SOLAR BOX COOKER

Final Presentation

CE 290

May 6, 2009

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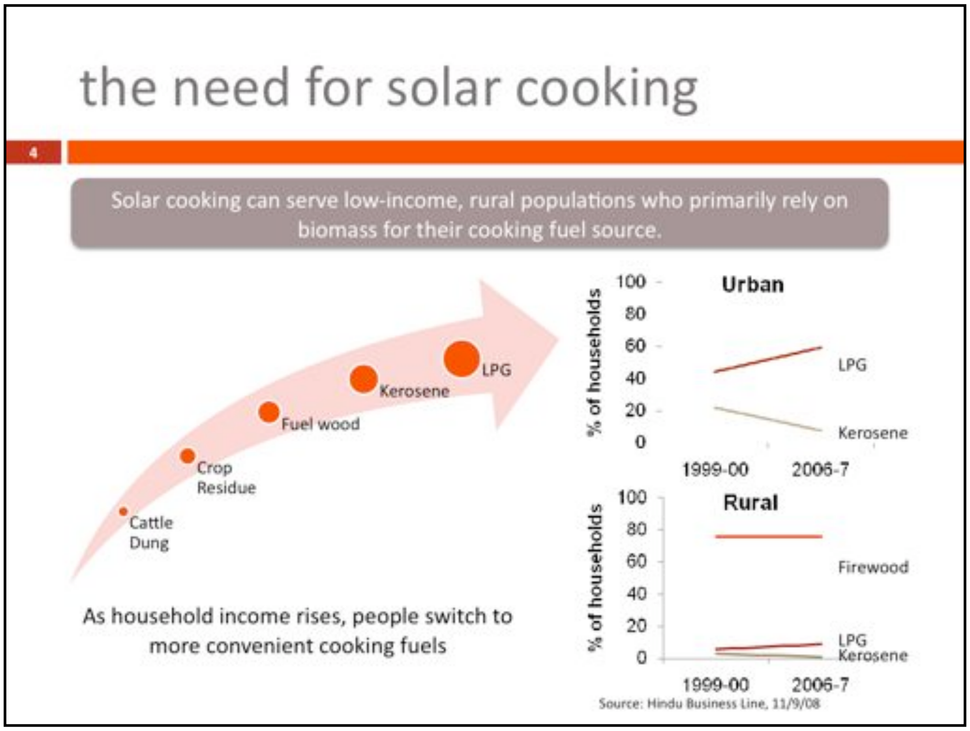
outline

- Background information
- Team goals and structure
- Modeling overview and results
  - SBC Model
  - Cost Analysis
- Prototyping overview and results
- Conclusions and recommendations

Photo Source:

Professor Gadgil's Old Solar Box Cooker: Fair Fabricators

Solar Cooking International - http://solarcooking.wikia.com/wiki/CooKit

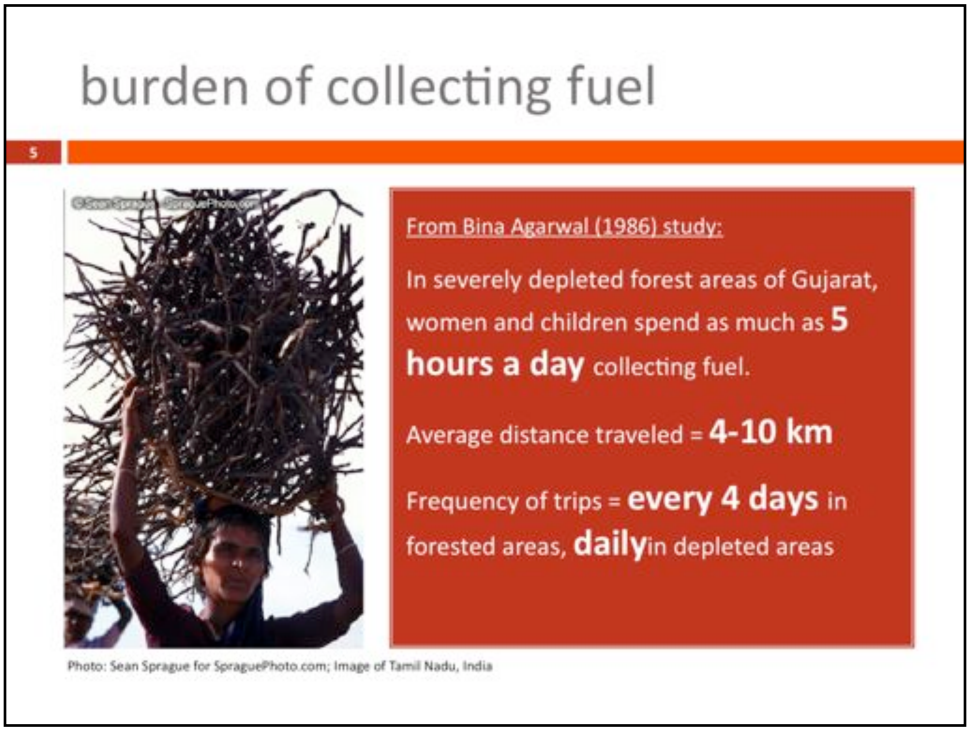


Throughout most market studies, the type of cooking fuel used by a household depends largely upon income and/or location. For example, the middle class relies primarily upon kerosene in urban areas and firewood in rural areas (Srinivas, 2008). Regardless of location, though, the higher income class largely prefers liquefied petroleum gas (LPG), and the lower class mainly gathers firewood or cattle dung (Pohekar et al., 2005).

Source:

Srinivas, A. (2008). LPG use rising in urban areas as kerosene usage falls. *The Hindu Business Line.* Retrieved May 5, 2009 from http://www.thehindubusinessline.com/2008/11/09/stories/2008110951040500.htm.

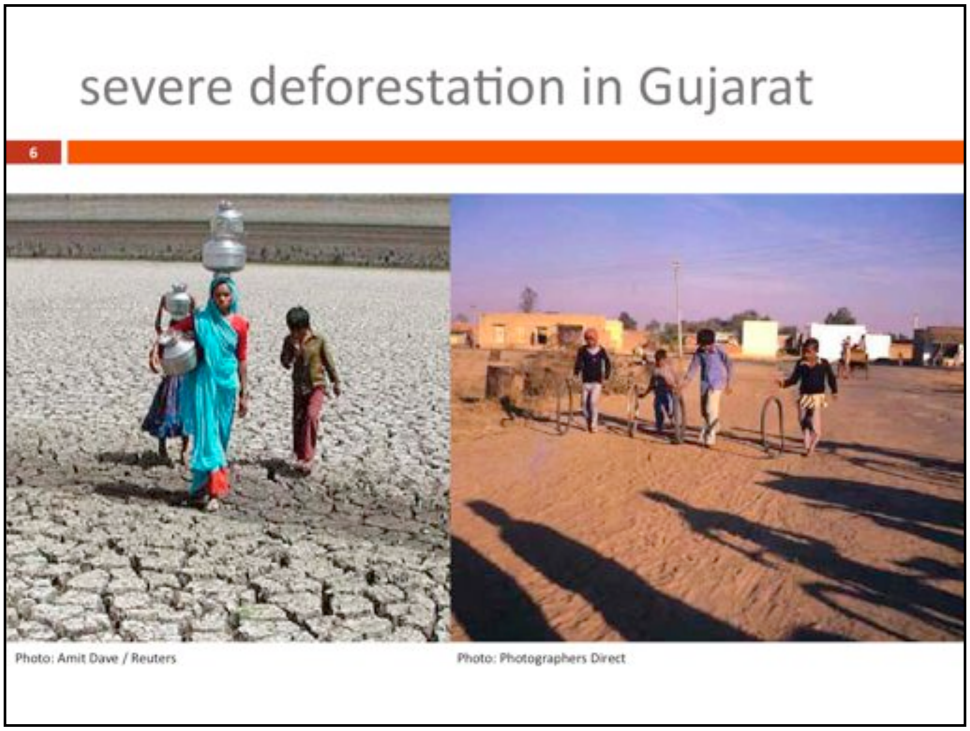
Pohekar, S.D., Kumar, D., & Ramachandran, M. (2005). Dissemination of cooking energy alternatives in India - a review. *Renewable & Sustainable Energy Reviews, 9*(4), 379-393.



Deforestation is a major issue when considering the use of fuelwood as cooking fuel. Due to the extent of use, women and children can spend a large amount of time collecting firewood. During a typical trip in Gujarat, women can travel 4-10 kilometers every 4 days to replenish fuel storages. As deforestation worsens, these trips usually occur everyday and can be a major burden on everyday life.

Source:

Sen, Mitali. (2003). The Cost of Cooking: The Impact of Bio-fuel Use on Women's Lives in Rural India. *Paper presented at the annual meeting of the American Sociological Association, Atlanta Hilton Hotel, Atlanta, GA Online.* Retrieved on May 5, 2009 from http://www.allacademic.com/meta/p107182_index.html.

