Ultra Low Cost Solar Water Heater

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Problem Formulation and Project Planning

Document

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Introduction

In the U.S. a high startup cost combined with a lack of knowledge about solar water heaters has contributed to low usage. Solar water heaters are a viable way of reducing energy consumption as well as reducing a household's carbon footprint. Solar energy is abundant and free which makes it the best option for a low cost energy source. Many factors must be considered when looking to reduce cost and improve or maintain efficiency of solar water heaters.

The U.S. Environmental Protection Agency (EPA) wants to change how solar water heaters are perceived which drove them to fund the project through the P3 – People, Prosperity, and the Planet Award Program. This program gives students the opportunity to research, develop, and design solutions to real world problems involving the sustainability of society as a whole. This program was developed in order to meet the technical needs of society in relation to a sustainable future.

Problem Definition

Current solar water heaters are too expensive and it takes a long period of use to make them financially sensible, therefore current solar water heater designs are financially impractical over a short period of use.
The solution to this need is to design a low cost solar water heater that is efficient enough to produce a quick financial return.

Objectives and Constraints

- **Heats Water:** The objective of this project is to create a low cost solar water heater that heats water by solar convection.
    - **Specification: Potable Fluid Temperature (^{o}C):** This solar water heater will maintain a specified temperature throughout a 24hr period.
- **Weather Proof Design:** The solar water heater must be weather proof since water heaters will typically be outside, either in a yard or mounted on a roof. Exposure to the elements is inevitable in these cases.
    - **Specification: Durability (Pa & Km/hr):** The solar water heaters must be able to withstand high wind speeds; impact forces from hail, rain and debris; and in some cases, pressures from snow. It is necessary that the solar water heater withstands all of these forces to allow for a reliable system that requires no repair every time foul weather is introduced.
- **Low Initial Cost:** One significant problem with solar water heaters currently in the market is the initial cost of the heater is too expensive, and therefore requires the need of long-term use before there is a financial return. The objective is to create a solar water heater that has a low enough initial cost to provide the consumer quick financial return.

- **Break-Even Cost (USD):** Things that influence the initial cost of the solar water heater are: materials used, complexity of the design, quantity of materials used, difficulty of manufacture and difficulty of production. As any of these cost multipliers increase, initial cost will increase. All of these cost multipliers will be closely monitored in the design of the solar water heater.

- **Low Maintenance Cost:** The Solar water heater should be easily maintained on a routine maintenance schedule. The cost of maintenance should also be low to optimize break-even cost.

    - **Specification: Routine Maintenance Cost/Frequency (USD/Years):** While cost and frequency of maintenance increase so does the time for the consumer to get their initial investment back. Frequency of maintenance should be at reasonable intervals varying slightly between geographical regions as well as daily use.

- **Quick Financial Return:** The main reason solar water heaters are not more widely implemented is because the consumer has to reap the benefits of them from a very long time in order to see any return. A solar water heater must show positive capital quickly in order for it to appeal to the general public.

    - **Specification: Break-Even Cost (Years):** The solar water heater must conserve energy while maintaining a satisfactory working temperature of the potable fluid. Sacrifices in efficiency must be balanced with initial cost to obtain a quick financial return.

- **Implemented into Current Water Heating Systems:** A high percentage of houses in the world have an existing water heating system currently installed. Many systems which use solar heat also use gas or electricity for times when solar energy is not available.

    - **Specification: Able to be Integrated into Current Systems (yes/no):** To maintain marketability and appeal it is crucial for the solar water heater to be easily integrated into current water heating systems. The ease of installation will be measured with a yes/no metric based on surveyed data. A general knowledge of plumbing will be required to properly and safely install the solar water heater.

- **Safe Operation:** Operating the solar water heater should be safe under all condition.

    - **Specification: Safety (yes/no & ^{o}C):** Safety and energy conservation are factors to be considered when selecting the water temperature setting of a water heater. High water temperatures can cause severe burns or death from scalding. Basic water uses like showering, dish washing, and cloths washing should operate safely in daily basis. The solar water heater design should meet all government safety standards and regulations.

- **Sensible System Size:** A properly sized water heater system will provide a significant portion of a home's hot water.
    - **Specification: Size (m^3):** A water heater should be easily contained inside a house or apartment. Designing a solar heating system for small use should have a reasonable size. Materials sizes should be taken in consideration when designing and building this project.

