GE105: Introduction to Engineering Design

”Solar Oven Project”

Concept Generation and Evaluation

Dr. Mohammed A. Khamis

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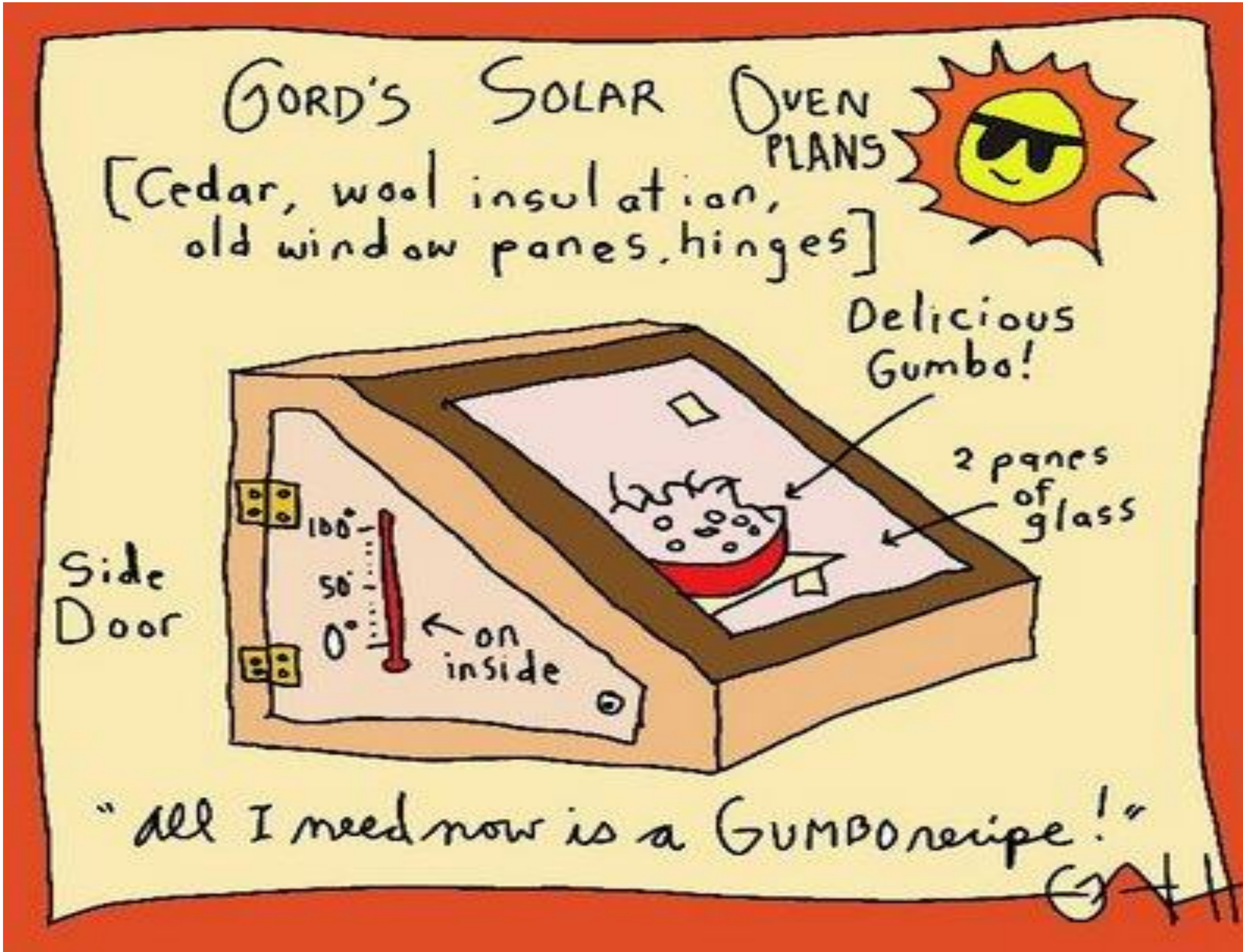
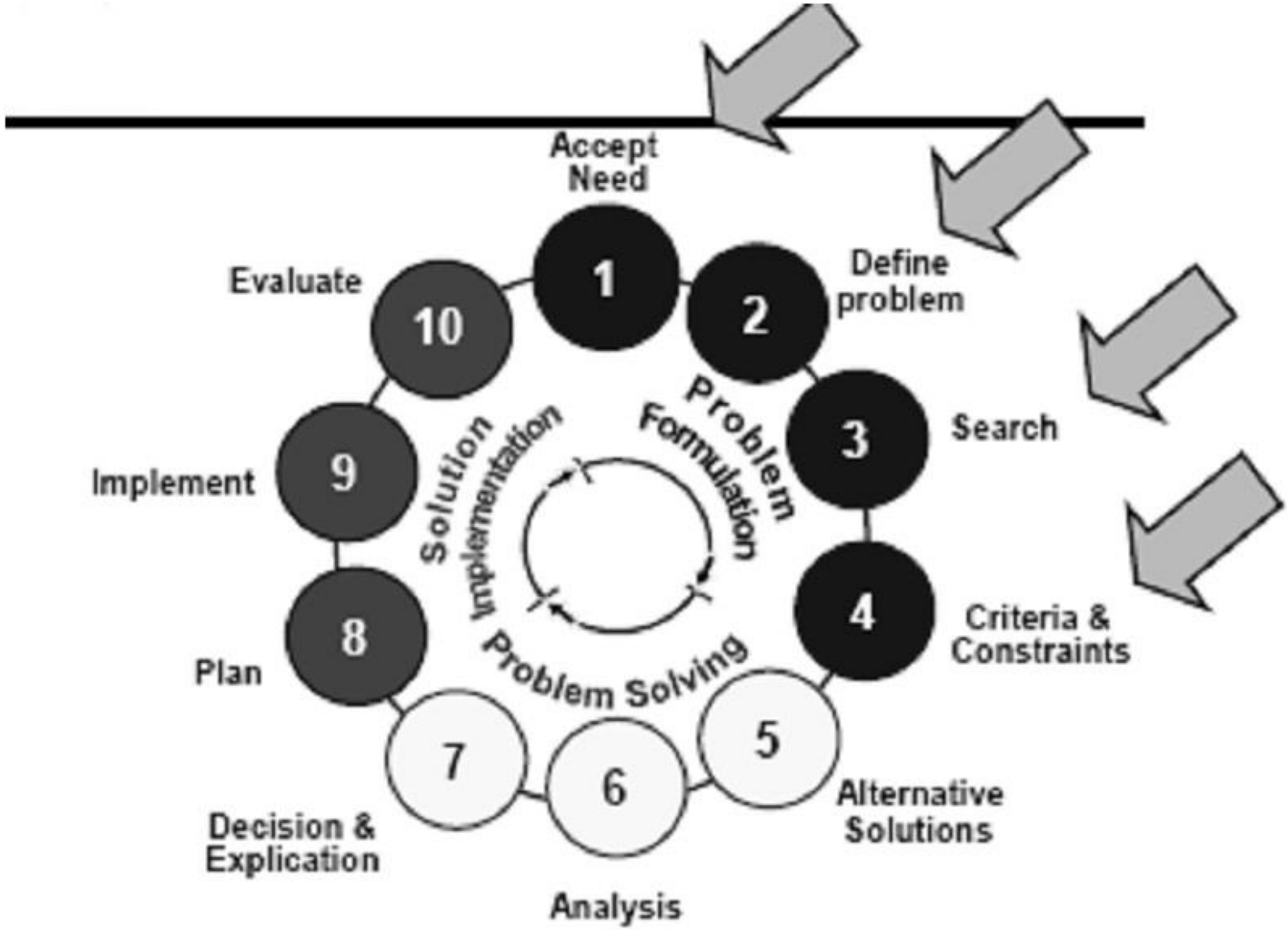
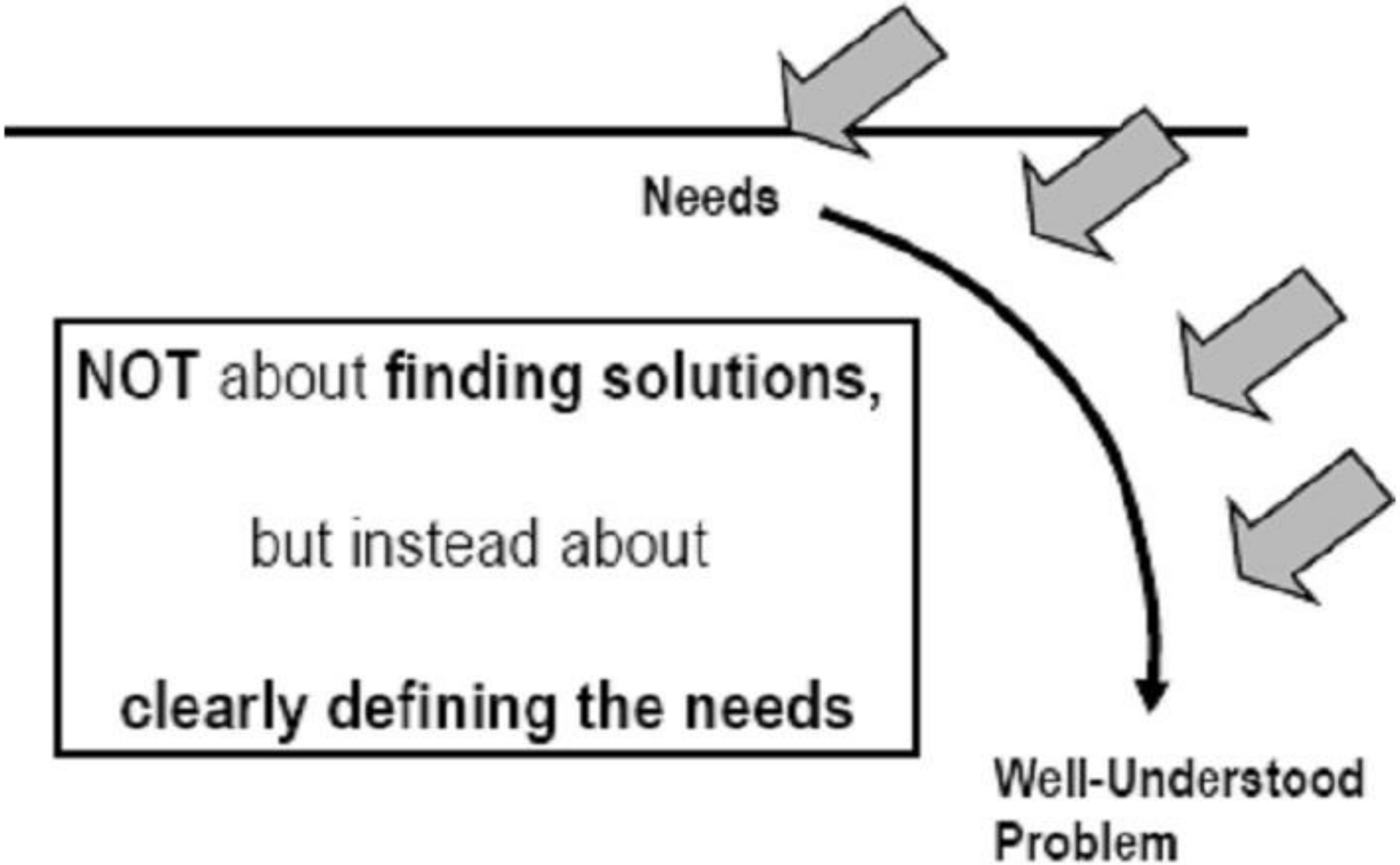

