خمسون عاماً من الإنجاز والعطاء
Fifty Years Of Achievement And Giving

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# GE105: Introduction to Engineering Design

## "Solar Oven Project"
## Concept Generation and Evaluation

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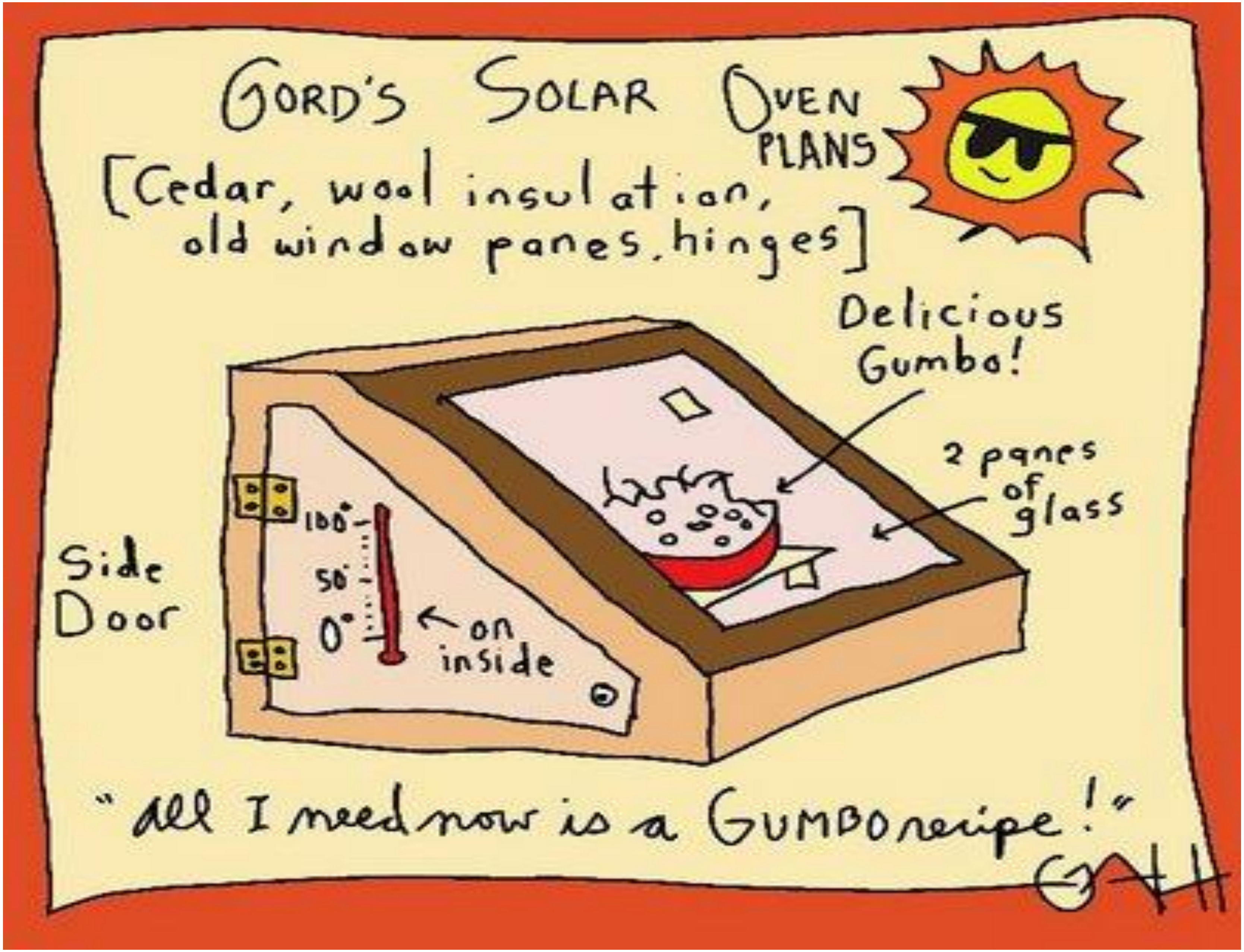
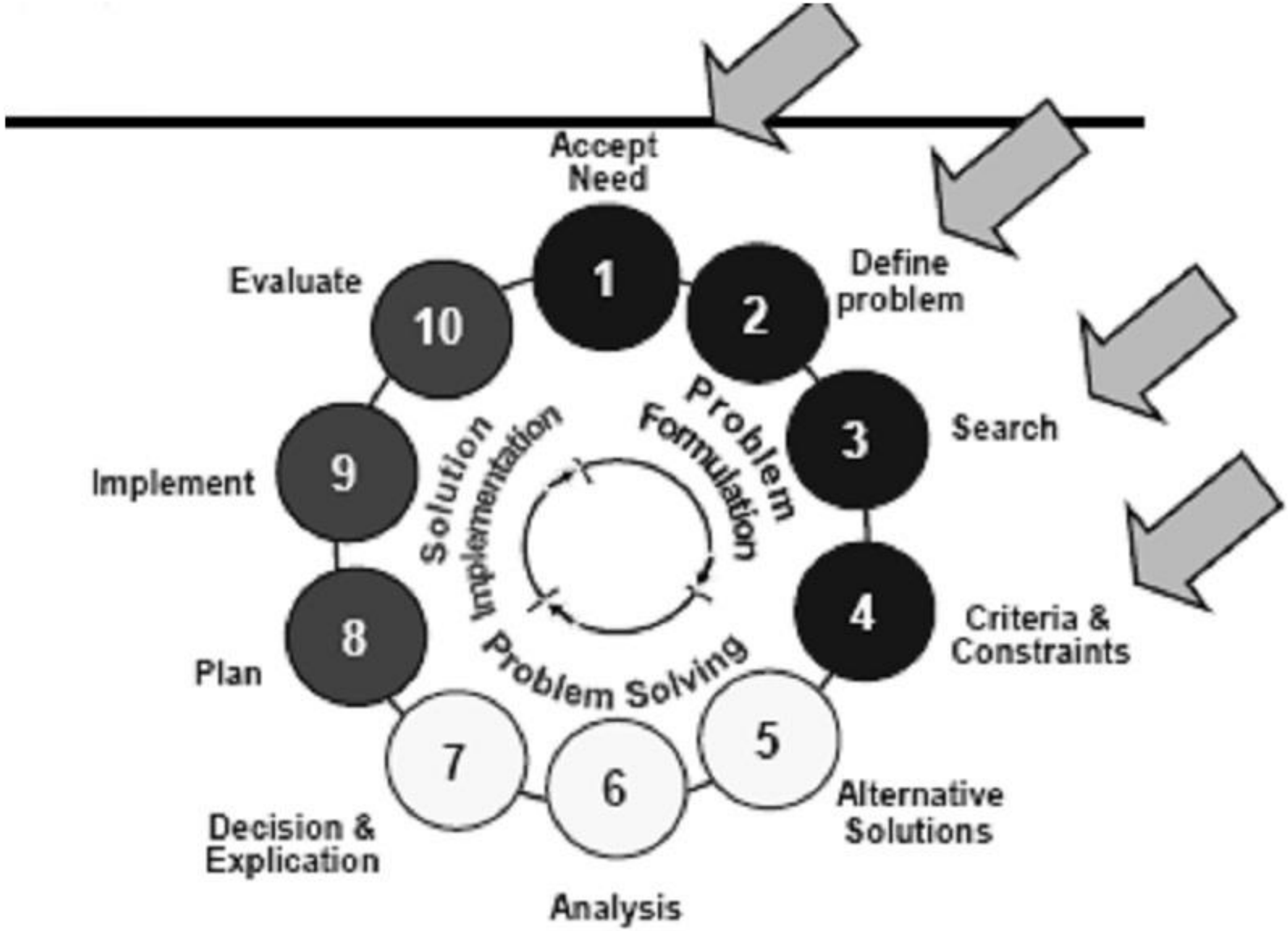
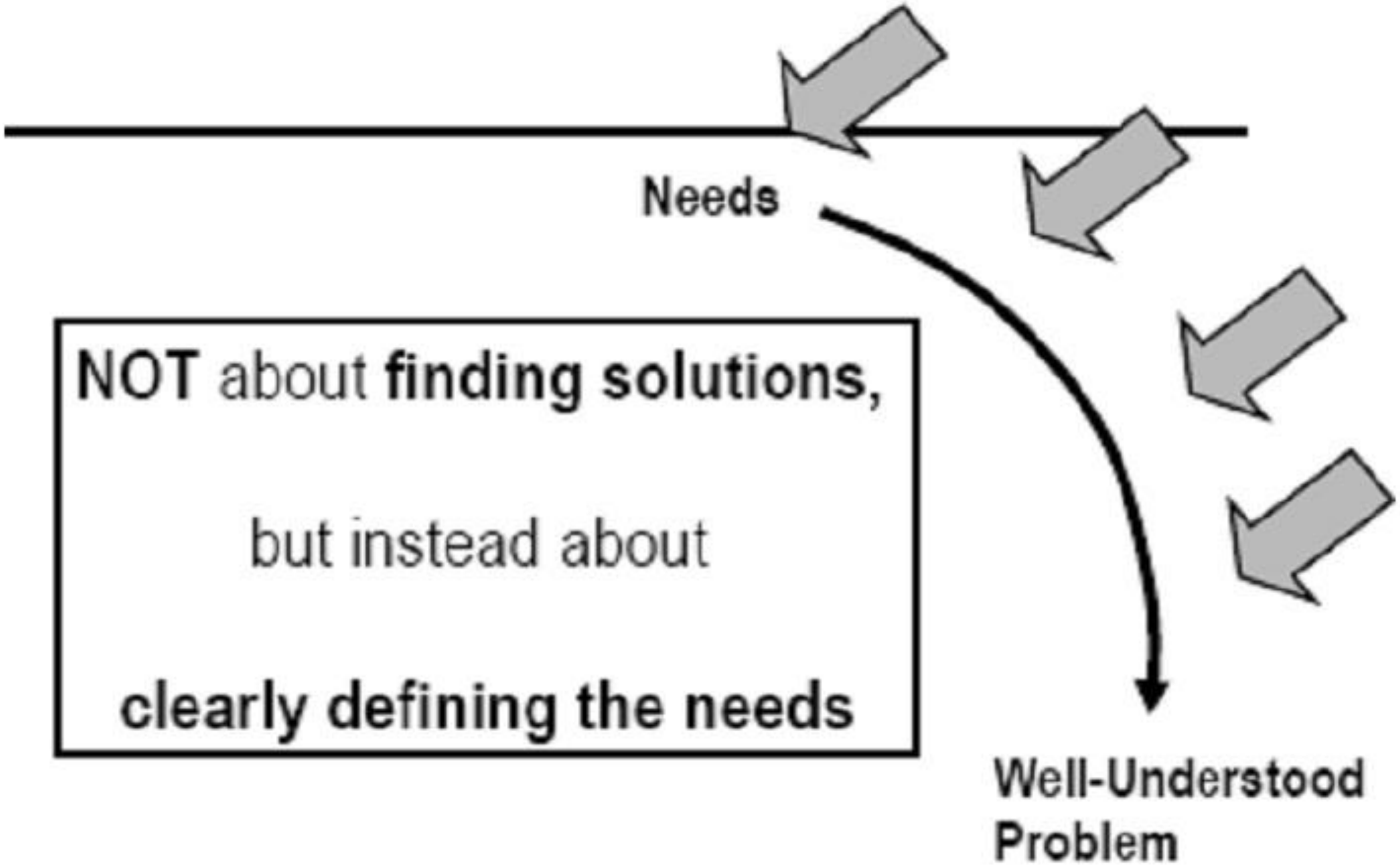