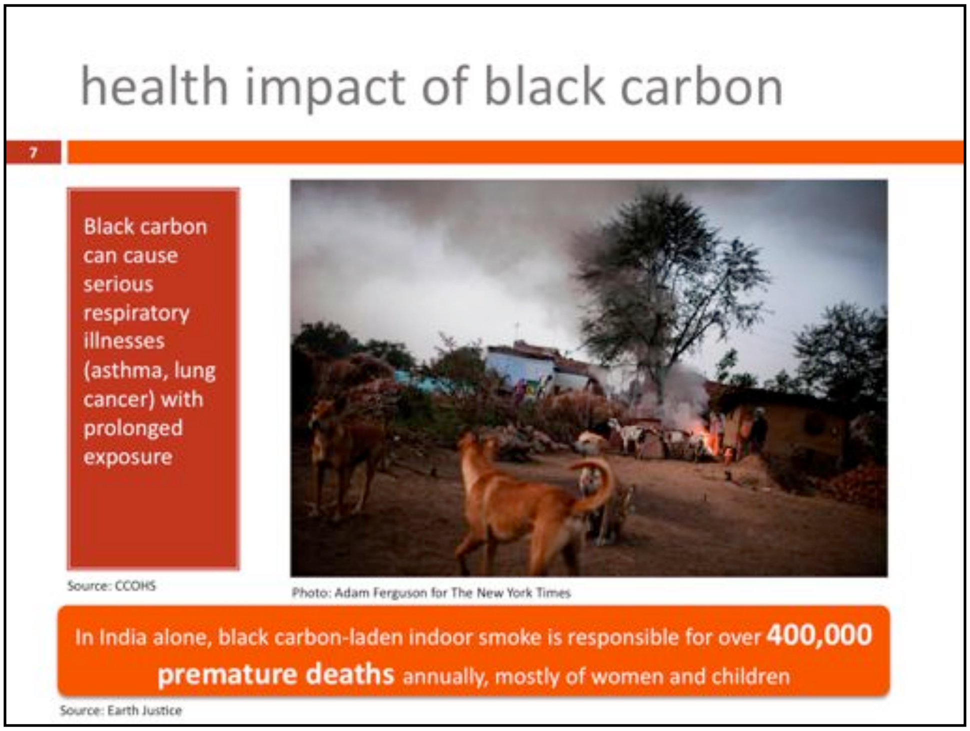


Here are photos that show the deforestation occurring in Gujarat, India.

Photo Sources:

Amit Dave / Reuters <http://www.pbs.org/wnet/wideangle/episodes/the-damned/photo-essay-indias-water-woes/3137/attachment/wa_img_thedammed_pe_1/>

Photographers Direct <http://www.photographersdirect.com/buyers/stockphoto.asp?imageid=2181849>

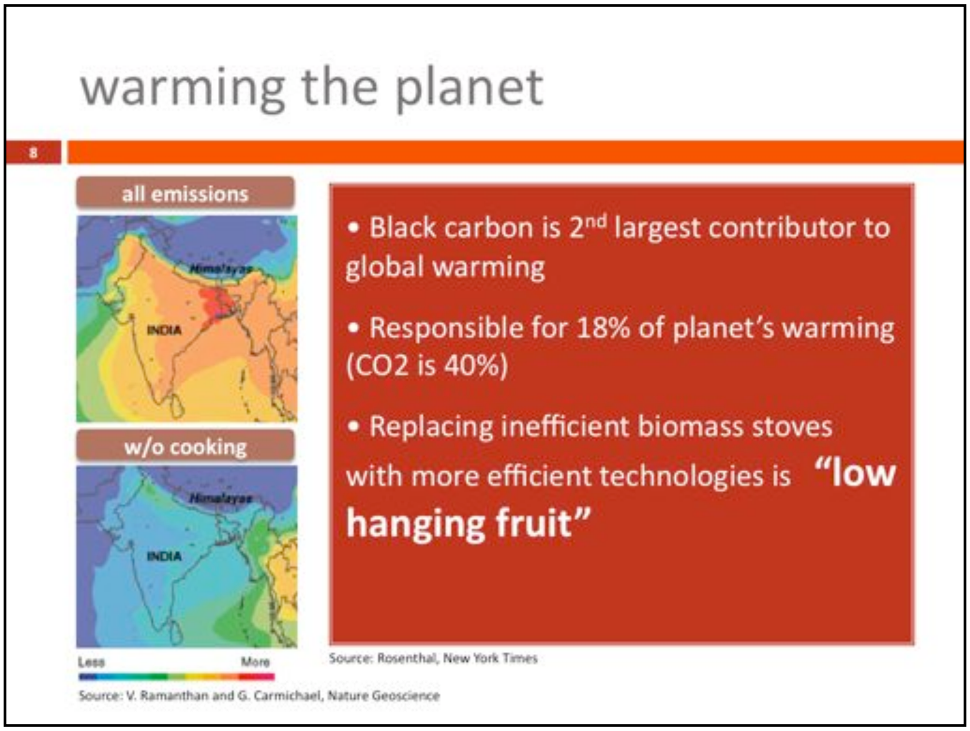


Burned firewood releases a large amount of black carbon that can negatively affect a person's health with repeated exposure. Respiratory problems are the main concern with black carbon exposure. Nearly 400,000 annual premature deaths in India are attributed to black carbon.

Source:

Canadian Centre for Occupational Health & Safety. (December 29, 1997). *2-Health Effects of Carbon Black*. Retrieved May 5, 2009, from http://www.ccohs.ca/oshanswers/chemicals/chem_profiles/carbonbl/health_cb.html#_1_1.

Earth Justice. *A Global Warming Story You Haven't Heard*. Retrieved May 5, 2009, from http://action.earthjustice.org/campaign/blackcarbon_0409a?qp_source=homepage.



In addition to health effects, black carbon is the 2nd largest contributor to global warming (Responsible for 18% of the warming). Scientists have described black carbon as the easy way to reduce the warming observed in India. On the left are two figures representing the global warming emissions in India. The top figure includes all emissions, including black carbon. The bottom figure excludes the black carbon emissions from cooking, illustrating the impact of switching to more efficient technologies.

Rosenthal, E. (2009). By Degrees – Third-World Stove Soot Is Target in Climate Fight. *The New York Times*, A1. Retrieved May 5, 2009 from

http://www.nytimes.com/2009/04/16/science/earth/16degrees.html?_r=1&sq=india%20carbon&st=cse&adxnnl=1&scp=1&adxnnlx=1241360436-KijFnBQQgT8LYTfbwJqrpQ

If solar ovens are so good, why isn't everyone using one? — Possible reasons could be:

•lack of awareness about the fact that one can use solar energy to cook;

•potential users might not want to cook in the open, and may not really be convinced that solar cooking is a viable proposition;

•easy availability of cooking gas and kerosene in the urban cities could be stopping people from trying this option;

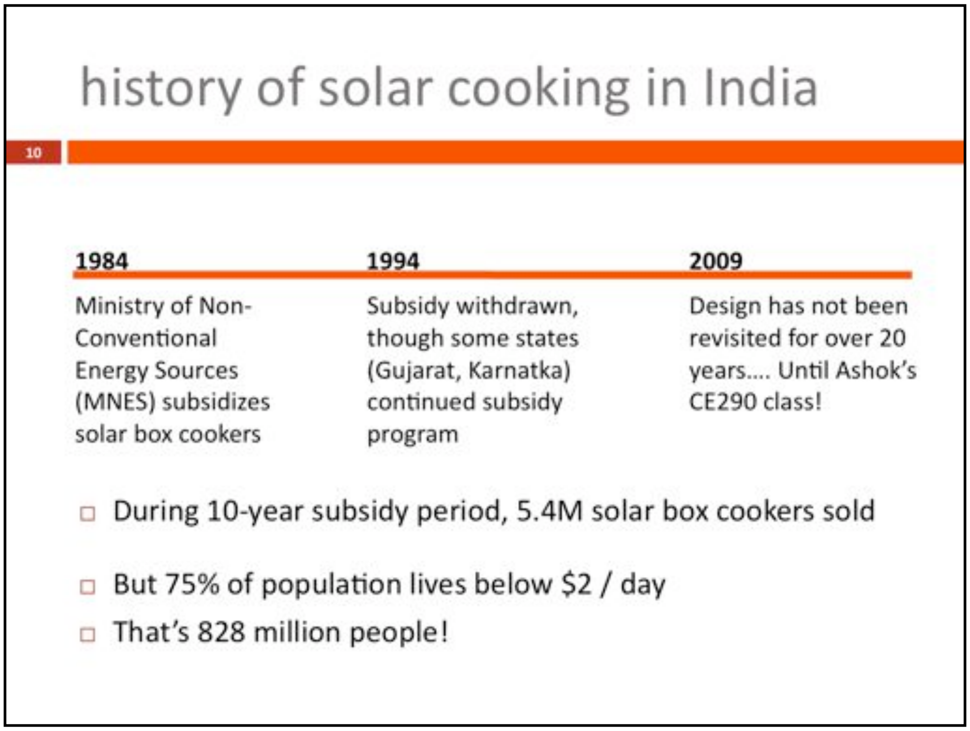
•people may be sold on the idea, but do not have adequate open area with sunlight in their homes;

•Although the parabolic cooker is supposed to allow in-door cooking, it comes with far too many riders. For instance, the kitchen window should face north, with no buildings or trees to block sunlight. The building should be single-storied with slanting roof. For all practical purposes, this immediately knocks off 90 per cent of urban users;

•in the rural areas cooking with firewood has become so much a part of their culture that an alternate medium will need a lot of effort to popularize.

Source:

Kumar, V. *Make Food When The Sun Shines: a Look at the Solar Cooker Scene in India*. Retrieved May 5, 2009 from http://www.chillibreeze.com/articles/SolarCookersinIndia.asp.

