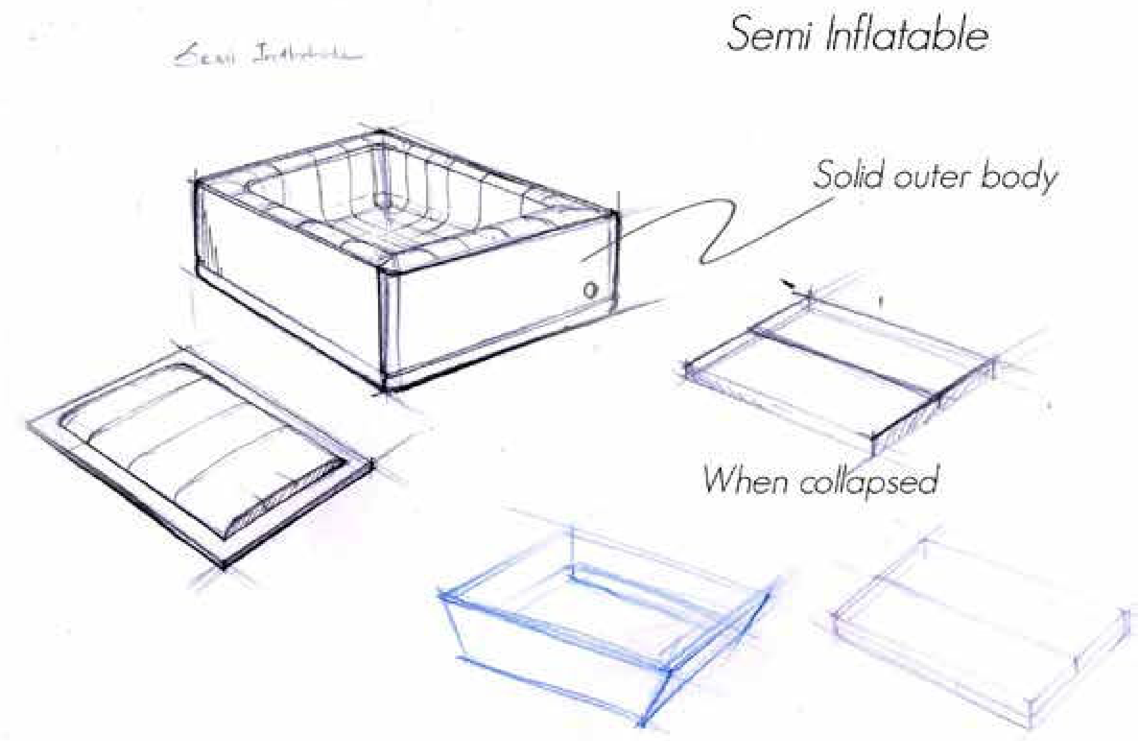
Mock up models,
which gave the idea about the implications in extendible design with wide angled mouth

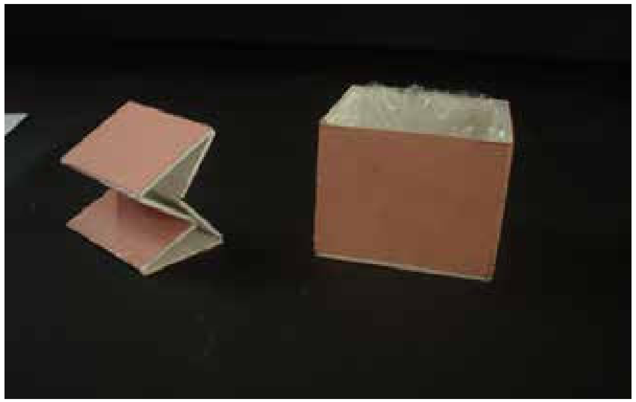
Concept 2: Inflatable



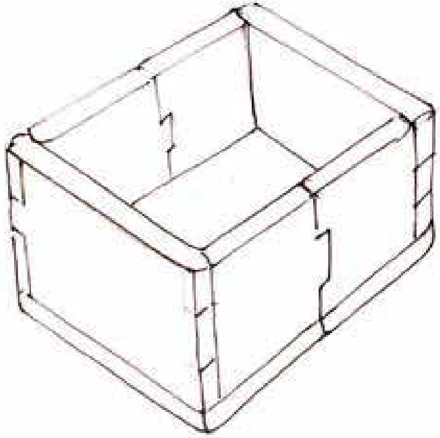
Plus+
The foldability and collapsibility is the main feature of this concept which helps in transportation and saves space when not in use.

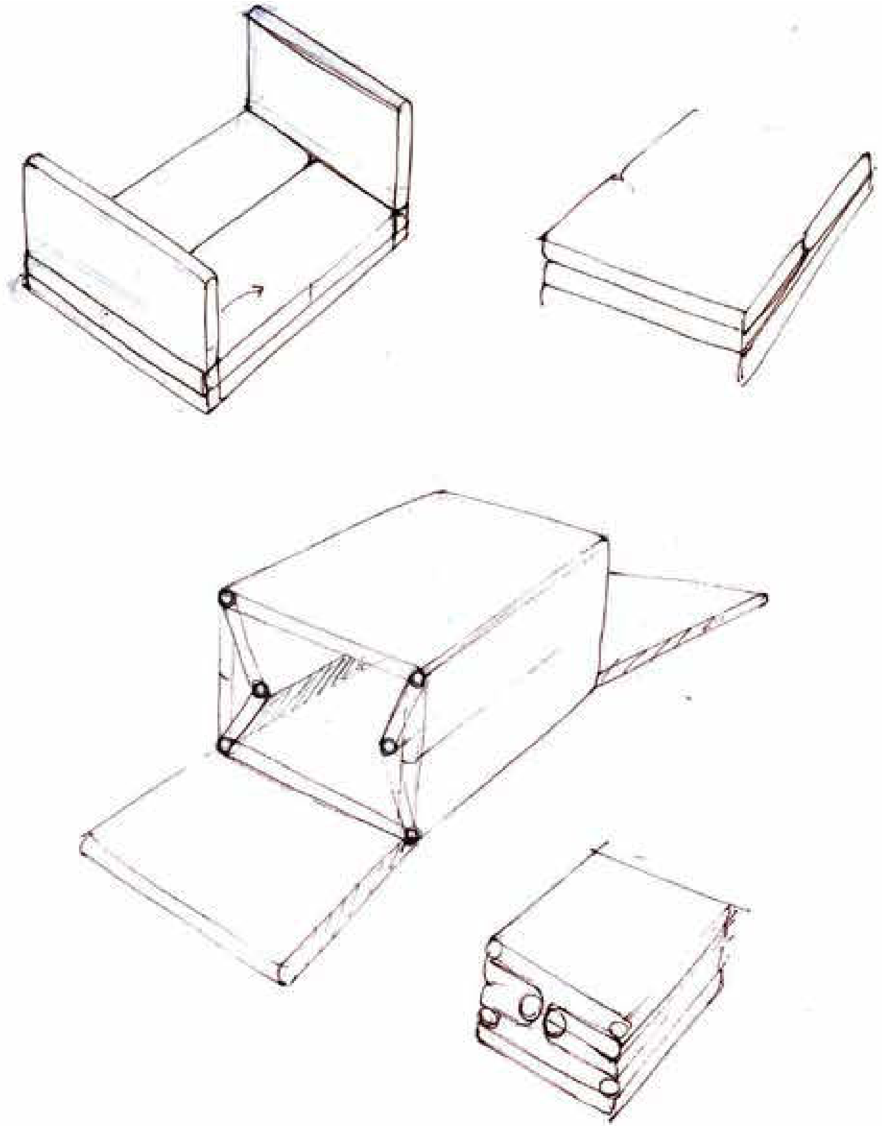
Minus-
Inflation is not a very reliable option due to its delicateness and it is prone to maintenance issues.



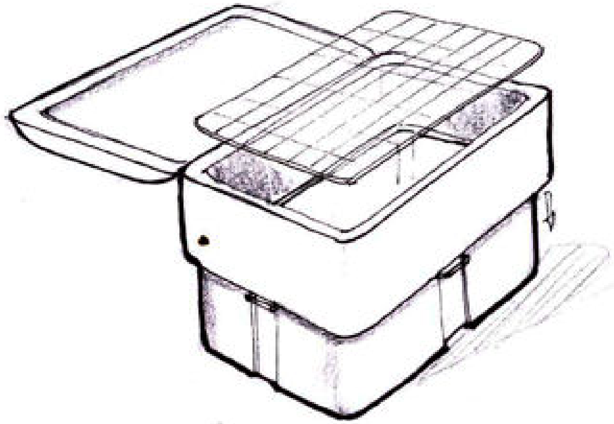


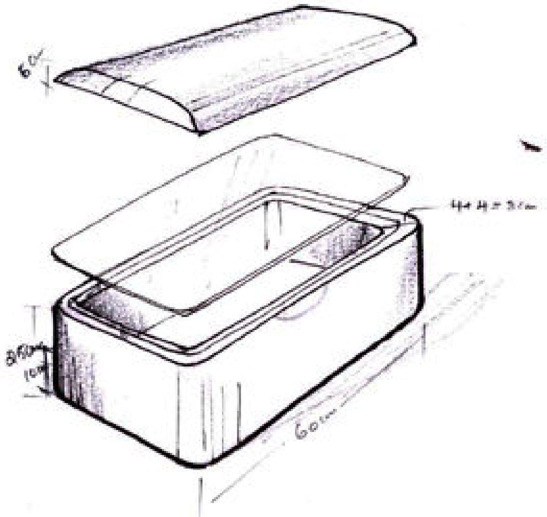
Exploring on the possibility of collapsibility