GORD'S SOLAR OVEN PLANS
[Cedar, wool insulation, old window panes, hinges]
Delicious Gumbo!
2 panes of glass
Side Door
100°
50°
0°
← on inside
"All I need now is a GUMBO recipe!"

# Topics

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


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

# 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

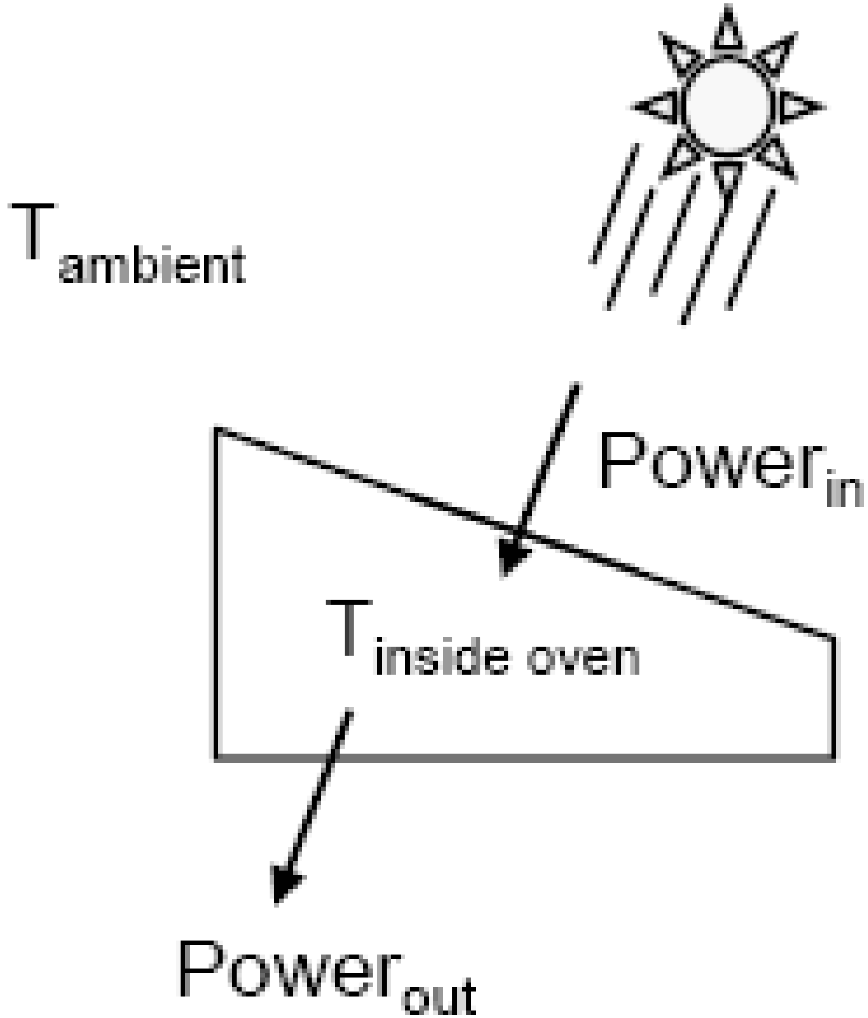
Well-Understood Problem

# 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 $\Delta T$ 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

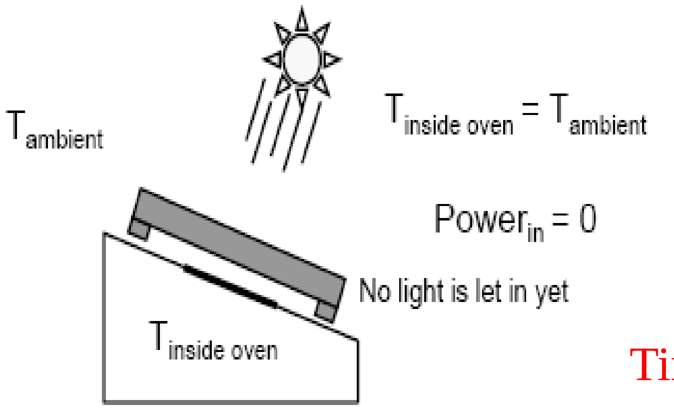
# Key Constraints

What are the key constraints?

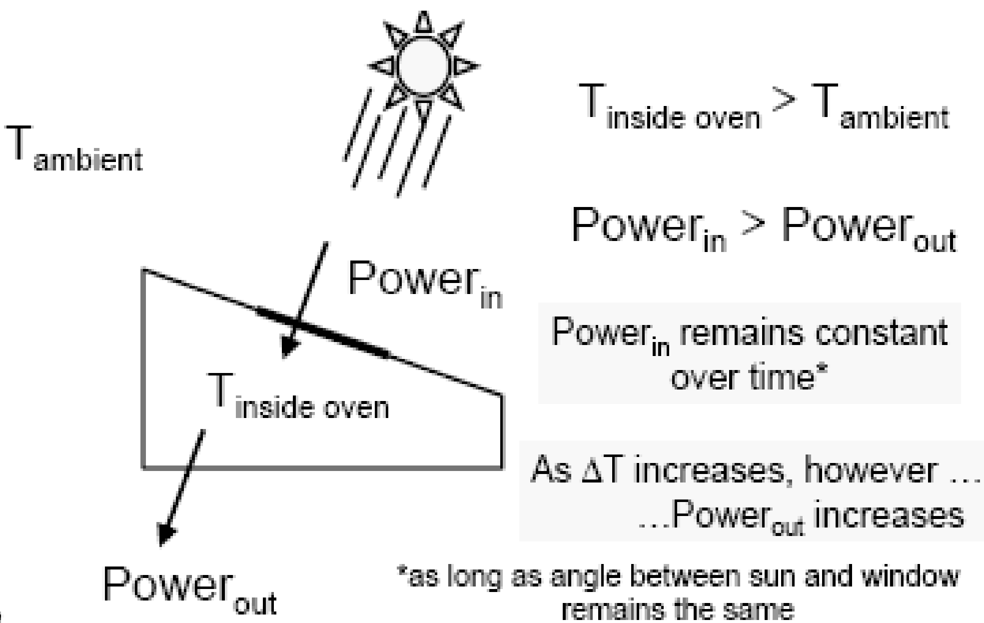
- No lenses
- Size of chamber
- No preheating
- Design must hold a thermometer
- …