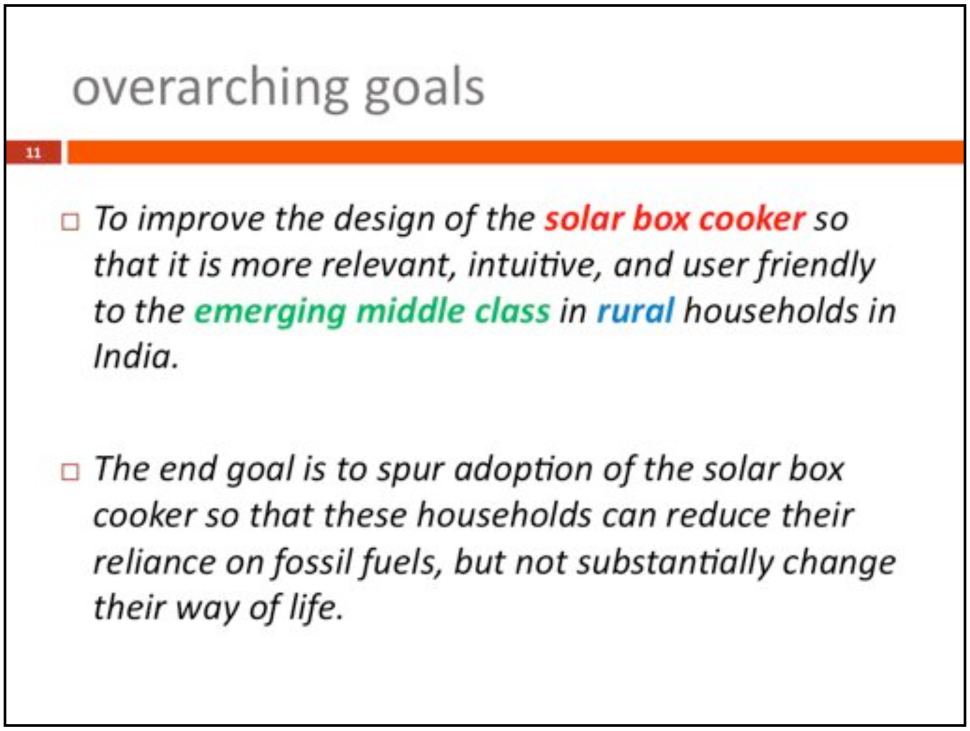


Sources:

IST, TNN. (August 27, 2008). One-third of world's poor in India: Survey. *The Times of India.* Retrieved May 5, 2009 from http://timesofindia.indiatimes.com/India/One-third_of_worlds_poor_in_India/articleshow/3409374.cms.

Kumar, V. *Make Food When The Sun Shines: a Look at the Solar Cooker Scene in India*. Retrieved May 5, 2009 from http://www.chillibreeze.com/articles/SolarCookersinIndia.asp.

Narayanaswamy, S. (June 2001). A bright idea. *India Together*. Retrieved May 5, 2009 from http://www.indiatogether.org/stories/suncook.htm.



To focus our project, we chose to target the emerging middle class in rural India. We came to this goal through a pros/cons analysis, which can be found in the appendix of the presentation.

semester deliverables

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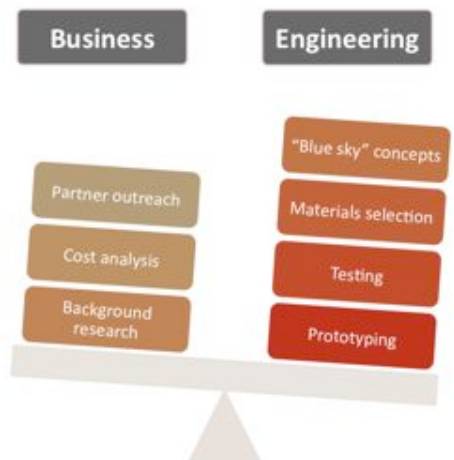
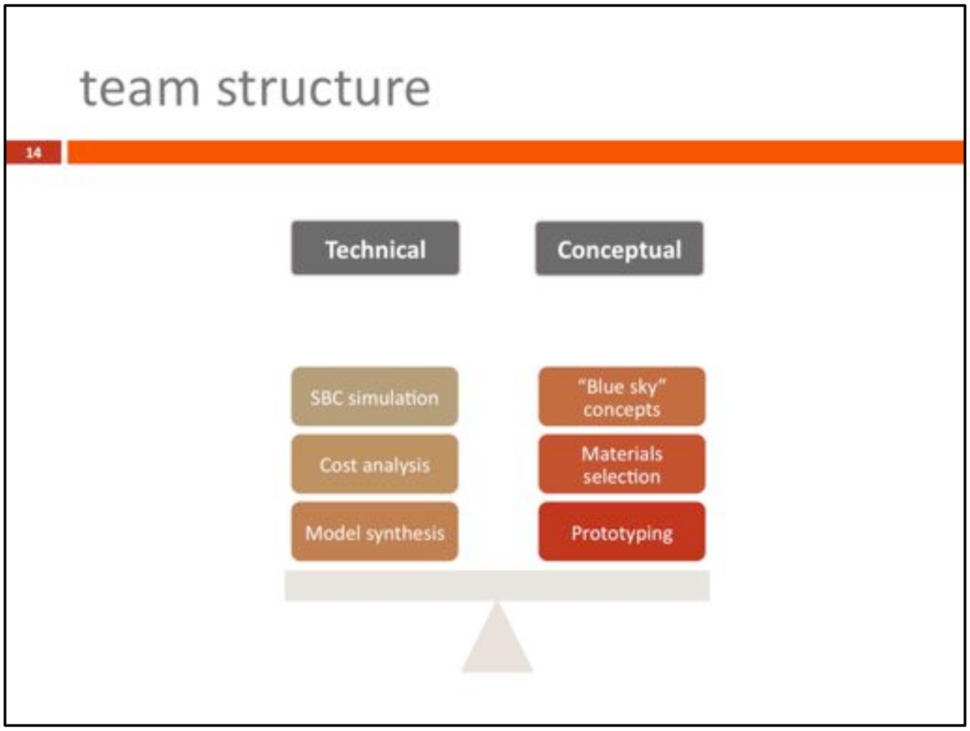
- Several proof of concept prototypes with documentation regarding design limitations
- Detailed cost analysis model
- Detailed SBC stagnation model
- Documentation about research findings, relevant studies, competitive analysis, etc
- Contact information for partners

team structure




team structure
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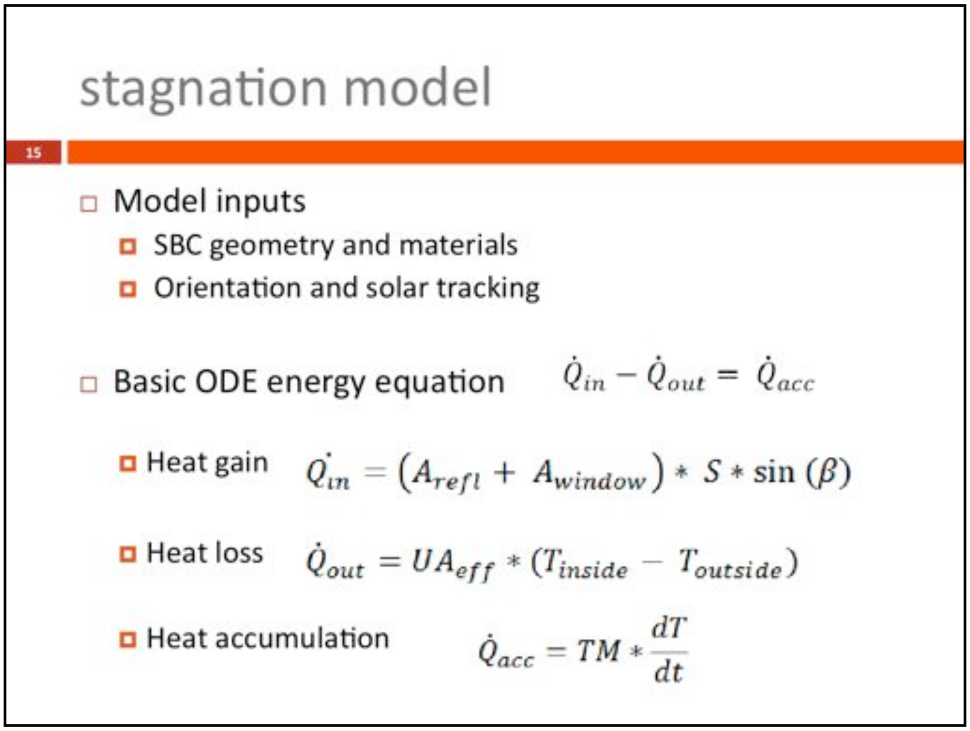
Technical
Conceptual
SBC simulation
Cost analysis
Model synthesis
"Blue sky" concepts
Materials selection
Prototyping



Heat gain: comes from the sun

S stands for solar radiation (W/m^2), beta stands for altitude

Since there is a reflector, heat gain will include indirect rays as well as direct solar rays. In our model we assume 100% reflectance, so depending on the SBC orientation a certain area of the window will in essence receive double radiation, hence Arefl +Awindow

Heat loss
Uaeff takes into account the resistance to heat loss properties of the wall and window construction

Tinside and Toutside are temperatures inside and outside the box

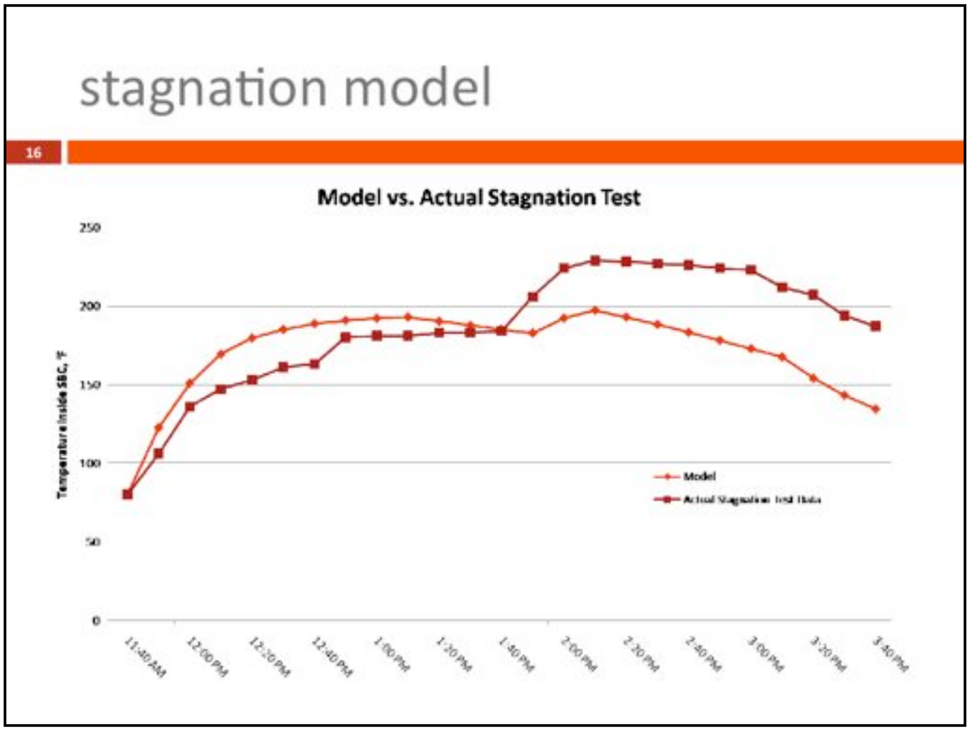
Heat accumulation

TM stands for thermal mass which takes into account that of the air inside the box as well as half of the box mas