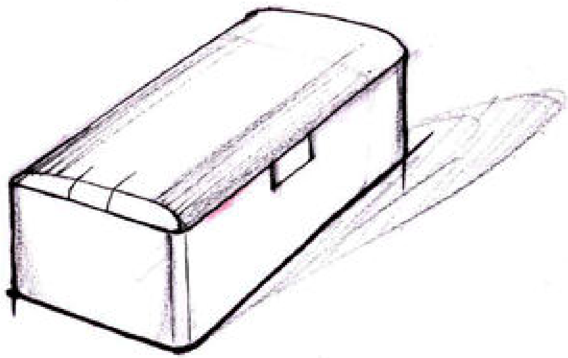




Concept 3: Extendible







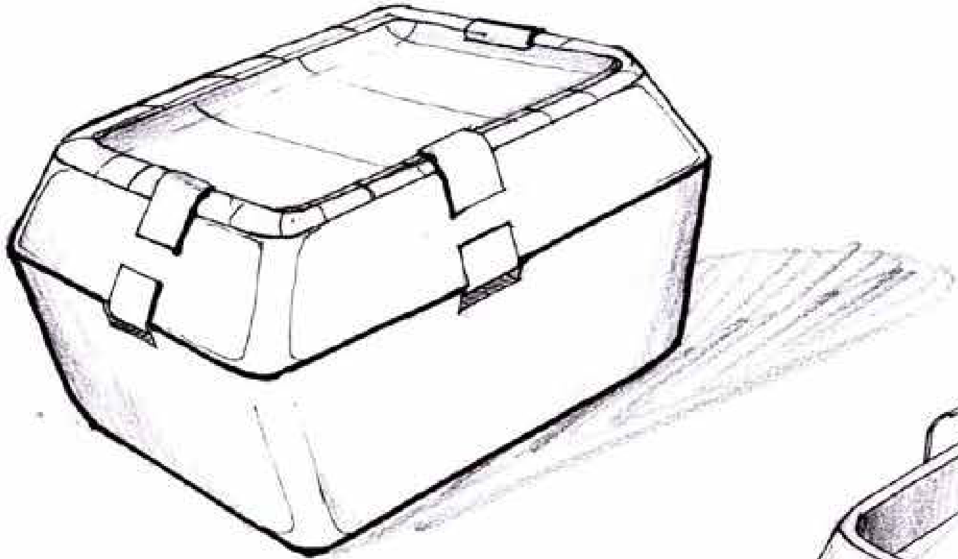
Plus+

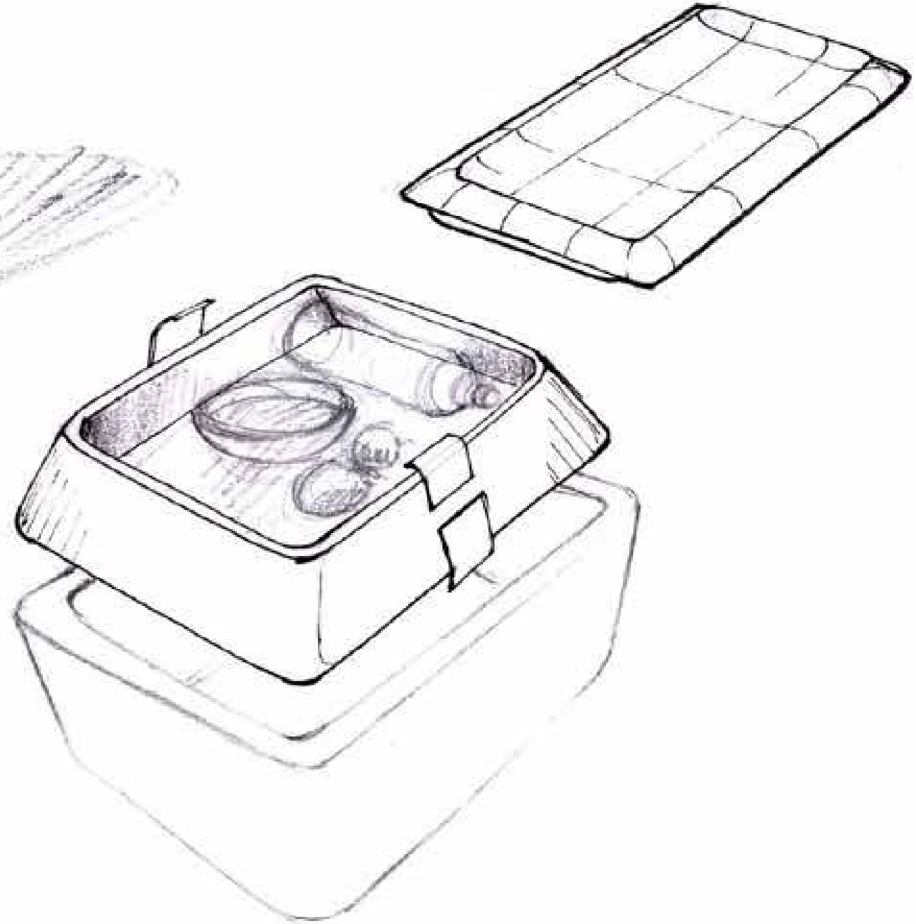
Options for storing food and ice separately.
Stackability and the container takes a compact form when not in use.

Minus-

Manufacturing difficulty and maintenance issues.
Also it is not supporting the wide angled mouth required for increased efficiency.
Doesn't help in temperature distribution.

Concept 4: Lid storage





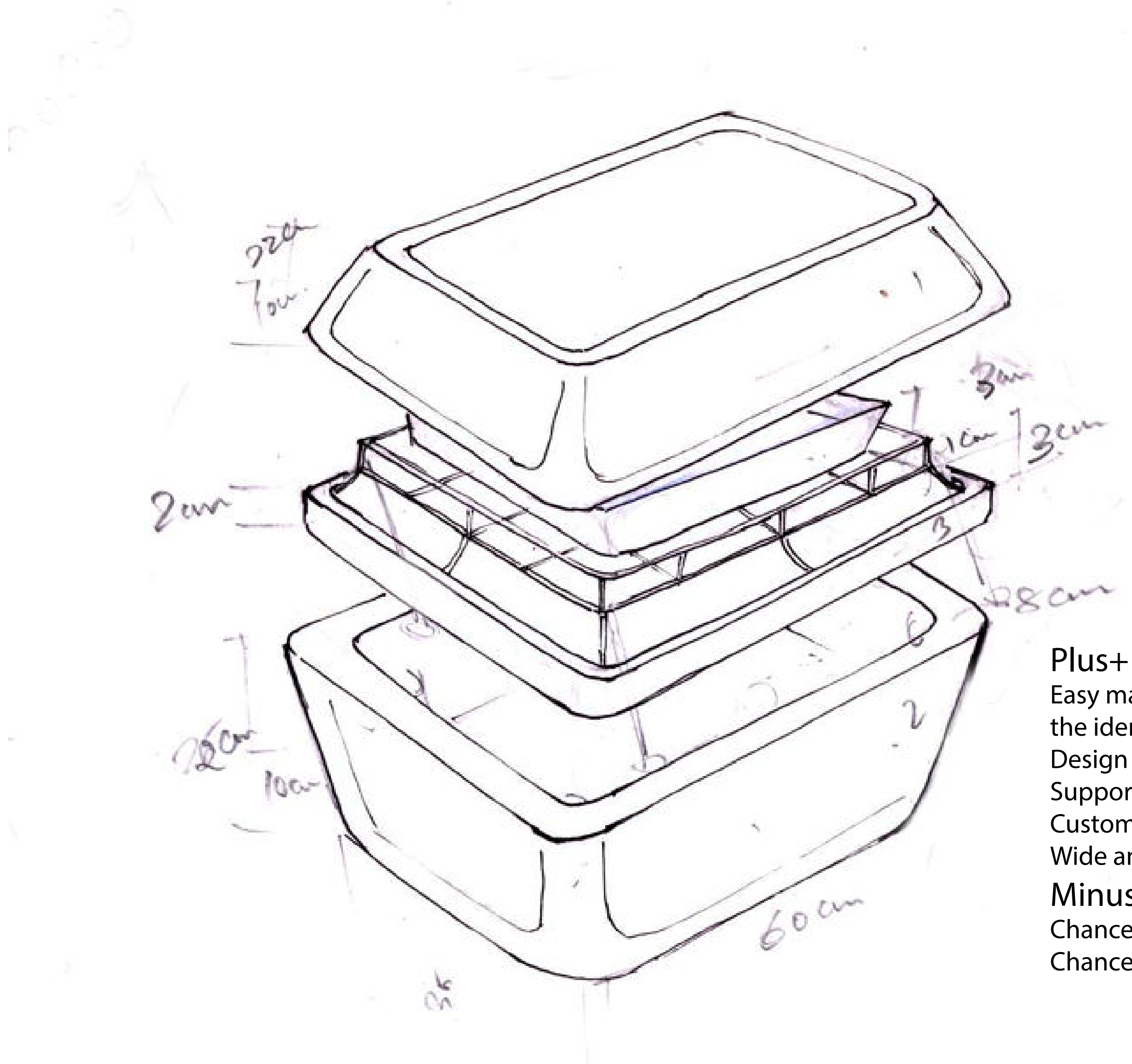
Plus+

Clean and simple design with food storage at the lid, which doesn't disturb the ice storage.
Easy handling and maintenance.