# Solar Oven Heat Transfer

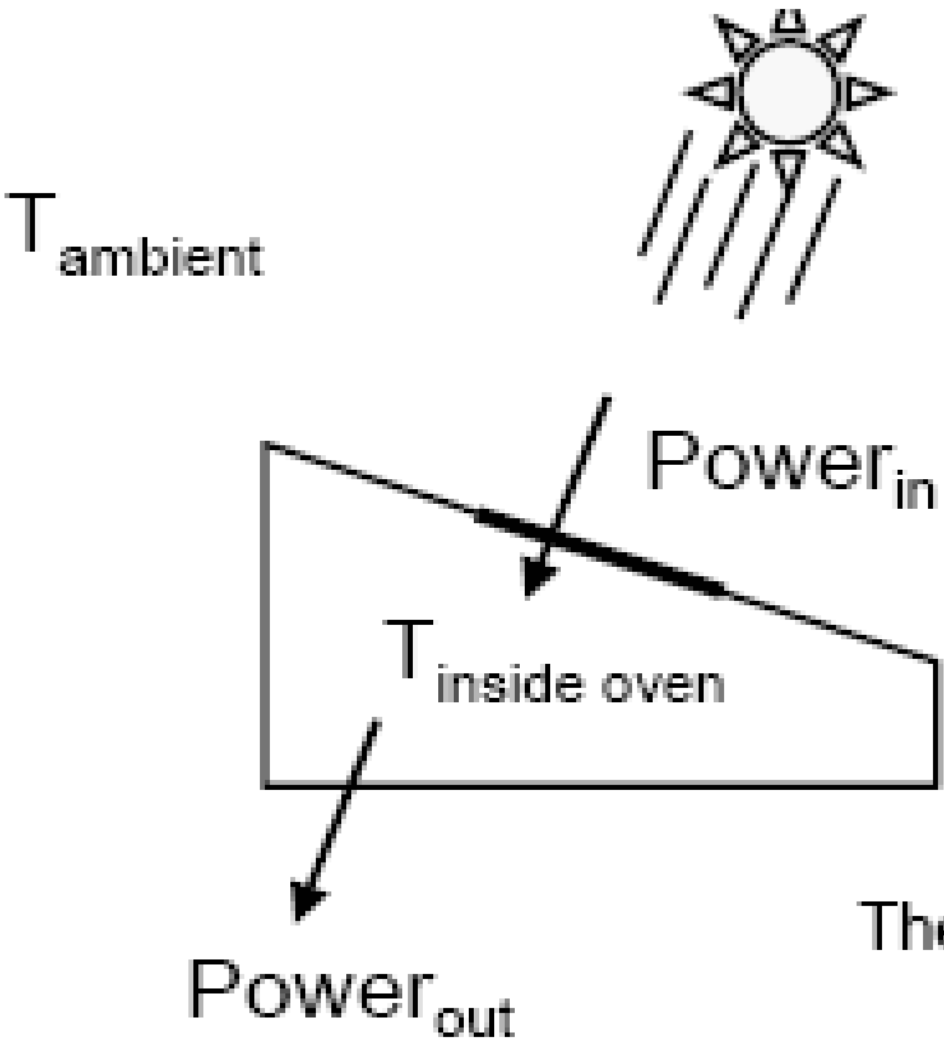
Time = 0




Time = shortly after cover removed



# Time = a long time after "0"




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

$Power_{in} = Power_{out}$

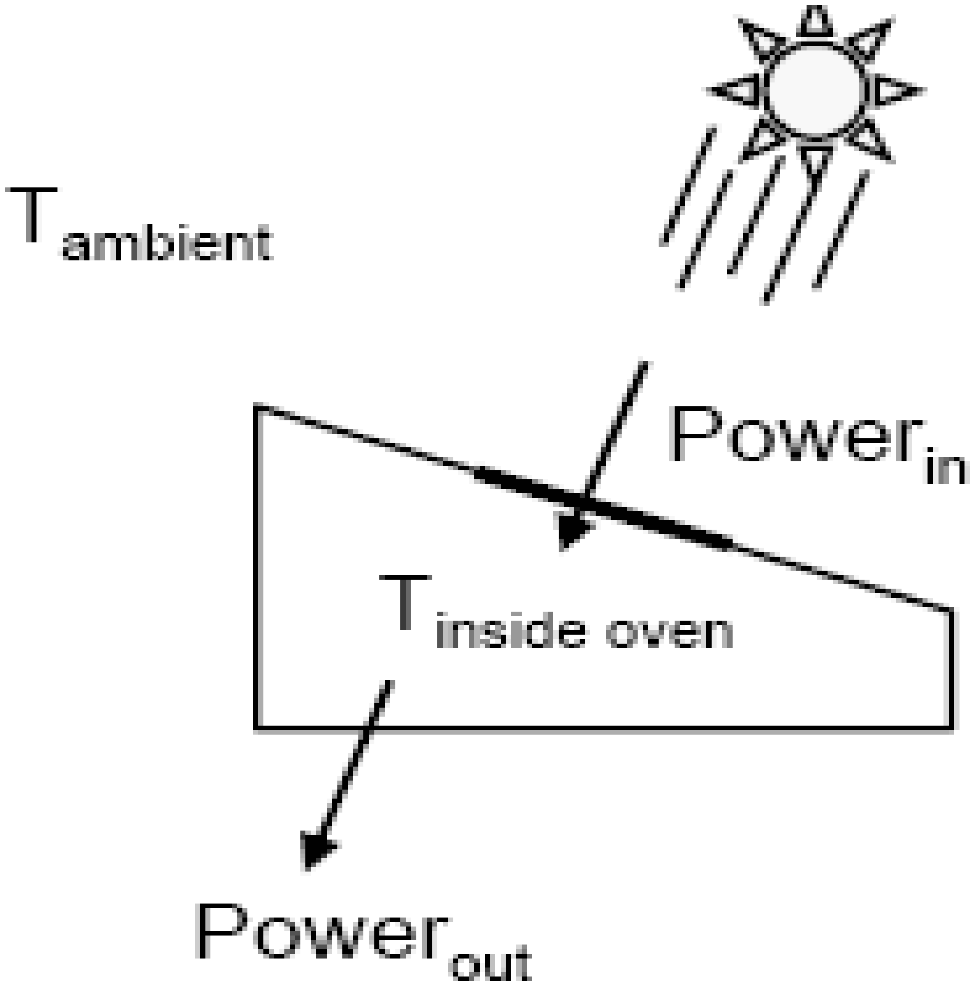
$\Delta T$ increases until $Power_{out} = Power_{in}$

