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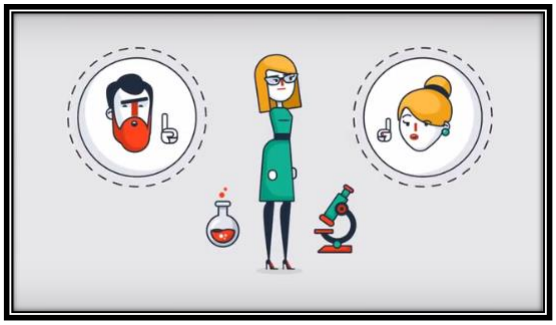

- Know your career options
- Develop strategies to strengthen your skills
- Map a plan to achieve your career goals

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Mark DeWitt, Project Scientist, Innovative Genomics Institute, UC Berkeley

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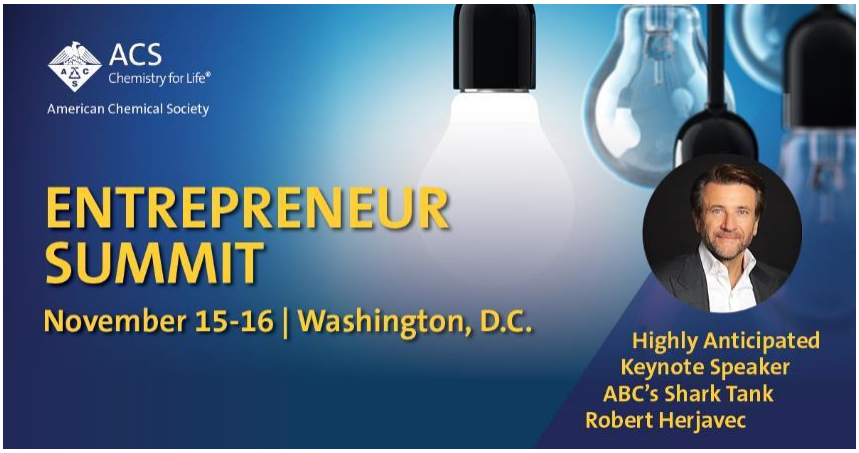

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We are all consumers!

* We buy products and services; they all have impacts, they are all primed for improvement with respect to environmental footprint.

14

If you're at a US university in the chemical sciences (chem. & chem. Eng.), **it's very hard to incorporate sustainable product design into your program**

- **Product design** (core to mechanical engineering).
- **Life cycle impact analysis** (core to civil & environmental engineering).
- **Project management** (core to business schools, industrial engineering).
- Etc.

Hence, a whirlwind trip through sustainable chemical product design: merging cutting edge product design paradigms with use of sustainability metrics

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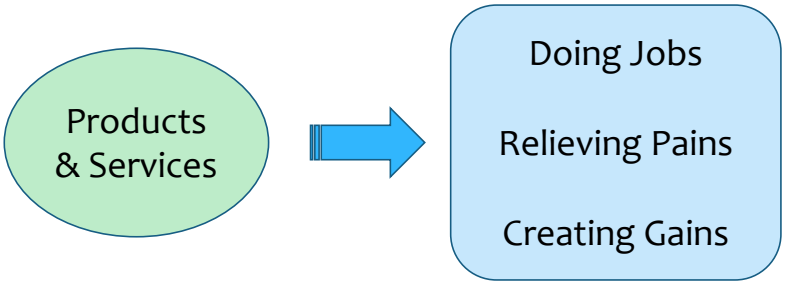


16

Jobs: Functional, social, emotional

What functional jobs are you helping your customer get done?
(e.g. perform or complete a specific task, solve a specific problem, ...)

What social jobs are you helping your customer get done?
(e.g. trying to look good, gain power or status, ...)

What emotional jobs are you helping your customer get done?
(e.g. esthetics, feel good, security, ...)

What basic needs are you helping your customer satisfy?
(e.g. communication, sex, ...)

17

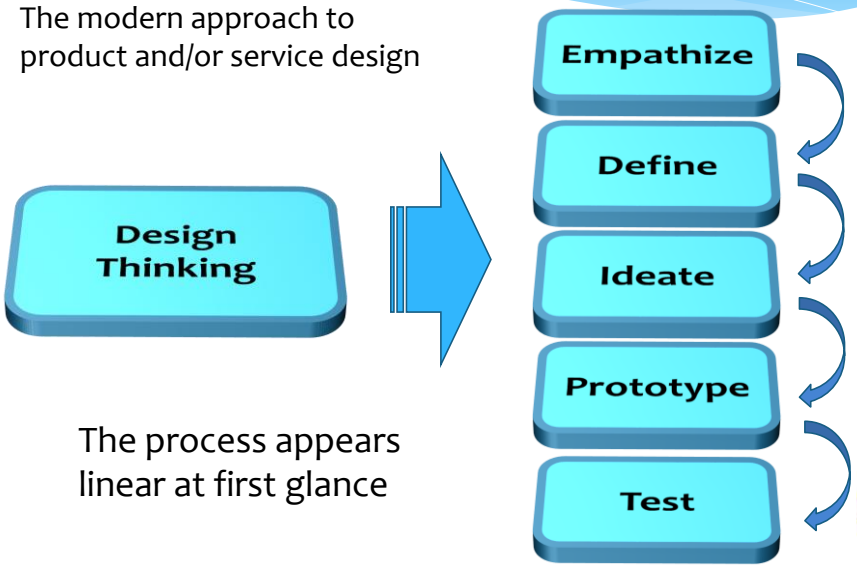
Modern Approach to Product Design: Design Thinking

