Evaluating Cost and Energy Implications in Refrigerator Design

Amanda Regan, Felix Raj, & Cassie Allison
GE - Appliances & Lighting

FOR EDUCATIONAL AND INFORMATIONAL PURPOSES ONLY

All material included in this packet is fictional and is intended for the sole purpose of teaching engineering design and critical thinking skills

General Electric

- Operating in more than 100 countries for over 125 years
- Over 300,000 employees worldwide

Appliances & Lighting

Appliances

- HQ: Louisville, KY
- Eco-friendly appliances
- 486 Energy star rated appliances

Lighting

- HQ: East Cleveland, OH
- Concentration on energy efficiency
- LEDs & CFLs

Appliances & Lighting

$8B global business headquartered in Louisville

Global headquarters of GE Appliances & Lighting

- Appliance Park production began in 1953
- 3,200 employees on 900 acres
- Produces 3.6 million units per year
- Manufactures dishwashers, washers, & top-freezer refrigerators
- Location of 1st computer installed outside the U.S. government
- Research & Development complex
- Customer training facilities
- 40225 is the Park's dedicated zip code

Community Involvement

$4.2 million in contributions to Louisville in 2009 and ~9,000 volunteer hours

And, a great start to 2010….

$10.5 million grant from GE Foundation will help JCPS teachers prepare for new math, science curriculum

BY NANCY C. RODRIGUEZ • NRODRIGUEZ@COURIER-JOURNAL.COM • MARCH 19, 2010

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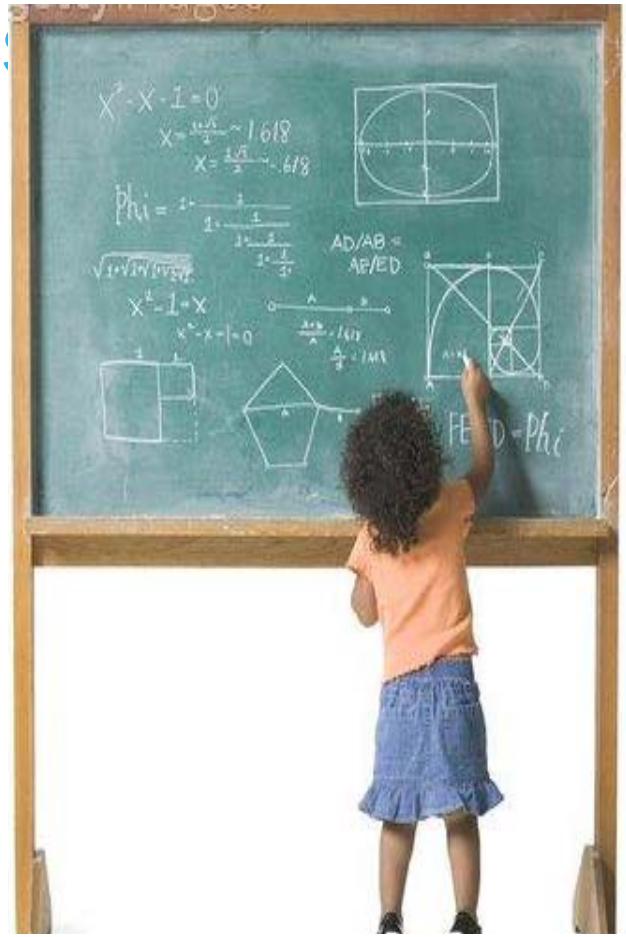
Jefferson County Public Schools has been awarded a $10.5million grant from the General Electric Foundation to further the major math and science initiative the company helped fund in 2005.



Total of $35.5 million from the GE Foundation to Jefferson County Public Schools since 2005

Refrigerator Design Simulation

Learning Objectives

- This is a critical thinking exercise that models the work performed by real engineers in a major global company and challenges students to hone their research and presentation skills
- In this simulation students will develop:
  - Critical thinking skills
  - Presentation skills
  - How to assess cost versus benefit
  - The importance of energy efficiency
  - Real world engineering tasks
  - Cross-functional business interactions between multiple teams including marketing, finance, manufacturing, and engineering
  - Math skills including percentages and rounding

Simulation Tasks

- Students will design a refrigerator that has the greatest profit and energy efficiency rating given a list of options and target market information.
- Students will evaluate the cost versus benefit on fifteen different features ranging from model and size to condenser and coolant used.
- Pre and post work modules will enhance the simulation with term definition, research, problem solving scenarios and discussion questions

Material List

- Computer with internet access (for pre-work assignments)
- Calculator
- Computer/projector in classroom with video capability (for movie)
- Scissors
- Tape
- Markers / Crayons
- Cereal/food boxes

Lesson Outline

- Pre simulation assignments (homework)
- Discussion & video (1 hour)
  - Common features and general opinions about students' refrigerators
  - Consumer trends
  - Government influences such as appliance rebates and "Made in USA" incentives
  - Importance of energy efficiency
- Simulation (2 hours)
  - Background story
  - Business challenges
- Post simulation analysis (1 hour)
- Wrap up discussion
- Presentations (1 hour)

Pre-work Assignments

- Research
  - Appliance manufacturers
  - Glossary terms
  - Consumer trends
  - Energy Star
- Study refrigerators at home noting features, size, type, color, storage space, and size restrictions
- Students bring in an empty cardboard food/cereal box

Glossary

Instructions: Use internet searches to define each term with as much detail as possible. Include pictures of at least 3.