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

# Summarizing what we know

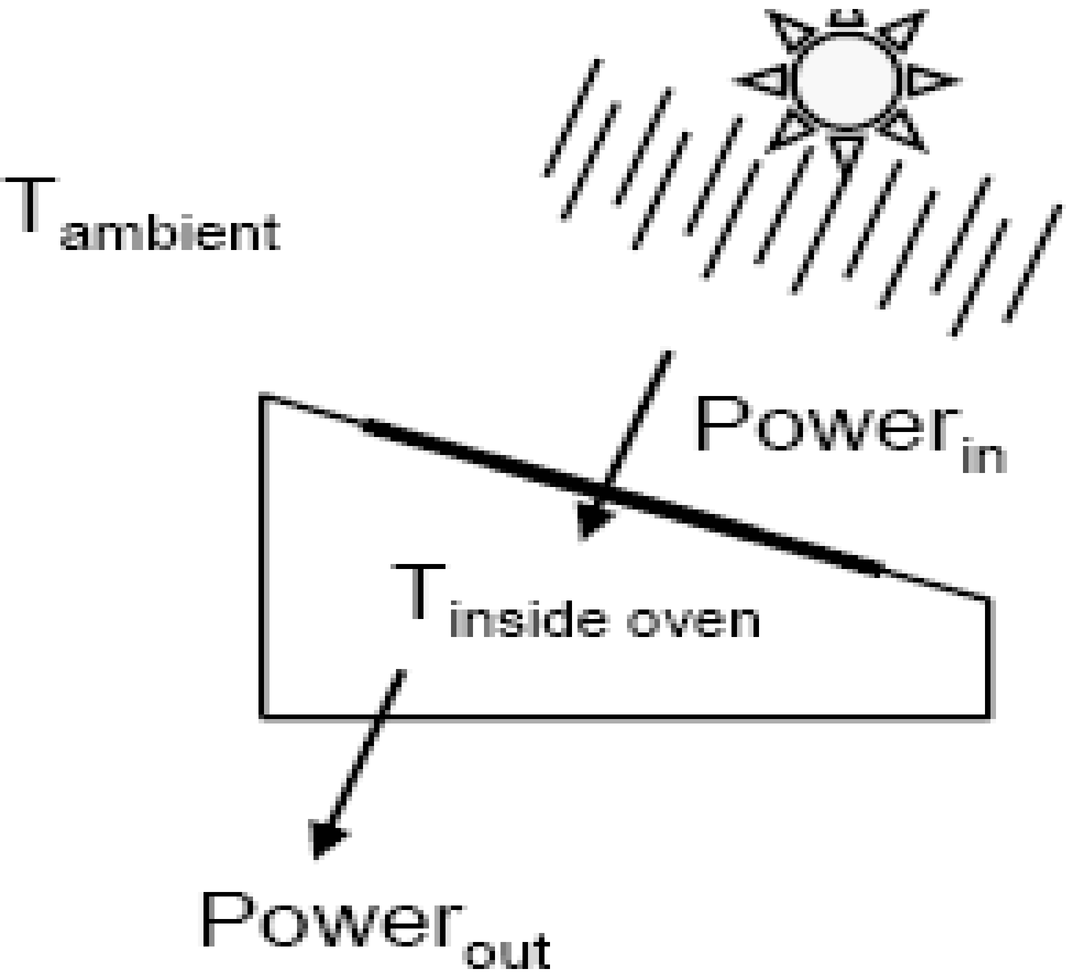
- We want the highest $\Delta T$ we can get for a given cost
- To get a higher $\Delta T$, we need either to
  - Increase Power-in
    - GET MORE SUN INTO THE OVEN
  - Decrease Power-out for a given $\Delta T$
    - FOR ANY GIVEN OVEN TEMPERATURE
      - WE WANT TO REDUCE THE RATE AT WHICH ENERGY IS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

