Towards sustainable relief-assistance

Applicability of the sunny solution

Universiteit Utrecht

Vajra Foundation Nepal

This report is submitted by:

Ralph Lindeboom and René Goverde
R.e.f.lindeboom@students.uu.nl
Renegoverde@gmail.com

Assigned by
Vajra Foundation Nepal

Under the supervision of
Dr. M. Hekkert
and
Dr. W.G.J.H.M. van Sark

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On the possibilities for solar cookers in the Bhutanese refugee camps, we also wrote the report 'solar cooking: one step ahead', presented to the UNHCR sub-office in Damak, Nepal in December 2004.

Executive summary

Since the early nineties the international community has, by means of the UNHCR, been providing basic relief assistance to Bhutanese refugees accommodated in Nepal. Apart from huts, food, drugs and education, these refugees are also being provided of kerosene to cook on, in order to prevent deforestation as a result of the chopping of firewood. Supplying kerosene to the refugees nowadays is much less a feasible solution than it has been in the past as the availability of kerosene has been unreliable and its price has risen enormously over the last five years (in 1999 13 NRs/l, in 2005 34 NRs/l). Since 1998 has Dutch/Nepali foundation Vajra been providing parabolic solar cookers to refugee groups in one of the seven refugee camps. This project is very popular under the refugees, which raises the question whether the UNHCR would not better give the refugees some less kerosene and more solar cookers.

To find the answer to that question, has the usage of the currently used (SK-14) solar cooker been compared to two alternatives, in which all cooking is done on respectively firewood and kerosene. For the SK-14 it has been assumed that in the time it can not be used due to whether conditions, kerosene would be used as a back-up.

The alternatives have been compared on the topics of primary energy usage, CO_2 emission, deforestation, costs and users' attitude. When doing so, the whole lifecycle of the alternatives and accompanying devices has been examined. In table 1, the outcomes of these sub analyses are being presented. Values are expressed per meal to make comparison possible.

Alternative	**Primary energy use (MJ/meal)**	**CO_2 emissions (kg/meal)**	**De-forestation (kg/meal)**	**Costs for the UNHCR (€/meal)**	**Users attitude (rel. score)**
Cooking on wood / chula	37.8	3.14	2.25	0	0.83
Cooking on kerosene / stove	8.97	0.64	0	7.6 ct	1.00
Cooking on a SK-14 solar cooker	4.17	0.31	0	4.4 ct	0.89

table 1

The SK-14 can reduce about half the environmental impact (in primary energy use and CO_2 emission compared to the kerosene stove. In fact, most of the energy use of the solar cooker can be attributed to the back-up need: the usage of kerosene when the solar cooker cannot be used due to bad weather conditions.

Cooking on a solar cooker turns out to be financially attractive as well: costs per meal have been estimated to be 4.4 €ct, while cooking on kerosene costs 7.6 €ct. For the firewood scenario, no costs for the UNHCR have been assumed: the refugees would cut or buy for themselves. If these costs would not be neglected, costs for the firewood alternative will be 5.3 €ct per meal. The payback time of investing in a solar cooker has in the current situation been estimated at 1.3 years, compared to the current situation of kerosene provision.

A Multi Criteria Analysis based on weighted summation has shown that given the 5 criteria considered and the data from the table, the solar cooker can be considered the best alternative of the three. Only when the most unlikely of six weight sets is being picked, the solar cooker finishes second best. So, it can be concluded that supplying the refugees of a SK-14 with some kerosene as back-up is a more than reasonable alternative to the current ways of aid relief.

Screening for possible improvements

No project is perfect, and there are always ways to improve a project and to increase its benefits. Having that knowledge, we have screened the Vajra project for possible improvements.

First it has been examined whether two alternate solar cooking devices might suit the project better than the currently used SK-14: the F1400 parabolic cooker and a standard-type solar kitchen. The F1400 is a new type of solar cooker, that turns out to have similar environmental benefits as the SK-14. In terms of costs (break-even at 3.3 years instead of 1.8 years for the SK-14) and performance it is however no good option. An adjusted F1400 design could make up these differences, especialy when production would be possible in Nepal or India. A big drawback of installing a solar kitchen in the camp is the resulting inflexibility. A solar kitchen is very hard to transfer, and as a result, there is a much bigger risk of not being able to break-even if the refugees would repatriate before the pay back period of 4.3 years. A solar kitchen furthermore is not likely to be a success, as in a questionnaire the refugees valued the ability to cook for themselves very high.

The currently used cooker, although comparatively already a good cooker, can also be improved. It now uses relatively much iron in the frame: environmental impact could be further reduced by decreasing this amount. Switching to stainless or galvanized steel can only decrease the environmental pressure and costs if much less material is used. The reflector plates are relatively expensive, both in terms of costs and environmental impact. Switching to aluminium laminate might be a good option, as this material already proved to cause less environmental pressure. Again it would be very beneficial if opportunities for production in the Nepali, Indian or even the Chinese industry could be found.

For the production both gains could be obtained by implementing quality control mechanisms for the cookers and rewarding the workshop employees when working more efficiently. To decrease the defect in the cookers due to transport, using packaging material seems an easy solution, but possibly equal benefits can be acquired by transporting only a set amount of cookers per shipment, as this takes away the main source of the problem.

Providing the refugees with environmentally sound technology obviously helps saving the environment, but creating environmental awareness amongst them could even prove to be a more sustainable solution. Starting to stimulate standard cooking fuel saving measures like using the hay box for finishing off the rice cooking, using less water and soaking lentils could already decrease cooking time significantly. Because the refugees are already organized (in monthly meeting users groups), such awareness can be trained very easy when in the monthly meetings not only the solar cooker would be discussed, but general environmental issues as well.

Attention for project management is needed every once in a while. Strengthening the institutional realities by creating a solar cooking archive, building evaluation mechanisms and addressing more and different human resources to the project will in the long run pay off in sustaining project benefits. The focus should be on sustaining the projects benefits, just as the solar cooking technology is focussed on sustaining the environment.

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1 Introduction

The global energy use has known an exponential growth since the days of the industrial revolution. Concerns regarding the environmental impacts of our daily activities have been raised since the late 1960s, and while some of our impacts are well understood, others are subject to scientific and public debate (e.g. the greenhouse effect). Energy usage being a major driver behind most environmental impacts (source) makes reducing fuel needs and switching to other fuel types two important ways to reduce our environmental impacts. Both are topics possibly even more challenging in developing countries than in developed countries, as there the real growth is\ yet to start[1].