"a ***human centered*** innovation process that emphasizes observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, and concurrent business analysis"

18

Design Thinking: Customer Focus

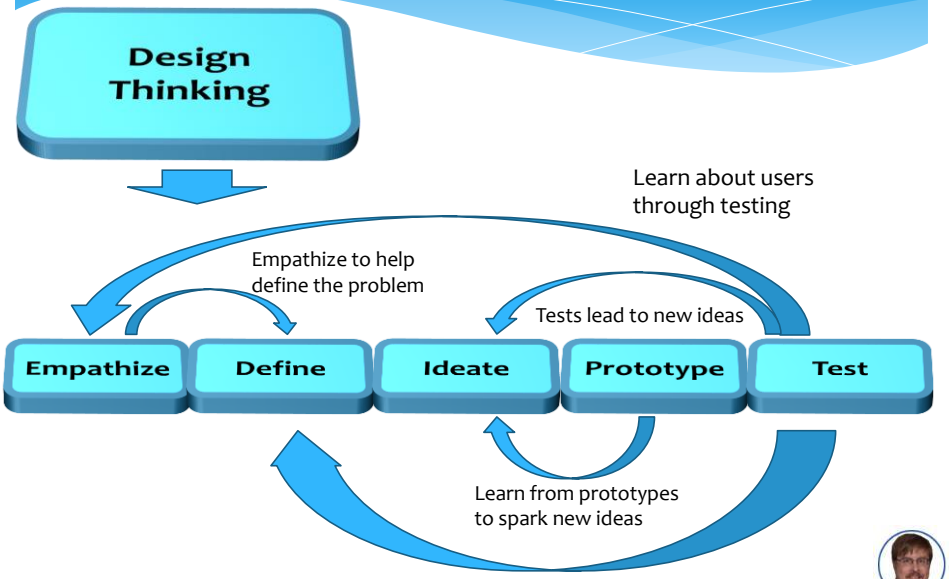
The modern approach to product and/or service design



The process appears linear at first glance

19

A Nonlinear Process



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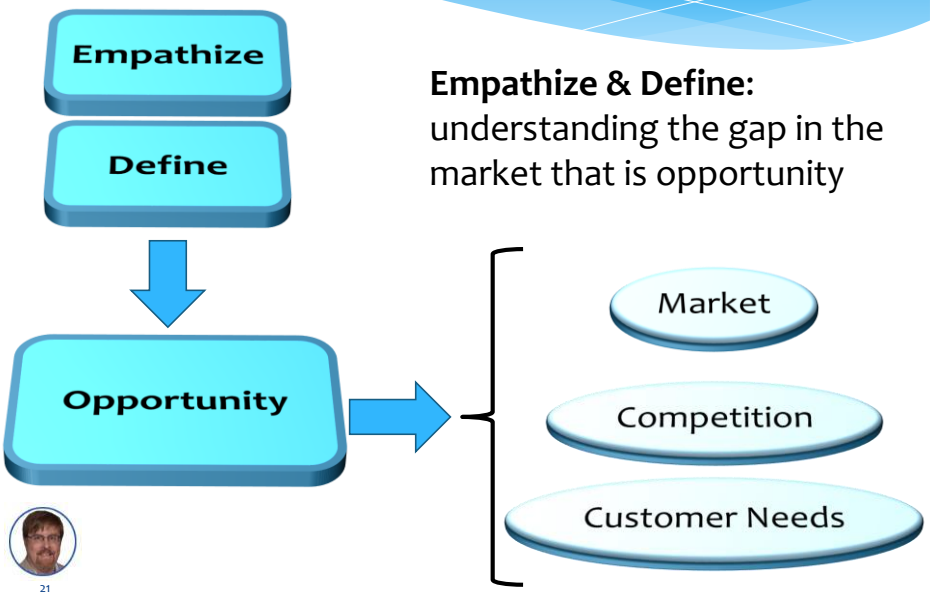
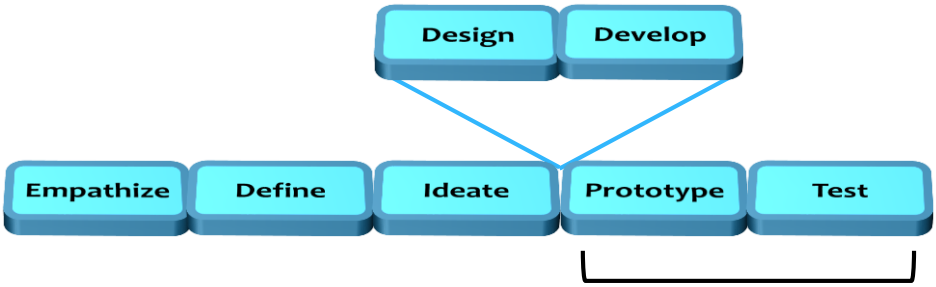