GORD'S SOLAR OVEN PLANS
[Cedar, wool insulation, old window panes, hinges]
Delicious Gumbo!
2 panes of glass
Side Door
100°
50°
0°
← on inside
"All I need now is a GUMBO recipe!"

Topics

- Exploring Design Process with Solar Oven Project
- Problem Formulation
  - Searching
  - Identifying Criteria and Constraints
- Problem Solving
  - Decision-making


Accept
Need
1
Define
problem
2
Search
3
Criteria &
Constraints
4
5
Alternative
Solutions
6
Analysis
7
Decision &
Explication
8
Plan
9
Implement
10
Evaluate
Problem
Formulation
Solution
Implementation
Problem Solving

Phase I
Problem Formulation



What is a "well-understood" problem – to an engineer? ...

A "Well-Understood" Problem

Needs

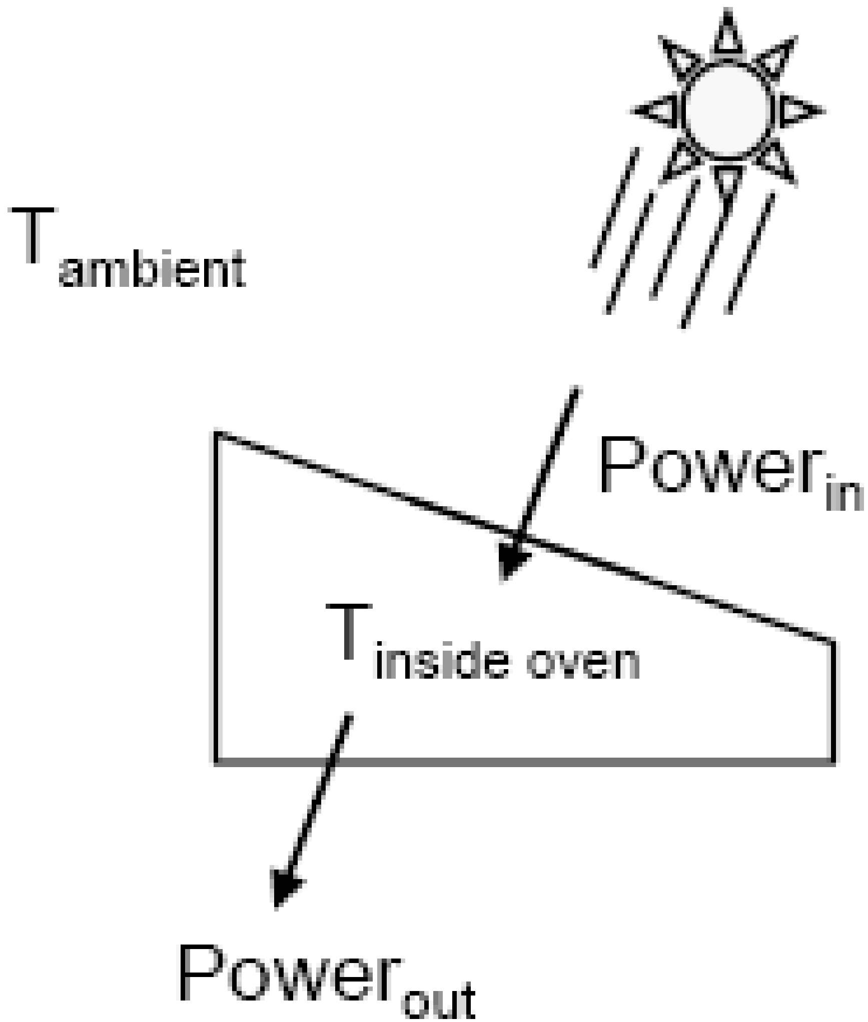
- Know the
  - criteria
  - constraints
  - variables you can control
- Understand how these 3 relate to each other
  - learn about solar ovens in general
  - learn about heat transfer

Well-Understood Problem

Where should I go to learn about solar ovens?