In Nepal, the energy problem arises not only from excessive reliance on non-renewable energy resources, but rather from the fact that the main energy source (firewood) is being consumed at an unsustainable rate, while the vast potential of other forms of renewable energy is virtually unused (Pokharel and Munankami, 2003). Firewood generally accounts for 75 percent of the primary energy use in rural areas of developing countries, and in Nepal as a whole it is 77 percent (Bhattarai, 2003). Especially because of rapid population growth, and increases of petroleum price, the local and national environment is being threatened.

In eastern Nepal a large number[2] of Bhutanese refugees reside. In the early nineties a conflict in their home country forced more then eighty thousands of Bhutanese to flea, and most of them ultimately found shelter in refugee camps in eastern Nepal. The UNHCR, also providing them with basic assistance like huts, food and drinking water, decided to deliver them kerosene for cooking as well, in order to prevent large-scale deforestation. Although the choice for kerosene originally has been positively evaluated (Owen et al., 2002), a continuous rise of the kerosene price has made it less feasible a solution as it was in the beginning. The UNHCR thus has to look for other ways of providing the refugees of cooking fuel. (UNHCR, 2004)

Such other ways are already being provided in one of the seven refugee camps by Vajra Foundation Nepal. Motivated by a similar objective of fighting deforestation and obtaining other environmental benefits by creating a positive awareness among potential users (Schapendonk, 1999), it has distributed solar cookers among the refugees since 1998. Providing the refugees with cookers is seen as a step in the process of promoting this technology for usage in other sunny countries as well. At the end of 2004, about 13000 refugees, almost 75% of the population of this camp, have been given the possibility to use sunlight as a complementary source of energy for cooking. (VFN, 2004). The situation of the Vajra project being heartily welcomed by the refugees, and the UNHCR looking for alternatives for kerosene lifts questions how feasible the solar cookers are to replace some of the kerosene supply. Just as significant a question is whether adjustments in project design the potential of solar cooking could increase.

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[1] In India, for example, the energy demand rose by 103% between 1983 and 2001. (http://www.eia.doe.gov/emeu/cabs/indiaenv.html datum 17 nov 2004) A demand for 2020 has been forecasted of 2.5 times the value of 2000. (IEA, 2002)

[2] Their number has steadily risen from 80,000 in 1992 to approximately 104,000 now, mainly because of births (UNHCR, 2004).

1.1 Research objective

This study should make clear whether solar cookers could be considered a worthy alternative to kerosene distribution when they will be provided as a substitute for kerosene usage. From the introduction it becomes clear that the environment should have benefited from the introduction of kerosene and thus should benefit from the introduction of the solar cooker as well. As only a strict budget is available, costs should be included as well. And finally, the refugees should use the technology and should thus be happy using it. When the comparison on the above mentioned aspects will be accomplished, the results will provide input for the second part. If solar cooking technology proves to be a less feasible alternative, possibilities for overcoming this will be assessed and if solar cooking proves to be a good alternative, ways for improving its practical performance will be assessed. Even though taking project management into account seems far from the focus of this study in first sight, this will be included. This choice is based on the fact that it could be useful for Vajra Foundation to obtain continuous benefits in the long term by running the project more efficiently.

The following research questions have been constructed:

1. *To what extent can solar cooking technology contribute to the relief assistance for cooking facilities in the eastern Nepali refugee camps in the coming ten years in terms of environmental effects, costs and users' attitude?*

2. *Which adjustments in project design should be made for a more optimal achievement of the goals of the solar cooking project?*

Project Characteristics

1990- First official refugee camps founded by UNHCR. They are being provided of all basic needs, including kerosene for cooking. (Kerosene price isless than 10 NRS)

1992- Last of 7 refugee camps erected. Stream of refugees holds at approximately 80.000.

1996- Maarten Olthof visits solar conference, advice to search for place where there are fuel shortages, and where the people are well organized. He gets the idea of distributing solar cookers among the refugees in order to spread the awareness on solar cooking technology and its environmental benefits. Convincing the Nepalese Government, the UNHCR and the refugees is the first step.

1997- Vajra Foundation founded.
Permission from Nepali government and UNHCR for the distribution of 242 box cookers

1998- Experiments with several types of cookers. Cooperation with University of Twente. The parabolic cooker (SK-14) seems to have the biggest potential. Vajra decides to quit its box cooker program and distributes SK-14 to refugees that have applied.

1999- Introduction of hay box

2000- Continuation of project in Beldangi-I

2003- Preparation of production mould for precise dish shape

2004- Kerosene price at 28 NRS.
Vajra proposes to the UNHCR to distribute solar cookers to all refugee camps and hopes to convince the UNHCR to adopt the technology completely.

2005- Kerosene price at 36 NRS.

box 1: project characteristics and map of the region concerned

2 Theoretical framework

In innovation theory, the implementation trajectory of new technologies is thought to go through a scheme of several stages before the actual implementation takes place (Tidd, 2001). This implementation cycle starts with the scanning stage in which the market is scanned for new technological or organizational opportunities to deal with known problems. This stage ends with choosing a technological path to proceed on. The second stage takes off at this point, a strategy should be chosen to implement this new technological path. This plan requires making choices for types of resourcing in terms of knowledge, funding and human capital and planning of the final implementation. When this plan is finished, resources have to be addressed before the final implementation plan can be started. In this final stage different kinds of pilot projects can be used to specify the final approach and increase the chances on a success. As all technologies evolve over time, the implementation stage should be followed by an evaluation by which learning will be enabled to optimize the project performance in the future. After evaluating, it is time to start the cycle all over again. In practice, all the different stages are not neatly organized in time. One can for instant be working on resources, when the implementation already has started for various reasons.

The field of development economics is important for putting such theory into the right perspective. One of the major differences between projects in developing countries and in developed countries is the way of financing a project. In developed countries the availability of finance is largely addressed by the market, while in developing countries market failure often prevents this from happening (Thirlwall, 2003). In developing countries resources are therefore often scarce, and different tactics are required for funding. To overcome the restrains on financial resources a good overview of opportunities, as well as a good strategy are crucial. Involving the implementation cycle of Tidd might therefore increase the chances on most efficiently addressing the scarce funds.