Quality Function Deployment Matrix

The Quality Function Deployment matrix (QFD) is used to break a project down into smaller components. It is used to help engineers focus in on viewpoints of the company, marketing, and technological needs of a given project. The QFD below goes over the objectives and constraints in designing a low cost solar water heater.

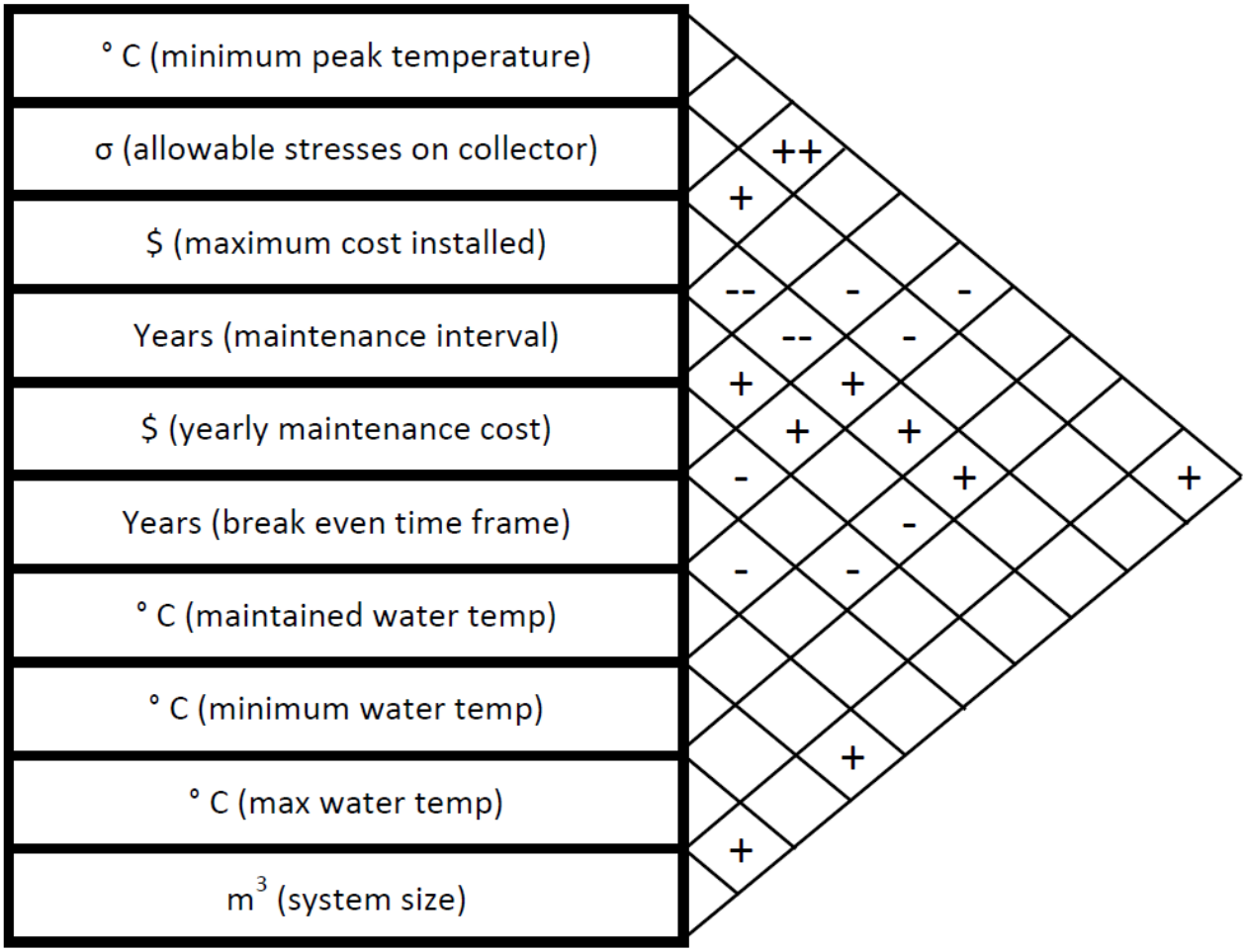
Table 1: Quality Function Deployment Matrix