Evaporator –

Compressor –

Auto-defrost -

Coolant –

Door Seal/Gasket –

Stainless Steel –

CleanSteel™ –

Kwh –

Energy Star –

Margin –

LED –

Incandescent lights –

Manufacturing Video

- This video is actual footage of dishwasher manufacturing in a GE Appliances factory.
  This video should be used to initiate conversation about how each manufacturing person performs the same job on each unit (assembly production) and how each job is critical to building a quality product for a consumer.

Background story

- “You and your team of refrigeration engineers work at Glacial Cool, Inc. Today, your company is selling 12 cubic foot compact refrigerators in the United States. Sales of these units are declining, as consumers are demanding more features and improved energy efficiency. Managers at Glacial Cool, Inc want to create an innovative and energy efficient refrigerator to meet changing customer needs with greater profits. Your marketing team has identified a number of options desirable to today’s consumers. You and your engineering team have been asked to evaluate the options to design the best appliance.”

- **The goal is to create the highest selling and most profitable refrigerator with the lowest energy usage**

Student Assignment/Simulation

Refrigerator Design Worksheet

Step 1: Choose your refrigerator type and input initial values from Marketing worksheet.

	OPTION	Cost ($)	Energy Usage (Kwh)	Sales Volume (#)	Margin ($)	Time to Market (days)
Base Unit	*COMPACT*	*$400*	*790*	*100,000*	*$50*	*0*
1 REFRIGERATOR						
(Example:	*Standard*	*+$0*	*+10*	*-2%*	*+$5*	*0)*

Step 2: Use Feature Selection Sheets for each refrigerator feature to design your appliance. Enter values on lines below.

2	ADDITIONAL VOLUME					
3	COLOR					
4	DOOR BINS					
5	FREEZER SHELVES					
6	BASKETS (1)					
7	BASKETS (2) *optional*					
8	BASKETS (3) *optional*					
9	AUTO DEFROST					
10	CONTROLS					
11	ICE MAKER					
12	DISPENSER					
13	BEVERAGE CENTER					
14	LIGHTS					
15	COOLANT					
16	EVAPORATOR					
17	DOOR SEAL					

Step 3: Sum each column to get TOTAL UNIT VALUE of your refrigerator choice.
***Sales Volume Total = Sum of % (#2 - #17) x Sales Volume (#1)**

TOTAL UNIT VALUE:				*		
BUSINESS CHALLENGE E-STAR BONUS		=				
FINAL RESULTS						

- Students should work together in teams of 4-5
- Each student should complete all pre/post work and simulation worksheets

Refrigerator Design Worksheet

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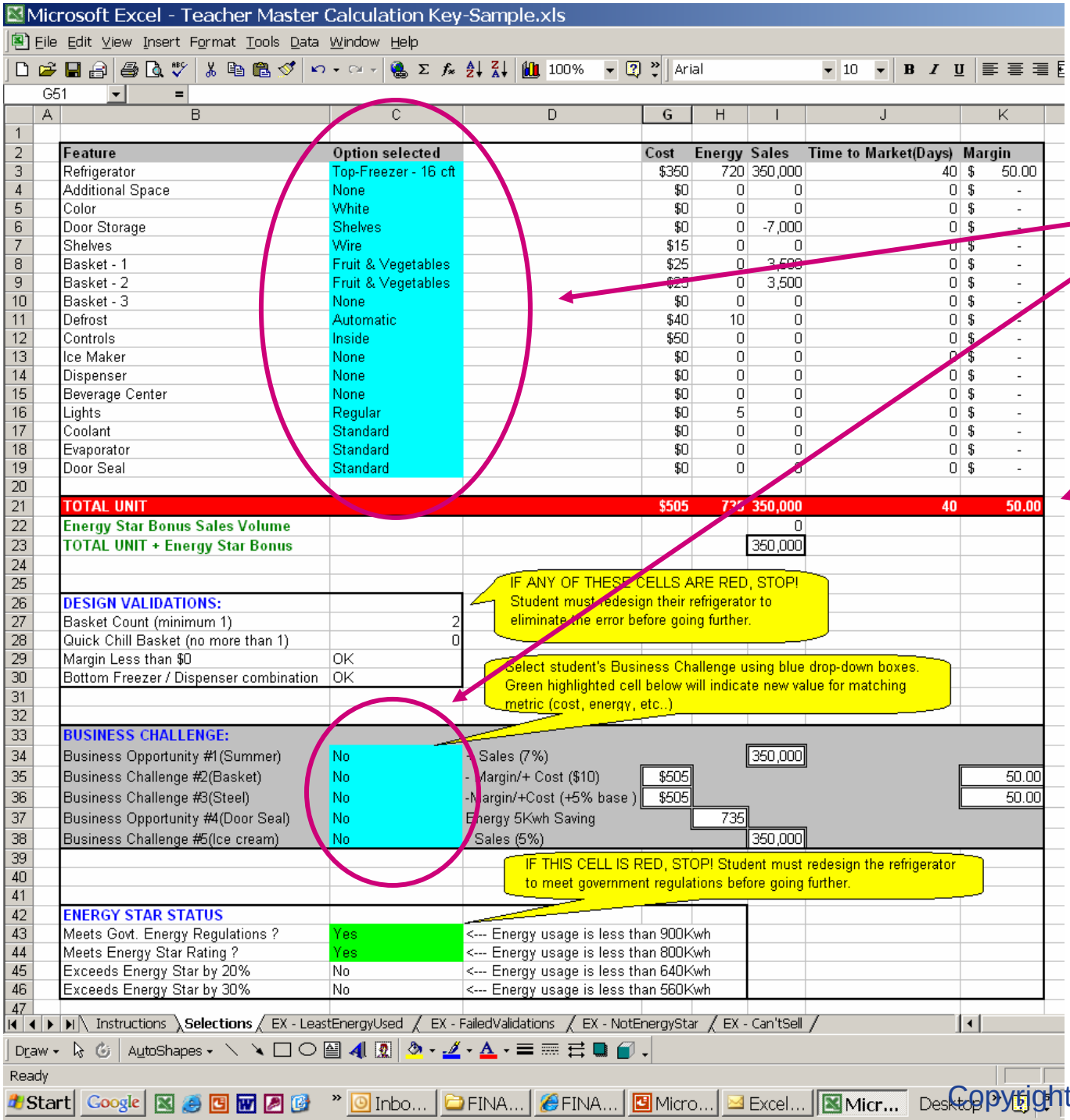
TOTAL UNIT VALUE:				*		
BUSINESS CHALLENGE E-STAR BONUS	=					
FINAL RESULTS						