There is often a scarcity in human resources as well. Qualified maintenance- or operating personnel is not always available, while bringing in foreign engineers or domestic educated people is a costly task. Therefore, developing countries benefit most when intermediate technology is being implemented with as little foreign inputs as possible (Thirlwall, 2003 chapter 12). In other words: local people must be able to use the technology properly on their own. This again requires extra cautiousness when implementing, and pledges for following a structuralized implementation cycle. In Tidds cycle, the current stage of the project can be descibed as the final pilot project, after which an evaluation should lead to a decision on larger-scale continuation.

Ultimately, the implementation should result in the adoption of a technology. That is, when a person or body starts using the technology. Rogers (1995) defines adoption as ‘the result of the decision process whether to fully use an innovation, because it is the best alternative available’. The goal of the Vajra project being convincing UNHCR and refugees to adopt solar cooking technology, adoption theory should be included. In Rogers’ standard work on adoption, the chances of a certain technology to be adopted are explained to be understood in terms of:

- Relative advantage, which addresses the benefits of the new technology over the to be substituted technology
- Complexity, which shows that decreasing simplicity of a new technology reduces the chances on adoption

- Compatibility, which induces that a new technology should be well-matched with the purpose and practice the old technology has been used for
- Triability, addresses that potential users adopt more rapidly if possibilities for trial exist without investing on a long term base
- Observability, which explains that the chances on adoption are positively influenced if a new technology attracts attention

For both the UNHCR and the refugees the solar cooker technology are nowadays very observable and triable, because of the pilot project. One cannot visit Beldangi-I without taking notice of a solar cooker. Complexity of the technology should not be a problem either, as Vajra Foundation already has experience for implementation, whereas the technology itself only consists out of a relatively simple frame and imported reflector plates. In terms of relative advantage the environmental impact, because of the original goal for providing kerosene, and the costs, as kerosene is becoming more and more expensive, are useful indicators. Compatibility, or the extent that the new technology fits in the refugees current' practices, is a crucial criterion for any solar cooking project (SCI, 1994), and therefore requires some more attention.

Past solar cooking projects show that solar cooking is judged by the users on the effort resulting from changes in their original cooking profile (GTZ, 1999; SCI, 1994). This can, using the terms defined by Rogers, be described as both a problem in the area of relative advantage, and compatibility. Complexity is once again not relevant as a solar cooker is a simple device. The other problem areas, observability and triability, can be easily covered by setting up a smart implementation scheme in which first a pilot is launched. This gives potential users the possibility for trying before adopting. GTZ had such a pilot project in South Africa, in which villagers could try and accept a loan for paying their cooker if they liked cooking by sun (GTZ, 1999).

In any case, the potential users' cooking profile should be observed thoroughly before implementing solar cookers. But as all people cook differently indicators should be determined for each different situation (GTZ, 1999; SCI, 1994). Combining common adoption theory with indicators used in past in solar cooking profile determination and fitting them to the current refugee situation leaves the following main area's, in which the first three can be characterized as a specification of the compatibility problem and the last as relative (dis)advantage:

- Cooking devices ownership & responsibility; while the scale of cooking alternatives could divert the amount of refugees owning one cooking device will be different. And this has implications for their responsibilities.
- Effort preliminary conditions; different cooking devices need different types of activities to prepare the device for cooking
- Effort cooking process; different alternatives use different activities to cook the food in the most optimal way.
- Cooking externalities; while all technologies have there own externalities, which could be an advantage over the other technologies this will be a rest group by which the significant differences that are not included in the former groups can be addressed.

The theory addressed above, is sufficient for completing the evaluation, but for focusing on improvements additional theory about obtaining environmental benefits in organizations and project management in developing countries is needed.

Firstly, for obtaining environmental benefits, theory prescribes the following categorization of measurements for obtaining environmental benefits in companies or technological projects (Moed, 1998):

- Change of technology;
- Change in product design;
- Changes in process design;
- Promoting good housekeeping

By changing from one technology to another, new opportunities can arise by which environmental savings can be made. As each technology has it own characteristics comparing them carefully could, besides having environmental benefits, easily lead to reduction of the costs and improvement in the users' attitude (Moed, 1998). Redesigning a product is always possible as it can be executed according to the desired benefits. Using less material for instant, will reduce the primary energy use for basic material, will reduce the cost of input material and could make a device lighter, which makes it easier to carry (Moed, 1998). However, it should be taken into account that the energy efficiency of a technology always has a thermodynamic maximum, which reduces possibilities to obtain benefits in this aspect (Blok, 2000, chapter 2).

Changing the process design is the third possibility of obtaining environmental benefits. Increasing the efficiency will most likely result in less squandering of available resources and will thus have a positive influence on both the environmental impact and the costs. Finally, good housekeeping offers also good opportunities for reduction of environmental impact (Moed, 1998; Cleovoulou, without date; Blok, 2000 chapter 12). Making users more conscious on more efficient methods of using end use equipment , more specifically cooking technology, and savings up to 30% in time, and thus also fuel usage, due to good housekeeping in this technology are viable (PRCA, without date; moed, 1998; Cleovoulou, without date; Blok, 2000 chapter 12).

Secondly, it is interesting what theory based on experience in developing countries state about the issues to take into account. Gow and Morss (1981; 1983; 1988) have selected nine 'problem areas' that were related to the organization and administration of rural development projects from reports on 24 such projects in several third world countries.

The identified problem areas, which they refer to as 'the notorious nine', are shown in box 2. Some of these problems, notably 'political, economic and environmental constraints', and 'differing agendas' most commonly lie on a high aggregation level, and are thus beyond direct project management control, even for the bigger players. In situations where solutions to the above mentioned problems seem out of reach, aborting a project could prove the best option. Problems regarding 'institutional realities' evolve when during a project institutions like administrative capacity, information flow or access to resources are not allowed to grow at the same pace as the project. Sufficient attention to the role of institutions is necessary, and flexible, process-oriented projects are needed rather than rigid blueprints.

box 2: The 'notorious nine'

1. political, economic and environmental constraints
2. institutional realities
3. host country personnel limitations
4. technical assistance shortcomings
5. decentralization and participation
6. timing
7. information systems
8. differing agendas
9. sustaining project benefits

The problems of ‘host country personnel limitations’ and ‘technical assistance shortcomings’ are especially interwoven. The shortage of skilled personnel in most development countries, combined with donor requirements for a certain amount of human and institutional resources, often results in projects having either too little personnel, or too many tasks being carried out. Technical assistance[3] (TA) is often introduced to manage that problem, but is very often reported to have its own drawbacks: dissatisfaction with the quality of TA personnel, confusion about the appropriate functions of TA and disagreement over the roles TA personnel should play. To make training a major project component, to simplify project activities and to use foreign advisors are being named as the most important ways to cope with personnel shortages. For TA, appropriate action depends on organization and project size, as well as type of TA needed. Like TA, decentralization and participation should in theory contribute to a projects success, but are in reality not always beneficial and sometimes even counterproductive. The reasons mentioned are hardly amenable: lack of political commitment, bureaucratic resistance or inadequate resources.