Minus-

Doesn't help in temperature distribution.
Manufacturing complexity
Not suitable for continuous ice making , day after day

Concept 5: Top ice



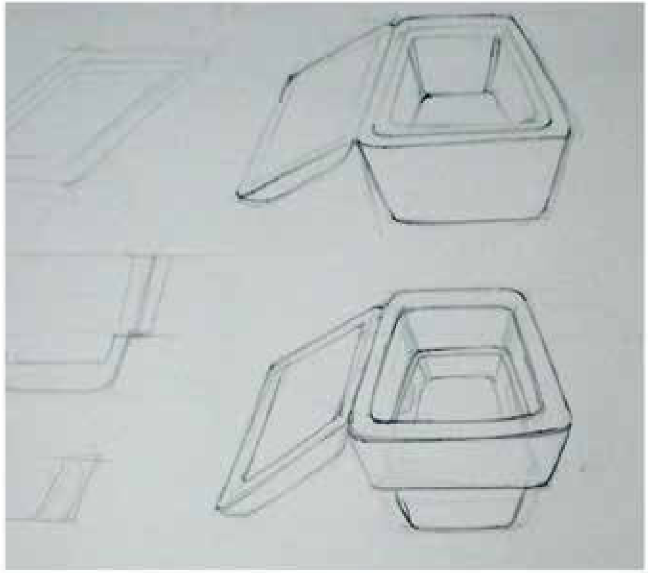
Plus+

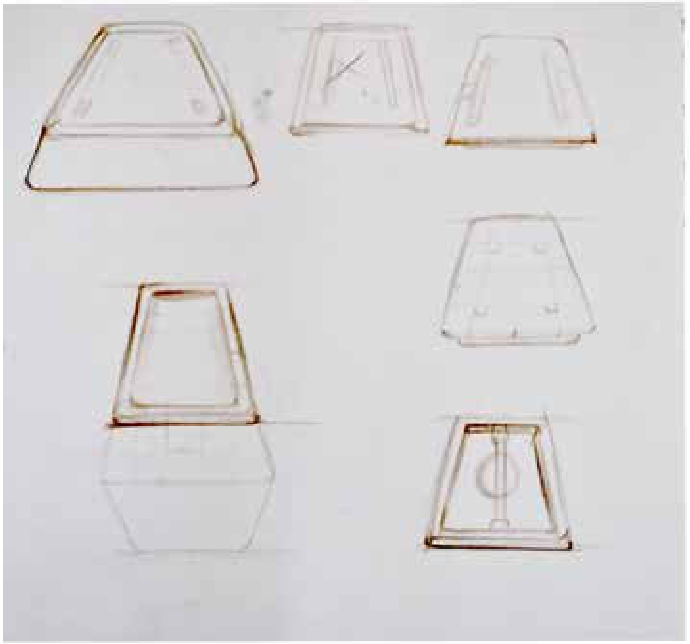
Easy manufacturing using same mould because of the identical parts.
Design helps in temperature distribution.
Supports the continuous ice making, day by day.
Customized interior space for food and ice storage.
Wide angled mouth increases the efficiency.

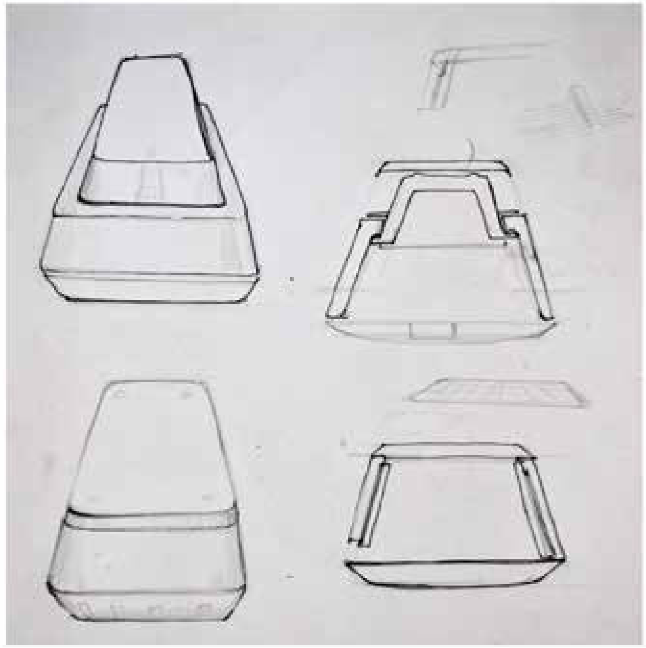
Minus-

Chances of issue in visual semantics.
Chances of confusion in operation.

Explorations







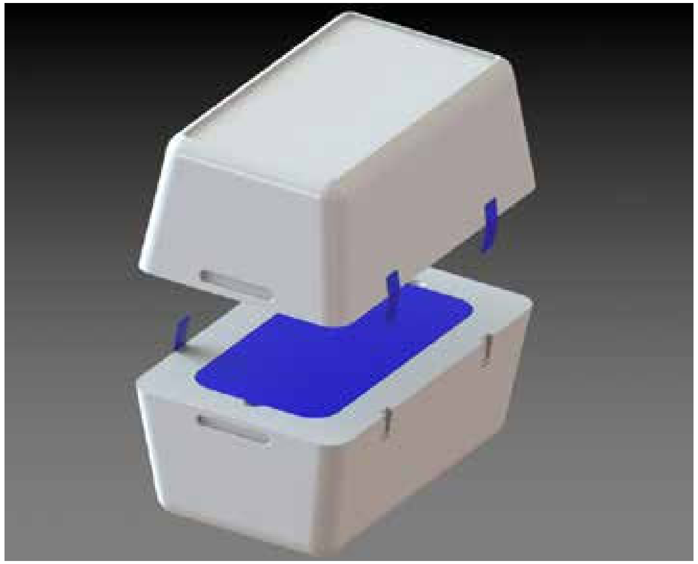
Concept Evaluation

Parameters	Concept 1/Solid form	Concept 2/Inflatable	Concept 3/Extendable	Concept 4/ Lid storage	Concept5/ Top ice
Efficiency	9	5	7	9	9
Maintenance	9	5	7	8	9
Manufacturability	8	8	7	7	9
Cost	8	9	7	7	7
Maneuverability	7	9	7	8	8
Storage	7	5	9	9	8
Stackabality	6	8	9	7	7
Multi purpose/Additional features	5	5	9	8	8
Total	59	57	62	63	65

CAD Modelling

Based on the criteria evaluated, concept 5 has been chosen for further refinement and model making.

• The identical top and bottom part , reduce the cost of tooling.