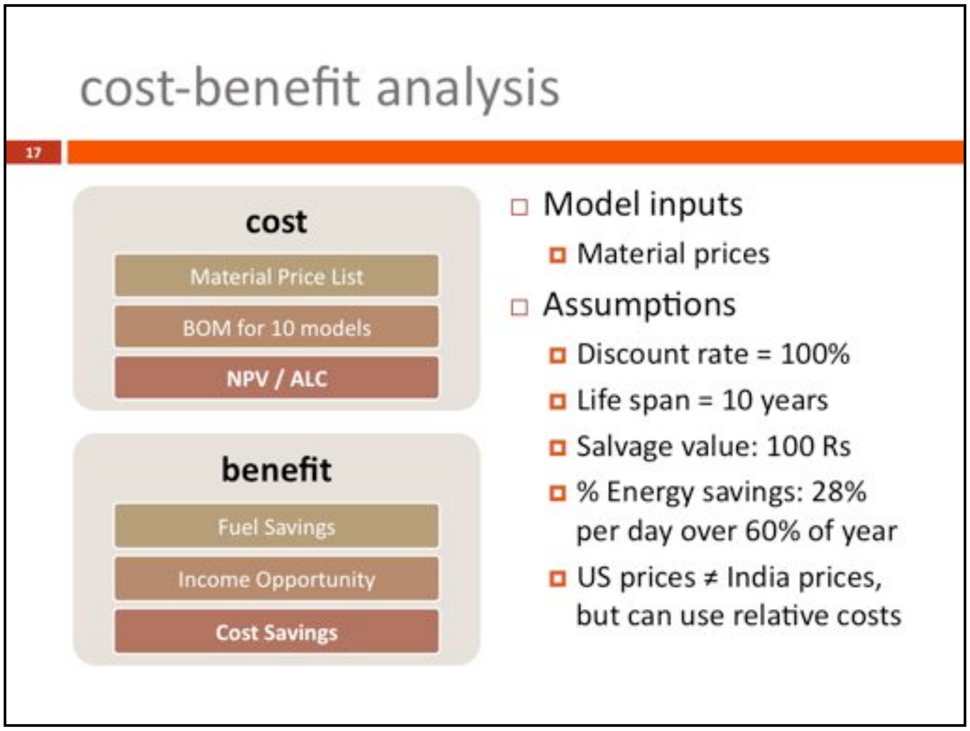
dT/dt stands for change in temperature over time

Heat loss: comes mainly from conduction through the windows and the walls. The resistance to heat loss of the insulation, box material and the windows are the driving factors to the heat loss rate and are incorporated into the UA eff term.

Inside temperature is determined by the heat accumulation term. Here TM stands for the thermal mass of the air inside as well as half of the box.

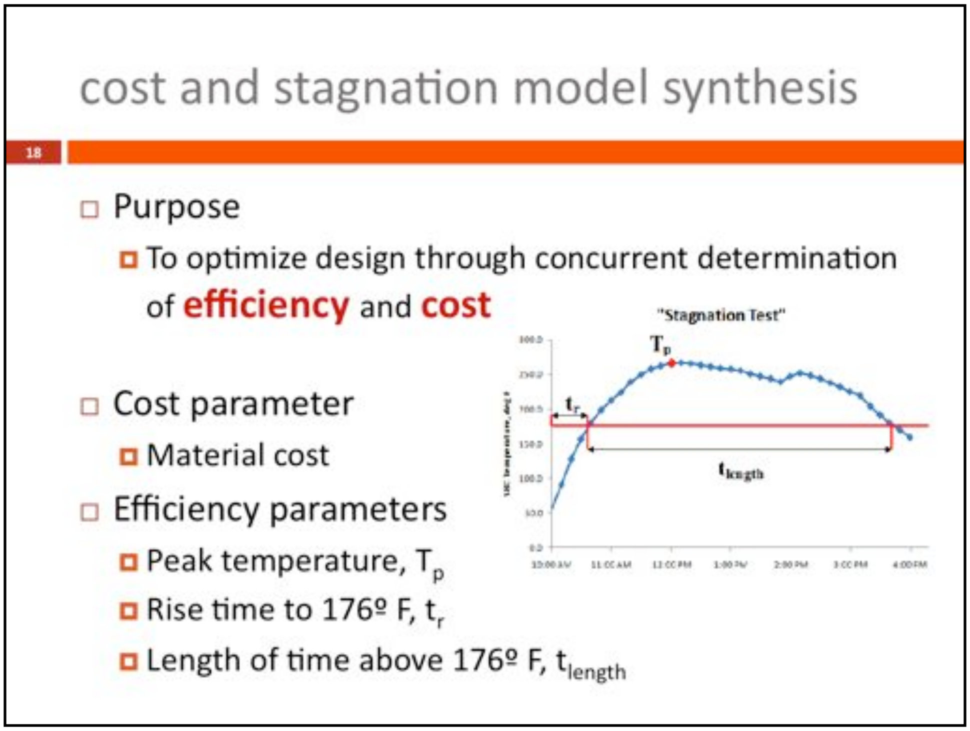


The model aligns fairly well with the actual stagnation test. Differences may occur in model assumptions and limitations, including taking average outside temperatures and radiance for the month of march.

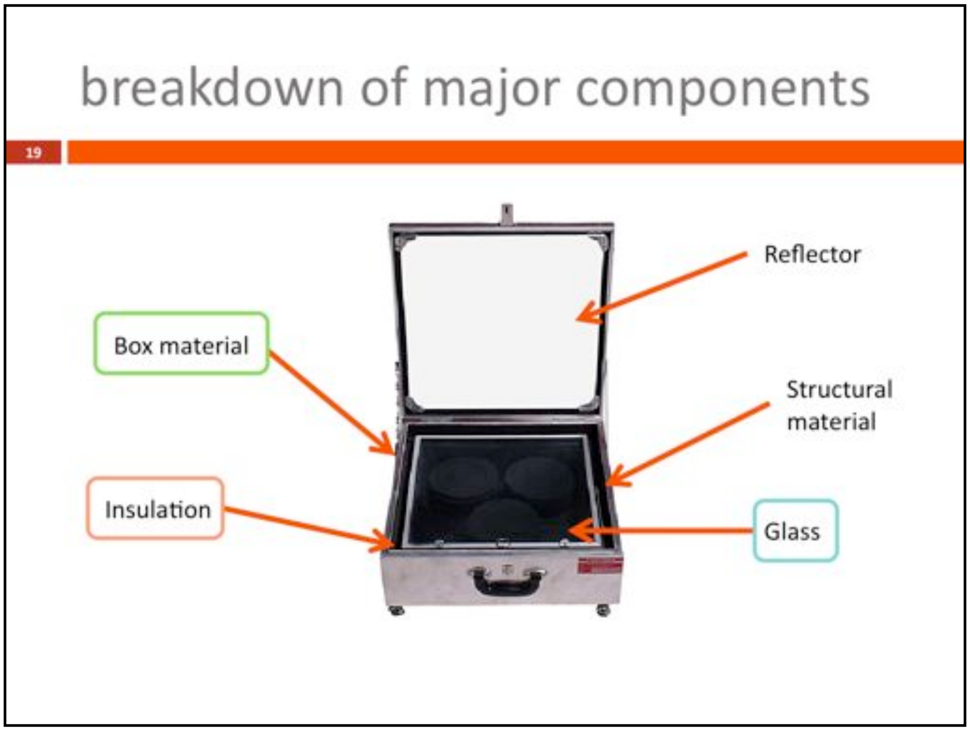


Our analysis focused on two main areas: cost and benefit. On the cost side, we created a comprehensive list of materials and used US prices as a benchmark to understand relative price differences from switching materials. If we had additional time, we would have expanded the cost analysis to also include a) manufacturing costs, b) shipping costs, and c) other duties, tariffs, and taxes. Please see the white paper for additional summary of these different options.

On the benefit side, we believed that the decrease in fuel consumption (= increase in income) and the increase in women's time (= increase in potential to earn income) were the two primary drivers. We relied on benchmarks and proxy data from different white papers and articles to build out this model.



After creating both models, it was important to compile the cost and stagnation analysis to concurrently determine the best combination of efficiency and cost. The four parameters chosen for analysis were: material cost, peak temperature, rise time to pasteurization temperature, and length of time at the pasteurization temperature.