‘Timing’ covers all problems that have to do with delays during the start-up and the actual implementation and bad planning, often causing unnecessary deterioration of the quality of the project. ‘Information systems’ addresses the problem of many organizations not learning from their own experiences and those of others. Setting up new or adjusting (most of the time: simplifying!) current information systems might help the learning capability of an organisation. In practice an information system can be created by identifying targets, auditing the current performance and exploring options for improvement (Tidd, 2001, p264-267; Gow & Morss, 1988; SCI, 1994).

The eight problems discussed so far all threaten the long term benefits of a project, which Gow and Morss refer to as being ‘the bottom line’. They state that in theory the principal objective of development initiatives should be to generate self-sustaining improvements in human capability and well-being. However, due to the invalid assumption that efforts initiated will take a momentum on their own, and by not adequately tackling the problems discussed above, the benefits of a project very often do not last when donor funding stops or a project is otherwise being abandoned. Making sustainability a major consideration and coping with the ‘notorious nine’ in an early stage can help to improve the performance of a project.

[3] Technical assistance is being defined as ‘the provision of qualified outside personnel to help with tasks for which local people with the necessary skills are not available in sufficient numbers’.

3 Methodology

After presenting the theoretical framework in the previous section, we will now discuss the practical approach of how to use these theories to answer the research question. This will be done for both parts of the research question separately, as the methods used differ.

3.1 First part of the research question

Q1: To what extent can solar cooking technology contribute to the relief assistance for cooking facilities in the eastern Nepali refugee camps in the coming ten years in terms of *environmental effects, costs and users' attitude* ***?***

This first part of the research question deals with a comparison of solar cooking to other cooking possibilities, currently used in the Bhutanese refugee camps. Quantifying the contribution cuts two ways as it indicates in to what extent the original projects goals have been achieved and it provides detailed information on the benefits of extending the project to the other camps. The feasibility of solar cooking is likely to be dependent on the current cooking standards. Solar cooking will therefore be compared to the two currently used 'alternatives': cooking on a kerosene stove and cooking on a chula (firewood stove). This will be done by answering the following subquestions:

1. To what extent does implementing solar cooking technology in the refugee camps contribute to the goal of saving the Nepalese environment?
2. How do the intended users (the refugees) perceive this new cooking technology?
3. Is solar cooking a feasible solution in financial terms?

Whether a solar cooker will be feasible cannot be answered using the answers on these questions separately. What is needed is thus an analysis which can add up these different answers to one final outcome, most commonly known as a Multi Criteria Analysis or MCA. The input for this MCA will be the results of separate analyses per criterion. Therefore, first the method to be used for calculating environmental effects, costs and users attitude will be explained.

Comparing on environmental effects
No matter what product or process is being examined, there is such a broad range of 'environmental effects' that it is very time consuming to take all or even most of them into account. For this research, deriving exact emissions is of far less importance than finding out how the emissions differ between the alternate ways of cooking. Therefore, only a small selection will be chosen out of all possible effects, which will be representative for the total environmental effects of an alternative.

The effects included are the primary energy use that an alternative requires (because a lot of other environmental effects find their origin in the use of energy), the amount of CO_2 emissions (because it is the component that can be accounted for most of the green house effect, and reducing this emissions is an important goal for national and international governments) and deforestation (because the initial incentive for the UNHCR to supply the refugees of cooking possibilities was to prevent deforestation, and furthermore because it is a big issue in Nepal nowadays). We will thus consider primary environmental effects only, rather than secondary environmental effects like the greenhouse effect, water pollution or land slides. Although focusing on secondary effects would have led to more visible results, it would have largely increased the subjectivity of the comparison, as the parameters concerned are object of much more uncertainties. Hence, concentrating on primary environmental effects will make the comparison more reliable.

For each environmental effect, the total lifecycle of a product or process should be examined (Engelenburg et al, 1994). For example, while calculating the CO_2 emissions due to cooking on a kerosene stove, not only the emissions of the kerosene usage should be taken into account but also the emissions during the stove production, transport of the stoves and the kerosene, and each other part of the lifecycle. Likewise will for each step in the lifecycle of the different alternatives, the primary energy use, CO_2 emissions and deforestation be calculated. To get grip on what energy and material streams are involved in each stage of the life cycle, the basic flow chart shown in Figure 1 will be used for each of the alternatives. As it was known in advance that the assembly takes place by the refugees no additional transport step is included.

The theoretical energy and material requirements, as well as emission factors of various processes will be derived by executing a literature and internet search. For basic materials, theoretic Gross Energy Requirement (GER) values will prevent having to find out the exact processes at the beginning of the lifecycle.

Comparing multiple lifecycles obviously requires setting the same system boundaries for each alternative, and expressing effects in the same, functional unit (Weidema and Wesnaess, without date). For that reason all effects will be measured in impact per meal (see attachment 1). The total value for an environmental effect can then be derived by adding up the values for all of the life cycle stages. Ultimately will it be possible to estimate for each alternative the primary energy use in MJ for each cooked meal, the kg CO_2 emissions due to each meal, and the amount of wood/forest cut per meal.