- Library website
- Search engines
  - www.google.com
  - www.sciencedirect.com
  - ………………

Solar Oven



Search engines

$$\Delta T = T_{inside\ oven} - T_{ambient}$$

Criteria:
Maximize ΔT while minimizing cost

Heat Transfer

Occurs through one of three modes <u>when a ΔT exists</u>

1. Conduction

Heat travels from atom to atom of a solid

- Doorknob is hot when a fire is on other side of door

2. Convection

With a gas or liquid, the heat propagates as molecules move

- When you open the door of an oven, the temperature in the kitchen increases
- Fans are blown on computer chips to cool them

3. Radiation

A heated surface emits electromagnetic waves which carry energy away from the emitting object

- Heat felt from a brick wall that has been in the sun all day

Key Ideas

- Sunlight contains energy
- You want a solar oven that gets as hot as possible
  (highest temperature in the oven chamber)
  - You want your oven to receive solar energy easily
  - You also want your oven to not lose solar energy it has captured

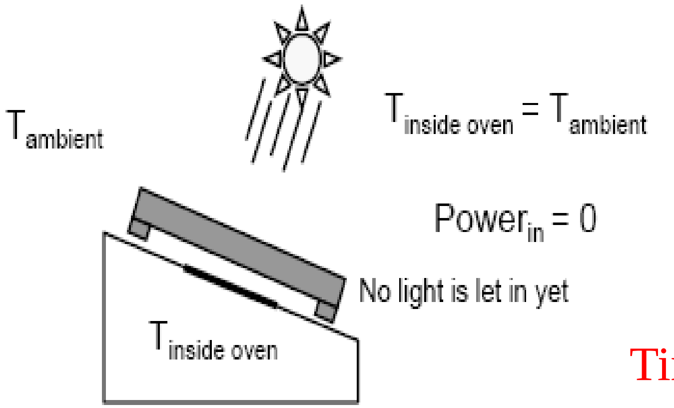
Key Constraints

What are the key constraints?

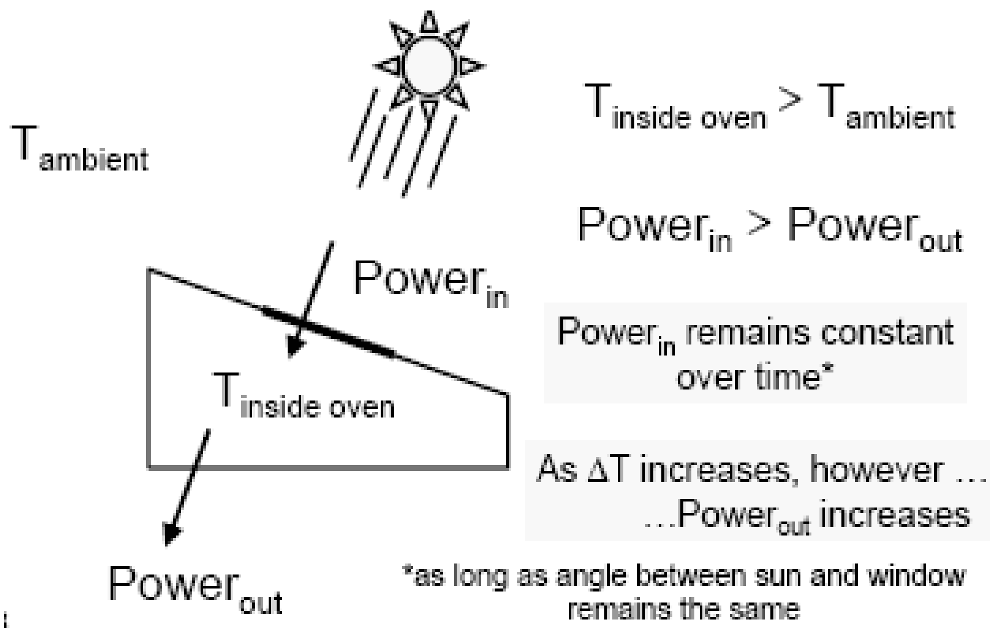
- No lenses
- Size of chamber
- No preheating
- Design must hold a thermometer
- …