To simplify our models, we disaggregated the model into five major components – the outer box material, insulation, glass lid, reflector, and structural internal material. We focused on the first three components and varied different materials to understand the cost/efficiency tradeoff.

testing scenarios

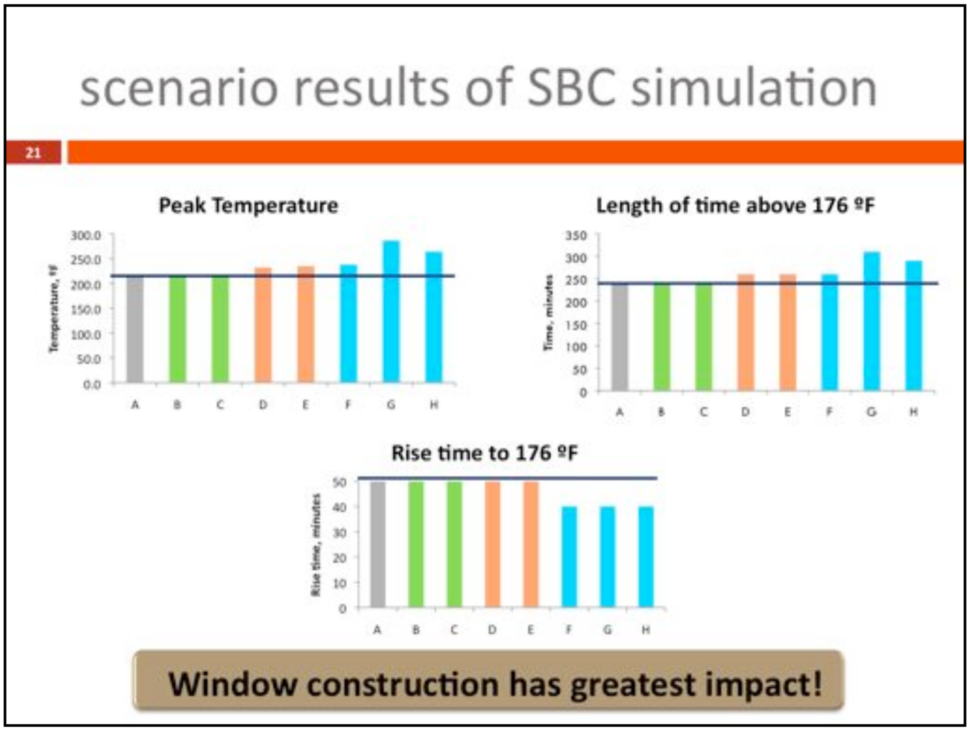
Scenario	Box material	Insulation	Window
A	Al sheet metal	Fiberglass	Double pane 0.1875" air space
B	Plywood	Fiberglass	Double pane 0.1875" air space
C	Hardboard	Fiberglass	Double pane 0.1875" air space
D	Al sheet metal	Fiberglass + foamed plastic	Double pane 0.1875" air space
E	Al sheet metal	Fiberglass + polyurethane foam	Double pane 0.1875" air space
F	Al sheet metal	Fiberglass	Double pane 0.5" air space
G	Al sheet metal	Fiberglass	Double pane 0.5" air space, e = 0.2
H	Al sheet metal	Fiberglass	Triple pane 0.25" air space

Scenario A is our benchmark scenario which is based off of the commercial solar box cooker.

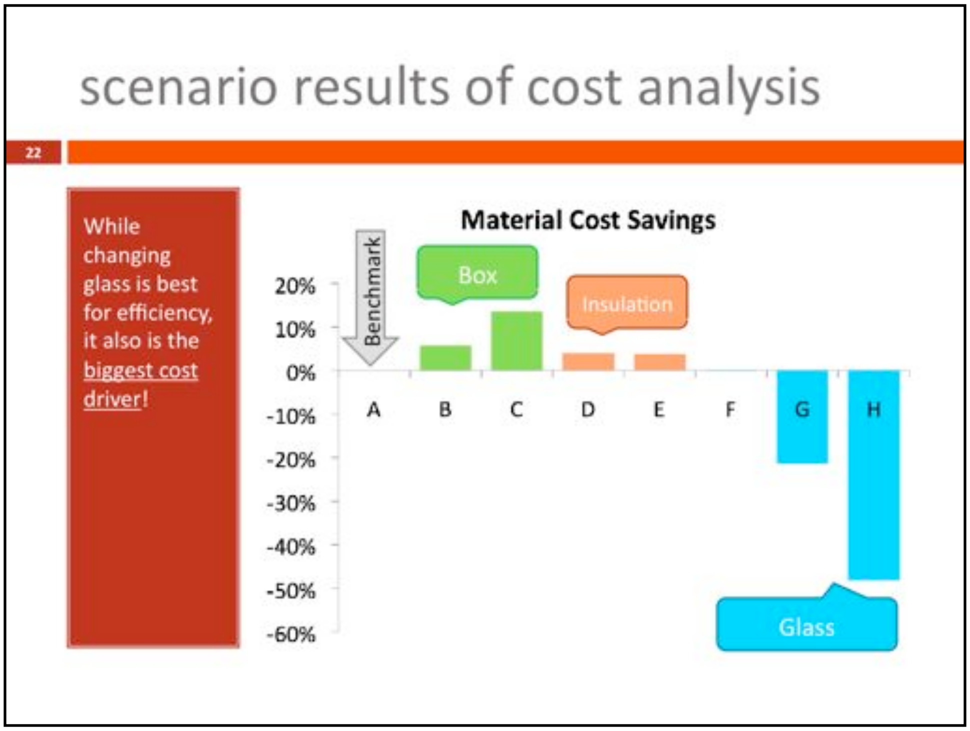
Scenarios B and C vary box material

Scenarios D and E vary insulation

And scenarios F – H vary window construction



The outer box material had no impact on the efficiency performance, while the insulation had a slightly positive impact. By far, the greatest impact was from the window construction – so varying the number of layers of glass and low e-coating.



While the box material and insulation had small cost savings from the benchmark model, any substantial changes to the glass component significantly drove up the cost. As well, availability of specialty glasses (triple paned, low e-coating) may be unreliable, so a more thorough analysis needs to be done to understand local materials.

Note that the scenario results of the cost analysis are provided in relative cost savings, rather than absolute numbers. We resorted to using US prices to cost out the BOM, and then focused on the percentage increase/decrease in the price from the benchmark.

combination scenarios

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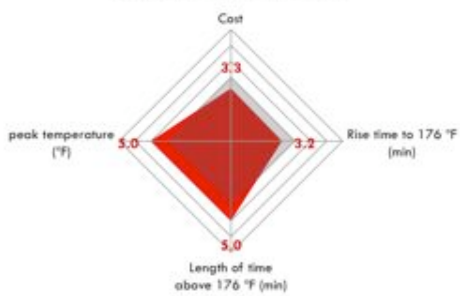
Scenario	Box material	Insulation	Window
A	Al sheet metal	Fiberglass	Double pane 0.1875" air space
I	Hardboard	Fiberglass + polyurethane foam	Double pane 0.5" air space
J	Hardboard	Fiberglass + foamed plastic	Double pane 0.5" air space, low-e

Combination Scenario I



Combination Scenario J

The goal of the combination scenarios was to combine our findings from the cost and efficiency analysis, to find an appropriate combination of components to allow us to:

•Minimize cost

•Minimize rise time

•Maximize peak temperature

•Maximize length of time

We normalized the results against scenario A results (4 on every dimension) and then plotted out each combination scenario's performance against these parameters.

The result is Scenario I, which improves performance while reducing cost, and Scenario J, which has a much higher performance but also increased costs. Until further market research is done, it will be difficult to assess which scenario is more appropriate for our target segment.

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now thinking outside the box…

In order to generate disparate concepts, five fictitious "personas" were created/. These personas reflected needs gathered during ethnography.

Personas include (from left to right top to bottom):

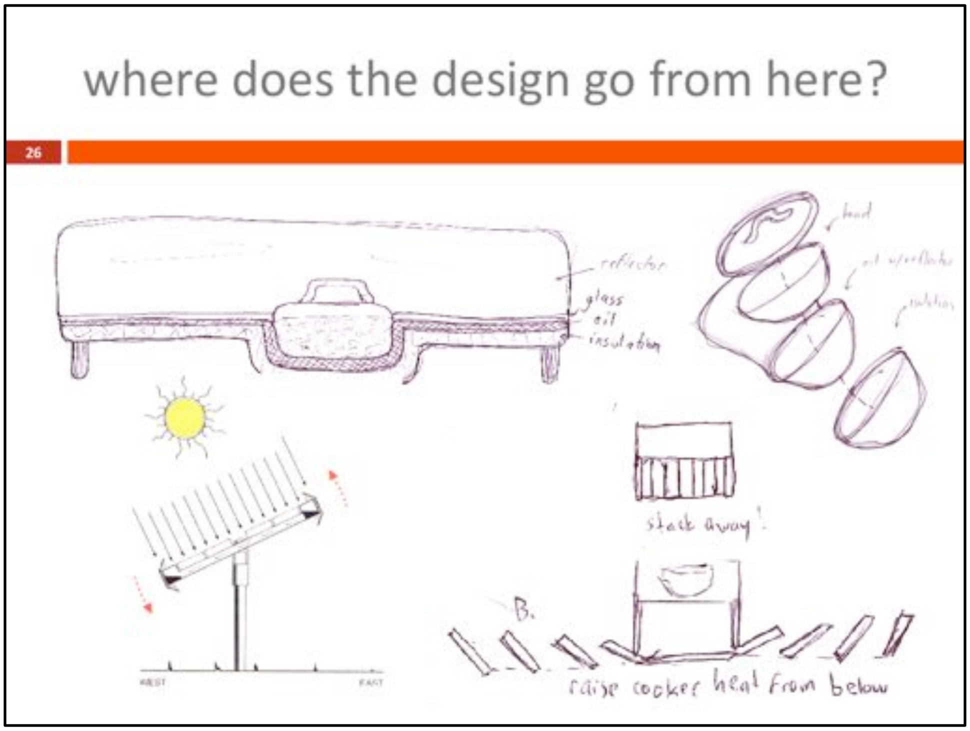
Arundhathi - 40 year old stay at home mother of 5 children living in rural areas of Gujarat