- Teacher Master file contains solutions to check student work
- Teacher Master file contains “E-Star Bonus” for students who design the most energy efficient refrigerator



Modify the blue cells to match student worksheet

Verify student calculations here

Business Challenges

As students near completion of their feature selection each team should be assigned a Business Challenge

- Steel costs go up 20%, add 5% to initial base cost of refrigerator (not total sum)
- Your basket supplier goes bankrupt, new supplier raises piece price, add $10 to cost and reduce margin $10 (regardless of number of baskets).
- Your competitor unveils a new refrigerator one month before you do with an automatic soft serve ice cream dispenser; you lose 5% sales volume
- Your design team creates accelerated life testing to launch early, reducing time to market by 10 days
- Your new super efficient door seal testing comes in more favorably than expected; your energy usage savings is an additional 5Kwh.
- Summer temperatures are far above normal; consumer market for new refrigerators goes up 7%, added sales volume.

Refrigerator Feature Selections

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Marketing Worksheet

Unit:	Top Freezer	Bottom Freezer	Side by Side
Cost	$350.00	$550.00	$450.00
Energy	720 Kwh	700 Kwh	750 Kwh
Sales volume	350,000	250,000	200,000
Time to Market	40 days	40 days	45 days
Margin	$50.00	$75.00	$100.00
Size	16 cft	23 cft	20 cft

Refrigerator Types:

Top Freezer

Bottom Freezer

Side-by-Side

Feature: Additional Space

- Additional space can be added to increase the internal food storage capacity of the refrigerator
- Depending upon the unit chosen additional space can have a positive or negative effect on sales

Additional Space:	Cost	Energy	Sales Volume	Time to Market	Margin
Top Freezer + 2 cuft	$50.00	20 Kwh	+2%	0 days	$50.00
+ 4 cuft	$100.00	40 Kwh	+5%	1 day	$100.00
+ 6 cuft	$150.00	50 Kwh	-10%	3 days	$500.00
Bottom Freezer + 2 cuft	$50.00	20 Kwh	+2%	0 days	$50.00
+ 4 cuft	$100.00	40 Kwh	+5%	1 day	$100.00
+ 6 cuft	$150.00	50 Kwh	-10%	3 days	$50.00
Side by Side + 2 cuft	$50.00	20 Kwh	+2%	0 days	$50.00
+ 4 cuft	$100.00	40 Kwh	+5%	1 day	$100.00
+6 cuft	$150.00	50 Kwh	-10%	3 days	$50.00

Feature: Color

- The outside of the refrigerator is made of steel. It can be any color, but some sell better than others.
- Stainless steel is the biggest trend in the appliance industry, but it is not magnetic and has a tendency to show fingerprints
- CleanSteel™ looks identical to stainless steel, but it resists fingerprints and is magnetic

Color:	White	Black	CleanSteel™	Stainless Steel
Cost	$0.00	$0.00	$40.00	$20.00
Energy	0 Kwh	0 Kwh	0 Kwh	30 Kwh
Sales volume	0%	1%	20%	15%
Time to Market	0 days	0 days	2 days	1 day
Margin	$0.00	$50.00	$100.00	$200.00

White

Black

Stainless Steel

CleanSteel™

Feature: Door Storage

- Door shelves are low in cost but cannot contain small items.
- Door bins conveniently hold large items like milk and can also contain small items.

Door Storage:	Shelves	Gallon Size Bins
Cost	$0.00	$40.00
Energy	0 Kwh	0 Kwh
Sales Volume	-2%	0
Time to Market	0 days	1 day
Margin	$0.00	$10.00

Shelves

Gallon Size Bins

Feature: Shelves

- Inexpensive wire shelves are a basic feature but are not sturdy for small objects
- Spill proof glass shelves have a raised border allowing them to hold up to a ½ gallon of spilled liquid

Shelves:	Wire	Glass	Spill Proof Glass
Cost	$15.00	$25.00	$40.00
Energy	0 Kwh	0 Kwh	0 Kwh
Sales Volume	0	3%	5%
Time to Market	0 days	0 days	1 day
Margin	$0.00	$10.00	$25.00

