# Whole System Mapping

# **Example 1**

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# Comments:

Again, this example has better graphs, but its system map is a little too graphically idealized--looks great, but not as good a representation of the real flows of time and causality in the system.

You've got the LCA comparisons, system map, priorities and metrics, decision matrix, and final design choice.

Excellent graphs comparing all the scenario LCAs. You actually don't even need to have different colors for every different material in every scenario, because here we're just trying to choose between scenarios, not trying to see details for any one particular scenario--our earlier LCAs were trying to find the biggest problems in each scenario, and let me see you'd done the LCAs right, and thus the detail was useful; here we assume the scenarios are set, and we're choosing which ones are best, so a single bar for each is ok. ...However, your extra detail could be useful for combining scenarios. Even then, all of the scenarios here are mostly energy (except for the "glass" and "plastic" scenarios), so if this were for a client, you could graph them by life-cycle phase (materials / mfg, energy use, transport, & EOL) instead of going all the way to the level of the SBOM, without losing important detail.

Your decision matrix had good reasons listed for the weight differences. Just FYI, it'll make more sense to your reader if your decision matrix lists objectives in order of highest priority to lowest priority. Then #1 is your #1 priority, etc.

Excellent presentation of the winning design. You really sold it, both usability-wise and sustainability-wise. Great graphic--I feel like I'm getting to know banana-holding woman by now. But what's up with her live chicken in the fridge??









# WHOLE SYSTEM MAP









# PRIORITIES AND METRICS

Based on the systems map, priorities and metrics imperative to the new, redesigned model were identified.

#### DESIGN PRIORITIES AND METRICS

- 1. Reduce overall energy Impacts, both in total SMOB as well as carbon footprint: Reduce carbon footprint and total impact by 50%
- 2. Create a more lightweight system based on material usage, impacting manufacturing and transportation: Reduce weight of unit by 50%
- Create a more sustainable, usable and beautiful model with the added benefit of being less expensive than traditional models. Cost savings will be realized at the point of purchase, during the use phase, and in the longevity of food within the system: Reduce initial cost by 25% and long-term cost by 50%
- 4. Create a model with a lower impact on end-of-life models: Reduce fraction of weight of material to landfill by 25%
- 5. To create a model that has an impact, consumer adoption is key to realize the benefits of a redesigned model: Seek a 10% market share of new fridge purchases within two years of introduction. 15% within three years.







# LCA ANALYSIS

Based on the generated priorities, a Life Cycle Assessment (LCA) was conducted comparing 8 different scenarios. These scope of these scenarios is rooted in a cradle to cradle model (material extraction & manufacturing, transportation of the assembled product, use, & end of life), while the functional unit is measured as one year of service chilling 16 cubic feet of food items for a total of 15 years This assumes that the average fridge is largely wasted space. The initial LCA was conducted on a traditional model however in an attempt to compare like models, a compartmentalized concept was created as a comparable benchmark.

#### 9 SCENARIOS

- 1. Baseline Model, traditional consumer-grade refrigerator system
- 2. Smaller unit with a drawer system, replacing steel with bio-plastic, smaller size reduces component size as well, addresses end-oflife issues.
- 3. Battery system for mobility and off-peak energy use, makes system more resilient.
- 4. Mushroom insulation to replace PU foam for end-of-life considerations and improved insulation.
- 5. Solar panel to reduce grid energy and associated impacts, makes system more resilient.
- 6. Glass windows into unit to reduce drawer opening and improve insulation (vacuum between panes).
- 7. Plastic windows into unit to reduce drawer opening and improve insulation (vacuum between panes).
- 8. Smart Fridge unit adds some materials for sensors and a processor, improves food life and customer awareness of food stored.
- 9. Compost Bin unit attached to fridge to harvest waste heat and eliminate vegetable waste from the municipal waste stream, addresses end-of-life for food

LCA Final Recommendations 3



Example from





# LCA COMPARISONS

### **Total Environmental Impacts**









#### LCA COMPARISONS

**Total Carbon Footprint** 









### **DECISION MATRIX:**

After completion of the LCA analyses and comparison, the 8 concepts were placed into a decision matrix to determine the best concept. This matrix compared not just the LCA analysis, but other factors including energy impacts, weight, cost, end-of-life and user behavior. These 6 metric were weighted to determine the overall best concept:

- 1- The LCA is considered to be of medium importance to identify overall energy savings, reducing materials, increasing functionality and optimizing the food storage as well as at a good price point. As many of the improvements exist in current models but do not reach a large market saturation due to price point slowing their adoption. Weight 3
- 2- **The energy impacts** are considered to be of the highest importance as over the length of life as they had the largest impact overall impact particularly during the use phase. Weight 5
- 3- While **weight** was important during shipping it did not have a large impact on the LCA, as any improvement on the current norm is beneficial. Weight 2
- 4- **Cost** is likely the biggest factor in a high early adoption rate. Cost savings can be realized in material selections, long term cost related to energy savings, food saved by optimization, and reduced overall waste. Weight 4
- 5- EOL- The model itself is based on a modular design, reducing the need for improvement with interchangeable parts and repairable units. Additional material improvements include bio-plastics, mushrooms, re-usable glass were incremental. Weight 2
- 6- User Behavior- The design and acceptance of this model is based in the assumption that consumer behavior will change by reducing energy usage and optimization of food usage and purchasing behavior. Weight 4