Sunjay – field worker who has to walk 5 km to his worksite

Manjula - 85 year arthritic old woman who tends to a house in an urban area

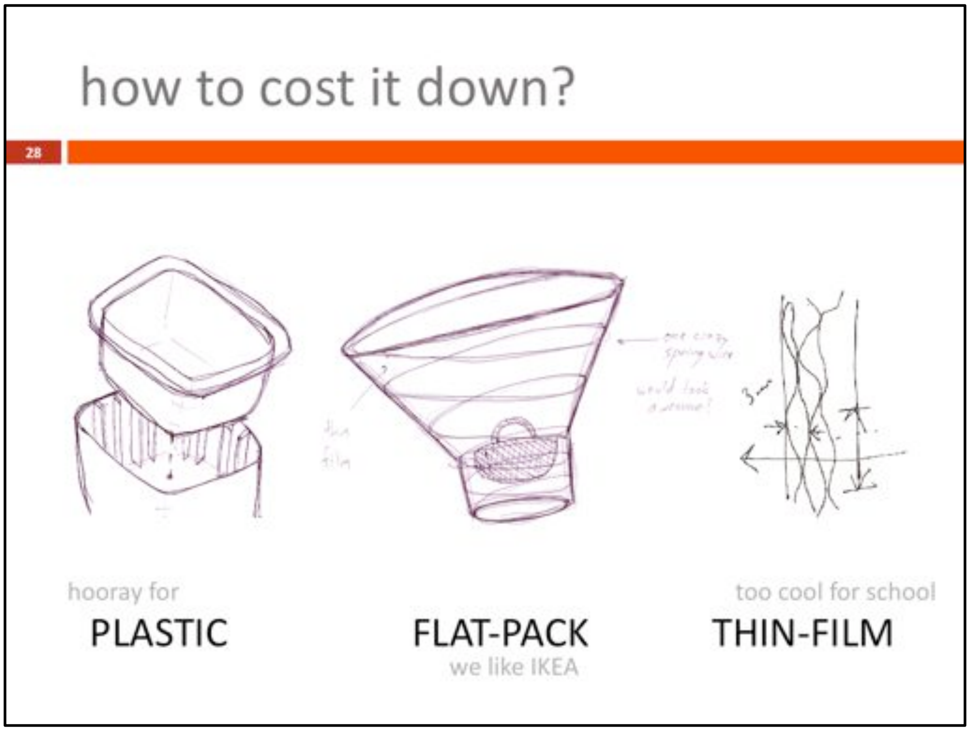
Saleem - 30 year old urbanite working in a box factory who likes to try new things

Shrijitha - 23 year old widow living in rural areas where she must gather firewood and cow dung for fuel



A wide variety of concepts were created attacking niche markers. It was difficult to assess the value added with these solutions.

Costing down the box cooker seemed like the most straight forward method of spurring adoption. This was chosen as the area to concentrate our efforts.

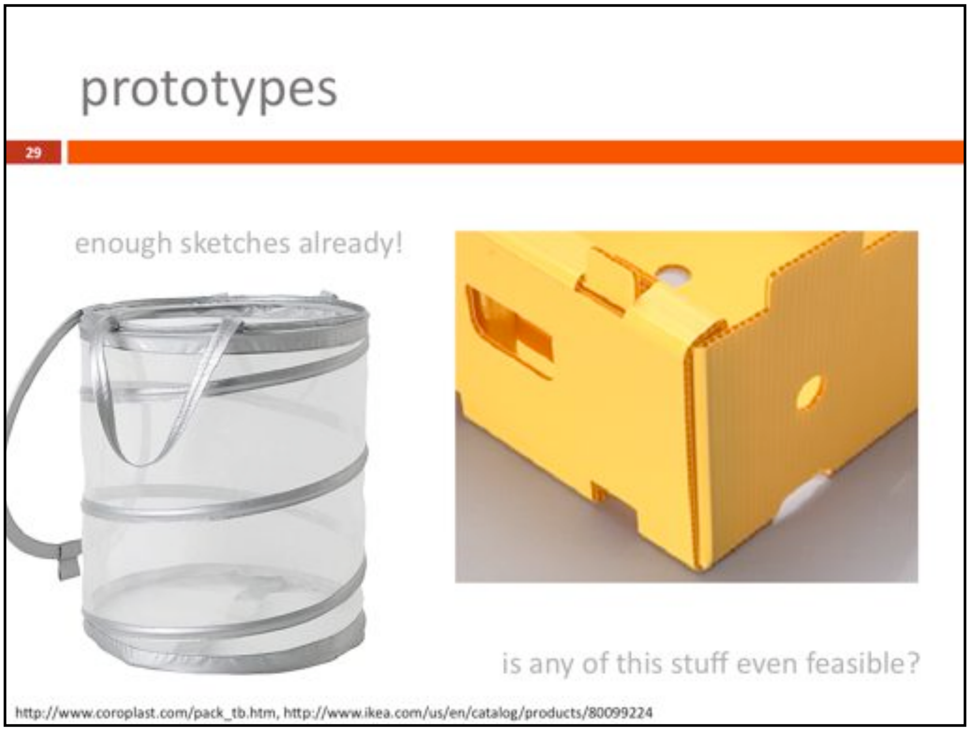


To cost it down, three avenues were explored:

Plastics – Plastics are cheap, lightweight, and can be quickly manufactured

Flat Pack – By reducing transportation and fueling costs, the cooker can be mass manufactured in a more industrialized location

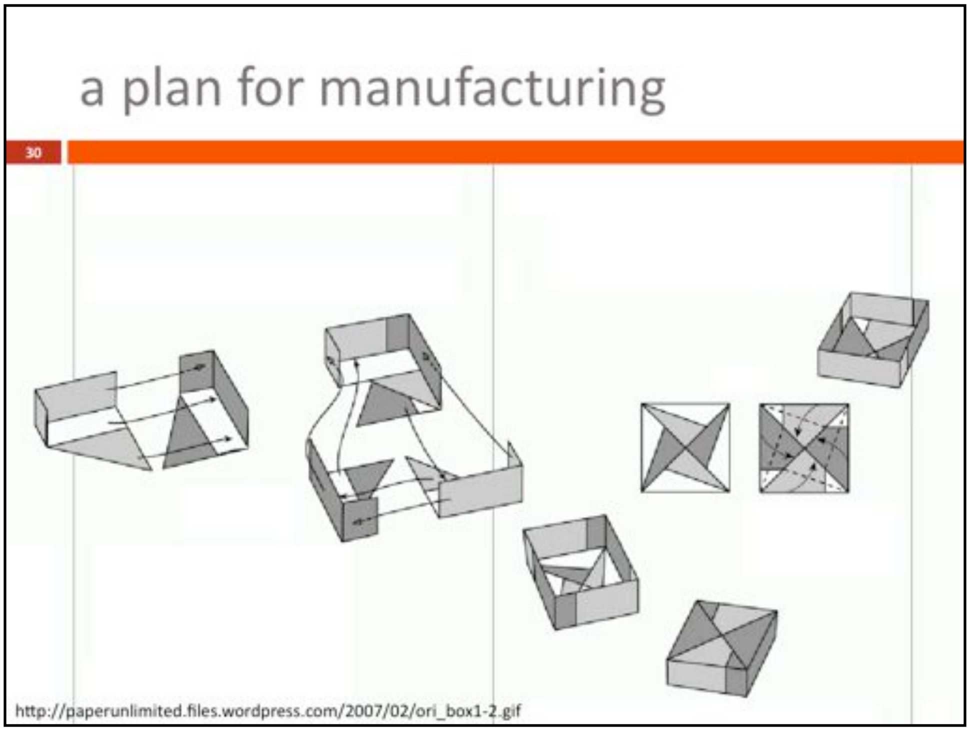
Thin Film – Revolutionary thin films have great benefits in flatpack insulation and structure while using minimal material



Prototypes include a costed down cardboard cooker, a plastic cooker, a lunchbox cooker, and a flat pack cooker.

Coroplast:
http://www.coroplast.com/pack_tb.htm

Ikea basket:
http://www.ikea.com/us/en/catalog/products/80099224



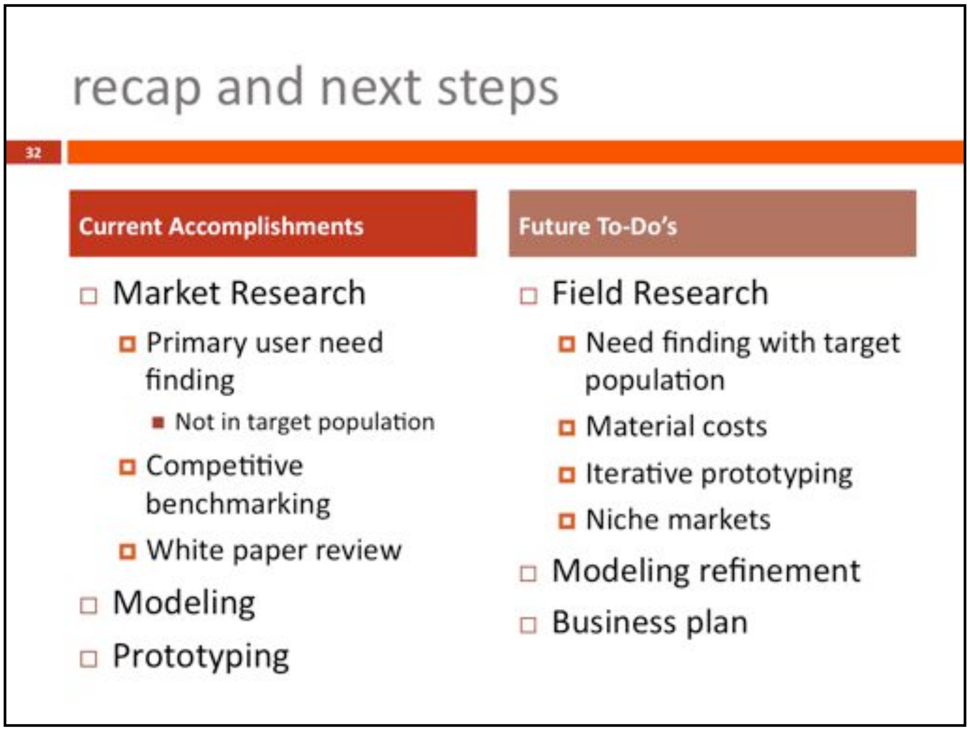
Manufacturing could be conducted in two avenues:

