Sustainability in Energy and Buildings: Research Advances:
Vol 3: Sustainability in Energy and Buildings (SEB-14) Short Papers pp.43-51 : seb14s-018

Analysis of user needs for solar cooking stove acceptance

Robert Wimmer[1], Chaipipat Pokpong[1], Myung Joo Kang[1], Ardeshir Mahdavi[2]

Center for Appropriate Technology (GrAT)[1], Department of Building Physics and Building Ecology[2], Vienna University of Technology (TU Wien)

Abstract

Many researches were conducted and proved that a solar-based cooking stove can provide high temperature sufficient for cooking foods. However, a solar-based cooking stove has not been widely used in households yet. This paper aims to investigate the reasons for the low acceptance of the solar cooking stove on the part of the households, based on an analysis of the user needs related to an electric cooking stove and the cooking behavior, in order to suggest a design guideline to design a cooking stove which is more likely to be accepted by households. The Kano model was used to classify user needs regarding an electric cooking stove in order to determine necessary features for a solar-based cooking stove. The result of this study is to improve user acceptance by using a design that bridges user needs and cooking stove features.

1. Introduction

With the aim to increase adoption of renewable-based household products, which will contribute to reducing the dependence on fossil-based energy consumption, multifold efforts are being made in different research and development areas. Efficiency has increased, facilities (e.g. photovoltaic, solar collector, etc.) have been installed, and governmental subsidies have been granted. Particularly based on the Appropriate Technology principles, the authors are currently designing a solar-based energy supply system to be integrated in a building, which is also elaborated in consideration of sustainability aspects.

The solar-based energy supply system in a wireless house concept operates not only thermal energy services, but it also includes the other household appliances. The three most energy-intensive household products, a refrigerator, a washing machine and a tumble dryer, together with a cooking stove have been chosen to demonstrate the feasibility of the energy system

ISSN 2054-3743 : http://nimbusvault.net/publications/koala/sebra

and its practical use. This paper will present the related research and development work done for the cooking stove.

It is crucial to gain market acceptance for the solar cooking stove because it is powered by a renewable energy source without conversion into electrical energy. It is still perceived to be very new and unknown to the majority of consumers. This unfamiliarity in some product categories, especially conventional household devices such as refrigerator, washing machine and cooking stove, can cause uncertainty of consumer insight and result in low acceptance.

Several solar cooking stove designs as results of many research and development projects have proved that such devices can be used for domestic cooking, with sufficiently high temperature, twice a day [1]. Nevertheless, actual and practical use of the same kind of devices in households has been very little known.

The main question which initiated this research was why a solar cooking stove is not widely used in households, although it meets the technical requirement of certain temperature for cooking.

2. Background and related work

The primary user need related to a cooking stove is cooking foods. Yet, since the new types of solar-based cooking stoves have already shown that they can cook foods, there must be other reasons why these solar devices have not immediately replaced the conventional electrical or gas cooking stoves, and even the wood fire stoves in developing countries. Thus, secondary user needs related to the cooking stove itself, as well as users' experience and expectation before, during, and after the process of cooking need to be investigated.

In order to find the answer to the main question, the following assumptions were made to be verified with a series of scientific research methods. Most of the assumptions have been set in comparison to a conventional type of cooking stove which is based on electricity or gas.

- Assumption 1: Users want to have the same or comparable functions which the conventional cooking stoves provide.
- Assumption 2: Users have a resistance towards a new visual design of product, even if it functions differently from traditional models.
- Assumption 3: There can be other needs which should be smartly addressed on the conventional cooking stoves to increase user acceptance.
- Assumption 4: Users accept a solar energy system as a new energy input to their appliances.

2.1. User needs exploration

To identify diverse user demands, three different research methods were applied: 1) questionnaires, 2) observations and 3) in-depth interviews.

2.1.1. Questionnaires

Two hundred sets of questionnaires were distributed to cooking stove users in Austria. The questionnaire comprised two parts. The first was to find out basic information, such as personal data and the users' cooking stove characteristics. The second part was to explore their opinion on their existing cooking stove by rating to gather qualitative data. For each question, the participants selected one of multiple choices as following: like, expect, neutral, tolerant and dislike, describing their satisfaction. The evaluation pattern was shown as a matrix (see table 1).

2.1.2. Observations

The purpose of observation was to gain a better understanding of how participants interact with a cooking stove. Cooking utensils were set up by providing a four burners electric cooking stove, pot, pan, spatula, scoop, bowls and dishes. Six participants were selected: three female and three male cooks. They were asked to cook a simple dish one by one. The actions of the participants were reviewed in seven stages as following: 1) goal establishing, 2) planning, 2) action consequence, 4) performance, 5) perception, 6) interpretation and 7) comparison. [2]

2.1.3. In-depth interviews

The six participants were interviewed after cooking demonstration to get qualitative data and understand their behavior during cooking.