Solar Oven Heat Transfer

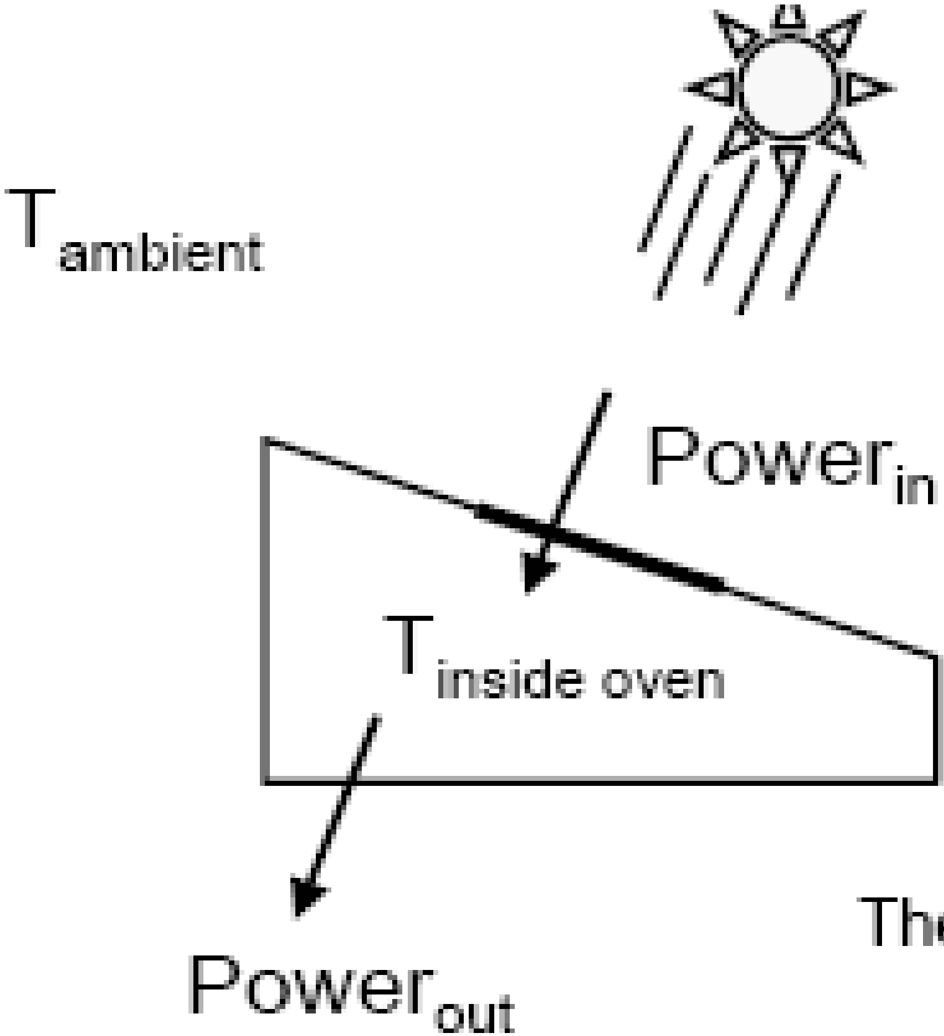
Time = 0



Time = shortly after cover removed



Time = a long time after "0"



$T_{inside\ oven} > T_{ambient}$

$Power_{in} = Power_{out}$

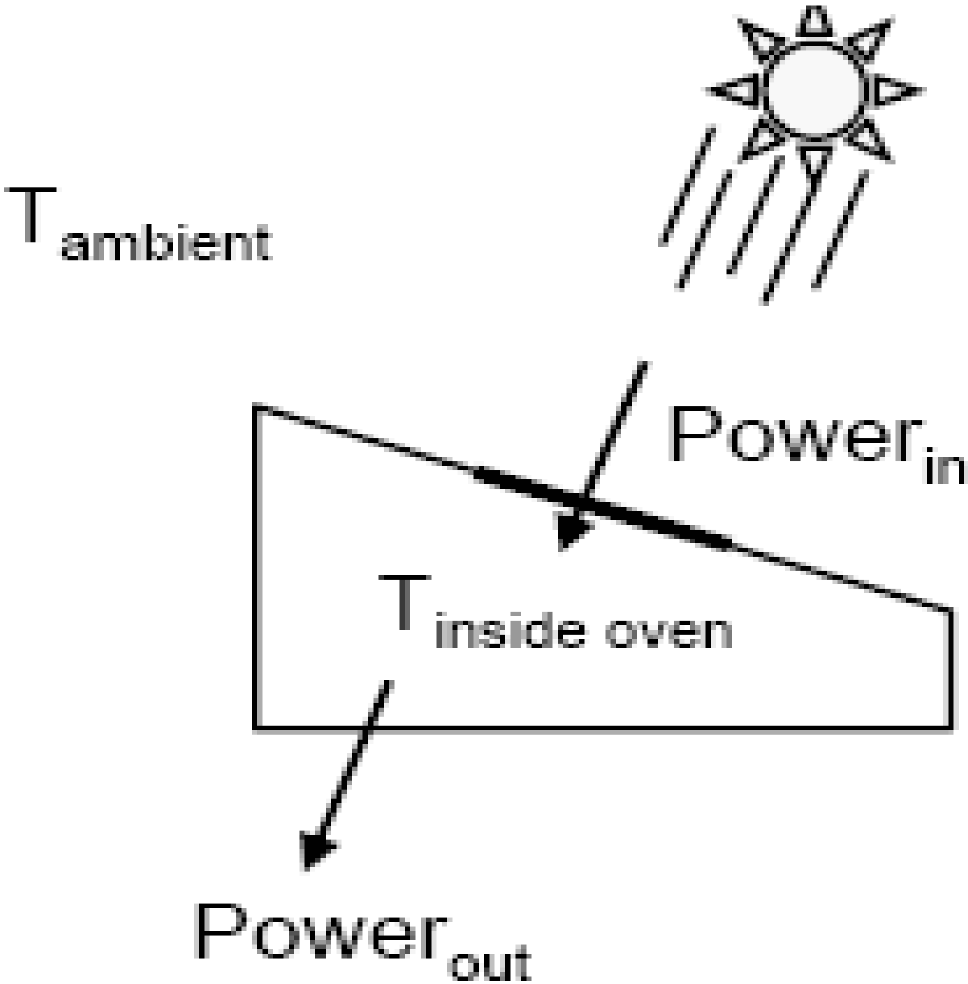
ΔT increases until
$Power_{out} = Power_{in}$