Empathize & Define:
understanding the gap in the market that is opportunity

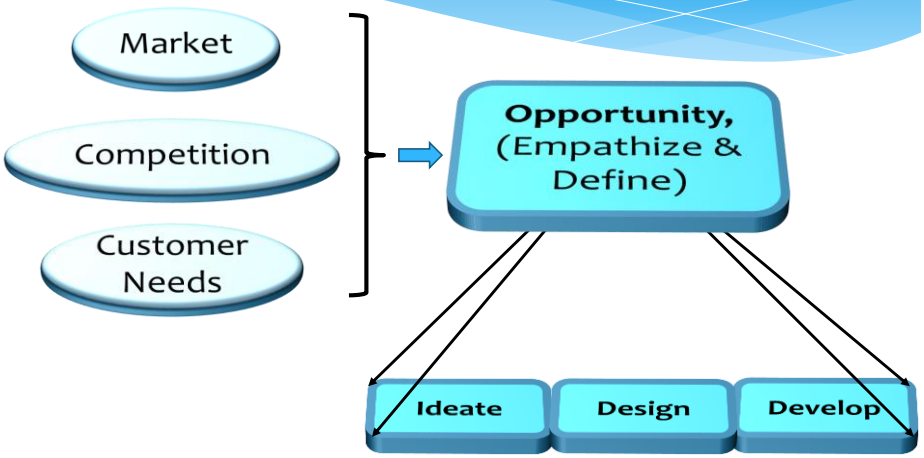
Adaptation to Molecular Products Not Straightforward



Rapid prototyping far easier to accomplish for widgets and software

Molecular MakerSpace?
Process issues?
Regulatory issues?

A Hybrid Process



Still relies heavily on customer interaction

23

Desired customer outcomes?

- **Ethnography** (craft the hypothesis)
- **Voice-of-the-customer** (try to confirm the hypothesis)
- **Further Confirmation:** Getting prototypes into customers' hands.

24

The key to **ethnography = observation** (initially) *without* hypothesis……the hypothesis comes as a result of the interaction.

Uncovering the Hidden Obvious

25

Uncovering desired outcomes: use of ethnography

Observing customers interacting with products; gaining insight not found from focus groups alone.

"If I had asked my customers, they would have wanted faster horses"

Henry Ford (well, not really…)

26

Ethnography and product design

27

Ethnography and product design

When asked about motors, sportsmen said that color and style were unimportant, but ethnographers noticed that they **tended to coordinate** their motors with their boats….and even their trucks.

28

Ethnography and product design

Further, observation suggested that the back pain suffered by fishermen was due to poor ergonomics of the foot pedal

- **Customers will say one thing, but do another**
- **Customers may not be aware of how they are altering their behavior to accommodate designs presented to them.**

29

Cognitive Bias: stuff that leads you down the wrong path

* **Say/Do Gap**: Researchers have found that consumers were not reliable predictors of their own purchase behavior for any of the types of goods studied. Even focus groups have a high error rate and routinely fail to perform satisfactorily.

What people say, what they do, and what they say they do are entirely different things

Attributed to Margaret Mead

30

Audience Challenge Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

An classic example of "Say/Do Gap" is New Coke…how much did they spend in 1985 on consumer interviews?

- About $100,000
- About $500,000
- About $ 1 million
- About $ 2.5 million
- About $ 4 million

31

The Say/Do Gap, if misread, can have catastrophic consequences

* **New Coke (April 23, 1985)**
  * $4 million and 200,000 consumer interviews
  * In focus groups, consumers clearly preferred sweeter "new Coke"

32

The Say/Do Gap, if misread, can have catastrophic consequences

- **New Coke (April 23, 1985)**
  - $4 million and 200,000 consumer interviews
  - In focus groups, consumers clearly preferred sweeter "new Coke"
  - In reality, consumers felt "a bond" with old Coke; classic Coke introduced 79 days later.

33

➔ Design Firm Sundberg-Ferar asked residents of a senior living community if they had problems with their walkers. **"We asked them for an hour: Is there anything you could do differently with this walker?"** he said. **"But, no, everyone loved the product."**

34

➔ Design Firm Sundberg-Ferar asked residents of a senior living community if they had problems with their walkers. **"We asked them for an hour: Is there anything you could do differently with this walker?"** he said. **"But, no, everyone loved the product."**

➔ As the group left the room and returned to the walkers, company researchers quickly noted how the customers had been working to improve the product, ***essentially unbeknownst to themselves***. "One woman has a bicycle basket tied with shoe laces to the front of the walker to carry stuff"; "Another guy had taken duct tape and fashioned a cradle for his phone".

35

"For 18 additional cents, we added a place for their telephone, bottle of aspirin, their magazine, all those things they can't carry," -- "And now this product has a compelling competitive advantage over other walkers."

36

Ethnography leads to a hypothesis

* Customer interviews
* Customer surveys
* Rapid prototyping and customer trials

If we understand desired customer outcomes, we can then propose novel concepts to address them.

