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GE105: Introduction to Engineering Design

”Solar Oven Project” Concept Generation and Evaluation

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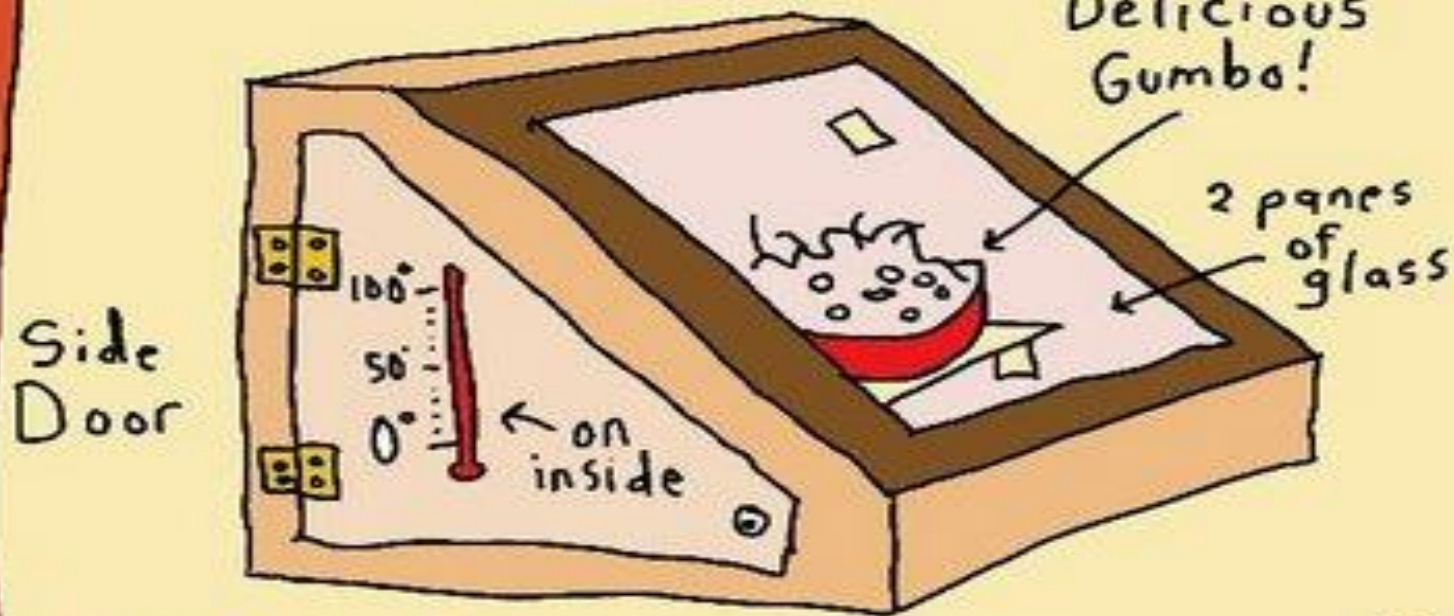
March 27, 2016

GORD'S SOLAR OVEN PLANS

[Cedar, wool insulation, old window panes, hinges]



Delicious Gumbo!