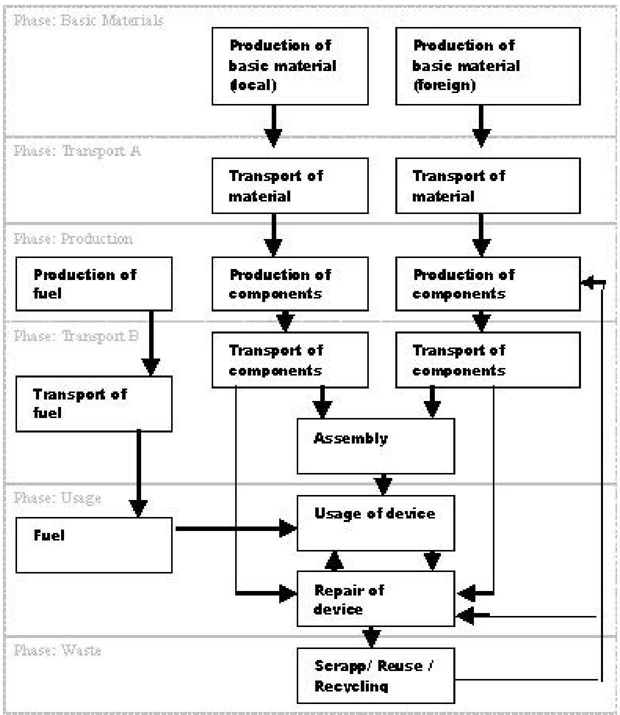

Figure 1: General flow sheet of a cooking device (based on Engelenburg et al. ,1994)

Comparing on costs

An alternatives' costs should be clearly distinguished from an alternatives' price[4]. In most technology comparisons, the costs of a technology is being used as criterion (Blok, 2002, chapter 12). By doing so, price fluctuations over place and time are to a large extent being avoided, resulting in possibly more reliable and broader applicable conclusions. The goal of this study, however, is much more specific than that of the type of studies just mentioned. Because time and place are well-defined, using the actual costs (and thus the prices) can lead to the more specific conclusions that are being sought.

The definition of costs to be used in this study is: *"the costs that the UNHCR or Vajra Foundation would have to make for supplying the refugees the possibility of cooking, calculated per meal, and taking the place and time of those costs into account."*

Eventually, it will be the UNHCR to decide whether solar cooking is feasible or not. Their decision will largely depend on the costs of solar cooking compared to that of other alternatives. As practically all costs in any of the alternatives will have to be covered by them, the alternative will be compared on 'the costs that the UNHCR would have to make'. This definition implies that sometimes the cost and sometimes the price of the technology will be included, depending whether the organization produces goods on its own, or buys them on the market. To make a fair comparison possible, all values again have to be expressed per meal.

Given the (global) scale of the processes and organizations involved, different currencies have to be involved. When products are being bought in places with other currencies, then the prices will be expressed in the currency of that place, and will afterwards be converted to euros. This will be done by using an average global market exchange rate.

As prices, values and costs vary over time, it is necessary to include a time factor when calculating costs. This will be done by using the present value method (in which all costs and benefits of a project are compared at a certain point in time) and incorporating the concepts of inflation rate, interest rate and taking into account the differences in these rates per geographic location (Brealey & Myers, 2000; Thirlwall, 2003 chapter 10).

Data for cost calculating will be gathered by inquiring at (present and possible future) suppliers, by interviews with the UNHCR, their 'implementation partners' and Vajra, and literature and internet searches. It will not be necessary to make a flow chart for money flows, as much less money flows are involved than energy or material flows. However, the lifecycle stages will again be used to categorize the money spend.

Comparing on the users' attitude

The users' attitude will therefore be determined by (1) objectively listing the aspects of their cooking in which the alternatives differ and (2) executing a multi criteria analysis to derive a final output (Hellendoorn, 2000).

The first step will be conducted by structurally comparing the alternatives on the aspects of cooking devices ownership & responsibility, needed effort for preliminary conditions, needed effort during the cooking process, and cooking externalities. Output will be a list of aspects on which the alternatives differ. The refugees will then be given the opportunity to rate the

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[4] The price of the technology is also referred to as the market price and should be clearly distinguished from the costs of a technology which are the costs bared for producing one device (Brealey & Myers, 2000).

importance of each of the aspects by means of a questionnaire. The aspects will be used as the criteria of the MCA.

The MCA approach includes the following steps:

1. Determining the weight factors of the different criteria
2. Determining the order/value of each criteria for each alternative
3. Standardizing these input data
4. Using the weighted summation method to add up the different criteria scores to final scores for each alternative.

To complete the first two steps the opinion of the refugees should be measured. A questionnaire will be held among the refugees by which the importance of the aspects and the valuation can be determined. The refugees considered are obviously the refugee cooks of Beldangi-I, and it will be assumed that their attitudes towards an alternative (in comparison with the other alternatives) can be fully contributed to the differences in cooking profile that that alternative has as they are frequently using firewood, kerosene and the solar cooker. As this group is well organized in monthly user group meetings, it will be possible to hand out a questionnaire, and ask them their opinion.

The importance given by the refugees will be used as basis for the weighting factors. For the determination of the weighting factors, the expected value method will be used. This method forms a common approach to transform (semi-) quantitative data into more quantitative data (see appendix 13.2). Assuming a non-linear division of the weights, a total weight of 1 is being shared among the criteria, the difference between two consecutive weights being biggest at the most important criteria, and smallest between the least important criteria (Hellendoorn, 2000).

An advantage of using the expected value method is that a criterions weight can be easily varied without affecting the weights of the other criteria, thus leaving more options open for a sensitivity analysis. Biggest drawback of this method is the fact that it assumes a non-linear division of the weights and criterion scores, which can only globally be tested on correctness (Hellendoorn, 2000). Different methods will be used in the sensitivity analysis to overcome this problem.

However determining the valuation takes a slightly different approach. By observing cooking in the camps and performing field tests on cooking profile data on the rank of the different alternatives will be gathered. To test our assumptions, questions about ranking the alternatives will be included in the questionnaire as well. So, this will result in a valuation from two different perspectives.

Before these data can be summated they should be standardized. The criterion weights and criterion scores will be standardized according to the standard method used in this approach as explained in appendix 13.2. Adding up the standardized criterion scores multiplied by its weighting factor will determine the best alternative.

Multi Criteria Analysis

For each of the alternatives, scores on environmental effects, costs and users' attitude follow from the above described analyses. These scores will form the data-input for another MCA, which finally will lead to the answer of the first part of the research question.