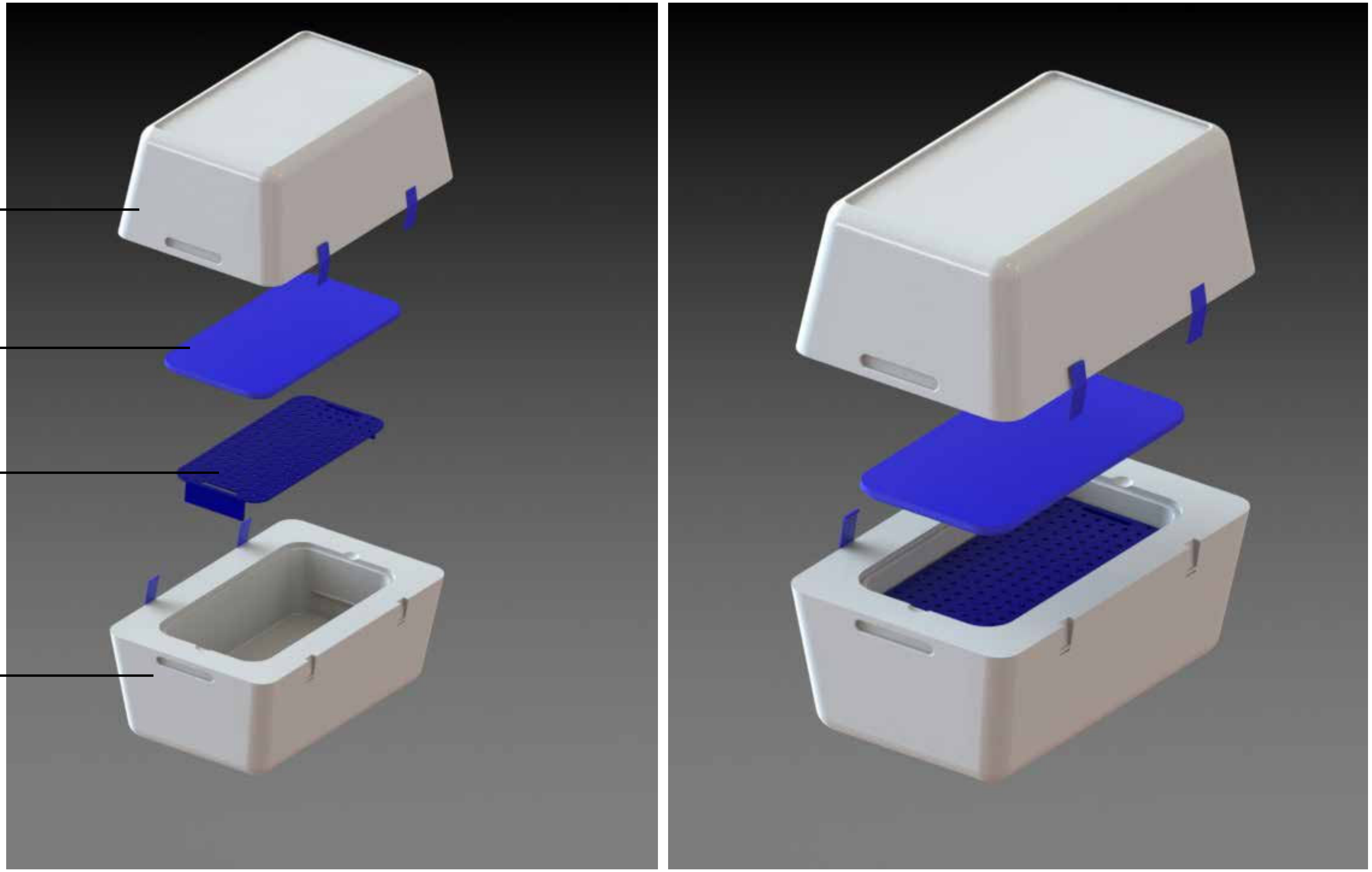
Exploded view of the Ice maker

Lid / Ice maker

Lid for closing the container when storing ice

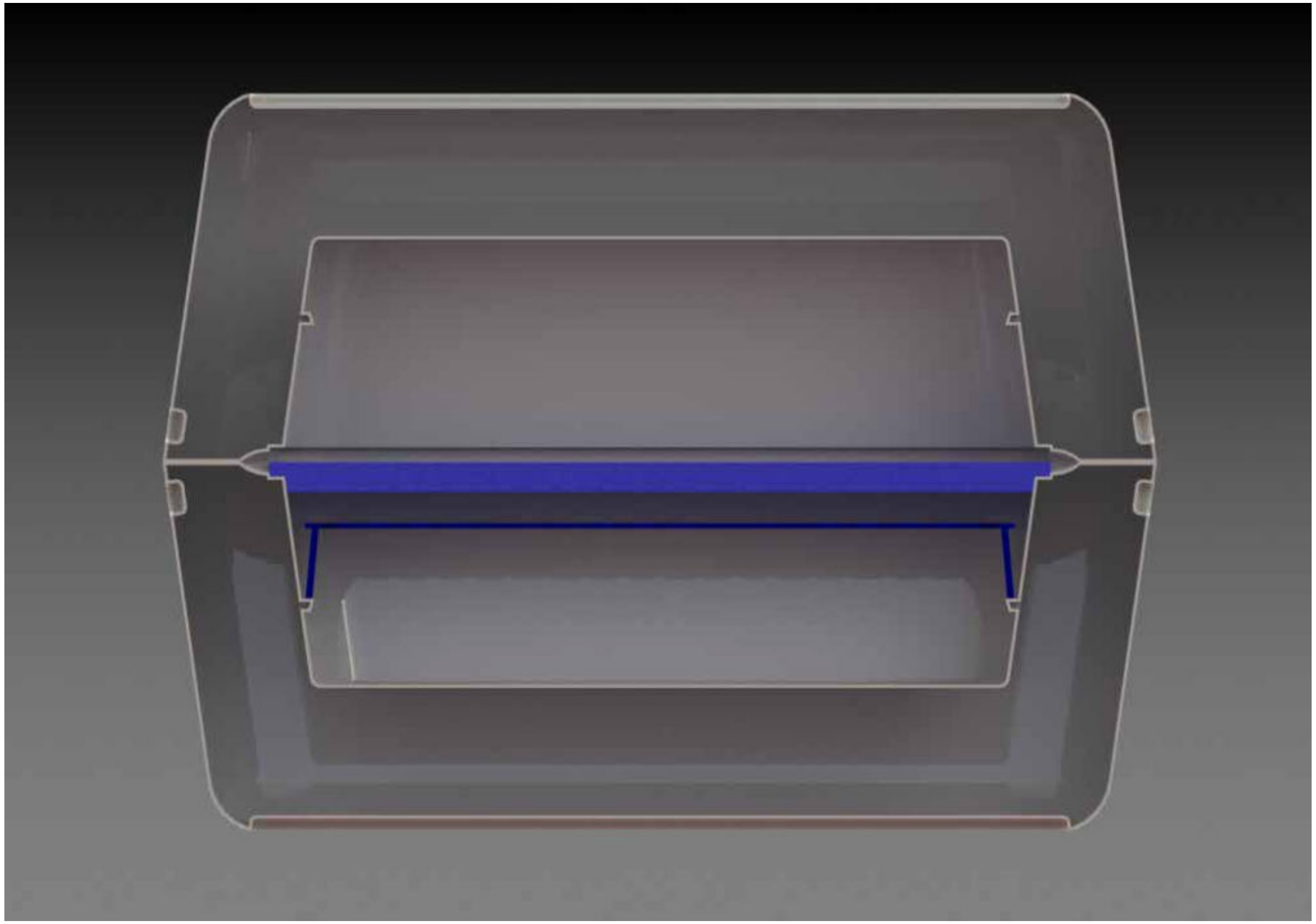
Height adjustable tray which keeps ice when there is food to be stored

Ice /food storage, Ice maker

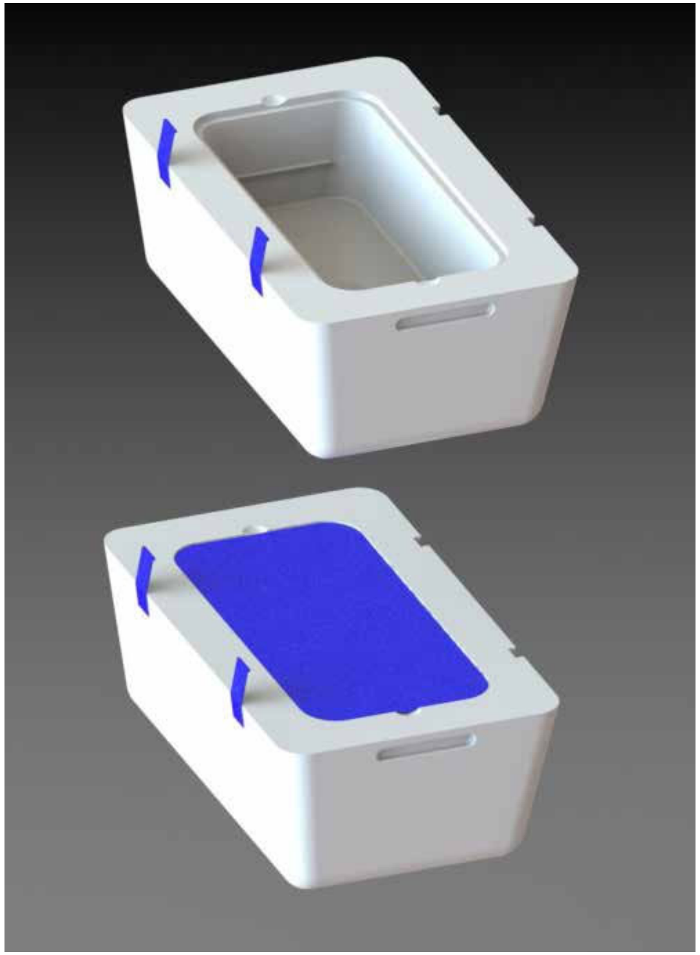


Cross sectional view of the Ice maker

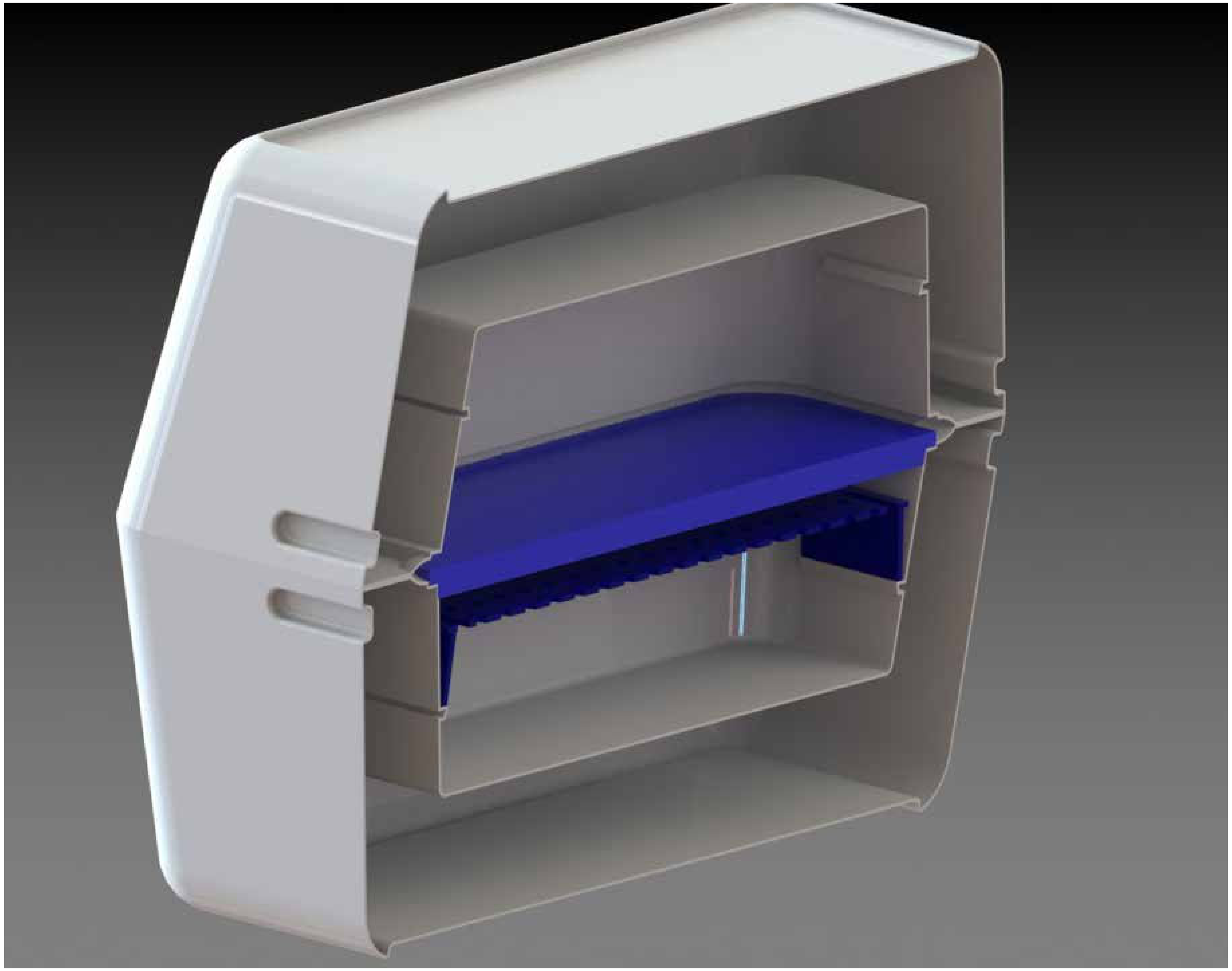
The double walled structure filled inside with the insulator , will stop conduction from the surface.