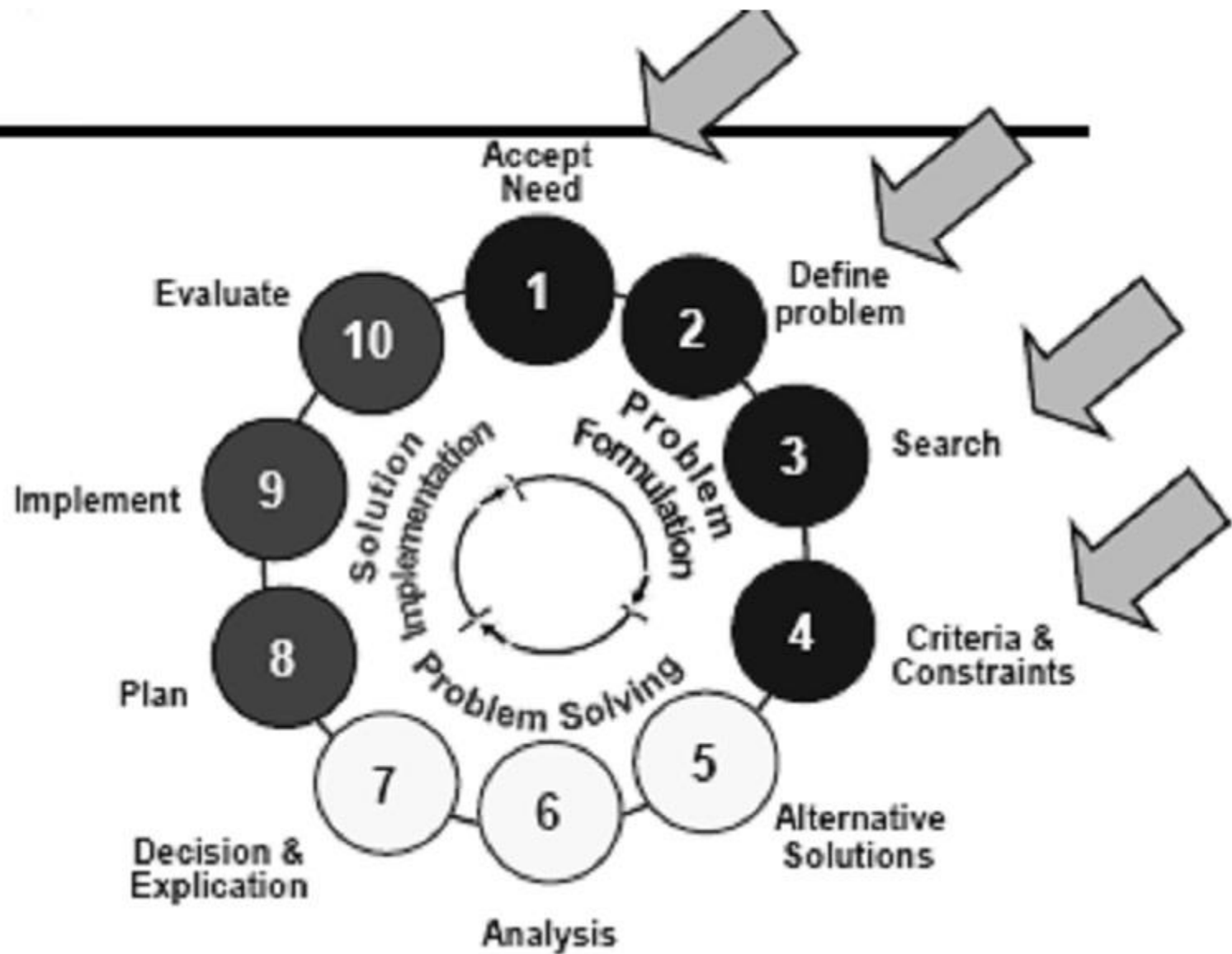


"all I need now is a GUMBO recipe!"