# How can we Increase Power-in?



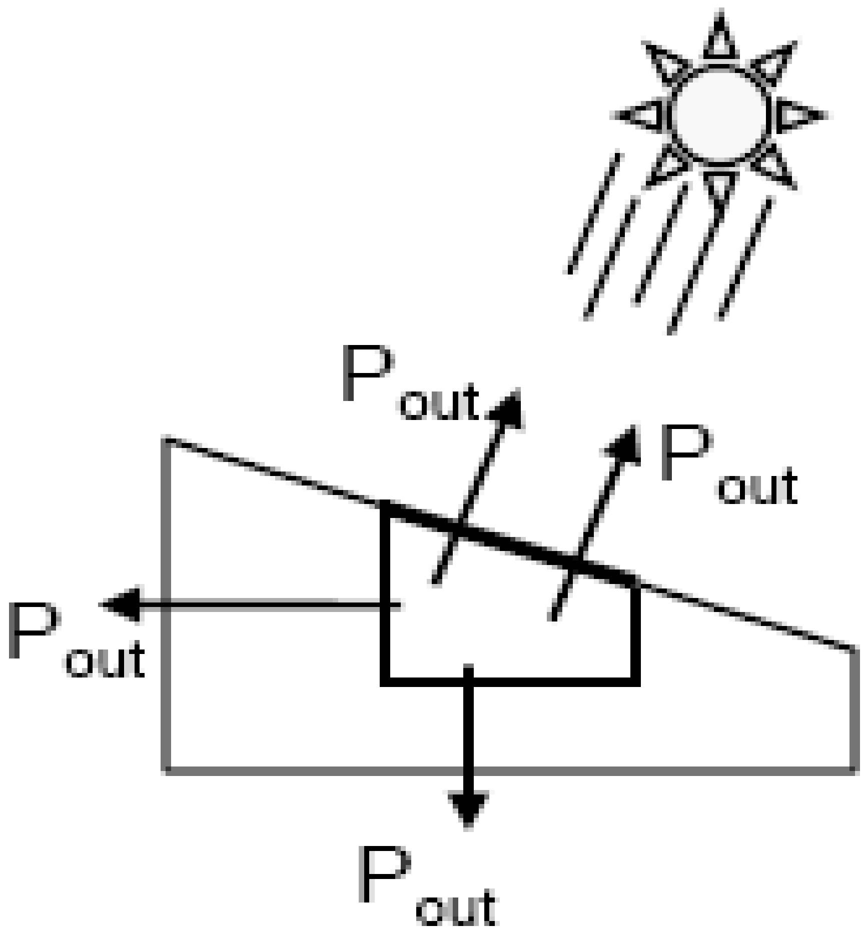

- What determines $Power_{in}$?
  - Window size
  - Intensity of Sun
  - Window Thickness
  - Angle light hits window
  - Color of oven wall

# 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

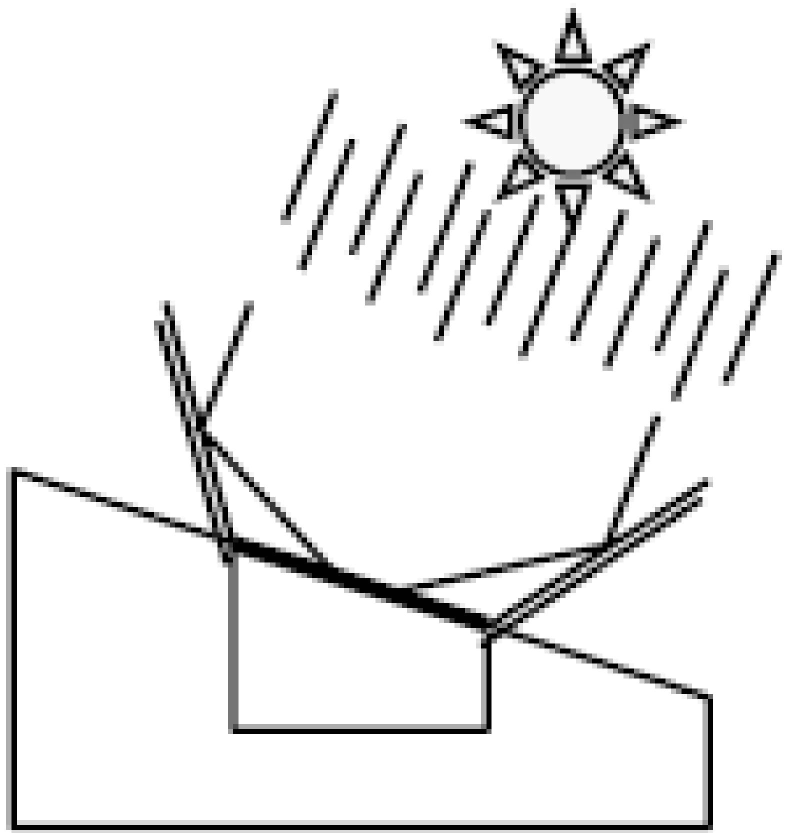
- To decrease Power-out
  - decrease window size
  - Increase window thickness