Input of Multi Criteria Analysis					
	Primary energy use (MJ/meal)	CO_2 emissions (kg/meal)	De-forestation (kg/meal)	Costs for the UNHCR (€/meal)	Users attitude (rank)
Cooking on wood / chula	…	…	…	…	…
Cooking on kerosene / stove	…	…	…	…	…
Cooking on a SK-14 solar cooker	…	…	…	…	…

Figure 2: Data-input table of MCA, to be filled with the outcome of other analyses.

All the environmental criteria and the cost criteria have been measured quantitatively. The users' attitude however has not been measured quantitatively in first instant, but as for finalizing the score on this criteria use has been made of the expected value method for standardizing the scores and weights it can now be used as a quantitative value. This leaves the possibility open for using the weighted summation method to compare the alternatives on these multiple criteria. For this method once more weights and effect scores are needed.

The effect scores have already been determined and should therefore only be standardized. The criteria on primary energy use, CO_2 emission, deforestation and costs will be standardized by addressing all criteria as "costs" and relating the highest (worst) value to 0 and zero effects as 1. The values of the second and third alternative will now lie somewhere in between, proportional to their original relation to the worst alternative. The users' attitude however will be addressed as "benefits", but will standardized in a same manner, relating the highest value to one and the value of the second and third alternative proportionally.

The weight of each criterion will be determined by applying the weights manually, using the opinion of the UNHCR to determine the rank of importance. Because this leaves space for subjectivity, the sensitivity analysis will be needed to show the effects of applying different methods and thus weights.

Sensitivity analysis

Three types of uncertainties will be examined: uncertainties in data, uncertainties within alternative outlook, and uncertainties in method (Weidema and Wesnaess, without date). The quality of quantitative data normally can be considered dependent on the reliability (of the source) of the data, the data's completeness, its temporal and geographical correlation with the processes concerned, and further technological correlation (Weidema and Wesnaess, without date). For all data a range of an upper and lower value will be constructed, if possible on basis of concurring values, but otherwise based on other ranges and data within the data sheet.

Uncertainties within alternative outlook include uncertainties due to critical choices in system boundaries, due to difficulties in and the like. Most of these problems will already be addressed in the chapter 'description of the alternatives'. In the sensitivity analysis, it will be examined what influence the most important of the uncertainties have on the conclusions by adjusting the data sheet in line with these changes.

Alternative methods examined:
method 2, based on a linear distribution. *n* being the amount of aspects considered, the least important aspect has been given a weighting factor of 1/(n+1), the second least important 2/(n+1) and so on.

method 3, in which criteria with little difference within their importance scores have been given equal weighting factors.

Critical choices of method have been made regarding the MCA and the users' attitude analyses. Therefore a few other methods will be used to validate the acquired scores. Method 2 is included to check whether the assumption of non-linear distribution has influence. And method 3 is included to validate the main uncertainties in the ranking of the alternatives have been covered.

3.2 Second part of the research question

Q2: Which adjustments in project design should be made for a more optimal achievement of the goals of the solar cooking project?

Central in the second part of the research question is the 'performance' of the project. This performance is defined (in line with the goals of the project) as 'to increase the number of refugees that have access to solar cooking, to cut costs, to improve the service to the refugees, to increase the environmental benefits or to make the project more efficiently managed in general'. The total project shall, along with its history be structurally screened on possible improvements; by attending all of the activities that together make up the project. This screening will be structuralized by answering the following sub questions:

1. To what extent could the introduction of two different type of solar cookers increase the benefits of the solar cooking project substantially?
2. Which changes in the current cookers design could increase the benefits of the solar cooking project substantially?
3. Which changes in production process could increase the benefits of the solar cooking process substantially?
4. Which changes in good housekeeping could increase the benefits of the solar cooking project?
5. Which changes in project management could increase the benefits of the solar cooking project?

Assessment of different solar cooking techniques
Two alternative ways of solar cooking, brought forward by Vajra Foundation, will be compared to the currently used solar cooker. This will be done on basis of the same criteria that the SK-14 has been compared to conventional alternatives. The environmental and economical costs of the devices will be calculated using the same methods. Because of a lack of users having experience with both, the old and the new devices, the users' attitude can not be determined in the same manner. Interviews with experts and the results of field tests will be used instead to sketch a global indication.

Assessment of changes in cooker design and production
During the answering the first part of the research question, the most costly parts (either in terms of environment, economics or users attitude) of the SK-14 can be identified. From the experience of attending the major steps in production, transport and assembly of the cookers, as well as the actual usage of the cookers in the camp, possibilities for improvement can be listed. For most of the measures, the possible benefits can be estimated by using the data sheet of the comparison.

Assessment of good housekeeping possibilities

The wide range of energy saving measures for cooks that is listed in literature will be screened on applicable measures for the situation of the refugees. The potential will be determined by examining the current ways, already described in the first part of research. For the hay box that is already being used by many refugees, it will be examined whether performance is satisfactory and how usage can be improved.

Assessment of better project management

As already mentioned in the introduction the results of this part should contribute to the continuation of the project and assuring the environmental benefits in the long term and expanding it to a larger scale. So, improving project management has no direct influences on environmental performance, but better management will contribute to environmental awareness in the long run.

By studying the history of the project and the current ways of management, the key-issues for a successful continuation of the project will be determined. For these key-issues it will then be identified for what factors of Gow and Morss the project is most vulnerable. The theoretical solutions proposed by Gow and Morss, and Tidds framework for organizational innovations will be used to identify measures by which the sustainable benefits of the project can be best preserved.

4 Description of the alternatives

In this chapter, the alternatives will be described in terms of the criteria. This will be done by giving an overview of the processes involved in the lifecycle, by summing up the costs that the UNHCR would have to make, and by describing the different cooking profiles. Where necessary, it will be explained how the system boundaries have been applied. To start, however, it will be important to describe the average meal for an average family of 6 persons (see appendix 13.3) , which will be referred to as its local name "Dal Bhaat". The meal contains 1.23 kg's of rice, 0.12 kg of lentils and 0.26 kg of vegetables (potato, onion and green banana). This meal is eaten almost twice 365 days a year. For further details appendix 13.3 can be acknowledged.

4.1 Cooking on wood

Firewood is the traditional cooking fuel of the Bhutanese refugees. It is gathered in the forest and is cut into small pieces to be dried above the cooking pot while cooking. As near the refugee camps "Dalbergia Sissu" is abundantly available, this type of tree is most commonly used by the refugees when they cook on firewood.