GTH

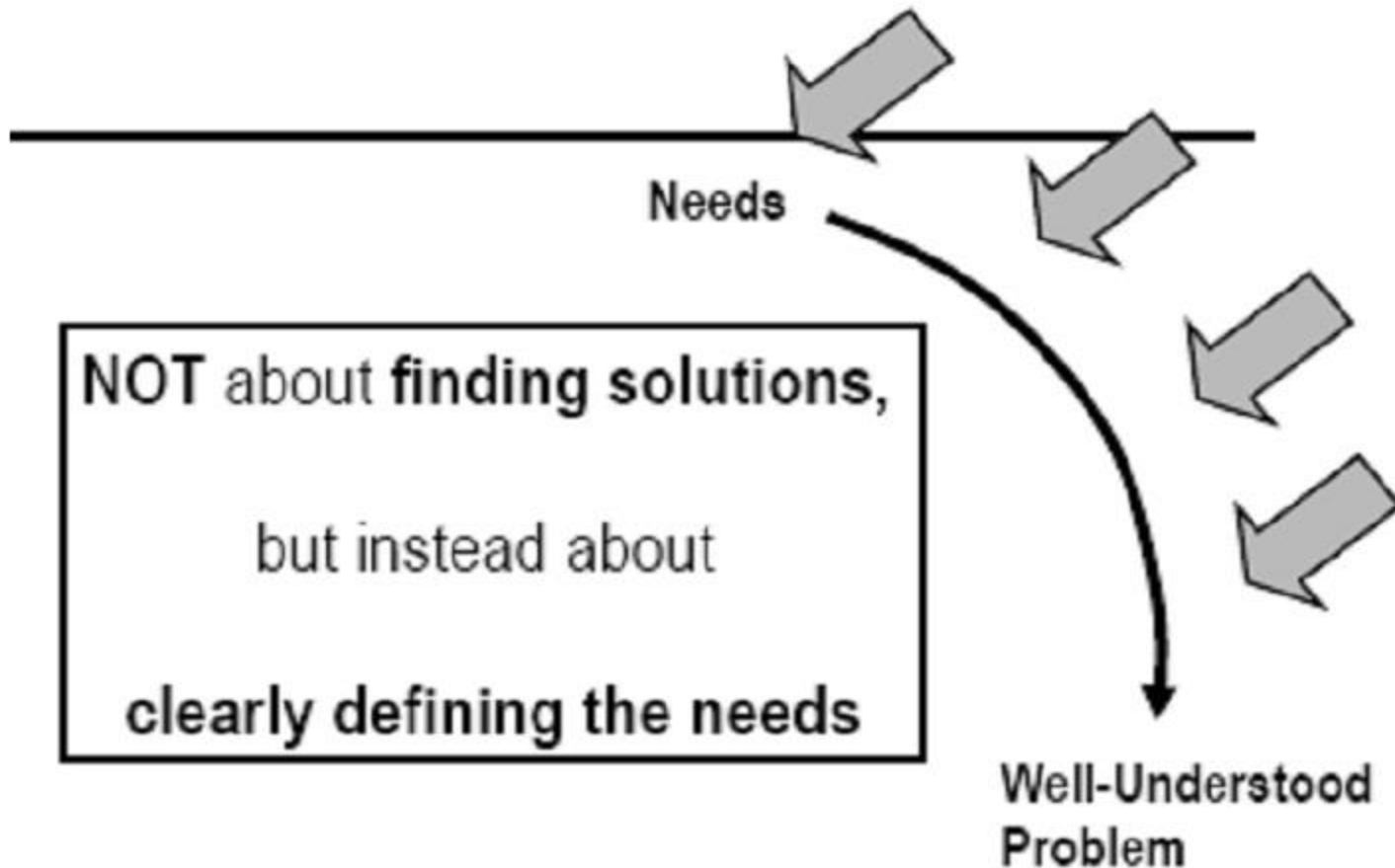
Topics

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



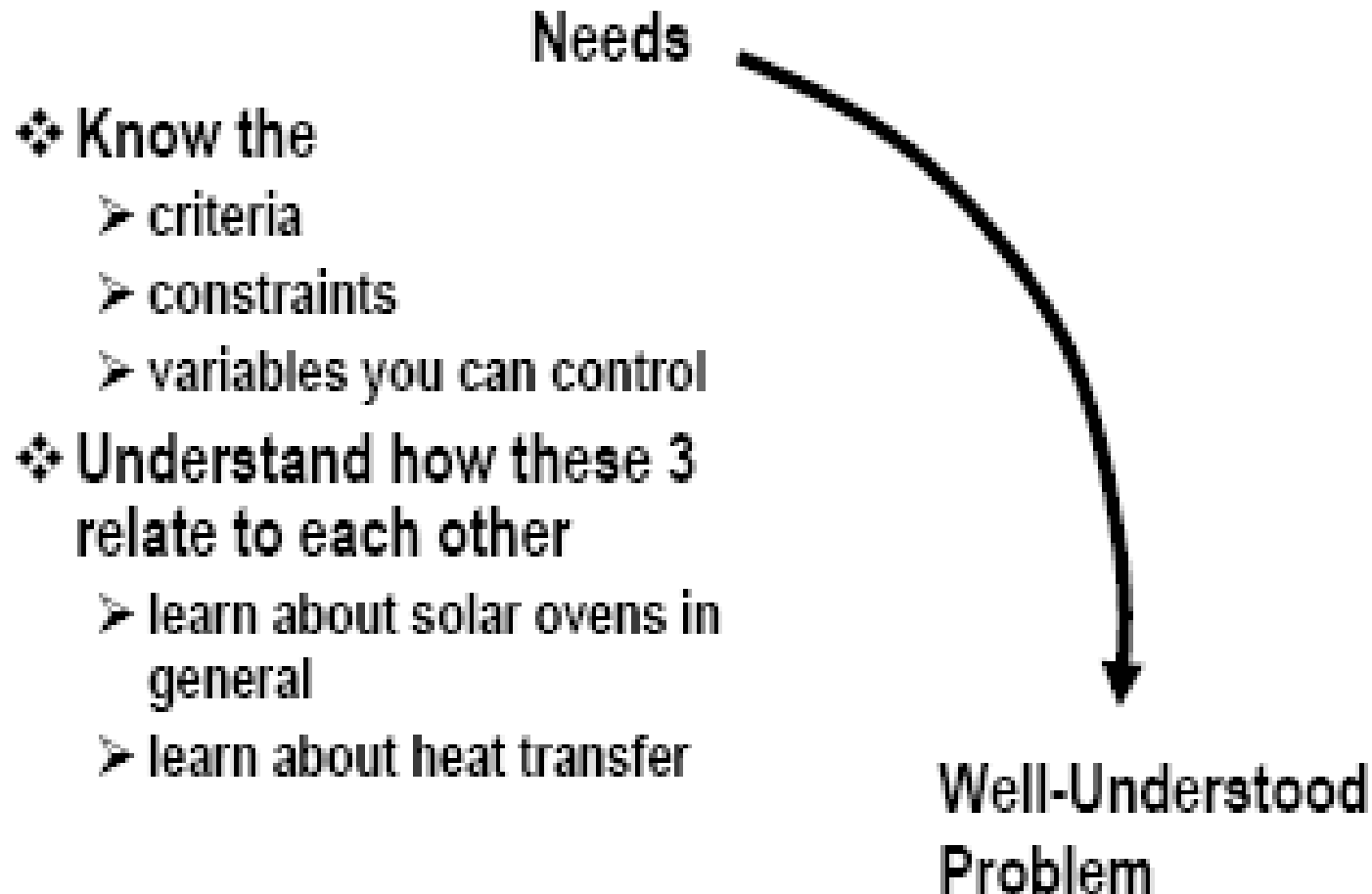
Phase I

Problem Formulation



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

A “Well-Understood” Problem

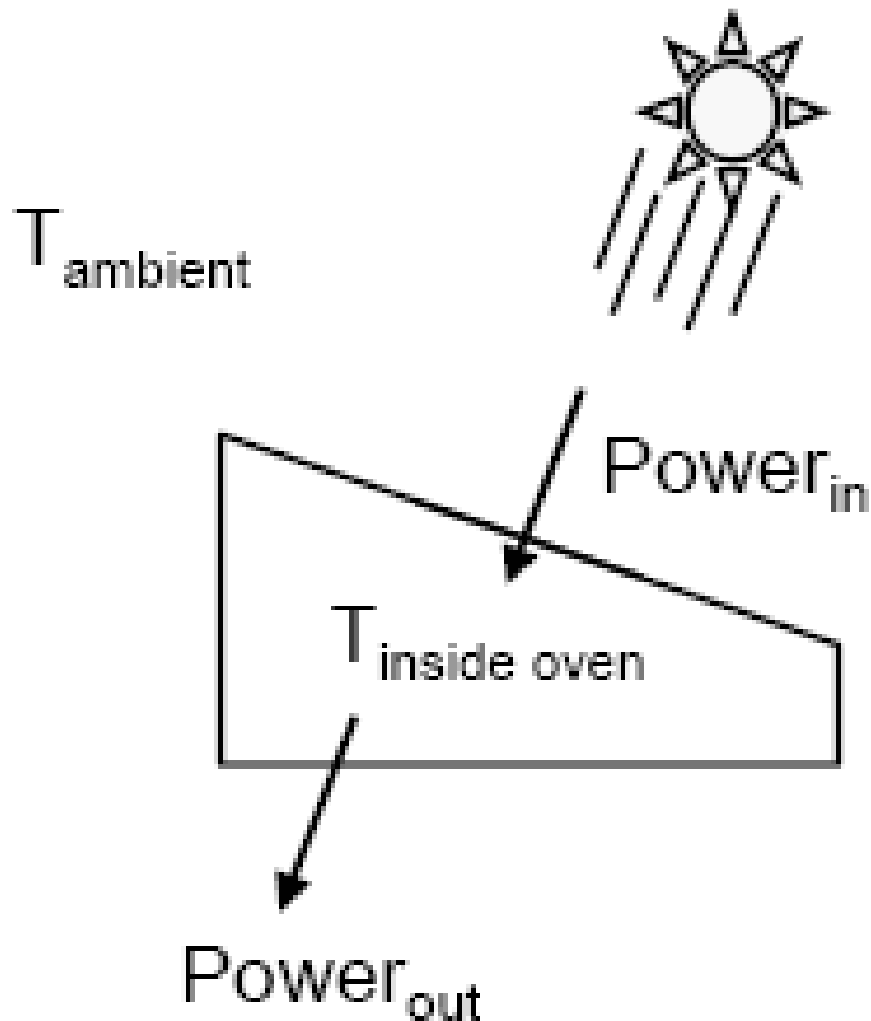


Where should I go to learn about solar ovens?

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

Solar Oven

Search engines