The solar oven is said to be in:
(thermal) <u>EQUILIBRIUM</u>

Summarizing what we know

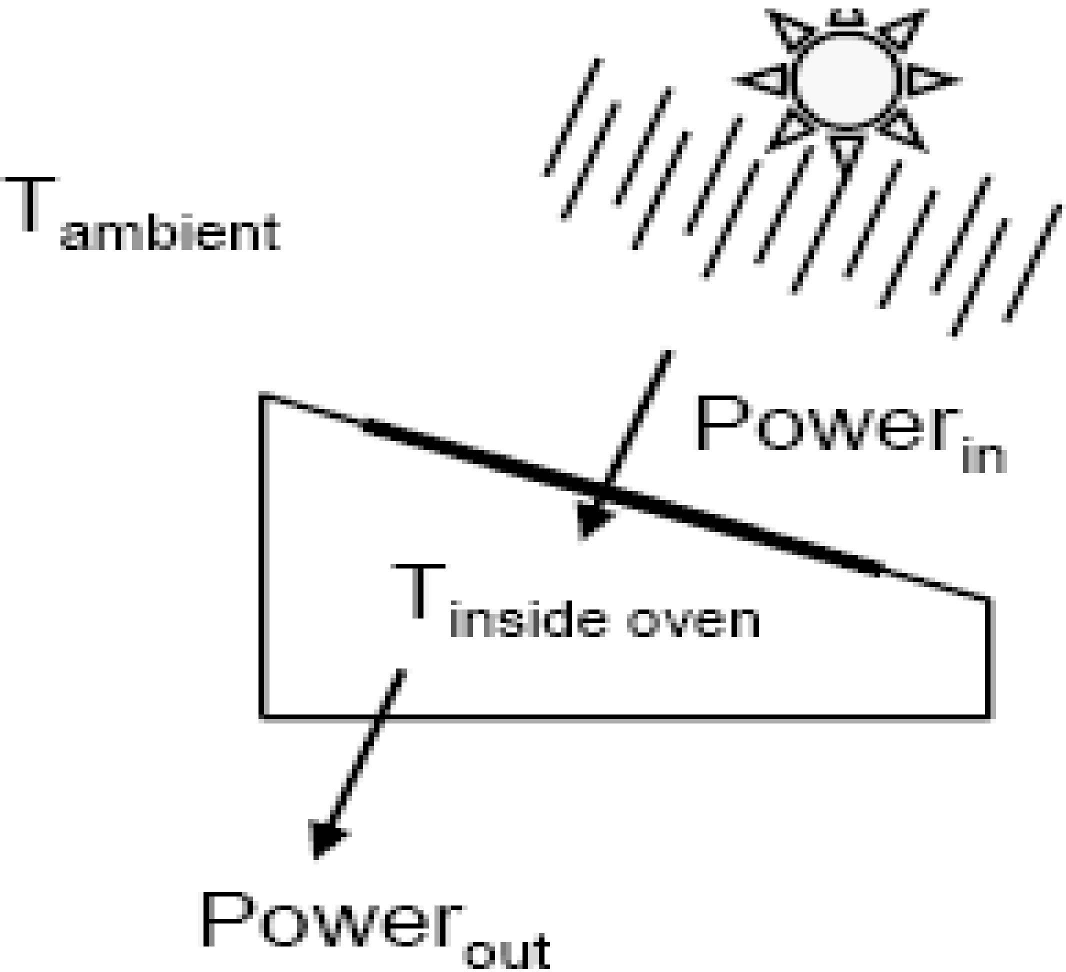
- We want the highest ΔT we can get for a given cost
- To get a higher ΔT, we need either to
  - Increase Power-in
    - GET MORE SUN INTO THE OVEN
  - Decrease Power-out for a given ΔT
    - FOR ANY GIVEN OVEN TEMPERATURE
      - WE WANT TO REDUCE THE RATE AT WHICH ENERGY IS LEAVING THE OVEN

How can we Increase Power-in?



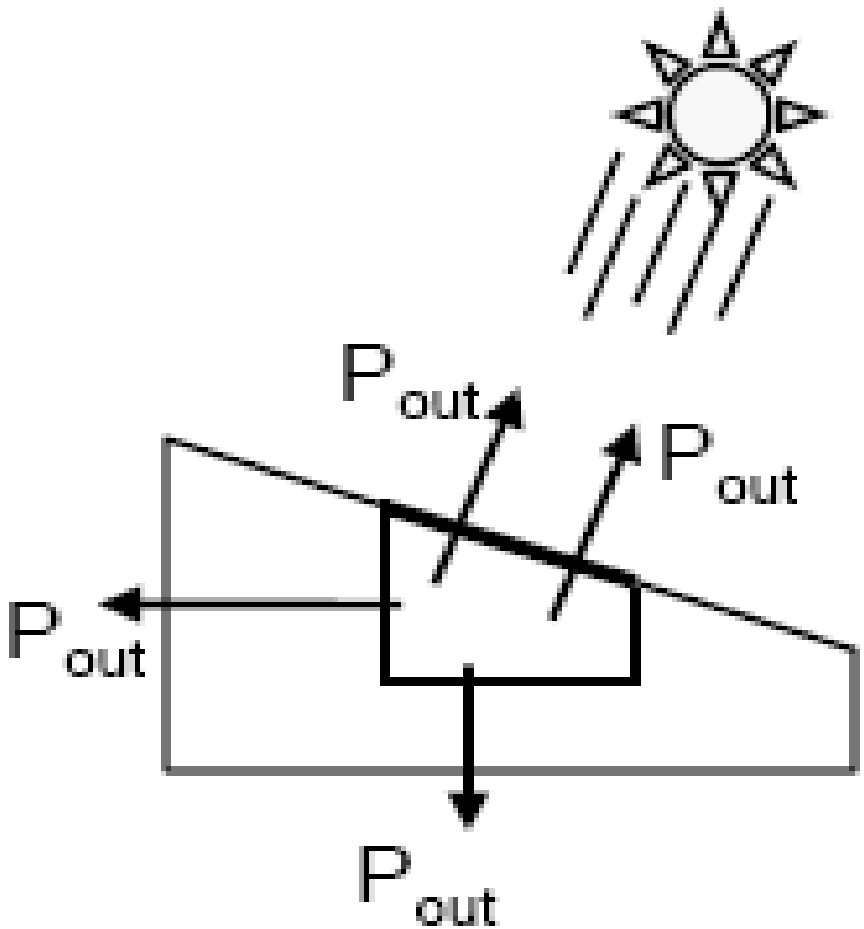
- What determines $Power_{in}$?
  - Window size
  - Intensity of Sun
  - Window Thickness
  - Angle light hits window
  - Color of oven wall

How can we Increase Power-in?