37

Ideation to create novel concepts

Concept vs. Design?

* Concept is a broader grouping, contains multiple possible manifestations of actual designs, *all of which* satisfy the key desired customer outcome(s).
* Design is specific - incorporates features (which lead to specifications) + molecular structures, specific materials, costing

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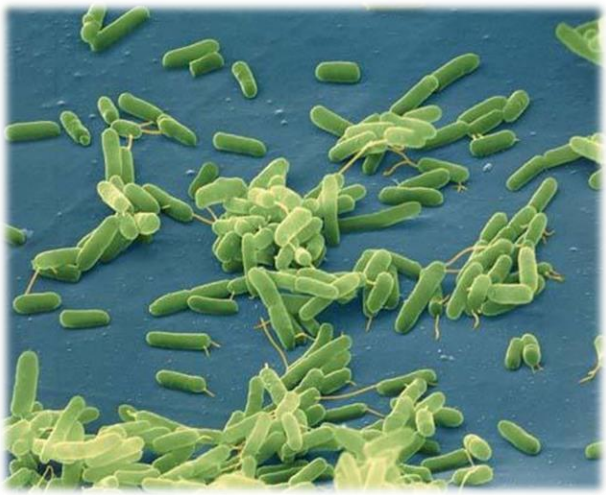
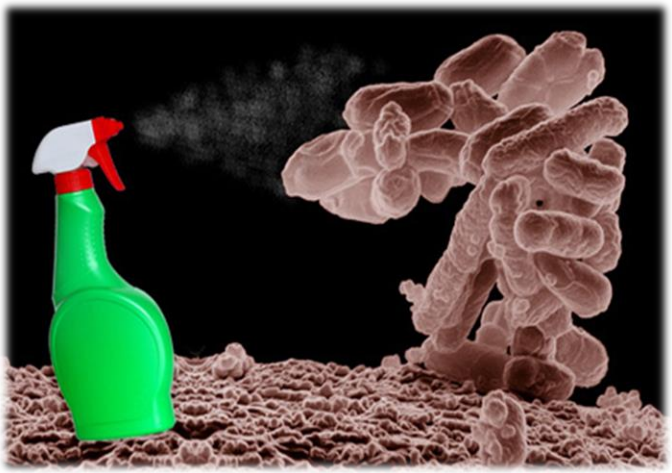


Customer desired outcome is *no bacteria on surfaces*

39



We could sell them a spray…..

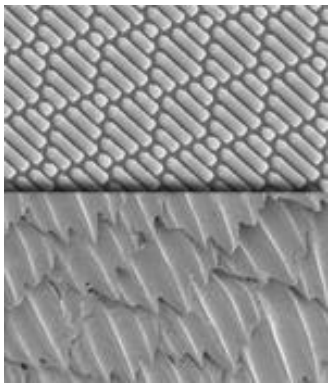
40

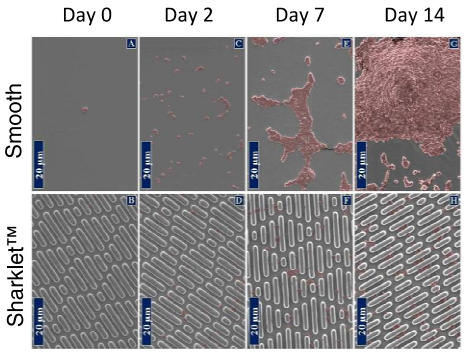
Customer desired outcome is *no bacteria on surfaces*

We could sell them a "greener" spray

41

Sharklet Technologies (Aurora, CO) patterned surface





Shark skin: Very low surface frictional drag;
B. Dean & B. Bhushan, *Phil. Trans. Roy. Soc. A* (2010); 368, 4775-4806

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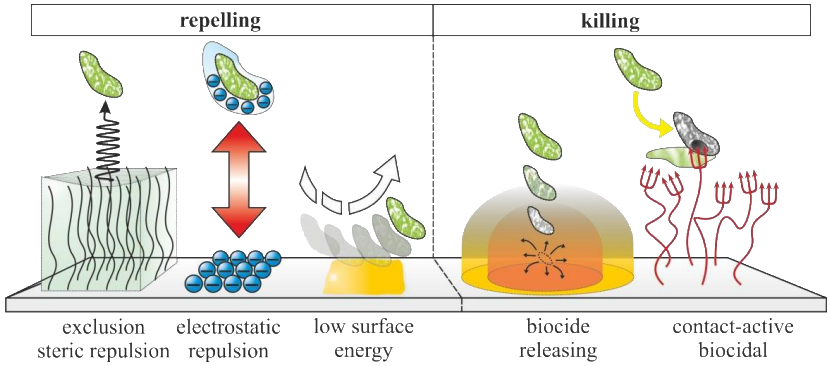
Numerous Surface Concepts



Siedenbiedel & Teller, Polymers (2012)

43

Concepts can be chemical or "non-chemical"

Xenex's "Violet" robot in an OR.