Applying Kano model

The user needs for cooking stove usability were analyzed through the Kano model to clarify the relation between user requirements and user satisfaction. The Kano model is a user need classification tool which corresponds to user satisfaction. If the user demands are met, the user will be satisfied; if not, they will be dissatisfied. The user will be delighted when a cooking stove has attractive design attributes. However, when an attractive design is expected as basic requirement, user satisfaction will be decreased. The initial survey results showed eleven design attributes that users need for comfortably using a cooking stove. The needs were classified into five groups in the Kano model to define need levels for using a cooking stove; 1) must-be quality; 2) one-dimension quality; 3) attractive quality; 4) indifferent quality and 5) reverse quality.

Table 1. Pattern of user needs classification according to Kano model

Customer requirements		Dysfunctional (negative) questions				
		1	2	3	4Tolerate	5
Function (positive) questions	1 Like	Q	A	A	A	O
	2 Expect	R	I	I	I	M
	3 Neutral	R	I	I	I	M
	4Tolerate	R	I	I	I	M
	5 Dislike	R	R	R	R	Q

M = must be, O = one dimension, A = attractive, I = indifferent, R = reverse, Q = questionable

3. Finding and discussion

3.1 User needs and acceptance criteria for using a solar cooking stove

The results of this survey and literature researches revealed 11 attributes that users consider important for comfortably using a cooking stove.

3.1.1. Cooking temperature requirements

Temperature performance of cooking should be between 75°C and 232°C for safe cooking. Cooking time depends on the temperature level and food characteristics. Cooking time can be shortened by adding higher temperature. Those different temperatures can kill germs for safe foods consumption.

Table 2 shows general cooking requirements between 75°C and 190°C only to make cooked foods. The higher range 177°C-233°C is used for baking.

Table 2. Safe minimum cooking temperature requirements

Category	Foods	Cooking methods	Temperature (°C)
Meat	Beef, pork, lamp, turkey, chicken, duck, seafood	Varies	75[1]
		Deep frying	175-190[3]
		Steaming	100<
Soup	Water, stock	Boiling	100<
Bakery	Bread	Baking	218-232[2]
	Cake	Baking	177-190[2]
	Cookies	Baking	177-205[2]

[3][1], [4][2], [5][3]

3.1.2. Fast reaching of high temperature

Users prefer to shorten their cooking time. In the last ten years, average use of a cooking stove was about 45-60 minutes per cooking time. The survey showed that 76% of the participants spent only about 20-30 minutes for using a cooking stove. They need a high performance cooking stove to achieve this goal.

3.1.3. Precise control

A user needs to know the current temperature for cooking. An interaction between displays and control design is very important for user perception. The surveys reveal that 67% of participants do not know the cooking temperature during their cooking. There are three methods to perceive the current cooking temperature: 1) users monitor a flame characteristic of gas cooking stove, 2) users look at the lighting signal from an electric cooking stove to predict cooking temperature from their experience, 3) users use a knob position and graphic to indicate a cooking temperature level. A solar cooking stove needs to show the current temperature level or preferred temperature to help control cooking temperature. The results of the surveys also reveal that cooks do not need to know an exact temperature for their cooking. Three temperature ranges were suggested by the participants that are sufficient for cooking as following: high, medium and low heat.

3.1.4. Easy temperature controlling

A good ergonomic design can help users to control temperature during their cooking. A good relation between displays and control can help users to easily control the cooking temperature. A good grip on a control knob should consider: shape, size, movement direction, position, color and non-slip materials.

3.1.5. Prompt use

The result of the survey showed that the participants use their cooking stove at least twice a day. They need on average 20-30 minutes per cooking time. A cooking stove should have sufficient energy input and backup system for that basic need. The literature study found that a solar cooking stove can provide sufficient heat for cooking 25 hours. [6]

3.1.6. Safety

Users can be harmed from using a cooking stove because of heat and physical sharp edges. Product designers should avoid using ambiguous cooking zoning that cause skin burning from touching. Warning graphics or interface designs are needed to clearly indicate a hot zone on a cooking stove surface. A cooking stove design should avoid small corners and gaps which are difficult to clean. A sharp edge can also harm users when they clean a cooking stove surface. Users need a warning system, both sound and visual signals, for security reasons.

3.1.7. Number of burners

The survey result showed that all participants would like to have more than one burner. 85% of them have four burners on their cooking stove. It clearly indicates that users need a multi-burner with different sizes for their cooking. Users can cook with two burners at the same time to save cooking time. However, users have negative feedback on a cooking stove that has more than four burners.

3.1.8. Easy to clean

41% of the participants clean their cooking stove every day after cooking. One fourth of the participants are not satisfied with their cooking stove because it is very difficult to clean. The interview indicated that users need a dirt-free surface during their cooking. The users are satisfied with a flat and smooth surface on their cooking stove because it is comfortable for removing dirt stain.

3.1.9. Energy saving and alternative energy used

The feedback from the surveys showed that the participants would like to use alternative energy input for their cooking stove to reduce electricity load,

and to increase self-sufficient living by decreasing fossil energy consumption.

3.1.10. Aesthetics and appearance design

There is a broad range of definitions among participants of what makes an attractive physical appearance of a cooking stove. For the most part, it can be assumed that the design should be compatible with furniture and the surrounding environment. However, there are some users that prefer a dominant design to make the cooker different from a conventional design.