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

Criteria:
Maximize ΔT while
minimizing cost

Heat Transfer

Occurs through one of three modes when a ΔT exists

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

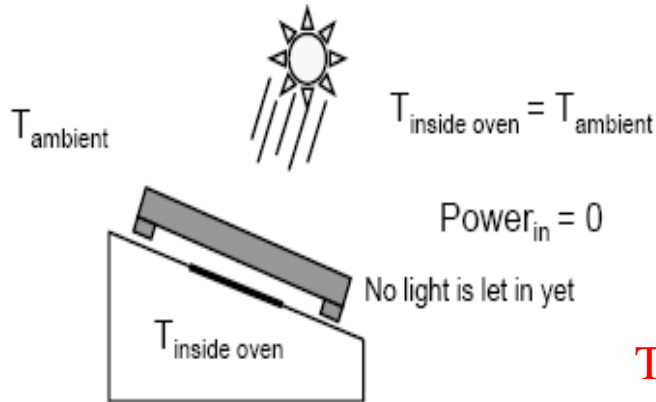
Key Constraints

What are the key constraints?

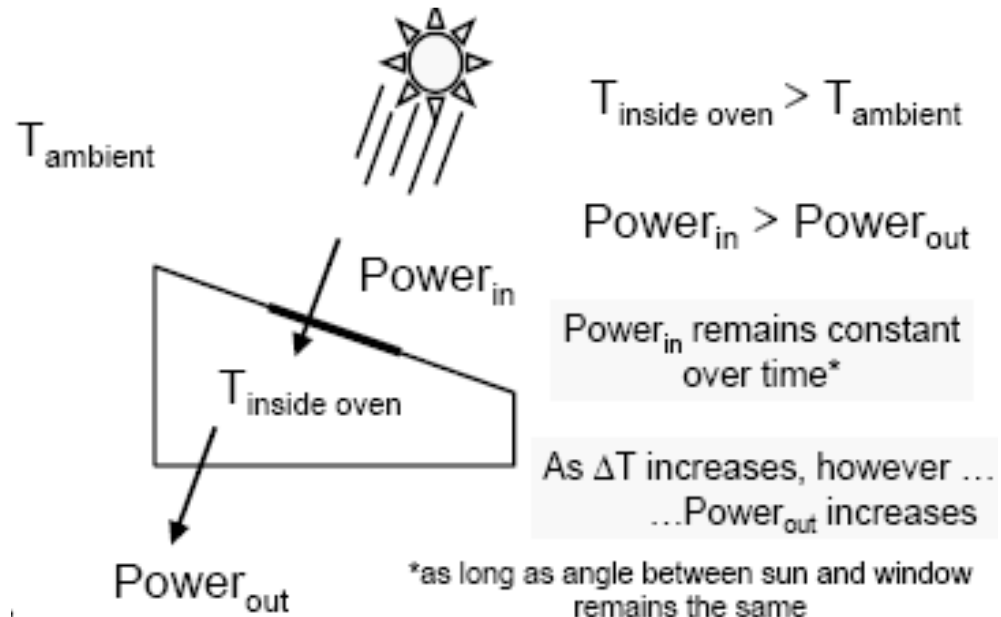
- No lenses
- Size of chamber
- No preheating
- Design must hold a thermometer
- ...