44

Concept versus Design

Example: Desired customer outcome = “no bacteria on surfaces”

Concept 1: = “anti-bacterial spray”

Design 1A = spray of triclosan + ethanol
Design 1B = spray of lactic acid/water

Concept 2: “Anti-bacterial surface”

Design 2A = ammonium *chloride-functional acrylic coating*
Design *2B = Coating impregnated with silver nanoparticles*
Design *2C = shark scale mimic (Sharklet, Aurora, CO)*

Concept 3: “Radiation”

Design 3A = UV emitting robot

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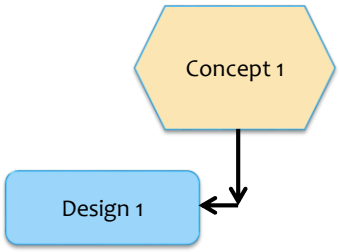
Concepts & Designs



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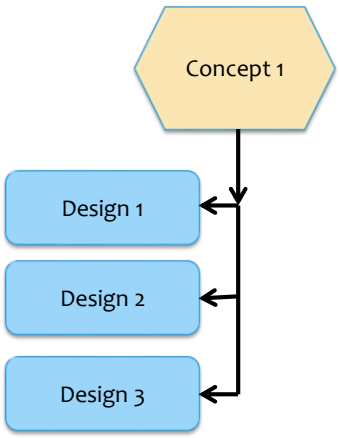
Concepts & Designs



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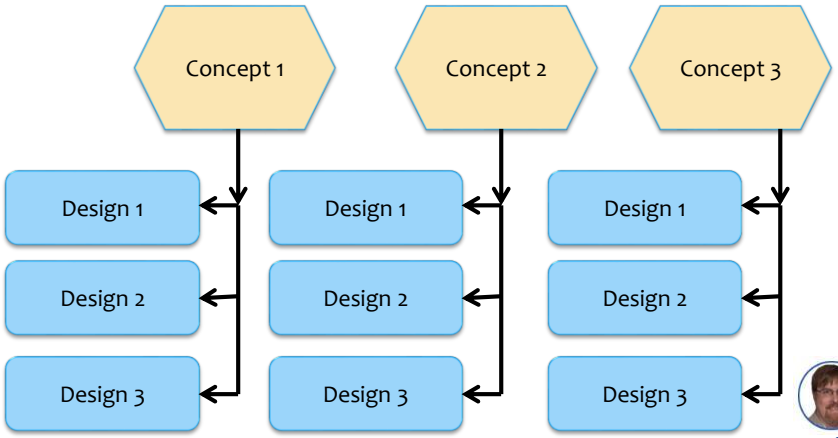
Concepts & Designs



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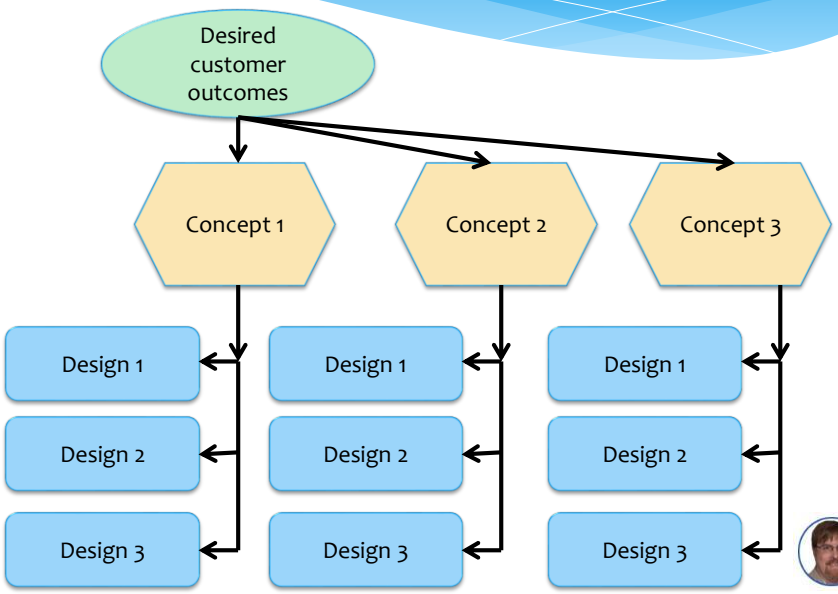
Concepts & Designs



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Cognitive Bias: stuff that leads you down the wrong path

- **Projection Bias**: tendency to over-estimate the extent to which their future experience will resemble their current experience [hence the famous line from DEC Computer CEO Ken Olsen, "***there's no reason for any individual to have a computer in his home***"].
- **Egocentric Empathy Gap**: Decision-makers overestimate the similarity between what they value and what others value.

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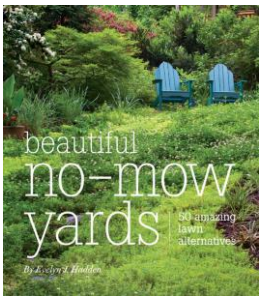
Needs versus Solutions

51

Needs versus Solutions

52

Needs versus Solutions



"no-mow" grass

53

Needs versus Solutions

We sell mowers

I want a nice looking yard

"no-mow" grass

54

Using goats to clear brush from "difficult" lots

55

Adding Sustainability?