			Specifications			
		Weighted Importance	Volume	Material Strength	Temperature	Cost
Objectives	1. Heats Water	10			9	9
	2. Weather Proof	3		9		
	3. Low Initial Cost	10		1	9	9
	4. Low Maintence	9	1	3	1	9
	5. Quick Financial Return	10		9	1	9
	6. Implement Into Current Systems	9	3		1	
	7. Safe Operation	3	1	3	3	
	8. Sensible System Size	3	9			3
	9. Easy to Use	1				
		Score	66	163	217	360
		Relative Weight	0.18	0.45	0.60	**1.00**
		Unit of Measure	m^3	kPa	°C	$
		Technical Target	< 27		> 38	< 300

House of Quality

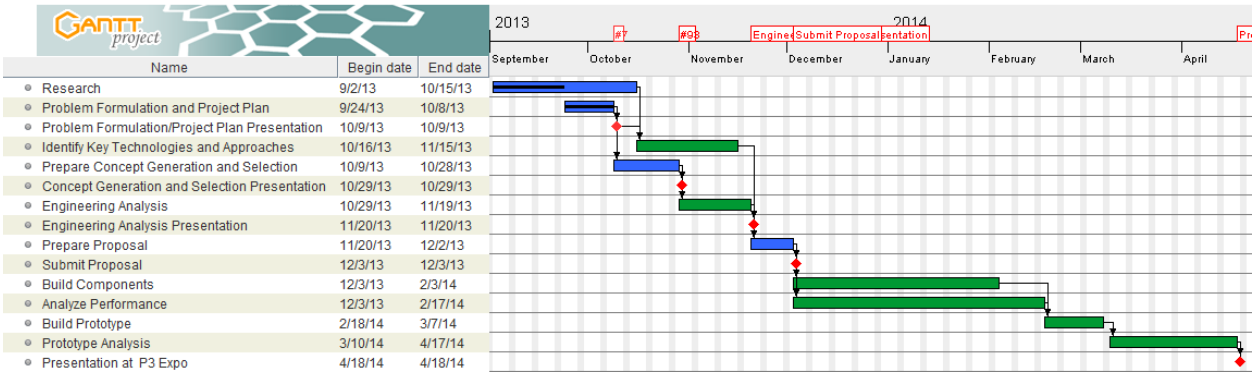
The house of quality highlights several specifications which greatly influence other specifications. The maximum installed cost influences three other specifications: the maximum peak temperature, the maintenance interval, and the yearly maintenance cost.
The project goal dictates that the maximum installed cost be reduced. When this cost is reduced the maintenance interval and the yearly maintenance cost normally increase. Conversely, reducing this cost will increase the yearly maintenance cost will increase, which is also a negative effect. The project goal also dictates that the break even time of the SWH system must be minimized. Decreasing the break even time will have the following effects: decrease in the maintenance interval, decrease the maximum installed cost, and increase the yearly maintenance cost. While decreasing the maintenance interval and decreasing the installed cost of a unit are positive effects, increasing the yearly maintenance cost is a severely negative effect. In order to achieve this goal, the negative effects of reducing the installation cost and reducing the break even time must be minimized while at the same time maximizing the positive effects

Table 2: House of Quality Matrix



Gantt Chart

The Gantt chart below shows the timeline for the project. Notable dates are indicated by red triangles. The final project presentation is April 18th and 19th in Washington, D.C.



Name	Begin date	End date
Research	9/2/13	10/15/13
Problem Formulation and Project Plan	9/24/13	10/8/13
Problem Formulation/Project Plan Presentation	10/9/13	10/9/13
Identify Key Technologies and Approaches	10/16/13	11/15/13
Prepare Concept Generation and Selection	10/9/13	10/28/13
Concept Generation and Selection Presentation	10/29/13	10/29/13
Engineering Analysis	10/29/13	11/19/13
Engineering Analysis Presentation	11/20/13	11/20/13
Prepare Proposal	11/20/13	12/2/13
Submit Proposal	12/3/13	12/3/13
Build Components	12/3/13	2/3/14
Analyze Performance	12/3/13	2/17/14
Build Prototype	2/18/14	3/7/14
Prototype Analysis	3/10/14	4/17/14
Presentation at P3 Expo	4/18/14	4/18/14

Summary

Solar water heater technology is too expensive for the average American and therefore unused. The EPA wants to provide a more sustainable future through renewable and efficient energy sources such as solar water heaters. Through the P3 grant, cost effective solar water heaters are being developed to achieve a quick financial return. These solar water heaters must be both efficient as well as affordable. Other design factors, such as durability, size, functionality, and practicality also play a role in the marketability of the design. Once solar water heaters are regularly implemented the long term goal of a more energy efficient America can be realized.

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