For preparing their meal they use a so-called "chula", which is a small clay stove integrated in the corner of the refugee huts. Different types of chulas are being made: the size and number of pits varies, as does the size of the opening in front. Because the refugees generally only use one pit at a time, a simple chula with a single pit and one small opening in front will be the type assessed in this research. Such type of chula can be assumed to have an efficiency of between 10 and 15 % (Shakya, 2003).

The device is totally made out of locally available materials, like clay and stones, plastered together manually by usage of water and cow dung. The production therefore does not use any primary energy in terms of basic material preparation, transport and production. Every once and a while the chulas requires replastering, which doesn't require any primary energy either. And while the waste stage can be characterized as rain washing the clay away, the only primary energy use and CO_2 emission is coming from the usage stage.

This alternative assumes the UNHCR from retreating from providing the cooking facilities. Therefore this alternative means that the refugees will be collecting firewood illegally in the forests and that no costs for the UNHCR or Vajra are involved. To put things into perspective, the costs of the wood

4.2 Cooking on kerosene

Kerosene has been provided by the UNHCR to suppress the deforestation that would result from the refugees' traditional cooking method. The kerosene is distributed in each camp once in two weeks and the refugees use it for cooking as well as for lighting purposes.

For cooking, the kerosene is burned in small Indian made portable kerosene stoves which are distributed once every two years, and are transported to Nepal by truck (UNHCR, 2004a). The

type of stove provided changes over time, the acquisition policy based on a maximum price and weight (3 kg) of the stove. The metal of which the stoves are being made also varies. The latest models consisted of low quality steel, and therefore it will be assumed that they will all consist out of low quality steel.However, all provided stoves have the possibility of adjusting the kerosene flow during cooking (NRCS, 2004). The simplicity of the stoves makes it possible to make them by bending steel plates, perforating and a little welding.

How much kerosene a family is given, depends on the size of its members. The first two persons of a family obtain 1 liter each per week while from the fourth onwards only 0.5 l per person per week is being provided (UNHCR, 2004b). The Nepalese Oil Corporation imports the kerosene from Patna, India by truck, after which it is being purchased at the local price by the NRCS. They, on their turn distribute it to the refugees. As the type of stoves varies, the theoretical efficiency (61%) and the fuel usage (125gr /hour) can be estimated (Nutan, 2005), but might be different in practice. In terms of maintenance hardly any effort is undertaken by the refugees and sometimes stoves break down before two years have gone by. In such cases they generally repaire it manually.

Properties kerosene stove
Size: 15 x 15 x 30 cm.
Material balance:
low quality steel 3 kg
paint 0.1 kg (estimation)
Expected life span: 2 years
Theoretical efficiency: 61%
Power output: 500-1000W

After two years, all stoves are being collected and about 75% is written off as scrap. The remaining 25% of the material can be used for reassembly and reuse (UNHCR, 2004a).

4.3 Cooking on the SK-14 solar cooker

The third alternative to consider is the SK-14 solar cooker, which is currently used in Beldangi-I as a complementary device to the kerosene supply. Nowadays four families are sharing one cooker, but it will in this analysis assumed to be two, in line with the latest proposal of VFN to the UNHCR (VFN, 2004). The two families sharing one cooker was introduced because four families a cooker would be too much if the cookers would be provided as a substitute for kerosene. Two meals a day for two families seems possible as the fieldtest showed that it required a short two hours to prepare one average meal (see appendix 13.3) and while at least 8 sun hours is very common (NASA, 2004).

As the solar cooker can only be used during daytime and on sunny days they also need a kerosene stove and a certain amount of kerosene, which is used to cook on when the weather is cloudy. In the Vajra project, the refugees are also being provided of a high insulating ‘hay’ box, which is used to keep the food warm until dinner time. As the hay-box is made out of bamboo and left-over plastic sheets it will be neglected in the environmental analysis. For the impact of the kerosene stove and the kerosene usage the same assumptions will be used as are being described above.

The SK-14 consists of an iron rotating frame and a parabolic shaped anodized aluminium dish, which concentrates the solar rays underneath the cooking pot. The framework is produced in a local workshop by welding and cutting the 23 kg of iron, which is imported from India by truck. Plain aluminium is used as input material for the reflector plates. The 3 kg aluminium is anodized to increase the chemical and mechanical durability by forming a very thin and protective oxide toplayer. After that, the pores of the aluminium are sealed by forming so-called bhoemite crystals, which in fact decreases its power, but makes it less vulnerable for dirt.

Afterwards the plates are transported from Altötting, Germany by a combination of truck and plane transport to Damak, Nepal (EG solar 2004). Once arrived in the refugee camps, the refugees can assemble the plates to the framework by tying electricity wire through the holes. This does not require any primary energy. During cooking the SK-14 uses solar power at an efficiency of about 67% at an insulation of 700W/m^2 and uses neither primary energy nor emits CO_2 (Hoedt & Scheffler, 1998; EGsolar, 2004). So, all the energy usage during the usage stage can be related to kerosene use solely. To maintain the framework for about 12 years, it should be painted once a year, and sometimes small repairs have to be done manually. The producer expects the reflector plates to have a lifespan of at least 10 years (Czech, 2004) and should be gently cleaned before and after using. The plates lose some of their reflectivity during the lifespan, but this decreasing performance will be left out of the energetic comparison, because durability tests by the producer showed that this is neglectable (Czech, 2004). What will be done with the cookers during the waste stage still is highly uncertain. It will be assumed that the parts and materials that can be recycled or reused will be sold to metal traders, because this is nowadays even the case with the low quality steel of the kerosene stove.

Properties SK-14
Size: reflective area of 1.5 m^2
ground area 1.5 x 1.5 m^2
Material balance:
iron 23 kg
coated aluminium 3 kg
cement 1 kg
paint 0.1 kg (estimation)
Expected life span:
reflector plates at least 10 years
frame 12 years
Power: 700 kW at 700 W/m^2 insulation

The costs of the solar cooker alternative are being determined by the price of the reflector plates, the price of the frame and additional costs for training, the hay box etcetera. Maintenance of the cooker will be performed by the refugees themselves and will thus be excluded. Furthermore, usage of a kerosene stove and kerosene itself must be included for a fair comparison. These so-called backup costs will consist of the device, the maintenance, the transport and the fuel cost. They can all be derived from the kerosene alternative and will only be included for the percentage of the time a year the backup is used.