Design supports the continuous ice making, day by day, with the other half storing the food and ice



Cross sectional view of the Ice maker



The context of making ice under the night sky

Img 10

Context :

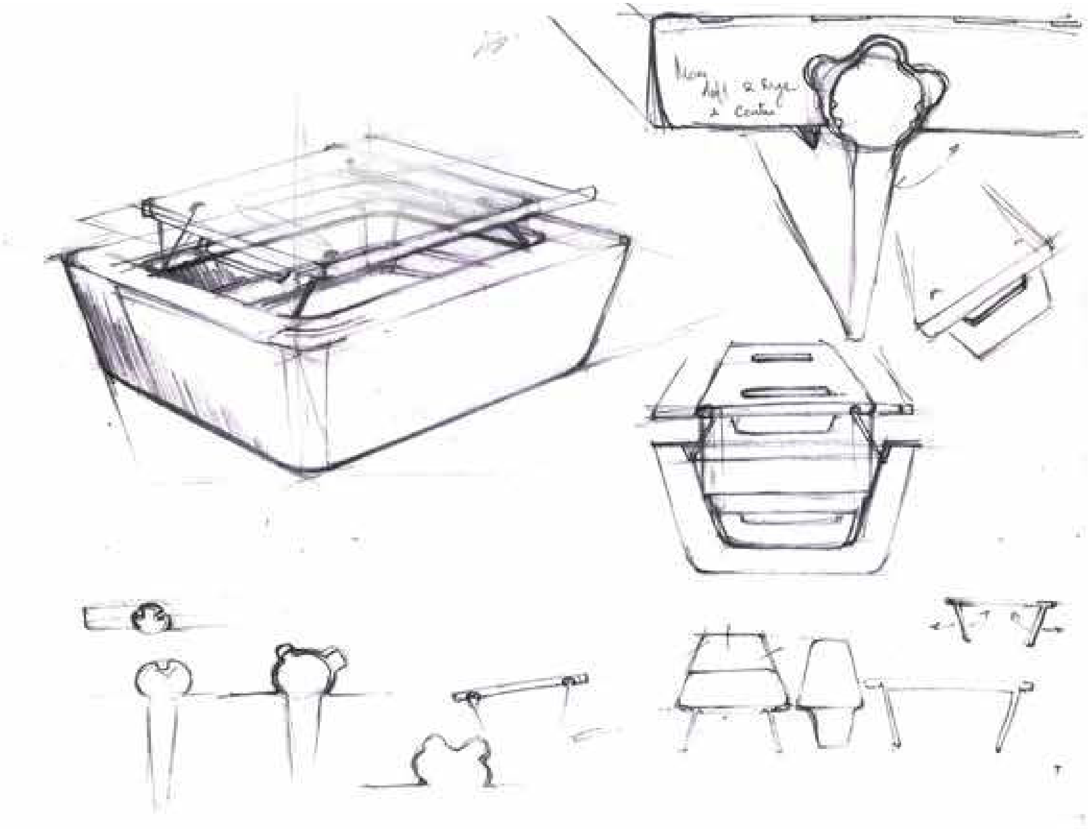
Rural household kitchen:

The form of the product goes with the corners and shelves of general kitchen room.

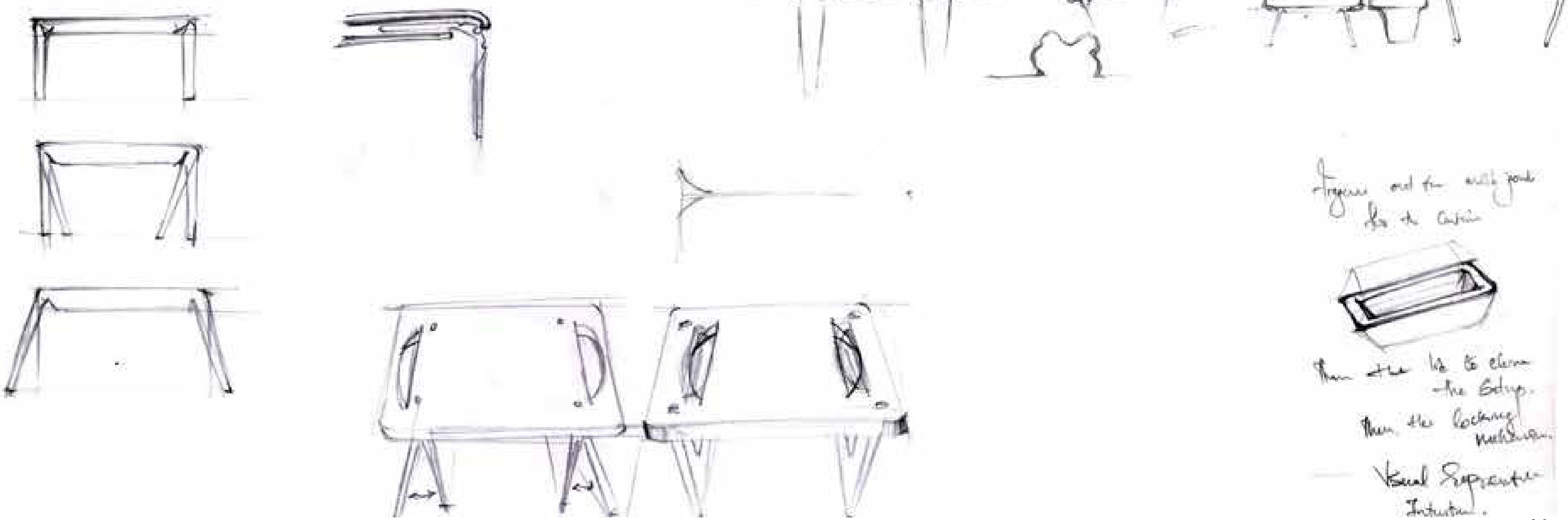
The product holds the semantics of existing ice boxes and kitchen utilities.