Wire

Glass

Spill Proof Glass

Feature: Baskets

6, 7, 8

Baskets:	Meat & Cheese	Fruit & Vegetable	Full Size Meat	Quick Chill
Cost	$25.00	$25.00	$50.00	$90.00
Energy	0 Kwh	0 Kwh	0 Kwh	20 Kwh
Sales Volume	1%	1%	1%	8%
Time to Market	0 days	0 days	0 days	1 day
Margin	$0.00	$0.00	$0.00	$40.00

- Baskets are features that consumers use to evaluate the style and organization of a refrigerator
- You may choose up to three baskets for your refrigerator and can have a maximum of one Quick Chill basket
- Full Size Meat baskets are twice as big as the Meat & Cheese and Fruit & Vegetable baskets
- Quick Chill baskets circulate extra cool air to bring the food inside to the desired temperature quicker

Feature: Defrost

Defrost:	Automatic	Manual
Cost	$40.00	$0.00
Energy	10 Kwh	-20 Kwh
Sales Volume	0	-25%
Time to Market	0 days	0 days
Margin	$0.00	-$100.00

- Cooling tubes carry heat away from the food storage areas, cooling the refrigerator
- Water in the air freezes on the cooling tubes and walls of the freezer causing a build-up of frost, which reduces the energy efficiency and usable space of the unit
- An automatic defrost system includes a heating element attached to the tubes that cycles heat on and off to melt the frost
- If the defrost process is manual consumers need to hand scrape the frost off the tubes and freezer walls to keep the refrigerator operating at peak efficiency

Feature: Controls

- Controls set the temperatures of the refrigerator and freezer
- All options shown here are digital but some refrigerators are controlled by knobs
- Touch screen controls allow more options such as precise dispensing, recipe displays, and nutrition information

Controls:	Inside	Outside	Touch screen
Cost	$50.00	$75.00	$300.00
Energy	0 Kwh	-30 Kwh	20 Kwh
Sales Volume	0	3%	5%
Time to market	0 days	5 days	15 days
Margin	$0.00	$20.00	$50.00

Inside

Outside

Touch Screen

Feature: Ice Maker

- Consumers in the United States like to have automatic ice makers
- If no icemaker is included consumers have to manually make ice in ice trays

Ice Maker:	Included	None
Cost	$30.00	$0.00
Energy	20 Kwh	0 Kwh
Sales Volume	15%	0
Time to Market	1 day	0 days
Margin	$20.00	$0.00

Feature: Dispenser

Water & Ice

Water Only

Dispenser:	None	Water & Ice	Water Only
Cost	$0.00	$40.00	$25.00
Energy	0 Kwh	20 Kwh	20 Kwh
Sales Volume	0	10%	5%
Time to Market	0 days	2 days	1 day
Margin	$0.00	$60.00	$25.00

- Water only dispensers are inside the unit; water & ice dispensers are outside the unit
- Currently your research team does not have a method for installing a dispenser on a bottom freezer refrigerator

Feature: Beverage Center

•Beverage Centers are small pull-down doors in the refrigerator door.
•Through this door, consumers can access one of the door storage bins inside the refrigerator

Beverage Center:	None	Yes
Cost	$0.00	$50.00
Energy	0 Kwh	-10 Kwh
Sales volume	0%	5%
Time to Market	0 days	1 day
Margin	$0.00	$50.00

Feature: Lights


LED

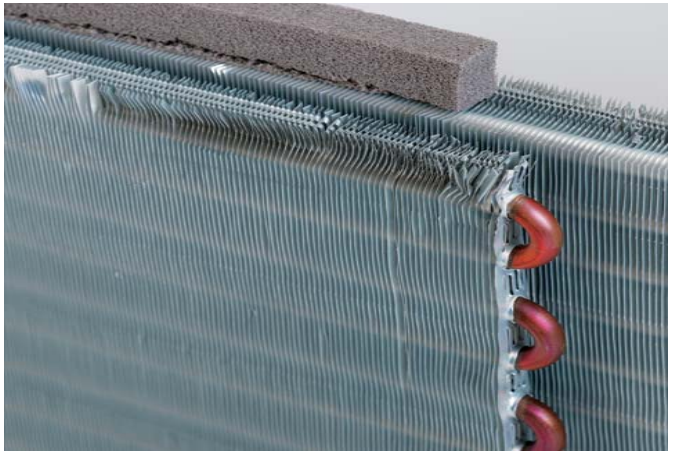

Incandescent

Lights:	Incandescent	LED
Cost	$0.00	$12.00
Energy	5 Kwh	-10 Kwh
Sales volume	0%	5%
Time to Market	0 days	0 days
Margin	$0.00	$10.00

•Lights placed in the refrigerator and freezer illuminate the food storage areas
•Incandescent lights are less expensive than LED lights but are less energy efficient
•LED lights last 40 times longer than incandescent lights

Feature: Coolant & Evaporator

- Refrigerators circulate a coolant gas through a series of tubes to carry heat away from the food storage areas, cooling the refrigerator
- The coolant transforms from a liquid to a gas and absorbs heat inside the evaporator
- The standard evaporator is reliable. The new custom evaporator has more surface area and can transfer heat more efficiently
- Your research team has recently discovered a new super efficient coolant that will be ready for production in a few months



Coolant:	Standard	Super
Cost	$0.00	$60.00
Energy	0 Kwh	-20 Kwh
Sales volume	0%	10%
Time to Market	0 days	90 days
Margin	$0.00	$40.00