- Sustainability, environmental performance as a design constraint (as a specification)?
- The environment as a "customer"?
- Using sustainability as a desired customer outcome during concept ideation?
- Use environmental problems inherent to competitive products as a means for finding opportunity?

Not all customers desire sustainability in their products, but no customer desires hazard

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A Variety of Green Opportunities

BPA FREE

Walmart To Ban Toxic Chemicals From Some Products

By ANNE D'INNOCENZIO 09/12/13 04:30 PM ET EDT

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Life Cycle Impact Analysis

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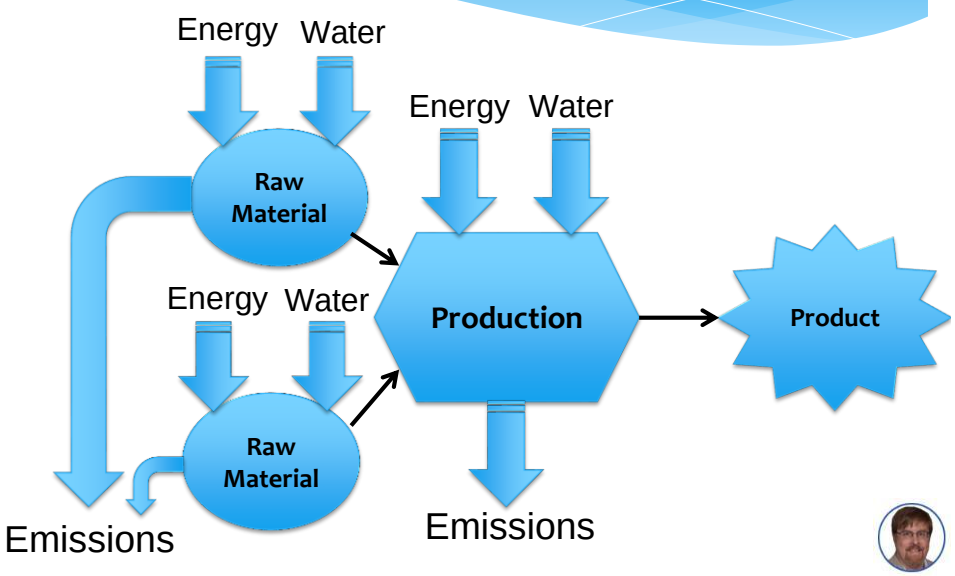
Life Cycle Impact Analysis: Inventory



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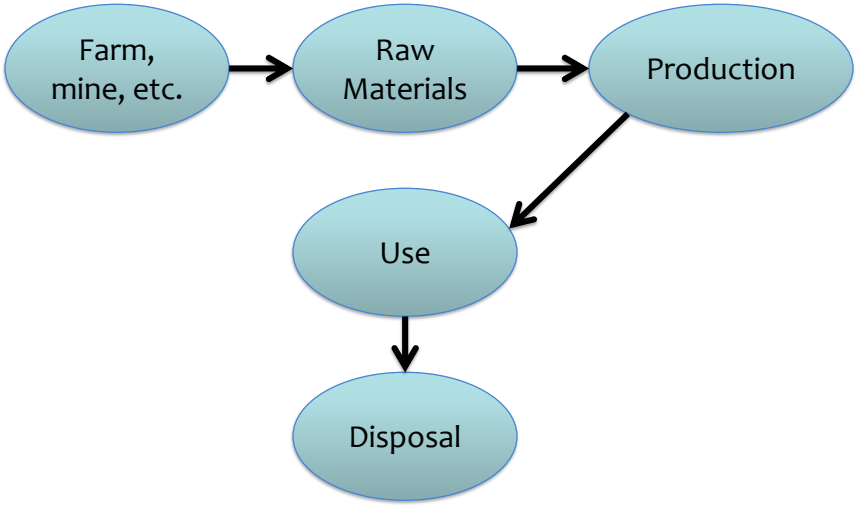
LCIA: Cradle to Grave



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TRACI: Tool for the Reduction and Assessment of Chemical and other Environmental Impacts

- Ozone depletion
- Global warming
- Smog formation
- Acidification
- Eutrophication
- Human health-cancer
- Human health non-cancer
- Human health criteria pollutants
- Eco-toxicity
- Fossil fuel depletion
- Land use
- Water use