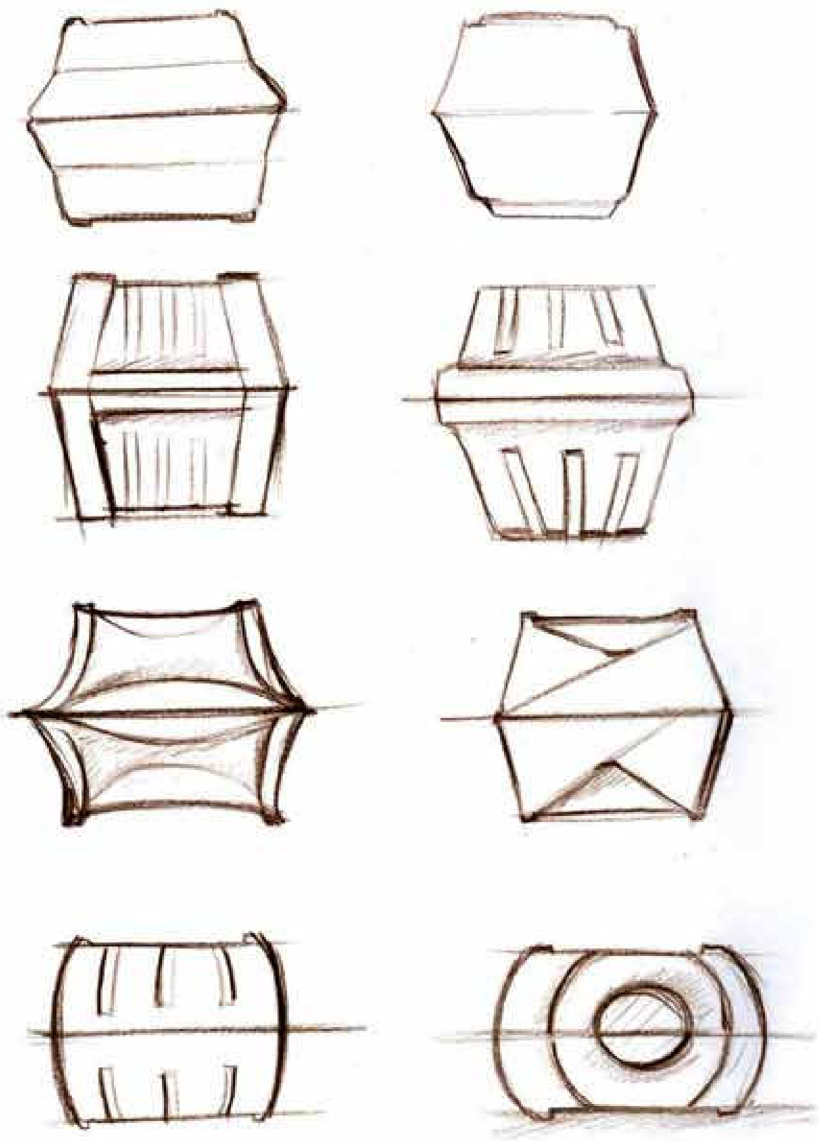

Img 11

Further Exploration

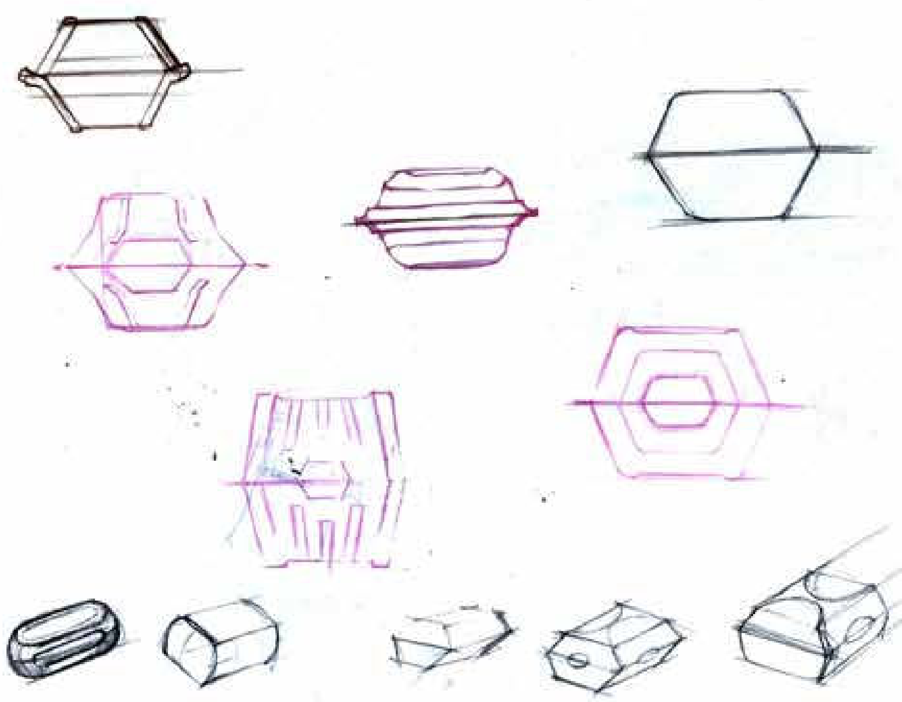


Further the detail and the form of the product is explored;
The sketches shows the action and movement of the inner platform.





The form of the product is further explored;

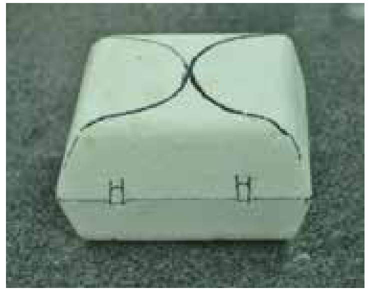


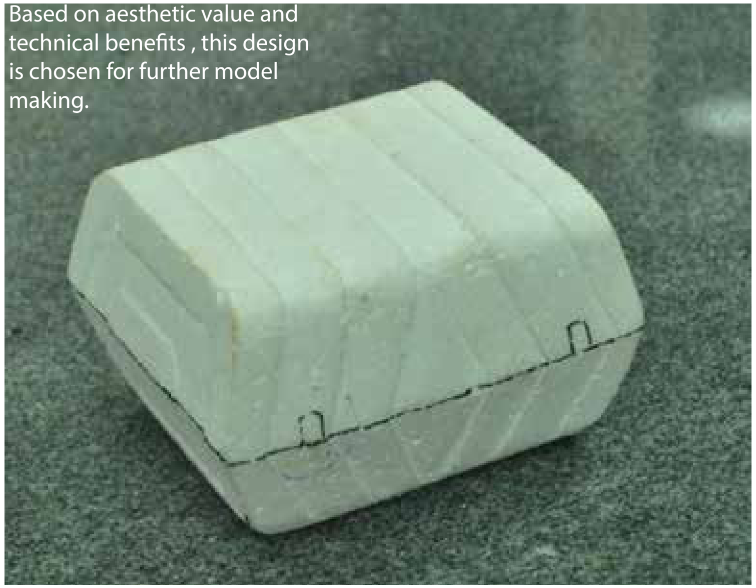
Full scale Rig model

Rig model is made to understand the size and volume of the product. The human interaction with the device is inferred for further design changes.