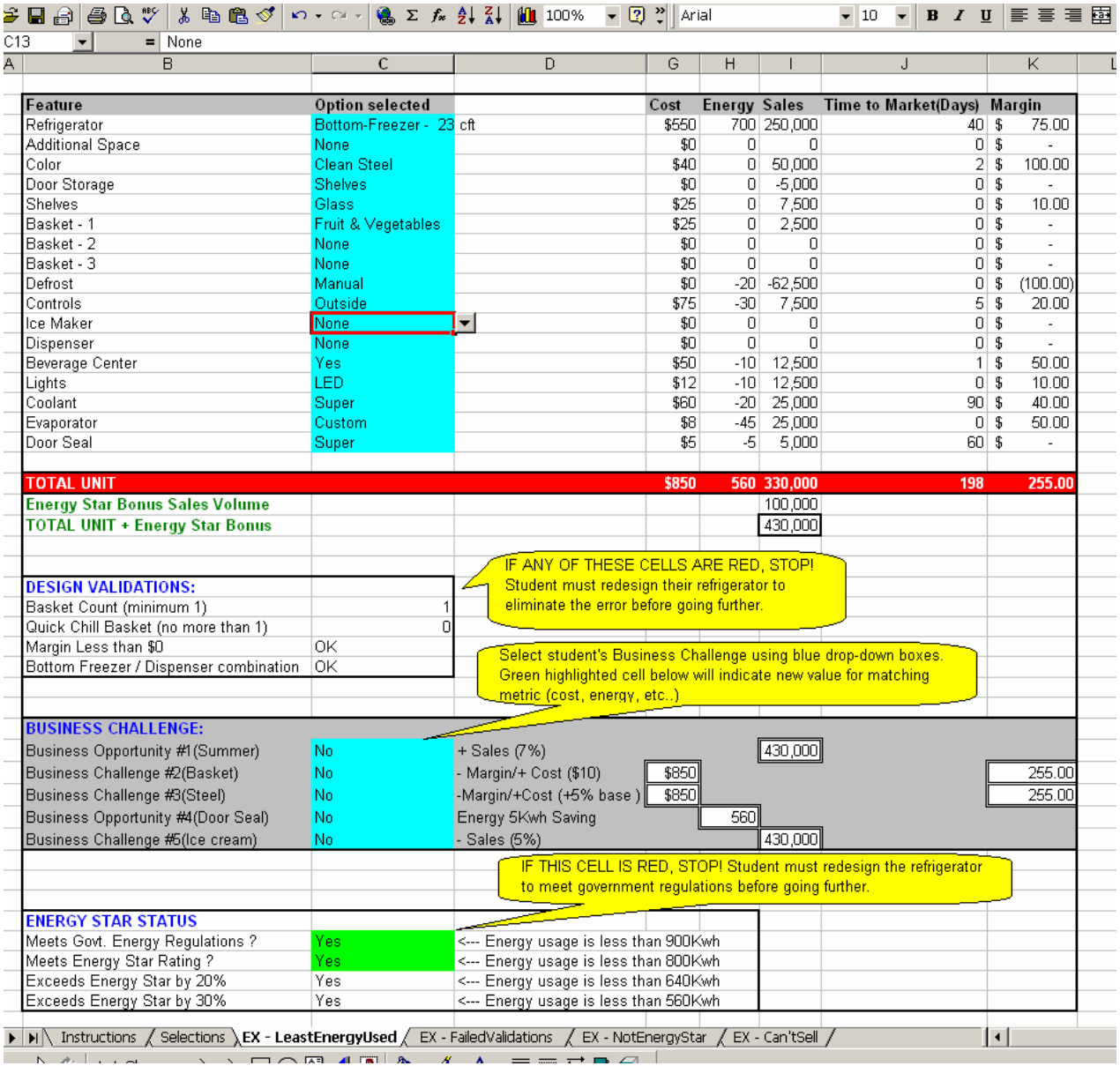
Evaporator:	Standard	Custom
Cost	$0.00	$8.00
Energy	0 Kwh	-45 Kwh
Sales volume	0%	10%
Time to Market	0 days	0 days
Margin	$0.00	$50.00

Feature: Door Seal

- A rubber gasket is used to seal the door to the refrigerator to minimize temperature loss
- The current gasket works fine, but the research team says they can make a better one out of a new material with a triple layer seal

Door Seal:	Standard	Super
Cost	$0.00	$5.00
Energy	0 Kwh	-5 Kwh
Sales volume	0%	2%
Time to Market	0 days	60 days
Margin	$0.00	$0.00

Simulation Process Check



C13 = None

Feature	Option selected		Cost	Energy	Sales	Time to Market(Days)	Margin
Refrigerator	Bottom-Freezer - 23	cft	$550	700	250,000	40	$ 75.00
Additional Space	None		$0	0	0	0	$ -
Color	Clean Steel		$40	0	50,000	2	$ 100.00
Door Storage	Shelves		$0	0	-5,000	0	$ -
Shelves	Glass		$25	0	7,500	0	$ 10.00
Basket - 1	Fruit & Vegetables		$25	0	2,500	0	$ -
Basket - 2	None		$0	0	0	0	$ -
Basket - 3	None		$0	0	0	0	$ -
Defrost	Manual		$0	-20	-62,500	0	$ (100.00)
Controls	Outside		$75	-30	7,500	5	$ 20.00
Ice Maker	None		$0	0	0	0	$ -
Dispenser	None		$0	0	0	0	$ -
Beverage Center	Yes		$50	-10	12,500	1	$ 50.00
Lights	LED		$12	-10	12,500	0	$ 10.00
Coolant	Super		$60	-20	25,000	90	$ 40.00
Evaporator	Custom		$8	-45	25,000	0	$ 50.00
Door Seal	Super		$5	-5	5,000	60	$ -
TOTAL UNIT			**$850**	**560**	**330,000**	**198**	**255.00**
Energy Star Bonus Sales Volume					100,000		
TOTAL UNIT + Energy Star Bonus					430,000		

IF ANY OF THESE CELLS ARE RED, STOP! Student must redesign their refrigerator to eliminate the error before going further.