- heat forming a plastic cooker
- cutting out sheets of corrugated cardboard and using existing coldpack liners

Origami box:
http://paperunlimited.files.wordpress.com/2007/02/ori_box1-2.gif

Recap where we've gone, market research, prototyping, interviews and modeling

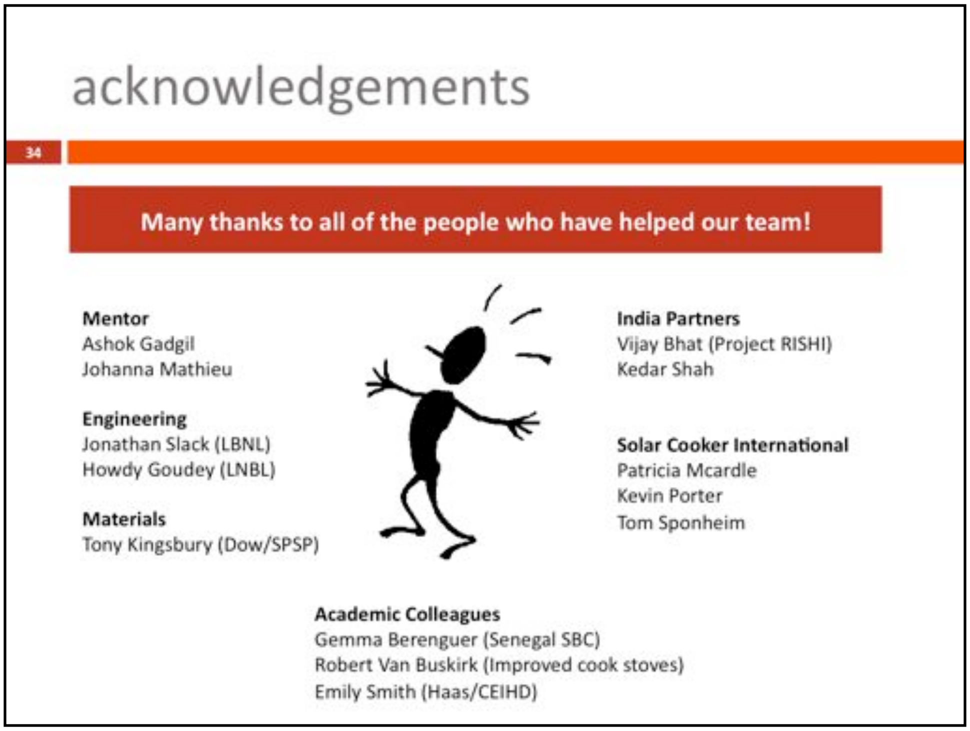
Conclusion: yes, we should keep looking



Our semester accomplishments include market research, primary user need finding through interviews, competitive benchmarking, white paper review, modeling, and prototyping.

Future items to be considered include field research in Gujarat, India. Although we did a lot of research in Berkeley, the most effective need finding can only be done on the ground. In Gujarat, the actual needs of the target population can be determined, accurate material costs will be easier to find, and prototyping can be better tailored to local needs. Also, the models can be refined to reflect local solar and business conditions. All of these components can then be compiled to produce an effective and sustainable business plan.

The challenges for future groups revolve around the idea that people need to actually spend time in Gujarat to research local customs, conditions, and people. This research will lead to a better product and one that will actually be adopted.



Thanks to all the mentors that helped our project along the way. Special thanks to Ashok Gadgil and Johanna Mathieu for their continued support and encouragement. We would also like to thank Jonathan Slack and Howdy Goudey for taking the time to brainstorm ideas and talk about the project.

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QUESTIONS?

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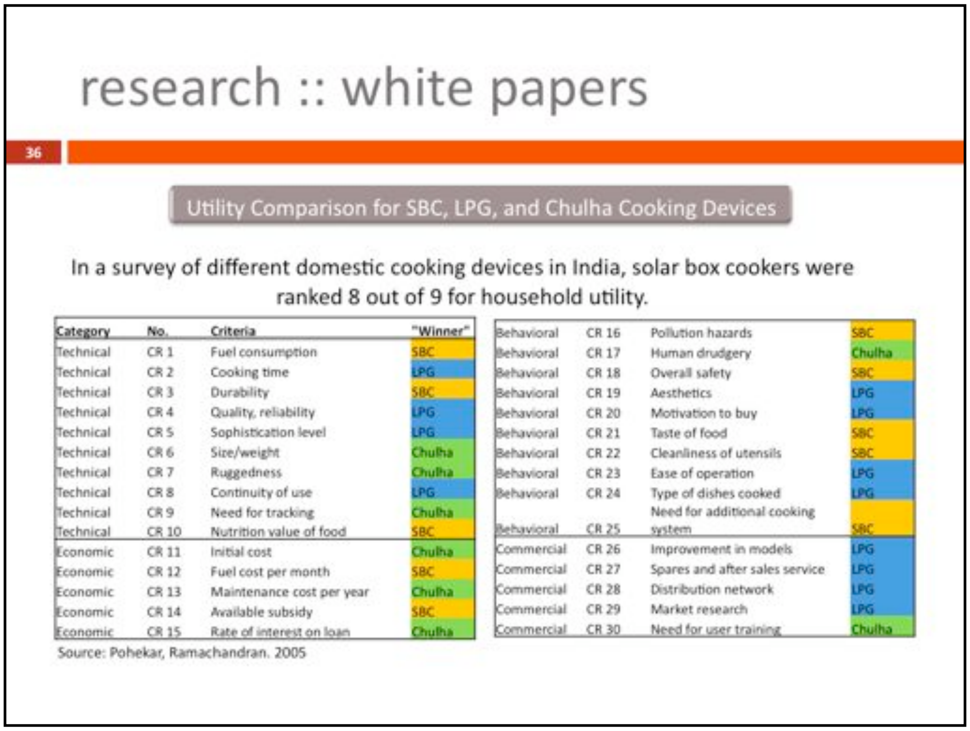


Category	No.	Criteria	"Winner"
Technical	CR 1	Fuel consumption	SBC
Technical	CR 2	Cooking time	LPG
Technical	CR 3	Durability	SBC
Technical	CR 4	Quality, reliability	LPG
Technical	CR 5	Sophistication level	LPG
Technical	CR 6	Size/weight	Chulha
Technical	CR 7	Ruggedness	Chulha
Technical	CR 8	Continuity of use	LPG
Technical	CR 9	Need for tracking	Chulha
Technical	CR 10	Nutrition value of food	SBC
Economic	CR 11	Initial cost	Chulha
Economic	CR 12	Fuel cost per month	SBC
Economic	CR 13	Maintenance cost per year	Chulha
Economic	CR 14	Available subsidy	SBC
Economic	CR 15	Rate of interest on loan	Chulha
Behavioral	CR 16	Pollution hazards	SBC
Behavioral	CR 17	Human drudgery	Chulha
Behavioral	CR 18	Overall safety	SBC
Behavioral	CR 19	Aesthetics	LPG
Behavioral	CR 20	Motivation to buy	LPG
Behavioral	CR 21	Taste of food	SBC
Behavioral	CR 22	Cleanliness of utensils	SBC
Behavioral	CR 23	Ease of operation	LPG
Behavioral	CR 24	Type of dishes cooked	LPG
Behavioral	CR 25	Need for additional cooking system	SBC
Commercial	CR 26	Improvement in models	LPG
Commercial	CR 27	Spares and after sales service	LPG
Commercial	CR 28	Distribution network	LPG
Commercial	CR 29	Market research	LPG
Commercial	CR 30	Need for user training	Chulha

This white paper compares different domestic cooking devices in India under four main attribute categories: technical, economic, behavioral, and commercial. The authors perform extensive surveys to understand the utility of each device against a slew of dimensions.

We took the findings from the paper and focused on three cooking devices –

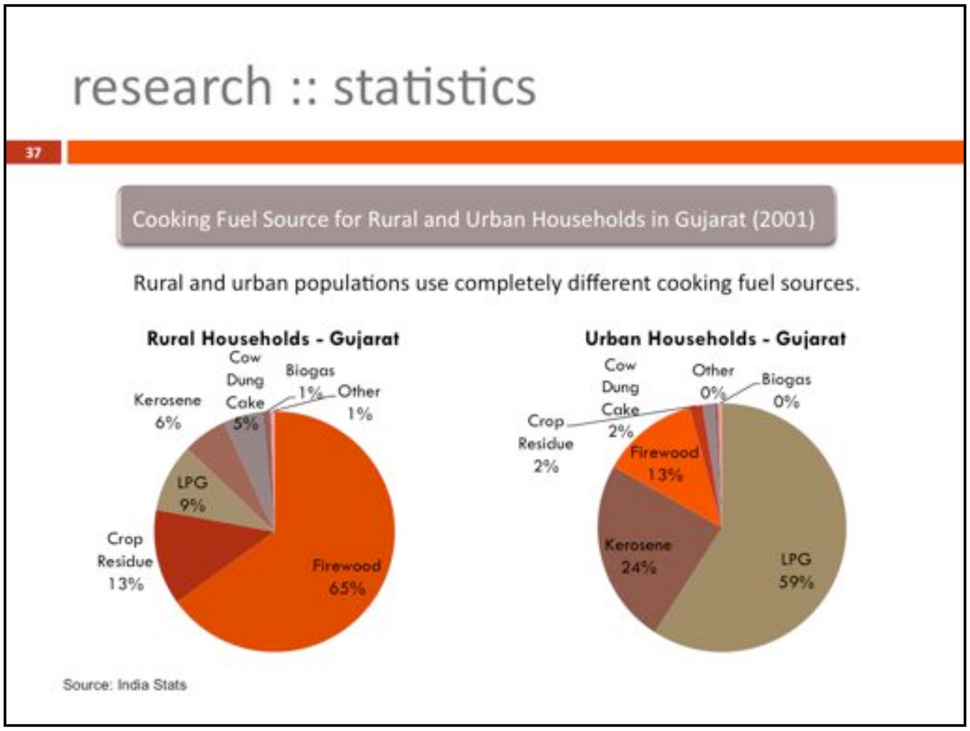
•SBC, or solar box cooker

•LPG stove, which generated the highest utility among users

•Chulha, a traditional cook stove which had the lowest utility.