See Jane Bare, et al., *J. Industr. Ecol*. 2003, 6, 49

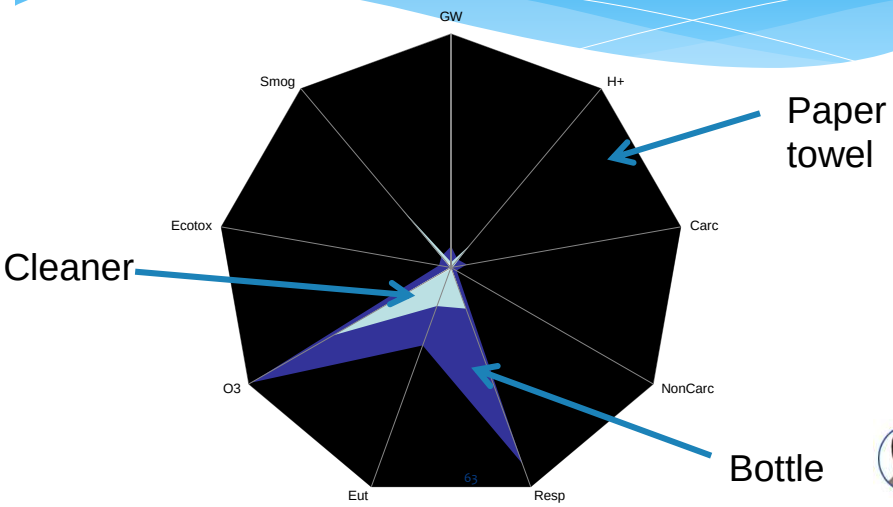
61

And sometimes, not so much

Traditional vs. "green" glass cleaner: the assumption is that the active ingredient will be the focus

62

Fortunately, we decided to include the use of a paper towel in the life cycle analysis



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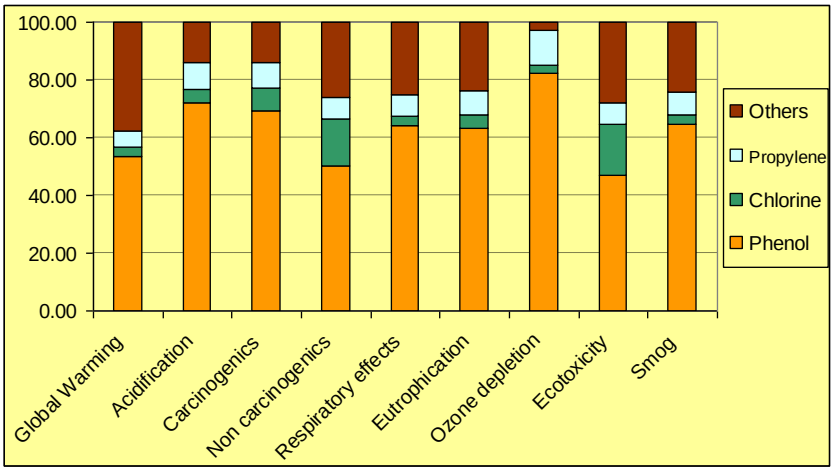
Normalized Impacts of polycarbonate components

Interfacial Process



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OK, so we understand our customers desired outcomes, and we also understand where the environmental bottlenecks lie for competing products and concepts… then what?

65

Eliminate the features that aren't directly related to desired customer outcomes and also degrade environmental footprint

- Steps in a synthesis and/or reagents
- Middlemen
- Parts, subsystems
- Whole products (including via product to service)
- Replacements (versus multi-use)

A key is to keep the desired customer outcome firmly in mind while trying to picture multiple concepts that deliver the outcomes desired – very difficult!

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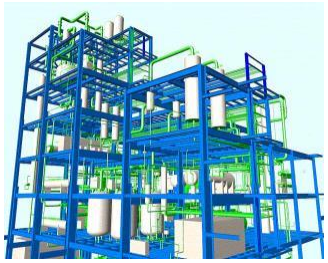
The desired outcome is“coffee without caffeine”

Coffee decaffeination using methylene chloride

67

The desired outcome is“coffee without caffeine”

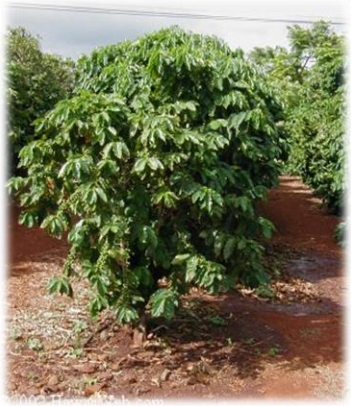
Coffee decaffeination using methylene chloride



Coffee decaffeination using CO_2 (not a “solvent” by FDA)

68

The desired outcome is“coffee without caffeine”



Coffee beans without caffeine

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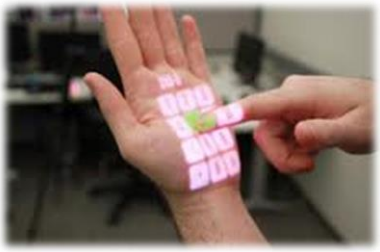
The traditional touchscreen: desired outcome is interaction

70

Or, any surface can be a touchscreen



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Bio-based Ethanol

Corn as feedstock

72

Bio-based Ethanol

Switchgrass or waste cellulose

73

Employ Cyanobacteria to Generate Ethanol

Bacteria employ CO_2 & sunlight as feedstocks;

Joule Unlimited (Bedford, MA) is in process of plant scale-up.