- Solar Intensity=
  - 1000 W/m^2
  - 0.125 hp/ft^2
- To increase $Power_{in}$
  - Bigger Window
  - Thinner Window

How can we decrease Power-out for a given ΔT?



How does energy leave the oven?

- Radiation
  - Back out window
- Conduction and Convection
  - Back out window
  - Through the sides and bottoms of oven chamber

How can we decrease Power-out for a given ΔT?

- Heat Transfer Via Window
  - ~25 $W/m^2/$ °C ΔT (when T inside oven=150°C)
  - ~12 $W/m^2/$°C (for a thicker window)
- Heat Transfer Via Sides and Bottom
  - ~1.5 $W/m^2/$ °C ΔT
- Per size, more heat is lost through window
  - Therefore, you want a smaller, thicker window to keep heat in!
  - some good insulation on sides and bottom

Putting it all together

- To increase Power-in
  - increase window size
  - decrease window thickness

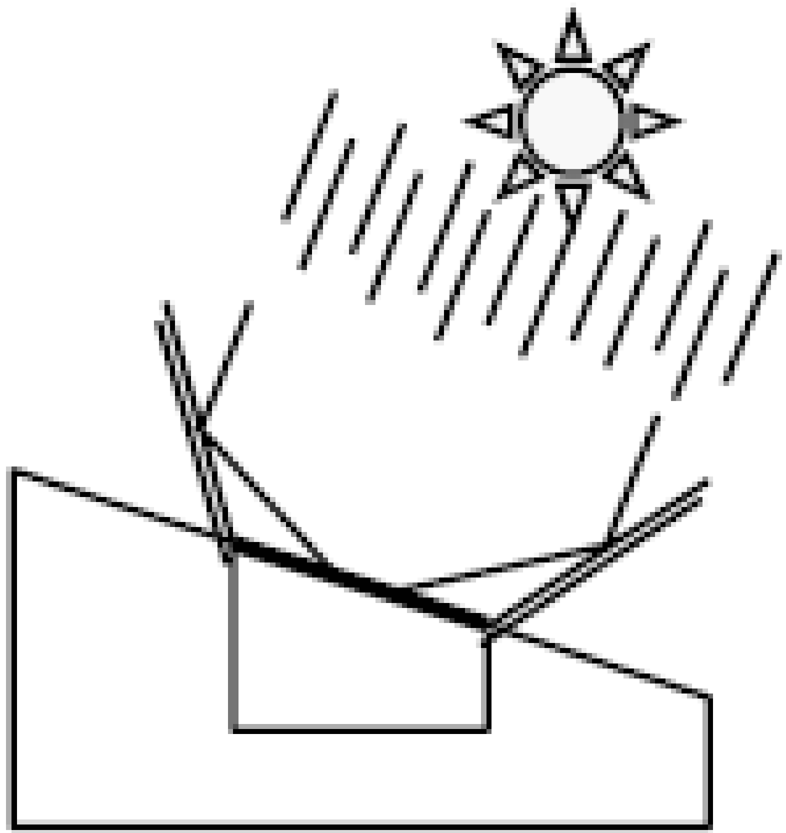
- To decrease Power-out
  - decrease window size
  - Increase window thickness

This is Engineering Design.
You must make trade-offs (a compromise).

- What would you do?

  A) Go for a larger window

  B) Go for a smaller window



A good designer does not make a trade-off unless there are no other alternatives.

Once trade-offs are unavoidable, a good designer will use analysis to find the best balance