Objective	Weight	Baseline	Concept	Mush	Glass	Plastic	Smart	Compost	Battery	Solar
1-LCA					50.00 (c) (C) (c)					
Improvement	3	1 (x3) = 3	3 (x3) = 9	3 (x3) = 9	5 (x3) = 15	4 (X3) = 12	4 (x3) = 12	4 (x3) = 12	2 (x3) = 6	2 (x3) = 6
2-Energy impacts	5	1 (x5) = 5	4 (x5) = 20	4 (x5) = 20	5 (x5) = 25	5 (x5) = 25	4 (x5) = 20			
3-Weight	2	3 (x2) = 6	5 (x2) = 10	4 (x2) = 8	3 (x2) = 6	4 (x2) = 8	3 (x2) = 6	3 (x2) = 6	4 (x2) = 8	4 (x2) = 8
4-Cost	4	2 (x4) = 8	4 (x4) = 16	4 (x4) = 16	3 (x4) = 12	4 (x4) = 16	2 (x4) = 8	2 (x4) = 8	4 (x4) = 8	3 (x4) = 12
5-EOL	2	2 (x2) = 4	4 (x2) = 8	5 (x2) = 10	4 (x2) = 8	3 (x2) = 6	3 (x2) = 6	3 (x2) = 6	4 (x2) = 8	3 (x2) = 6
6-User Behavior	4	3 (x4) = 12	4 (x4) =16	4 (x4) =16	5 (x4) =20	5 (x4) =20	5 (x4) =20	5 (x4) =20	4 (x4) =16	4 (x4) =16
	Total									
	Score	38	79	79	86	87	72	72	66	68

#### **Design Scenarios**







# **REDESIGNED REFRIGERATOR:**

#### **Design Overview**

The highest-ranking system identified in the design matrix is a polycarbonate, vacuum insulated system.

The revised system is a modular, transparent, polycarbonate-paneled system. The system itself is a mobile island, easily maneuverable in a kitchen environment. The system is made up of drawered compartments as opposed to one large door. Each drawercompartment is temperature-specific, optimizing the unique temperature necessary for the food enclosed within each space. The panels themselves serve a dual purpose; providing transparency to the contents within, reducing the amount of time the doors are open and creating a double layered vacuum system for insulation. The top of the unit serves as a workspace for food preparation, and the unit itself can fit within most counter top layouts, docking in and out and easily with its wheeled base.

Panels

the cold in









### **REDESIGNED REFRIGERATOR:**

# LCA Benefit Overview:

The compartmentalized, drawer-system concept eliminates 90% of energy loss through the opening of the door, by creating individual doors as opposed to one large unit. The addition of the polycarbonate transparent walls allows for an additional 5 % reduction in energy loss by reducing the amount of time necessary to keep the door open.

The polycarbonate vacuum insulated panels replace the need for traditional foam insulation. Exchanging foam insulation for vacuum insulation (with an R-value of 45) can eliminate 80% of the heat transfer through the walls of the unit.

### **Ecological Impact**

Electricity consumption during the use phase and steel used in the manufacturing phase were the two biggest areas of environmental impact for the baseline, standard refrigerator. As such, those two areas were the primary foci of the winning design. By replacing the structural steel and polyurethane foam insulation with polycarbonate-faced vacuum insulated panels, the winning design improved on the baseline scenario overall by approximately 90% in both the Total Impacts and Carbon Footprint. Looking at the primary structural materials, however, shows mixed results. While switching the primary structural material from steel to polycarbonate (PC) improves the Total Impacts by 53%, the Carbon Footprint for PC is more than double that of steel. Despite the decrease in performance in Carbon Footprint for the primary structural material, the overall improvements for this design greatly outweigh the performance hit in this particular category. This result highlights the importance of examining the entire system and not basing a decision on a single metric.

Design	Baseline	Winner	Improvement
Total (mpts)	34.1	3.31	90.29%
CO2 Equivalents (kgs)	537	49.4	90.80%
Structural Mat'l	Steel	PC	
Total (mpts)	2.04787	0.959	53.17%
CO2 Equivalents (kgs)	8.5841	17.7	-160.20%







### REDESIGNED REFRIGERATOR:

#### **Business Objectives**

The primary business objective of the redesigned refrigerator is to reduce the Beyond the environmental impacts associated with energy use and materials captured in the LCA, the winning design addressed other business metrics as well.

Reducing the weight of the unit from 186 to 97 pounds not only reduces the environmental impacts associated with shipping, but it also allows the user more freedom to place the unit where it is needed. The smaller size and kitchen-island-like form change the top of the fridge from a dust collector to useful food preparation surface.

By greatly improving the use-phase energy consumption, the cost savings on energy help to offset the increased purchase price associated with the vacuum-insulated panels when compared to the Concept model. It is expected that the purchase price of this unit would still be comparable to the Baseline model. The cost of the unit will play a significant role in the adoption rate of this innovative refrigerator.

The modular nature of the drawer system allows for direct reuse of components through a product take-back program, and while the extra transportation adds some environmental impacts, the savings associated with avoiding the landfill outweigh the costs. The end of product life is further improved by using less-toxic materials than the Baseline model.

A smaller unit will require a change in user behavior. To help encourage that change, the winning design incorporates a welcoming aesthetic, which combined with the lower sticker price and extreme long-term energy savings should encourage new users to try the product.

By identifying opportunities for improvement in a traditional model, a user-friendly, streamlined, and energy efficient model was identified. Design for function as opposed for form creates a more sustainable, common-sense model rooted in the benefits of the triple bottom line.