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

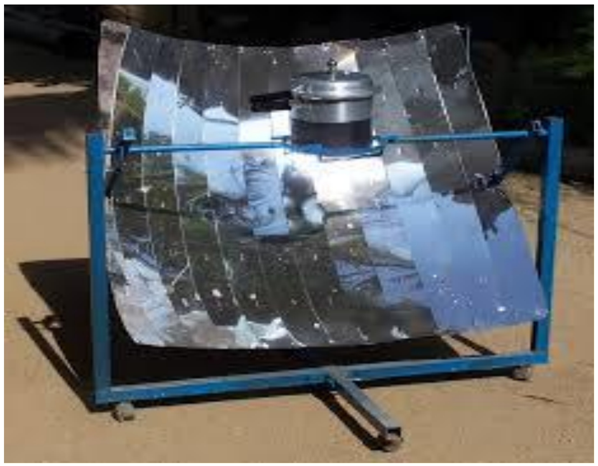
single flat reflector

4 flat reflectors, with corner

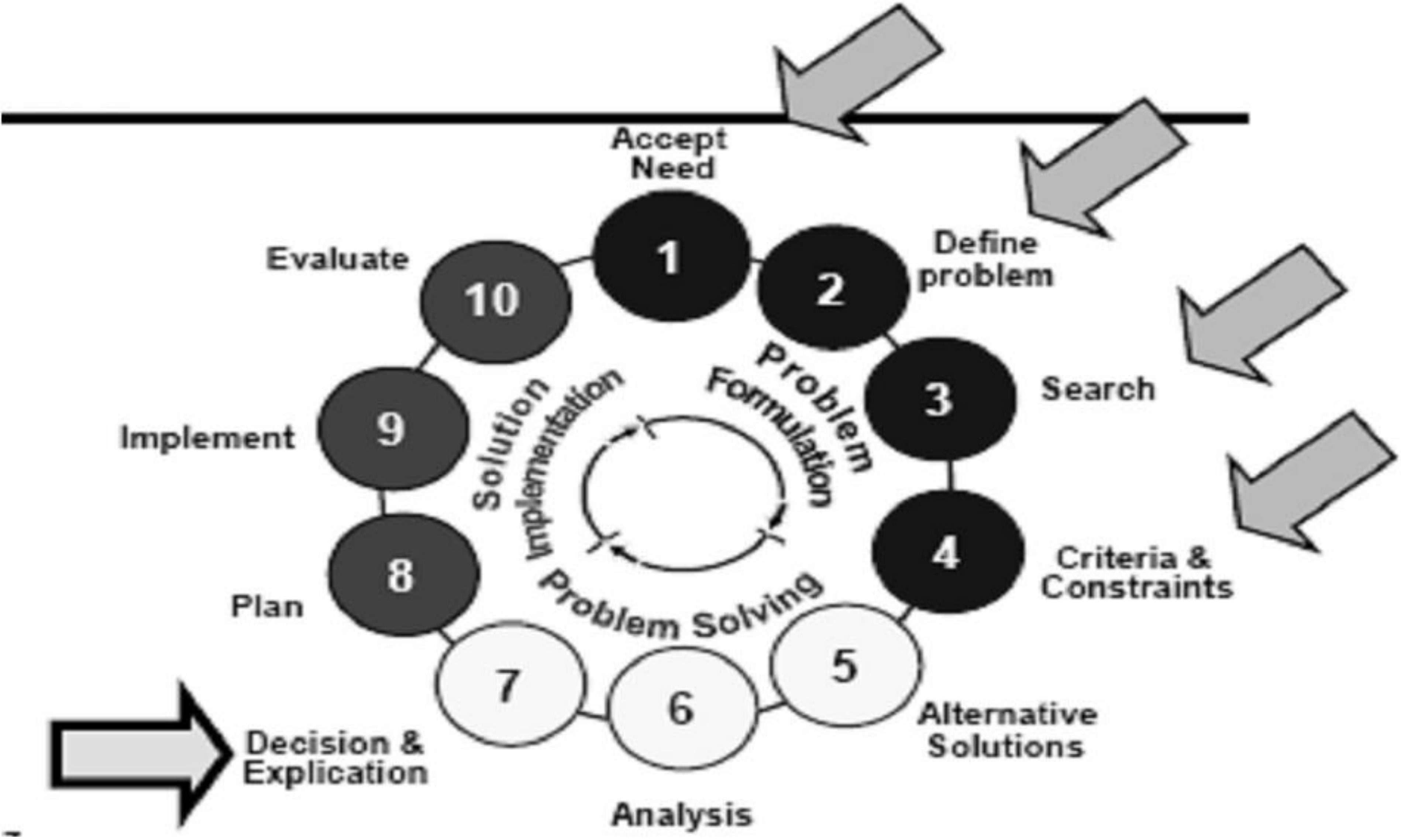
# Solar Oven Reflector Design Ideas - Brainstorming

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
  - Multiple interested parties

# 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

- How important is each attribute?

**A simple approach: Weights that sum to 100**

Multiply & Su

| | | 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 | Multiply & Sum SCORE |
|---|---|---|---|---|---|
| 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 | Multiply & Sum SCORE |
|---|---|---|---|---|---|
| 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 | |
| | | | | | |

# Decision Resolution

- Try more than one scenario
- What did you learn about the strengths and weakness of each concept?
  - What trade-offs will your team make?
  - Don't be driven by a single-objective mentality
- Use decision matrix to *help* you explore tradeoffs
  - You don't necessarily have to use the one with the highest score

# Review

Ideas
Attributes
Weight
Rate
Multiply & Sum

| | Direct Energy | Manufacturability | Room for Error in Aim | Hold Energy in Oven | SCORE |
|---|---|---|---|---|---|
| Weight → | 25 | 25 | 25 | 25 | |
| No Reflector | 1 | 10 | 5 | 10 | |
| | | | | | |
| 1 Reflector | 4 | 8 | 7 | 9 | |
| | | | | | |
| Parabolic | 9 | 2 | 4 | 3 | |
| | | | | | |

Use output to help resolve a decision

# 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