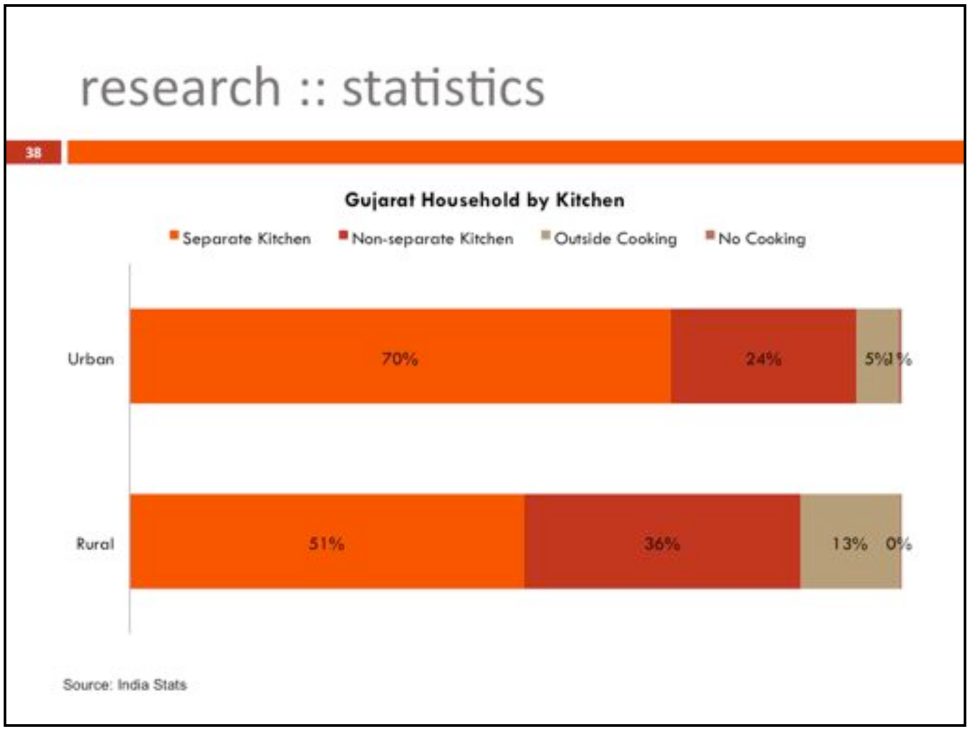
Looking at each score across the attributes, we then ranked the three cooking devices and determined a “winner” for the category. This analysis was useful to understand what areas SBC was strongest (fuel consumption = 0, high nutritional value of food, fuel cost per month = 0, available subsidy, pollution hazard, safety, taste of food, cleanlinesss, and need for additional device). We used these insights to better understand how solar box cookers compete within a highly competitive domestic cooking device market.

Pohekar, S.D., Kumar, D., &Ramachandran, M. (2005). Dissemination of cooking energy alternatives in India - a review. *Renewable & Sustainable Energy Reviews, 9*(4), 379-393.



Urban and rural households in Gujarat India use very different fuel sources for cooking. Almost 80% of rural households rely on biomass fuel sources (firewood, crop residue) which causes substantial indoor air pollution and release of black carbon in the atmosphere. On the other hand, urban households pre-dominantly rely on the heavily subsidized LPG and kerosene fuels.

(2001). Households by Type of Fuel used for Cooking. Retrieved March 15, 2009 from India Statistics database.



Rural households are more likely to cook outdoors than their urban counterparts (13% versus 5%). As well, many rural households do not have a separate kitchen, which means black carbon emissions from cooking will affect all inhabitants of the household.

(2001). Households by Type of Fuel used for Cooking. Retrieved March 15, 2009 from India Statistics database.

Solar box cooker vs. Parabolic cooker

	BOX COOKER	PARABOLIC COOKER
PROS	• Cheaper in most cases • Baking capabilities • Drying capabilities • Variety of food • **Safer** • **Less tracking/attention required** • **More durable/stable** • Design flexibility • Easy to use/Repair • Thermal couple	• **High temp** • **Faster/More efficient** • Frying capability • Aesthetically pleasing • Portable • Conceptually easier to use
CONS	• **Takes longer to cook** • **Bulkier/Heavy** • More materials • No frying • No use on a cloudy day	• **Unsafe – may blind or burn** • **Requires more solar tracking** • **Only specialized pots** • Training for safety and tracking • Limitations on what can cook • Expensive • Manufacturing more detailed • No use on cloudy day • No thermal couple

Please note that the comments are subjective in nature, and may not be factually correct. The brainstorm happened towards the very beginning of the semester when we were just embarking on the project.

Low income vs. Middle class

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	LOW INCOME	MIDDLE CLASS
PROS	• **Larger market** • More visibility • **Use less efficient/clean cooking options** • More attracted to energy savings from use • Less sensitive to time	• **More money to spend** • Access to more space for device • Conscious of energy benefits from use • **Lower discount rate** • Adoption much quicker • **More innovators and early adopters** • May have someone home to attend
CONS	• Cost must be lower • **Higher discount rate** • Lower adoption rate • Whole household may be absent during the day	• More sensitive to time • Compete with more efficient cooking options • **Smaller market** • **Smaller impact**

Please note that the comments are subjective in nature, and may not be factually correct. The brainstorm happened towards the very beginning of the semester when we were just embarking on the project.

Urban vs. **Rural**

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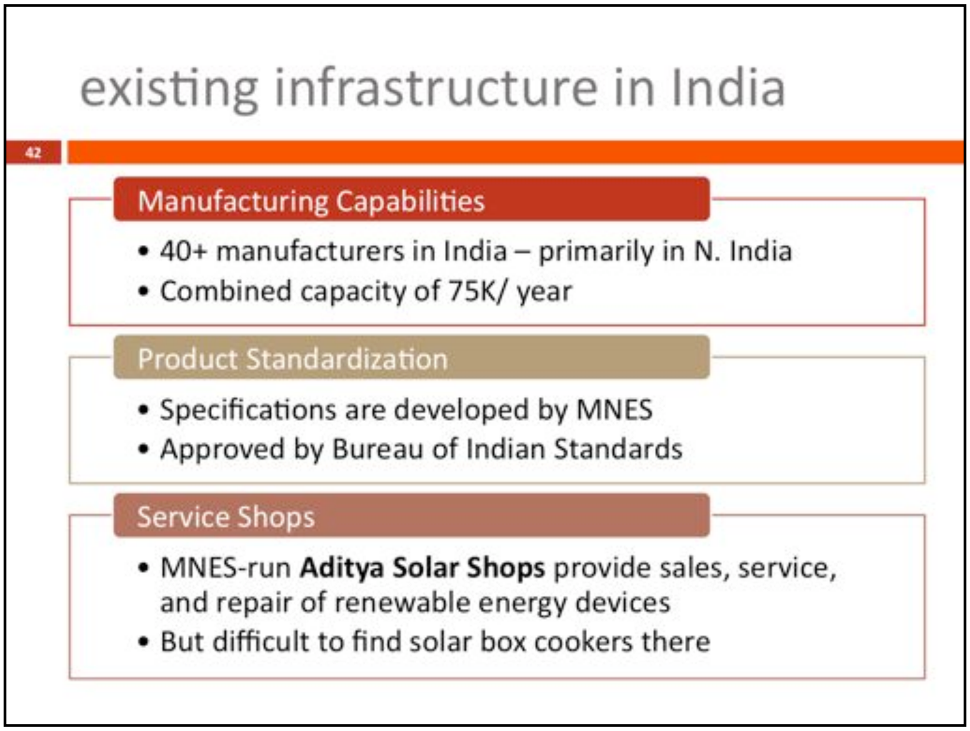
	URBAN	RURAL
PROS	• Larger Market **• Easier Access/Communication for marketing, distribution, and manufacturing** **• More open to innovation (more innovators and early adaptors)** • Higher visibility • Potentially higher income, easier access to finance	**•More space for use and easy accessibility** • More access to sunlight **• Difficult to acquire resources for other cooking options** • Less competition
CONS	**• More competition** **• Reduced space for sun access (roof or street)** • Theft could be a large concern • Reduced convenience for solar box cooker use (may have to carry to roof)	• More dispersed, Lower visibility • Less early adopters and innovators • Less contacts (NGOs/government accessibility

Please note that the comments are subjective in nature, and may not be factually correct. The brainstorm happened towards the very beginning of the semester when we were just embarking on the project.



Manufacturing of solar box cookers in India has been around for over 30 year. There is substantial infrastructure already in place, with most manufacturing happening in the Northern states. Despite this, sales of solar box cookers have been declining over time, as there is little design innovation occurring.

Kumar, V. *Make Food When The Sun Shines: a Look at the Solar Cooker Scene in India*. Retrieved May 5, 2009 from http://www.chillibreeze.com/articles/SolarCookersinIndia.asp.

Stagnation Test

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- Stagnation Test
  - Temperatures reached up to 220 °F
  - Solar tracking affects performance