74

Audience Challenge Question

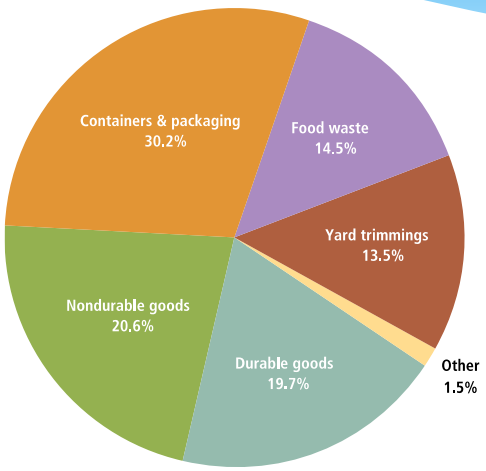
ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

About how much packaging waste was reported by the EPA in 2011?

- About 1 million tons
- About 10 million tons
- About 25 million tons
- About 75 million tons
- About 100 million tons

75

Packaging: Desired Outcome = "Protection until Use"



250 tons of MSW; packaging = 75 million tons

U.S. EPA: Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2011

76

The desired customer outcome is containment + protection


Willy Wonka: The "everything is edible" room

77

Coca-Cola Bottles: The Desired Outcome is Containment + Protection

The Coke Ice Bottle


78

Variations on the Theme

79

To summarize this very fast introduction

- Human-centered design; desired customer outcomes set the system boundaries
- Life cycle impact analysis reveals flaws in competitive products, and hence helps to ID opportunity
- Brainstorming to lead to new concepts, not just new designs from well-worn concepts.
- Check your work; LCIA to verify improved e-footprint

80

Look for folks struggling with existing "solutions"

Innovation is always possible

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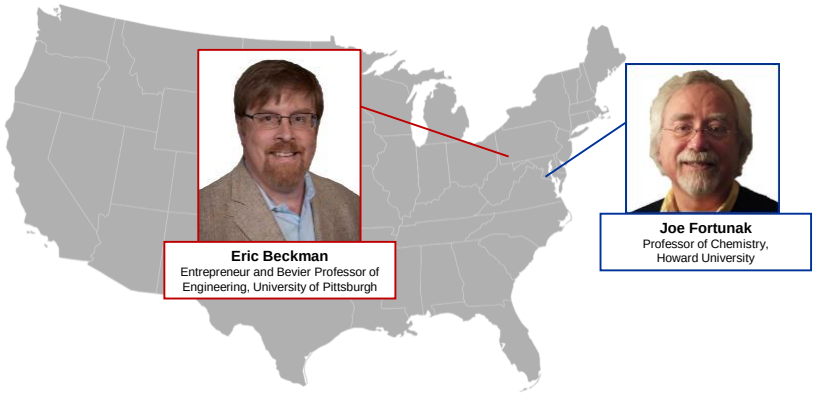

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Bill Carroll, Founder of Carroll Applied Sciences and Adjunct Professor of Chemistry, Indiana University

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Mark DeWitt, Project Scientist, Innovative Genomics Institute, UC Berkeley

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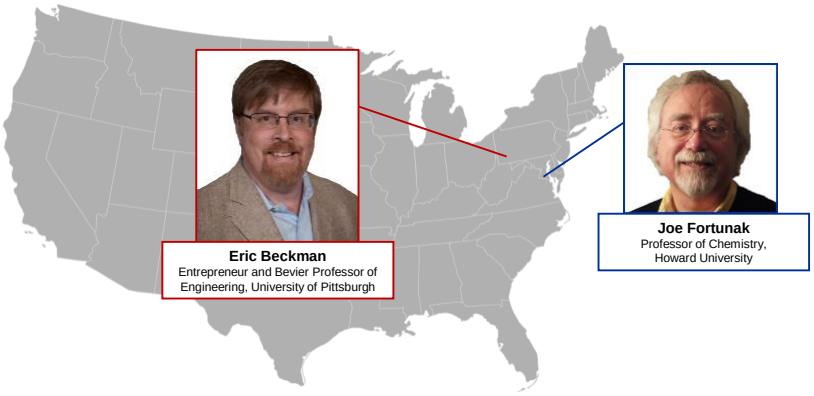

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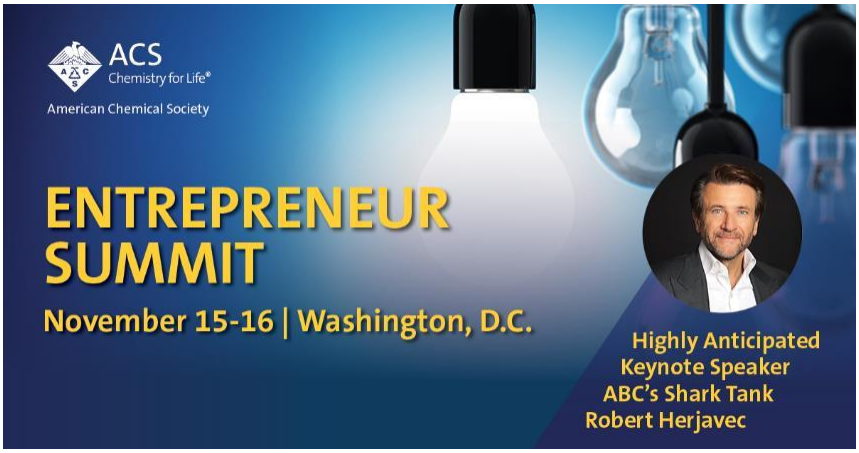

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