Solar Oven Heat Transfer

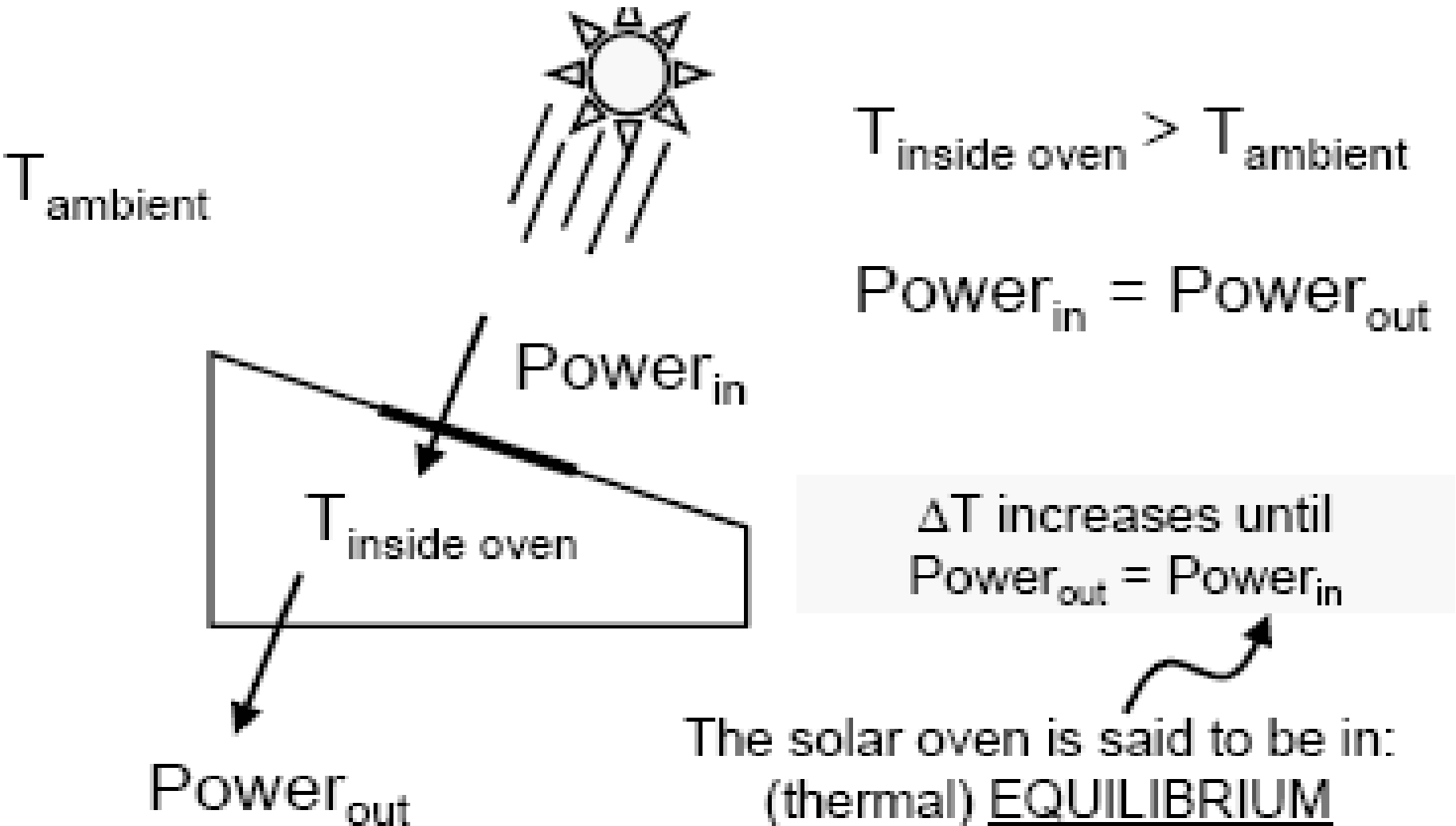
Time = 0



Time = shortly after
cover removed



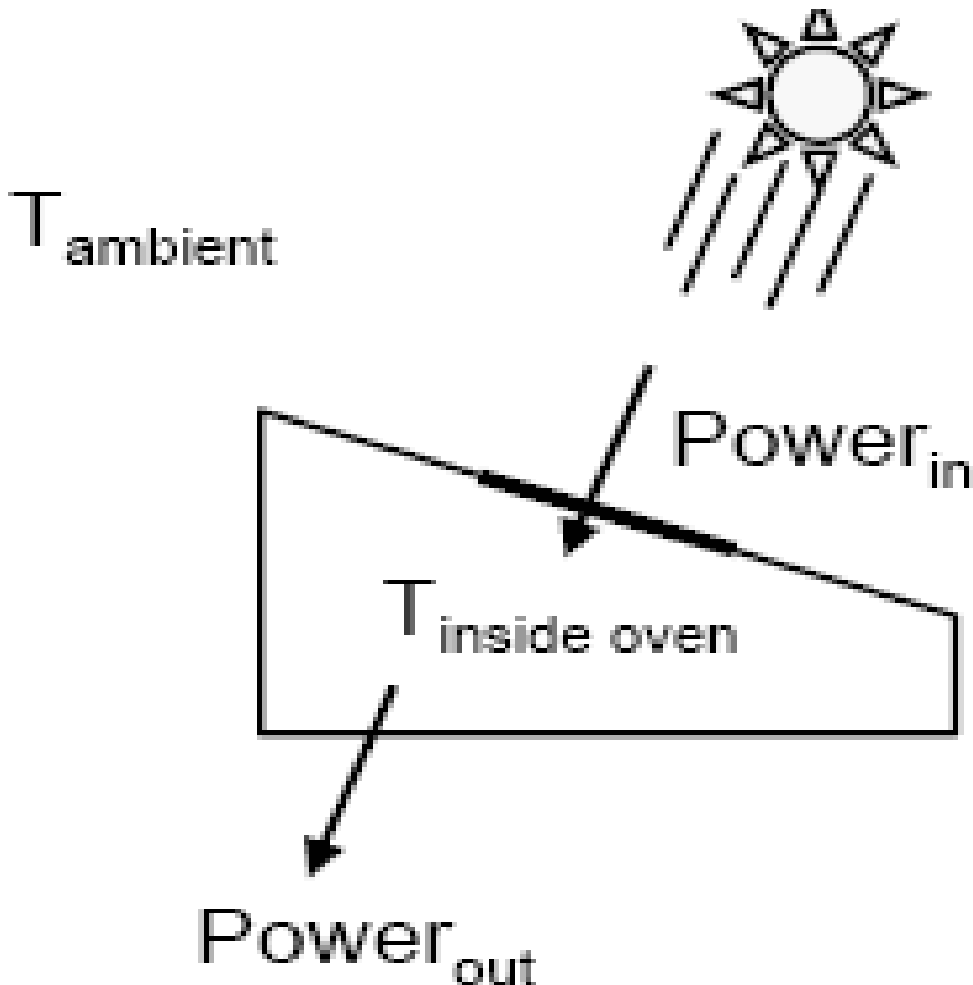
Time = a long time after "0"