Solar Oven Reflector Design Ideas - Brainstorming

no reflectors

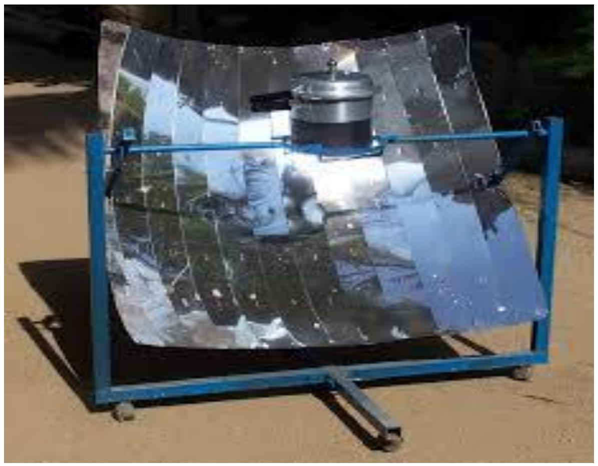
4 flat reflectors, open corner

single flat reflector

4 flat reflectors, with corner

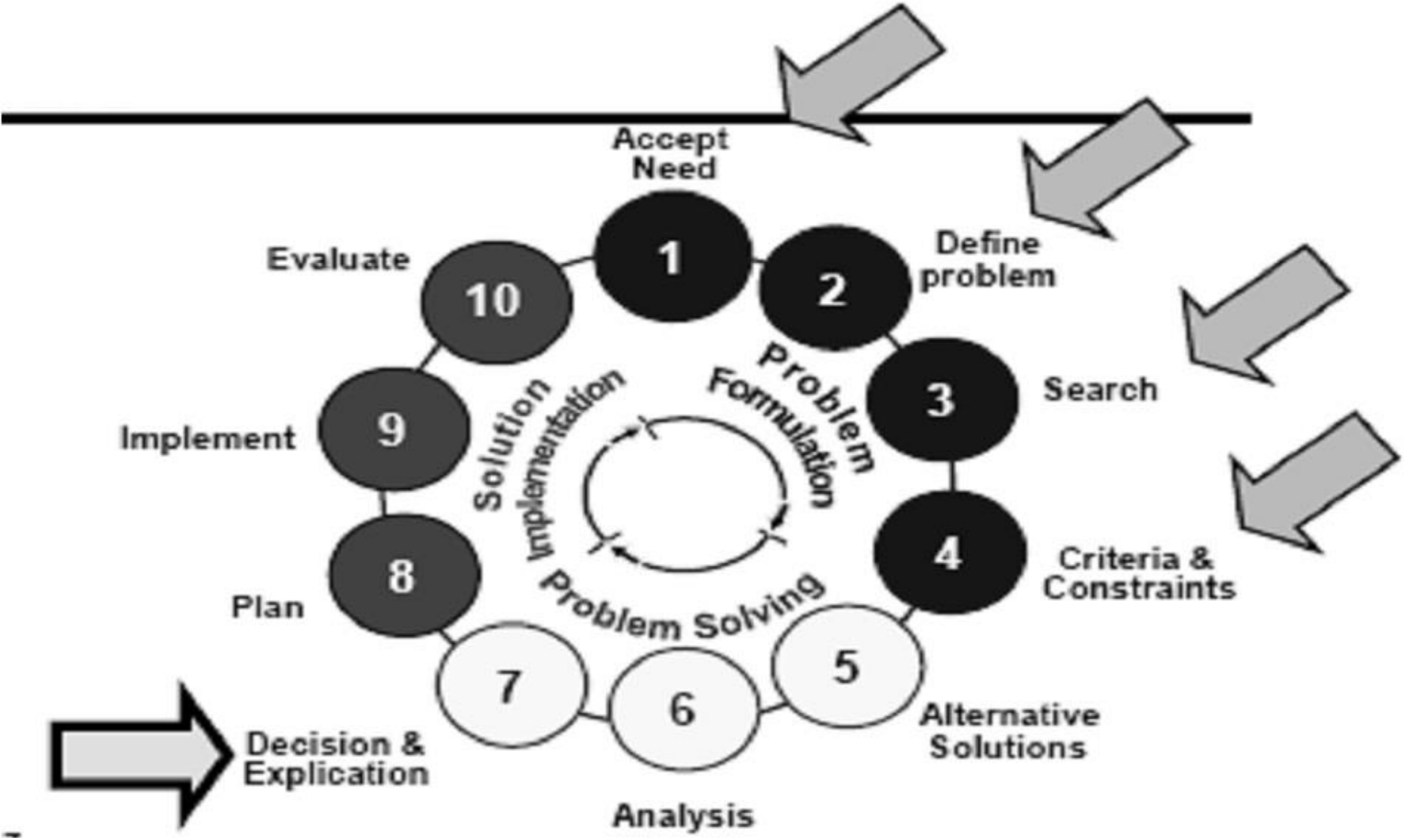
Solar Oven Reflector Design Ideas - Brainstorming

Parabolic



Others

Decision & Explication



Decision & Explication

Decision Matrix

- A straightforward decision
  approach to weigh pros (for) and cons (against)

Decision & Explication

Engineering Decisions

- Characteristics of Engineering Decisions
  - Multiple criteria
  - Criteria are of different importance
  - Criteria are conflicting

Decision & Explication

Engineering Decisions

- Characteristics of Engineering Decisions
  - Ideas
  - Criteria (Attributes)
  - Weight
  - Rate
  - Multiply & Sum

Attributes/Criteria for Selection

- What features of the solar oven design are important to you?
  - Direct energy into oven
  - Easy to manufacture
  - Room for error in aim
  - Hold energy in oven
  - Durable
  - …
- Keep attributes as independent as possible!

Attributes/Criteria for Selection

Weight

Multiply & Su

- How important is each attribute?

A simple approach: Weights that sum to 100

		Direct Energy	Manufacturability	Room for Error in Aim	Hold Energy in Oven
Scenario 1	Compromise	25	25	25	25
Scenario 2	Most Light In	40	5	15	40
Scenario 3	Easy to Make	20	40	20	20

Attributes/Criteria for Selection

Rating

- Rate each item from 1 (worst) to 10 (best)
- For this example, we will only use 3 ideas and 4 attributes…in reality, you would have more of each

Attributes/Criteria for Selection

Different Scenarios

	Direct Energy	Manufacturability	Room for Error in Aim	Hold Energy in Oven	SCORE (Multiply & Sum)
Weight →	40	5	15	40	
No Reflector, Big Window	1	10	5	3	
	40	50	75	120	285
1 Reflector, Small Window	4	8	7	6	
	160	40	105	240	545
Parabolic	9	2	4	4	
	360	10	60	160	690

	Direct Energy	Manufacturability	Room for Error in Aim	Hold Energy in Oven	SCORE (Multiply & Sum)
Weight →	25	25	25	25	
No Reflector, Big Window	1	10	5	3	
1 Reflector, Small Window	4	8	7	6	
Parabolic	9	2	4	4	

Review

- Problem Formulation involves
  - Learning about the problem through research
  - Identifying criteria, constraints, and design variables
- Decision matrices can be helpful tools for exploring trade-offs