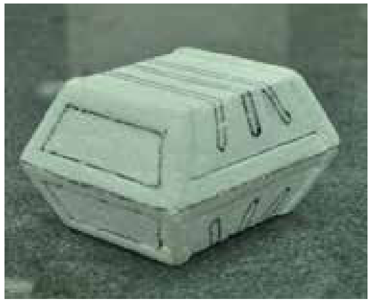
Mock up models

Mock up models were made to understand the form and expression of the product

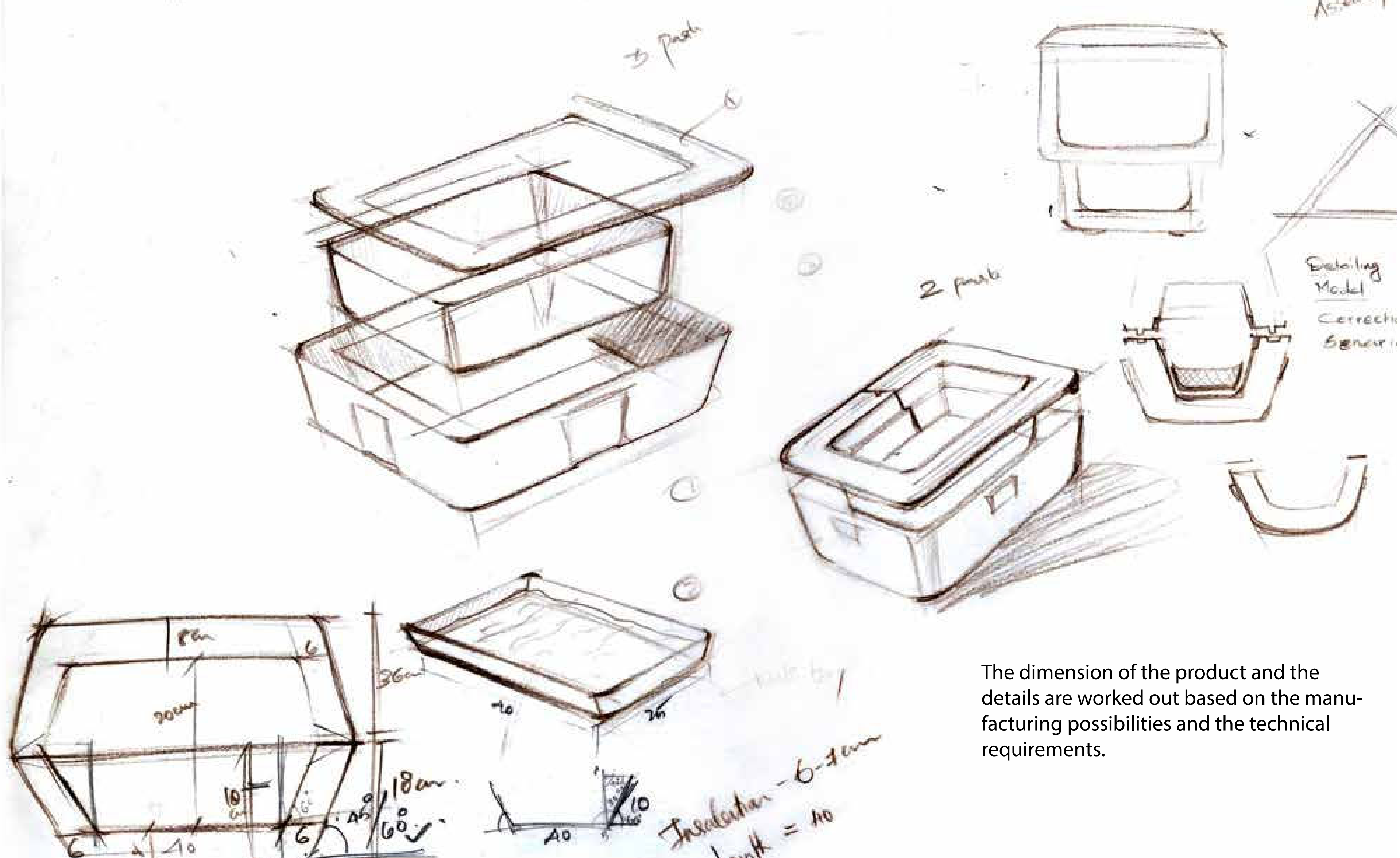




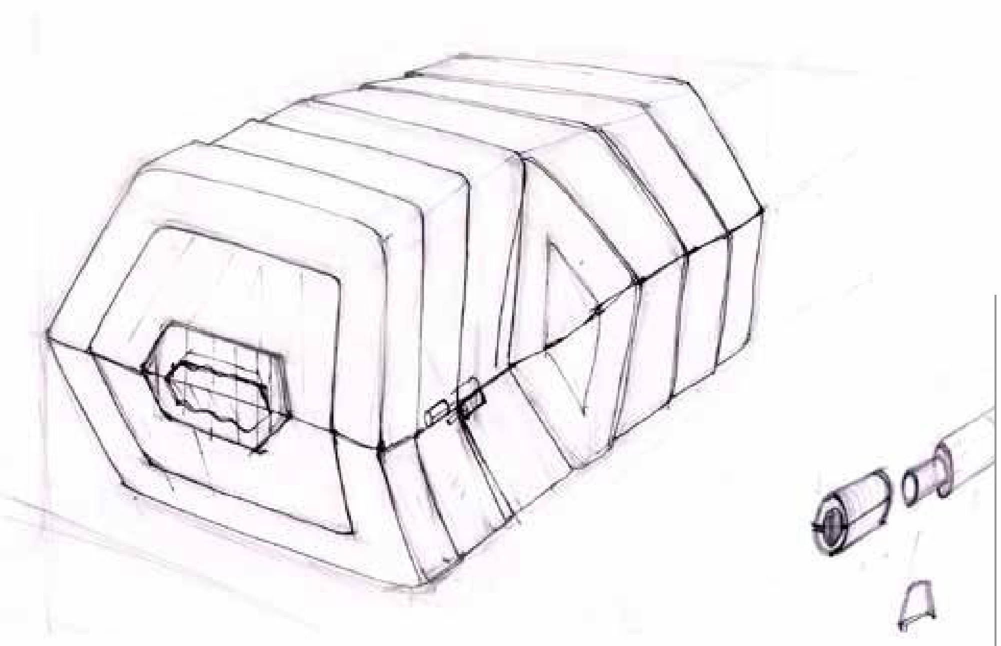
Based on aesthetic value and technical benefits , this design is chosen for further model making.



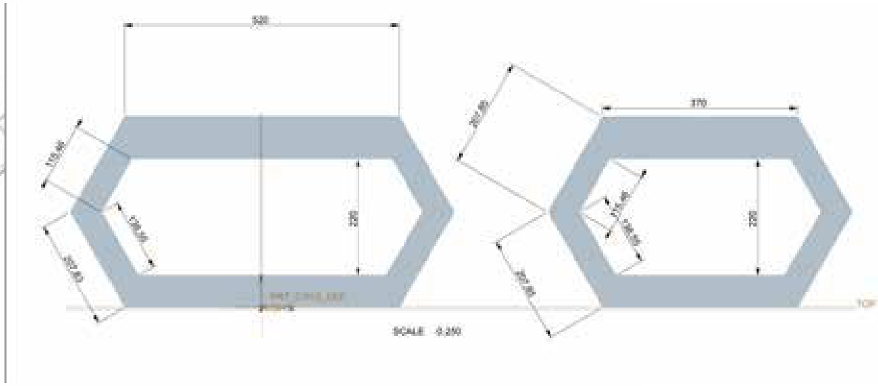
Explorations

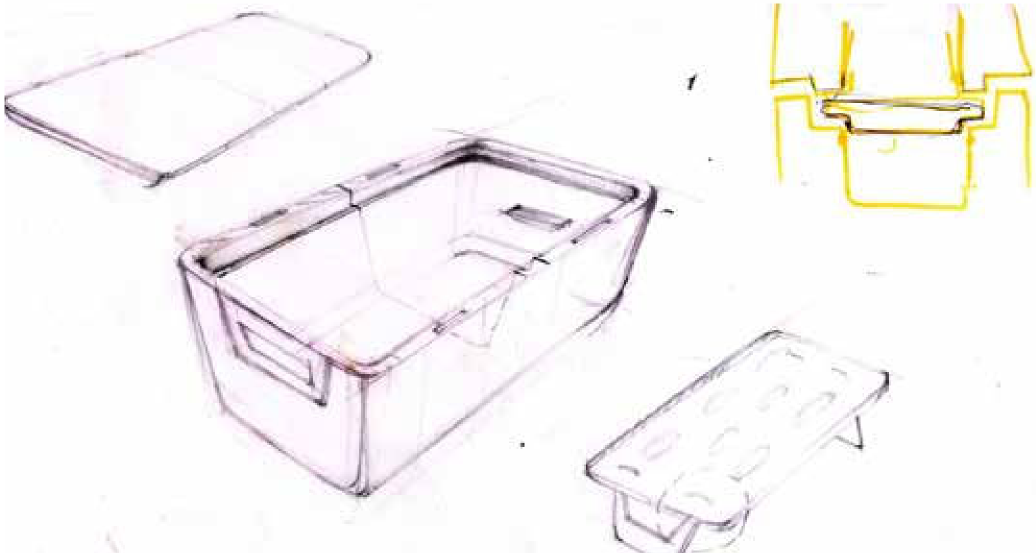


The dimension of the product and the details are worked out based on the manufacturing possibilities and the technical requirements.



Explorations





Final CAD Model

This is the final cad model of the proposed design.

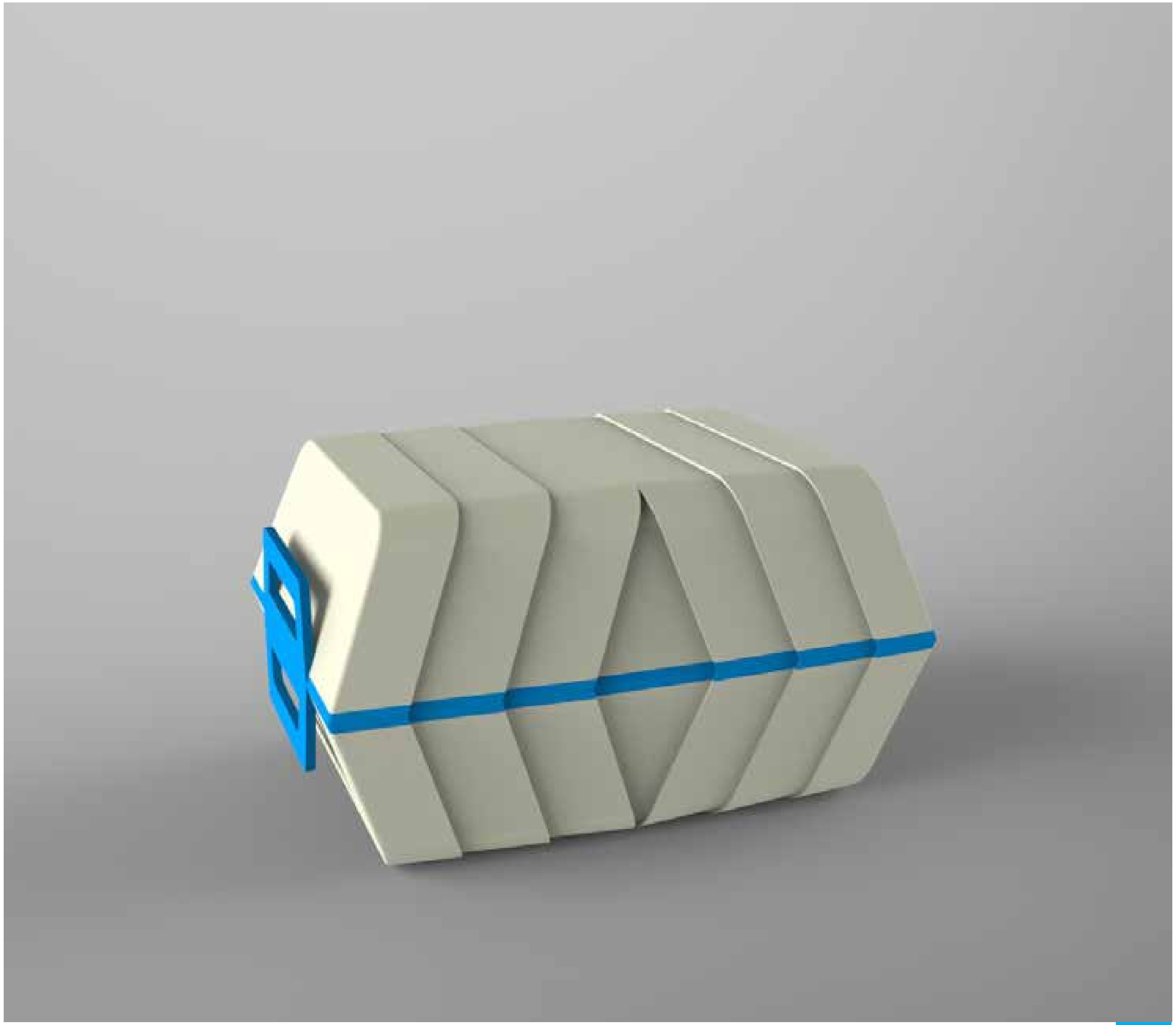
Product Description:
The device consists of two primary parts, which are symmetrical in shape and size for the easy of manufacturing.