DESIGN VALIDATIONS:	
Basket Count (minimum 1)	1
Quick Chill Basket (no more than 1)	0
Margin Less than $0	OK
Bottom Freezer / Dispenser combination	OK

Select student's Business Challenge using blue drop-down boxes. Green highlighted cell below will indicate new value for matching metric (cost, energy, etc..)

BUSINESS CHALLENGE:						
Business Opportunity #1(Summer)	No	+ Sales (7%)			430,000	
Business Challenge #2(Basket)	No	- Margin/+ Cost ($10)	$850			255.00
Business Challenge #3(Steel)	No	-Margin/+Cost (+5% base)	$850			255.00
Business Opportunity #4(Door Seal)	No	Energy 5Kwh Saving		560		
Business Challenge #5(Ice cream)	No	- Sales (5%)			430,000	

IF THIS CELL IS RED, STOP! Student must redesign the refrigerator to meet government regulations before going further.

ENERGY STAR STATUS		
Meets Govt. Energy Regulations ?	Yes	<--- Energy usage is less than 900Kwh
Meets Energy Star Rating ?	Yes	<--- Energy usage is less than 800Kwh
Exceeds Energy Star by 20%	Yes	<--- Energy usage is less than 640Kwh
Exceeds Energy Star by 30%	Yes	<--- Energy usage is less than 560Kwh

Instructions | Selections | EX - LeastEnergyUsed | EX - FailedValidations | EX - NotEnergyStar | EX - Can'tSell

Post Analysis Questions

Post Analysis – Teacher Guide

Question #1: If your current 12 cuft refrigerator has annual sales of 100,000 units with a profit margin of $50, use your results from the Refrigerator Design Worksheet to calculate your total profit for the year for both refrigerators (remember to use "Time to Market" in your calculation).

100,000 x $50 = $5,000,000 for 12cuft refrigerator annually

+ (sales volume) x (margin) x (1-(time to market/365))

Question #2: The compressor required in a refrigerator is directly proportional to the size of the refrigerator. Match the compressors to the appropriate refrigerators.

Small compressor	48cuft refrigerator
Medium compressor	16 cuft refrigerator
Large compressor	25 cuft refrigerator

Question #3: Consumers want refrigerators with ice makers capable of producing lots of ice quickly. Look at the picture of the ice maker on the option sheet and think of 3 ways you would redesign that area to satisfy consumers. What are the disadvantages of each?

- Add a second icemaker – cost of additional icemaker, less food storage space in freezer, can only make as much ice as bucket will hold
- Redesign the ice bucket to be wider and/or taller – can't make ice faster, more plastic material for bucket will raise cost, less food storage space in freezer
- Innovative solutions – redesign icemaker, redirect airflow in freezer to freeze ice quicker, etc...

Question #4: How would you change the design of your refrigerator to be handicap accessible? Think about arm reach and strength of the individual and describe where you would place the different features in the unit.

- Pull force to open refrigerator door needs to be reduced
- Dispenser with refrigerator controls needs to be accessible to seated person
- Heavy items (milk, juice, soda can rack, etc.) stored below shoulder height of seated person for ease of reach
- SxS and Top Freezer refrigerators may be better suited to handicapped people than bottom freezer with pull-out drawer.
- Innovative solutions – design pull-out shelves, design a shorter/wider refrigerator, etc...

Post Analysis – Teacher Guide

Question #5: Your supplier of water filters currently packages the parts in cardboard boxes of 50. The boxes are only used once and discarded. They cost $3/box. How much will it cost to purchase enough boxes for the whole year?

(sales volume) / 50 = number of boxes needed per year (Round up to next whole box)

Number of boxes needed per year * $3 = cost/year

Question #6: Vibration of the cardboard box packaging during shipping and flexibility of the containers causes damage to 2% of the water filters shipped to your factory. How many boxes of parts do you need to supply the factory for production for one year?

((sales volume) + (sales volume x 0.02)) = number of water filters needed

Number of parts / 50 = number of boxes needed per year (Round up to next whole box)

Question #7: The purchasing team at your company negotiates a rate of $12 for a plastic reusable container to replace the cardboard box pack. The plastic container holds 100 water filters and prevents damage. Your company plans to buy enough containers to reuse each of them 3 times/year. The total transportation cost of shipping the containers back to the supplier is $150/year. Which packaging is cheaper for the year – cardboard boxes or plastic container? Note: Break this down into multiple steps.
A Calculate the number of plastic containers you will need to ship all the parts (remember to divide by 3 and round up since the containers will be reused 3 times).
B Calculate the cost for the plastic containers and transportation cost.
C Calculate the cost of the cardboard boxes (cost/box from Question #5 and number of boxes from Question #6)