Summarizing what we know

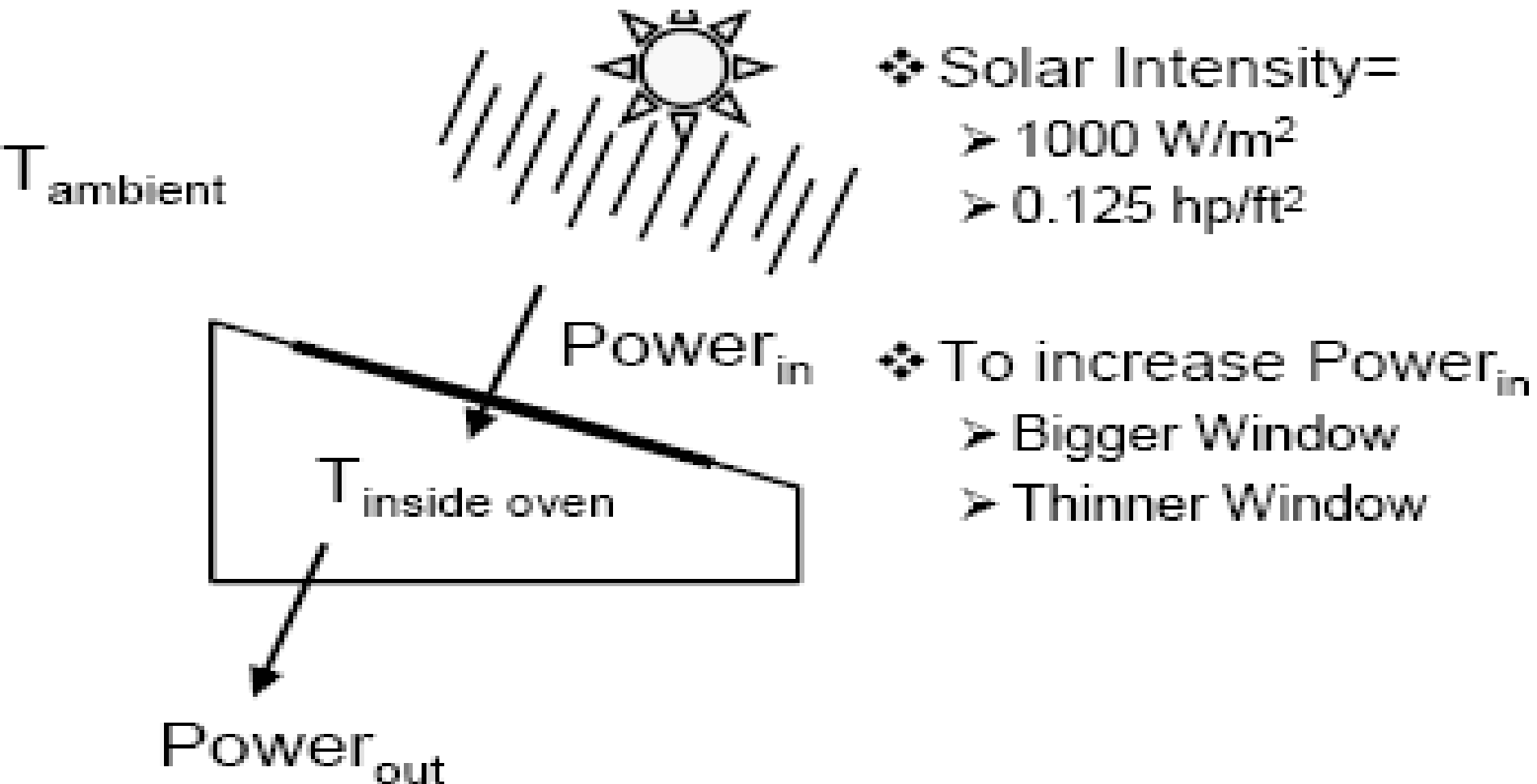
- We want the highest ΔT we can get for a given cost
- To get a higher ΔT , we need either to
 - Increase **Power-in**
 - GET MORE SUN INTO THE OVEN
 - Decrease **Power-out** for a given ΔT
 - FOR ANY GIVEN OVEN TEMPERATURE
 - ❑ WE WANT TO REDUCE THE RATE AT WHICH ENERGY IS LEAVING THE OVEN

How can we Increase Power-in?