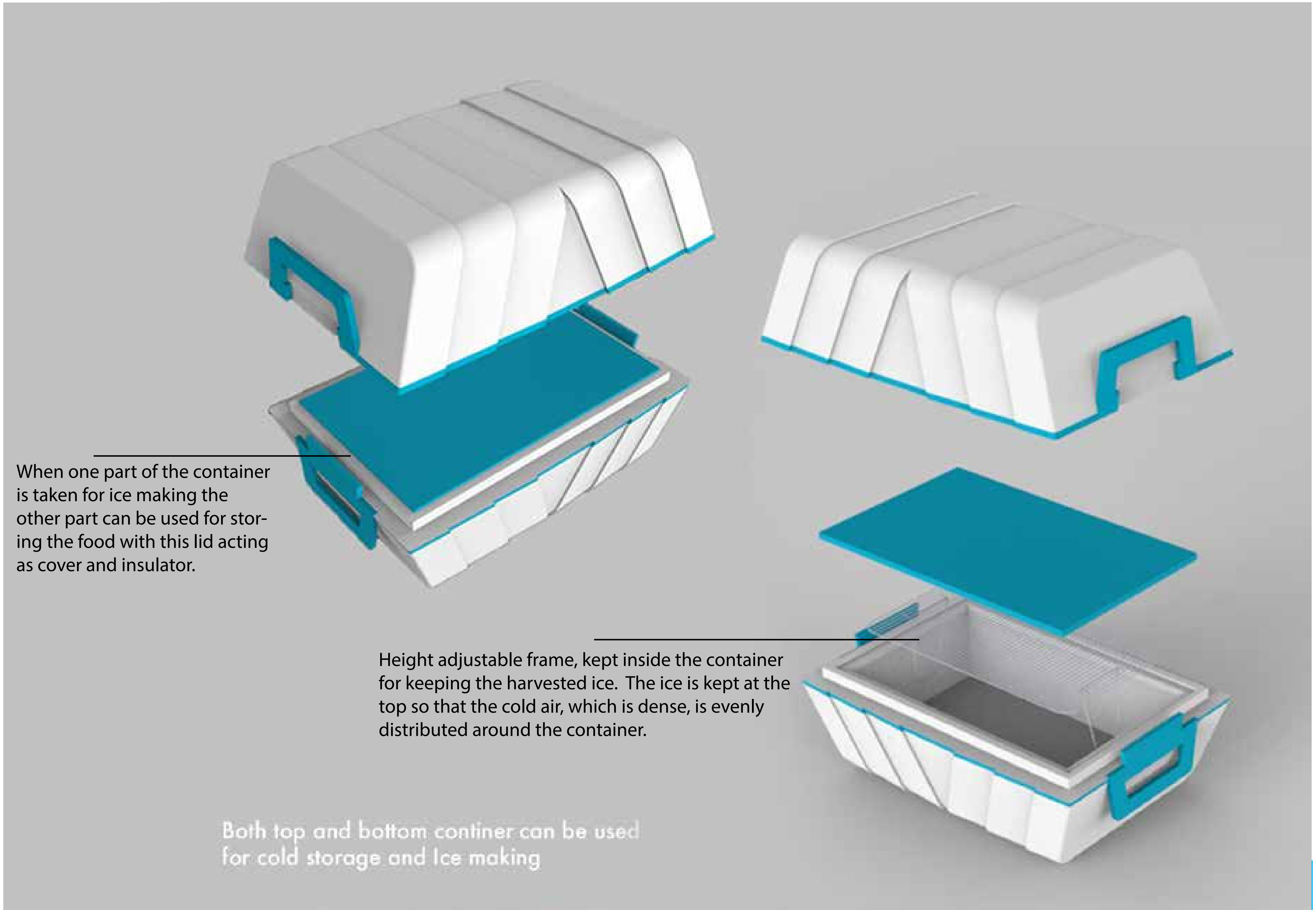
The one part of the device could be taken for ice making while the other one is used for storage. The contours in the form is chosen for increasing the strength of the device.

Poly propylene is preferred as the desired material for manufacturing, using the Roto moulding technique to create the double walled structure.
The hollow part is filled with highly insulating and light material like foam.

The handle is designed for easy carrying and closing of the two parts from both the sides. They close air tight at the centre with the snap fit arrangement.
Handle design in both the sides are kept similar for the simplicity in manufacturing.

The tapering of the wall is useful in increasing the radiation of the device.




When one part of the container is taken for ice making the other part can be used for storing the food with this lid acting as cover and insulator.
Height adjustable frame, kept inside the container for keeping the harvested ice. The ice is kept at the top so that the cold air, which is dense, is evenly distributed around the container.
Both top and bottom continer can be used for cold storage and Ice making

Process of Ice making using the device:

Under a clear night sky, the device is kept with its open side facing the sky after sunset.
Inside the container keep a shallow plate (readily available stainless steel plate is preferred) with water in it, without covering it up.

During the early morning hours before the sun rises, check the device for ice , which is formed due to radiation and cover it up with the provided lid.

That part of the device is again taken back to the house and ice is transferred to the respective tray and that part is used to cover up the entire unit, forming the whole space for cold storage

In the Scenario of making ice in the open ground at night; the image shows the scale of the device.

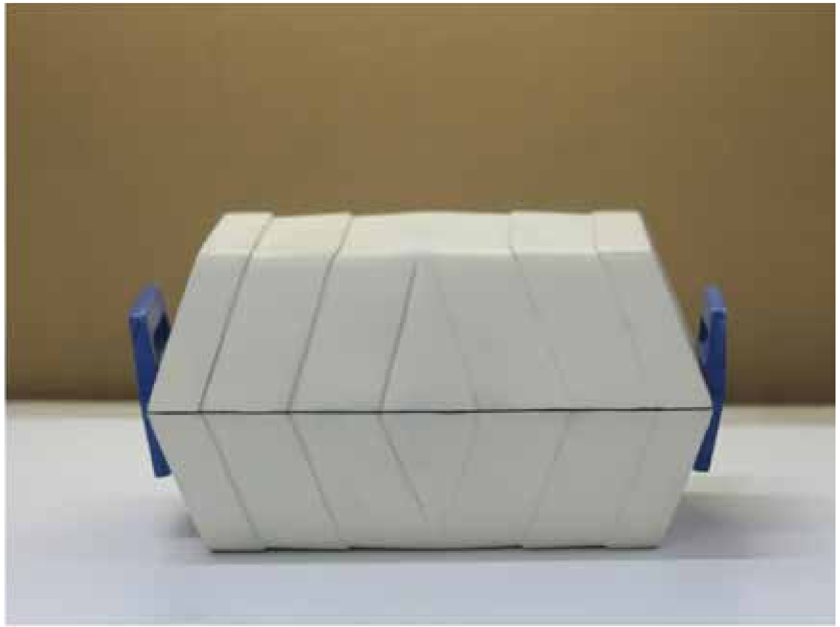
Both the top and the bottom units can be used for ice making.

Also, if it couldn’t make ice during the whole night period because of the unfriendly weather, the water which will be chilled enough can be used for the refrigeration purpose.

The images shows the scale and the possibility of keeping food and drinks inside the container.

Physical Model:

1:2 ratio, scaled physical model is made using Polyurethane foam and painted for the understanding of the form and the details.



The handle with its detailed design consideration, helps in easy handling and locking.
The whole unit can be formed as a single unit with the snap joint in the centre.
Also it gives a whole new profile to the device.

The images shows the handling of the device and the proportions of the model

References:

Literature:

Mechanical Engineering paper from IIT kharagpur on 'History of Refrigeration'

The book 'Indian Science and Technology in the 18th Century' by Dharampal

British archives on Indian traditional practices from internet

Residential consumption of electricity in India by The World Bank for 'India: Strategies for low carbon growth'

Night Radiative cooling,
The effect of clouds and relative humidity
by Mike Luciuk

Potential of night sky radiation to save water and energy in the state if New Mexico by Governor Richardson's

Desert Fridge Project by Qasid Ahmad Safir from College of Engineering, Swansea University

Practical Action on evaporative cooling,
The schumacher centre for technology and development, UK.

Websites:

http://www.deccanherald.com/content/352942/india-wastes-rs-44000-cr.html
http://home.howstuffworks.com/refrigerator1.htm;
http://en.wikipedia.org/wiki/Refrigeration
http://en.wikipedia.org/wiki/Evaporation
http://mynasadata.larc.nasa.gov/804-2/measuring-the-temperature-of-the-sky

Images:

Img 01: http://www.dreamstime.com/stock-photo-fresh-rotten-pepper

Img 02: http://en.wikipedia.org/wiki/Evaporation

mg 03: Desert Fridge Project by Qasid Ahmad Safir from College of Engineering, Swansea University

Img 04: Paper on 'Bamboo refridgerator'

Img 05: http://suzannesmomsblog.com/tag/environment/

Img 06: http://museumvictoria.com.au/discoverycentre/infosheets/the-coolgardie-safe/

Img 07: http://mynasadata.larc.nasa.gov/804-2/measuring-the-temperature-of-the-sky

Img 08: http://upload.wikimedia.org/wikipedia/commons/c/cc/Yakhchal_of_Yazd_province.jpg

Img 09: The book 'Indian Science and Technology in the 18th Century' by Dharampal

Img 10,11: http://danwgoodman.wordpress.com/page/3/