A (sales volume) / 100 = number of plastic containers needed

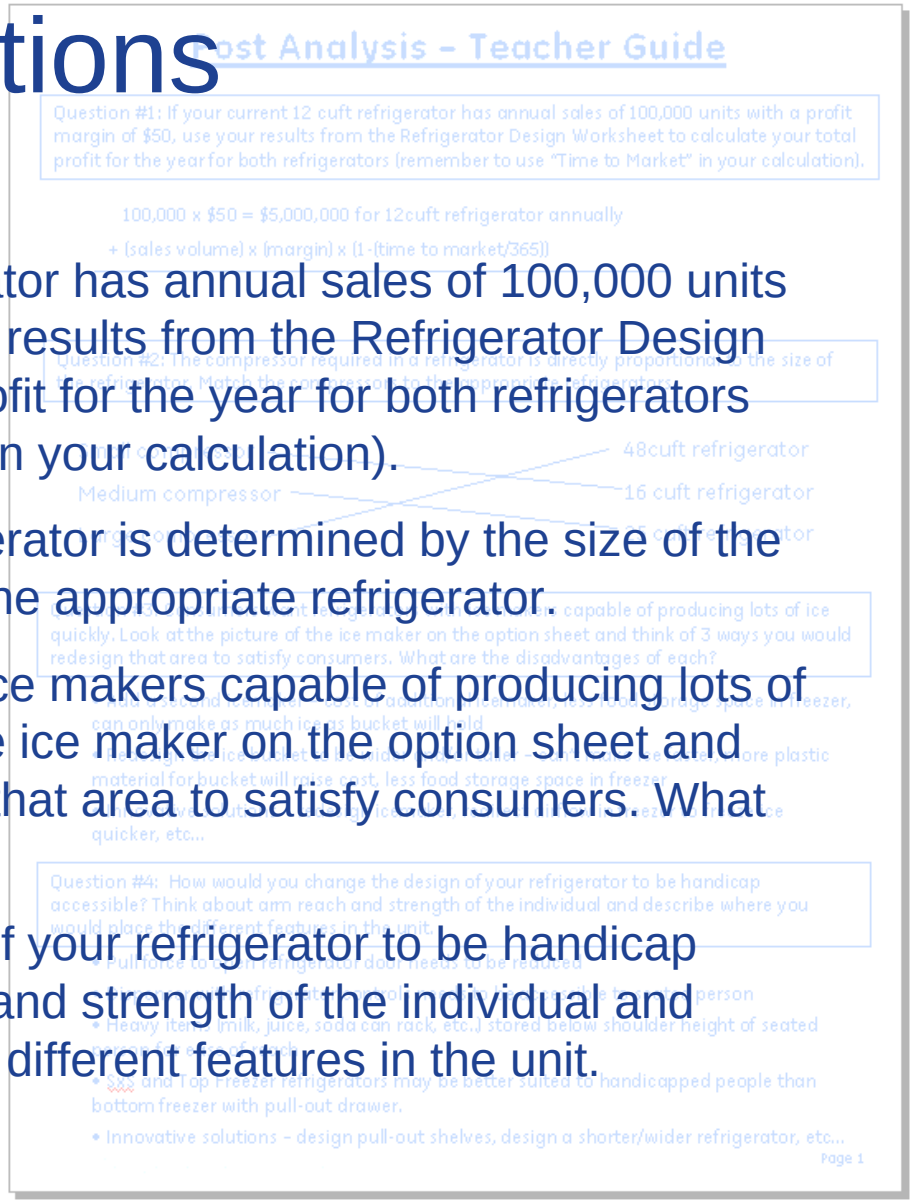
number of plastic containers needed / 3 = number of plastic containers purchased

B (number of plastic containers purchased * $12) + $150 = total cost of plastic containers

C ($3/box * number of boxes needed per year (from Question #6) = total cost of boxes

FINAL NOTE: Compare results of B to C to determine which cost is smaller/year

Post-analysis questions



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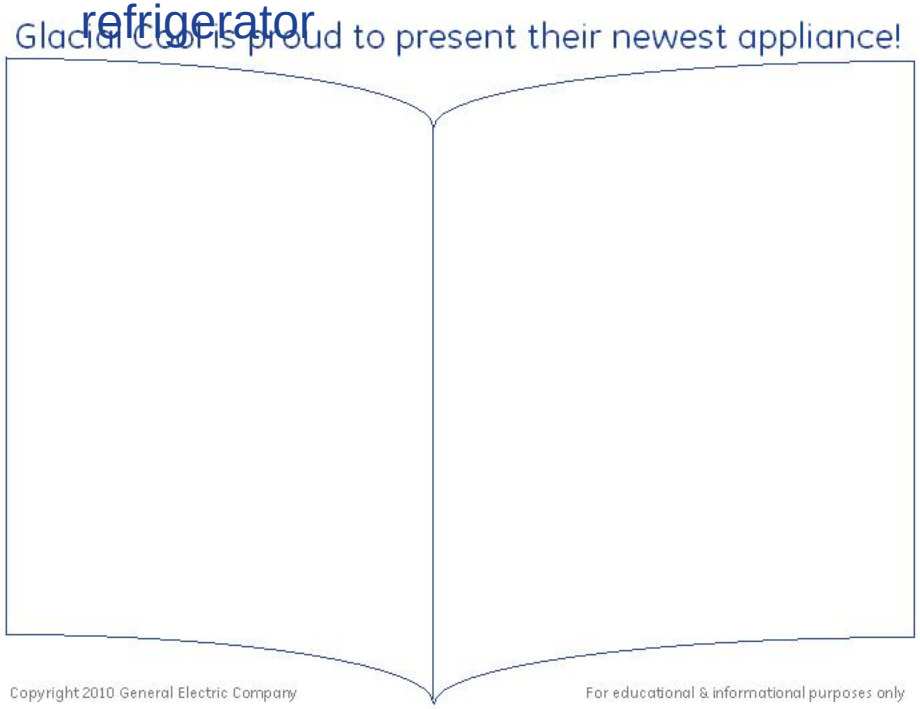
2. The compressor required in a refrigerator is determined by the size of the unit. Match the compressor size to the appropriate refrigerator.
3. Consumers want refrigerators with ice makers capable of producing lots of ice quickly. Look at the picture of the ice maker on the option sheet and think of 3 ways you would redesign that area to satisfy consumers. What are the disadvantages of each?
4. How would you change the design of your refrigerator to be handicap accessible? Think about arm reach and strength of the individual and describe where you would place the different features in the unit.