3.1.11. Durability and maintenance

The users are satisfied with their cooking stove if it has a long working life with regular maintenance. The participants expect that their cooking stove should work at least five years. Increase in satisfaction is directly linked to working life time of the cooking stove.

3.2. User needs classifications for new cooking stove development

3.2.1. Must-be quality (M)

The first group refers to basic attributes that, when missing in a design, users will absolutely be dissatisfied with. The temperature performance is of highest importance for using a cooking stove. The users immediately refuse to use insufficiently high temperatures for their cooking. However, when temperature can reach a sufficient high for cooking, it does not increase user satisfaction. The user considers it as basic need regarding a cooking stove.

3.2.2. One-dimension quality (O)

The one-dimension quality refers to a design attribute of cooking stoves that makes users satisfied, or dissatisfied when it is not fulfilled. User satisfaction increases proportionally with a better performance. As an example, a cooking stove that can quickly reach the expected cooking temperature will satisfy a user more than a slower cooking stove design.

3.2.3. Attractive quality (A)

The third group consists of quality attributes that influence user acceptance of a new design. An attractive quality attribute can add user satisfaction to a cooking stove but it does not cause dissatisfaction when the cooking stove does not have this attractive quality. For example, aesthetic appearance can add more value to a cooking design but it does not impact user satisfaction as long as the cooking stove is still properly working.

3.2.4. Indifferent quality (I)

An indifferent quality attribute refers to a quality attribute that can be either positive or negative for user satisfaction. For example, a cooking stove on-off switch is a critical issue in identifying a design direction. Even though

a switch that's easy to turn on and off can help a user control the cooking stove, it can be harmful for children by unintentionally switching on the cooking stove.

3.2.5. Reverse quality (R)

The reverse quality attribute group is similar to the indifferent quality group insofar as it might satisfy one user group while it also dissatisfies another user group. For example, a high technology cooking stove provides a precise temperature for cooking but users need to spend a lot of time for setting it right. Another group prefers a simple cooking stove design.

Table 3. Needs classification of cooking stoves according to Kano model

Needs	Category
1 Temperature performance	**M**
2 Fast reaching of high temperature	**O**
3 Precise control	**M**
4 Easy to control (switch on/off)	**I**
5 Prompt use	**M**
6 Safety – non toxic	**M**
7 Number of burners	**I**
8 Easy to clean	**A**
9 Energy saving	**O**
10 Aesthetic appearance	**I**
11 Durability	**O**

M: Must be, O: One dimension, A: Attractive, I: Indifferent, R: Reverse, Q: Questionable

Thermal energy is the most needed energy type for common living in a house. However, there are only a small number of household appliances that can directly use thermal energy without any conversion. Low-temperature thermal energy production in a house can be installed for many household appliances such as water heater for hot shower, dishwasher and washing machine. The investment for a solar thermal energy production system is still very high for very few numbers of appliances.

4. Conclusion

Based on the analysis of the research conducted with conventional cooking stoves, the result of this study showed that solar cooking stoves have not been widely used in the residential sector because of three main reasons:

4.1 The solar cooking stove can partly respond to basic attributes that users expect to have in their cooking stove, particularly timing such as prompt using and fast temperature responding.

4.2 Users partly accept solar technology for cooking because most of the prototypes in researches still show engineering looks. A solar cooking stove still needs further ergonomics design and aesthetics to increase user satisfaction.

4.3 A solar cooking stove requires an extra infrastructure in conventional buildings. A solar thermal energy system installation is not associated with a number of products that use medium temperature. However, sharing the infrastructure with other household appliances might increase investment value.

An accepted solar cooking stove design must consist of three attributes as following: temperature performance, precise control, prompt use and safety. There are four attributes: fast reaching of high temperature, energy saving ability, ease of cleaning and aesthetic appearance that can increase user acceptance for a cooking stove. In addition, an energy infrastructure system in a building can be adapted to supply and share with other household appliances to reduce building integration costs.

References

[1] U.S. Mirdha, S.R. Dhariwal. (2008). Design optimization of solar cooker. *Renewable energy*, 530-544.

[2] [4] Donald, N. (2013). *The design of everyday things.* New York: Basics book, ISBN 978-0-465-05065-9.

[3] Foodsafety. (2014, January). *Foodsafety.* Retrieved January 24, 2014, from Keep food safe: http://www.foodsafety.gov/keep/charts/mintemp.html

[4] Degraeve. (2010). *Degraeve.* Retrieved September 15, 2012, from Baking temperature and times: http://www.degraeve.com/reference/cake-baking-temperatures-times.php

[5] Canolainfo. (2007). *Deep frying: info and tips.* Retrieved April 2012, 24, from Canola info: http://www.canolainfo.org/recipes/index.php?page=21

[6] Derek hamm, Eric Uva. (2011, Spring). *Project the Willson Solar cooker*. Retrieved November 3, 2013, from MIT Architecture: https://architecture.mit.edu/project/wilson-solar-cooker