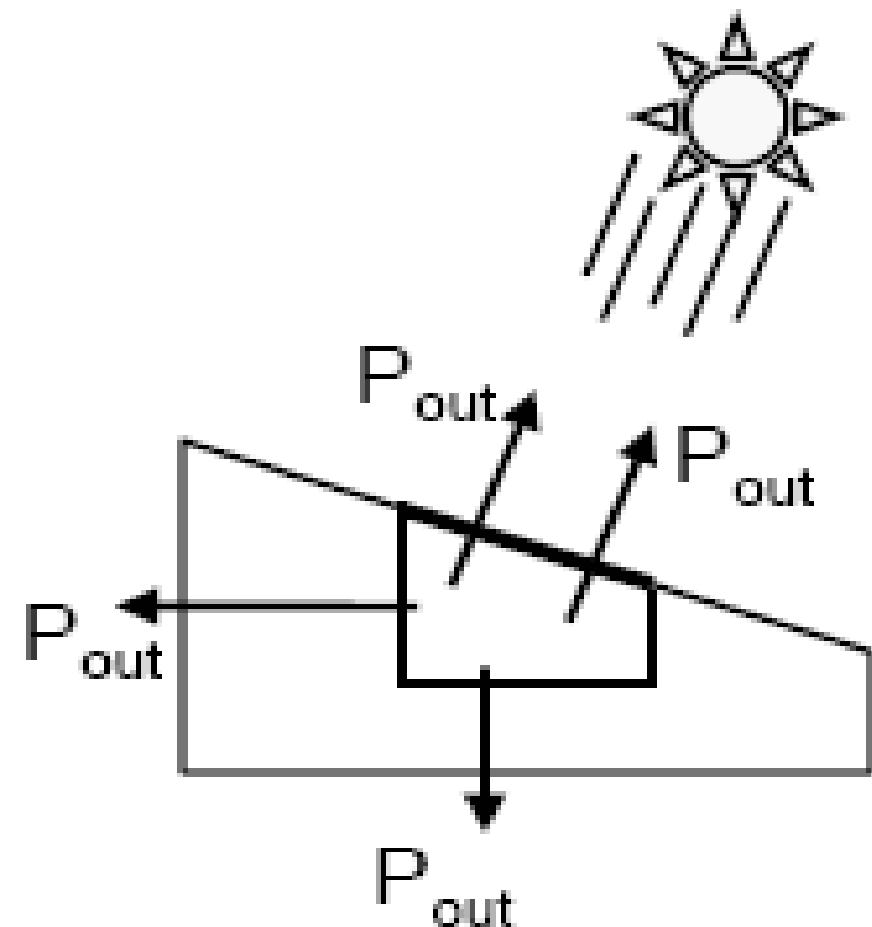


- ❖ What determines Power_{in} ?
 - Window size
 - Intensity of Sun
 - Window Thickness
 - Angle light hits window
 - Color of oven wall

How can we Increase Power-in?



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 ?

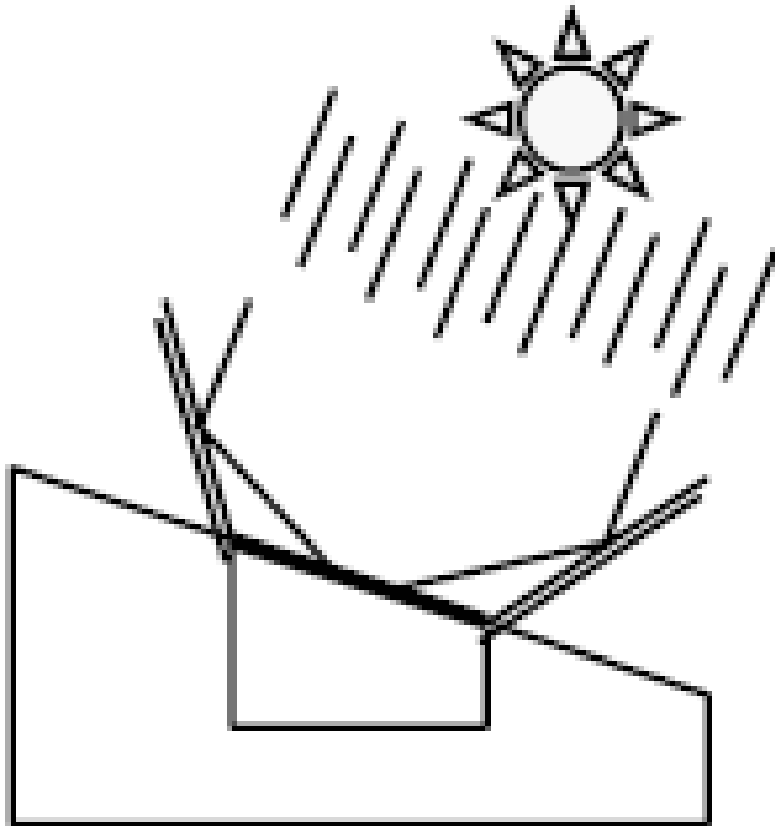
- Heat Transfer Via Window
 - $\sim 25 \text{ W/m}^2 / ^\circ\text{C} \Delta T$ (when T inside oven = 150°C)
 - $\sim 12 \text{ W/m}^2 / ^\circ\text{C}$ (for a thicker window)
- Heat Transfer Via Sides and Bottom
 - $\sim 1.5 \text{ W/m}^2 / ^\circ\text{C} \Delta T$
- Per size, more heat is lost through 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