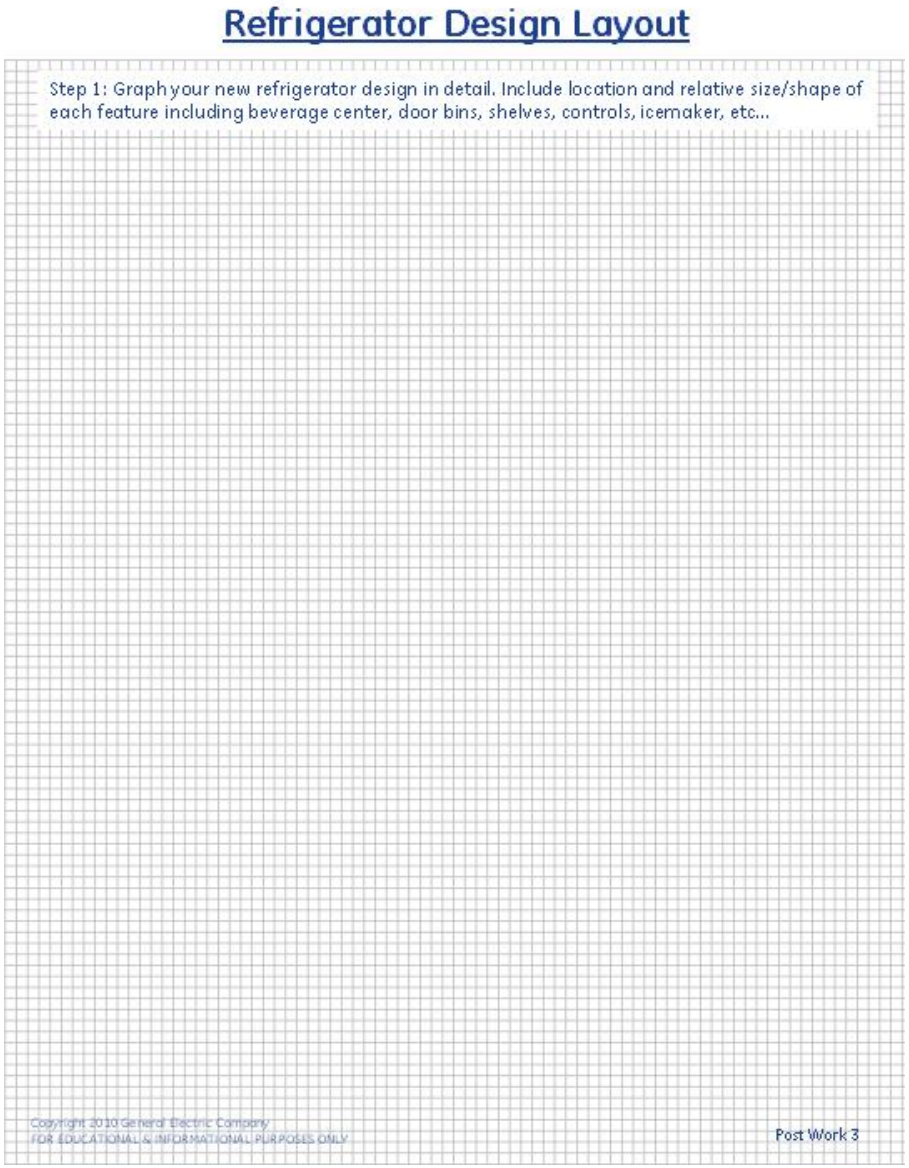
Post-analysis questions continued

5. Your supplier of water filters currently packages the parts in cardboard boxes of 50. The boxes are only used once and discarded. They cost $3/box. How much will it cost to purchase enough boxes for the whole year?
6. Vibration of the cardboard box packaging during shipping and flexibility of the containers causes damage to 2% of the water filters shipped to your factory. How many boxes of parts do you need to supply the factory for production for one year?
7. The purchasing team at your company negotiates a rate of $12 for a plastic reusable container to replace the cardboard box pack. The plastic container holds 100 water filters and prevents damage. Your company plans to buy enough containers to reuse each of them 3 times/year. The total transportation cost of shipping the containers back to the supplier is $150/year. Which packaging is cheaper for the year – cardboard boxes or plastic container? Note: Break this down into multiple steps.

Product and Marketing Design

- Students use graph paper to draw the layout of their refrigerator indicating the locations of all its features
- Students create an advertising campaign to market their refrigerator to consumers
- Students use the cardboard food/cereal box to create a 3D mock-up of their refrigerator





Questions?

Thank you for coming!