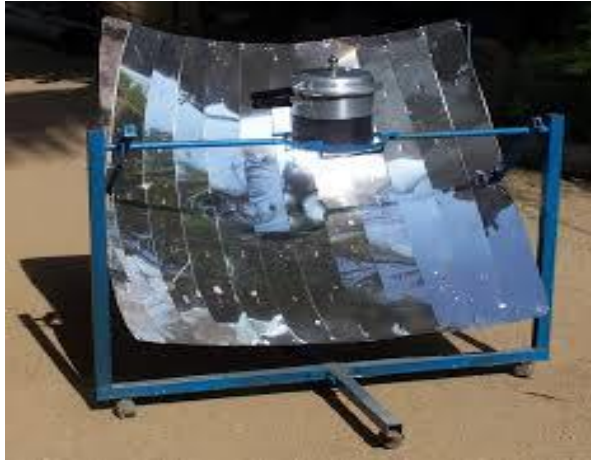


4 flat reflectors, with corner



Solar Oven Reflector Design Ideas - Brainstorming

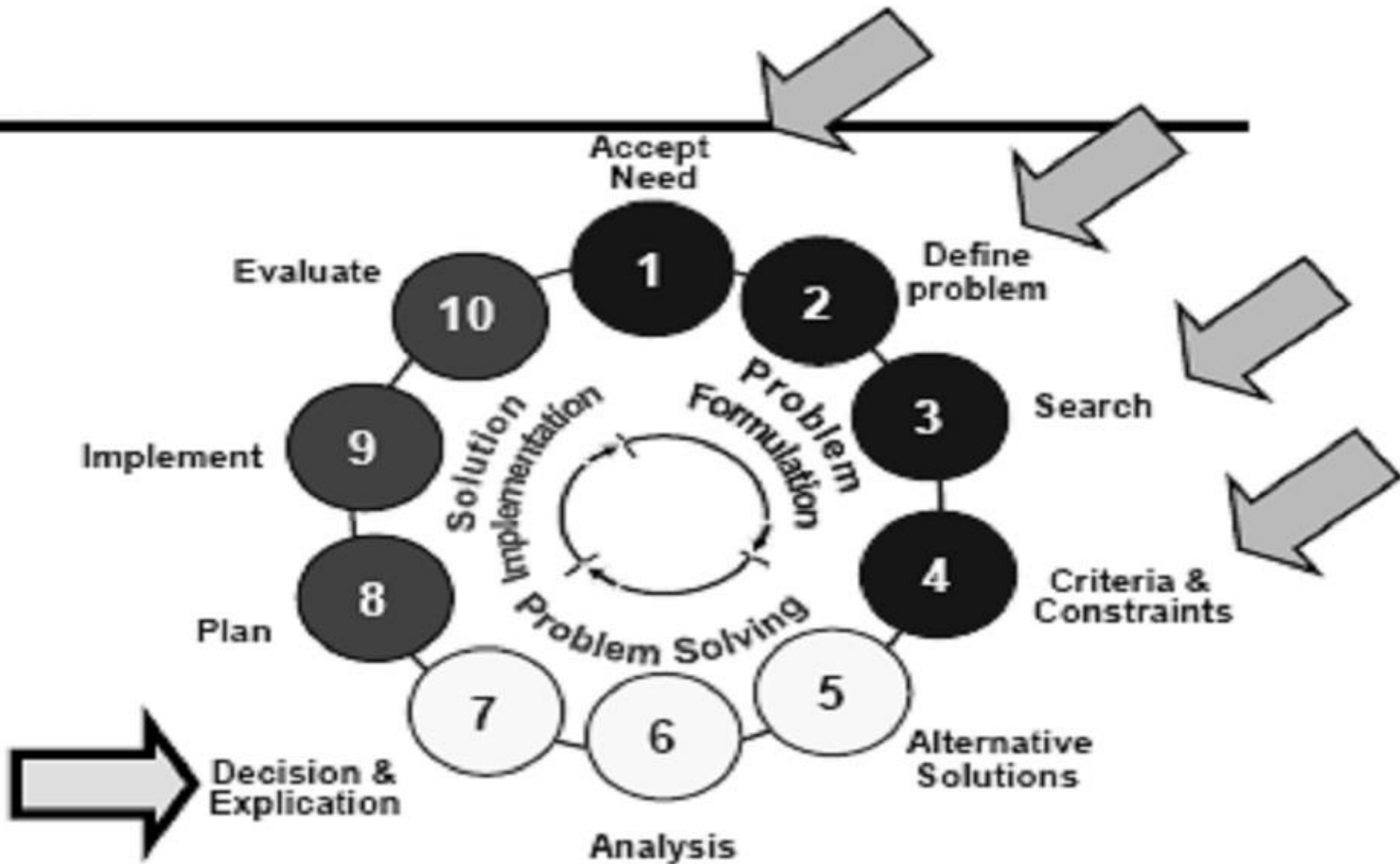
Parabolic



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?

Multiply & Sum

**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
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
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	

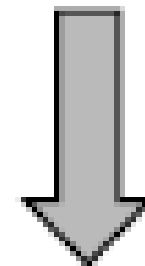
Decision Resolution

- 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



	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