5 Data

In this chapter the data input of the analyses of environmental effects, costs and users attitude will be described. All data will be accompanied by their sources and by comments on their validity if its temporal, geographical or technical correlation can be doubted. In cases where it proved impossible to find one specific energy or material requirement of a product or process (for example when values in literature did not correspond, or when no values could be found at all) the data is presented in form of an upper and lower range. In first the data for primary energy use will be given, followed by data for CO_2 emission, deforestation, costs and users attitude respectively.

5.1 Data for analysis of primary energy use

5.1.1 Basic Materials

For most basic materials GER values have been used. By doing so, all production processes in the basic materials stage have been taken into account, without the necessity to examine them in detail. The table below illustrates the GER values used. Because of the different places of production some extra comments on the validity of the GER for the specific production region are needed.

GER values	Value used	Range	Unit	Sources	Comments
Iron	20	14-25	MJ/kg	Energetics Inc, 2000; Mathiesen and Maestad, 2002	The lower boundary is the American GER for BOF iron production and the upper boundary is the value for developing countries. But as the development pace of India the last decade has been rapidly a value in between seems most likely.
Steel	35	20-60	MJ/kg	UNHCS,1991; Gielen and Moriguchi, 2003.	Whereas India made some progress in industry the last decade and not the highest quality of steel is used a relatively low value has been chosen compared to the upper boundary formed by the value derived from the UNHCS report.
Aluminium	187,1	170-200	MJ/kg	Worrell et al., 1994; Phylipsen and Alsema, 1995	All the aluminium used has been produced in Europe
Cement	3,5	3,3 – 6,0	MJ/kg	Karwa, 1998; Levine, et al. without date	As in 1997 about 86% of the Indian cement was produced by the dry process (the most efficient technology), even though it was less efficient than in western countries, the value chosen lies near to the lower boundary.
Paint	84	65	MJ/kg	Ecoinvent2000	No range has been found for paint, whereas the refugees

					buy their own paint, there is some uncertainty about this value
Kerosene	10	10%-25% of LHV[5]	MJ/kg	Blok, 2002 Ecoinvent 2000	Because of the rapid progress of India in this industry (source) the value is comparable to western countries

table 2: Energy requirement of basic materials

5.1.2 Transport stage

The second stage to discuss is the transport stage. In table 3 the fuel consumption for the different ways of transport needed for the alternatives are presented. Even though sea transport is not used nowadays for any alternative, this value has been included because there is a possibility that this will be the case in the near future. In the sensitivity analysis the change in environmental impact will be discussed due to the change in transport mode. Furthermore, the LHV of diesel has been used to convert the value for road freight in India and Nepal to a more easily usable variable. For the change in fuel use of an empty truck compared to a fully loaded one, a European value has been found only, as no Indian value was available. .

Fuel consumption	value	Range	Unit	Sources	Comments
Road freight India & Nepal	4,6	-	Mj/t/km	Ecoinvent2000	Value neglecting truck production and road construction.
Road freight Western Europe	3,6	-	MJ/tkm	WEC,1995	Because of the fact that the average truck in Europe can be considered of higher standard, and thus more efficient, this value is somewhat lower than for India& Nepal
Overseas transport (ship)	0,2	-	MJ/tkm	Mathiesen and Maestad, 2002); WEC,1995	-
Overseas transport (plane)	16,2	-	MJ/tkm	Ecoinvent2000, 2004	-
Fuel use empty return trip road freight	40%	-	-	Koudijs, 2000	This value is based on European trucks, but due to the lack of more precise data for the Indian situation it will be used for this region as well.
LHV diesel	43,3		MJ/kg	IEA Statistics, without date	

table 3: Energy requirement of transport

Distances	value	Range	Unit	Sources / Comments
Altotting - airport	300	+/- 10 %	Km	Estimations based on maps of India, Nepal, Europe and the world.

[5] LHV stands for lower heating value, which expresses the amount of energy production when burning a certain amount of substance (including the evaporation of water) (Blok, 2002)

Distance plane Germany - Calcutta	7000		Km	
Aluminium production site to Altötting	500		Km	
Calcutta - Damak	725		Km	
Patna - Damak	425		Km	
Biratnagar - Damak	80		Km	
Damak – ref. camps	40		Km	Average distance to the seven camps

table 4: Transportation distances

5.1.3 The production stage

The different alternatives all consist out of loose components that can be assembled by hand or by a little welding. Therefore the energy consumption for the assembly of the devices is to be neglected in comparison with the use of basic materials. However, making the components for the solar cooking devices is a different story. Anodizing the reflector plates for the SK-14 is an energy consuming process, using 16 kWh per kg.

	Value	range	Unit	Sources	Comments
Primary energy use of generating electricity	45%	-	-	Blok, 2002 (energy analysis reader)	Only valid for European situation
Primary energy use electricity Nepal	100%	-	-	IEA statistics, 2004	Nepal only uses hydro energy
Primary energy use electricity India	32%	-	-	IEA statistics, 2004 Karwa, 1998	Fuel mix consists mainly out of coal (80%) and hydro energy and some other renewables 15%. An efficiency of 24,8 % is used for electricity generation by coal fired power plants

table 5: generation efficiency

5.1.4 Usage stage (including maintenance)

For the amount of fuel that each alternative requires no specific data could be found. So, in order to determine the use of fuel wood and kerosene some field tests (see appendix 13.3) have been performed. The range of the obtained data about kerosene usage is relatively large, especially considering the fact that this is a crucial value in the comparison. As a result of bad housekeeping of the refugees, the NRCS lacking performance criteria for buying the stoves, which causes the quality of the stoves to vary per year, and the variety of the quality of the stoves coming from the repair workshop acquiring a more reliable value than the values determined during the field tests turned out to be impossible. However, the production characteristics of the most widely used 'Nutan' stove have been found and can be used as a reference.

Whereas solar energy is not being considered as primary energy, there was no need to include values on cooker efficiency and the like. Instead, data was needed on the amount of time that a solar cooker can and cannot be used. Multiple field tests have been performed to determine to what extent it is possible to save on kerosene when one SK-14 is used by two families. It showed that with the parabolic cooker on an ordinary sunny day in October both families should be able to cook both of their warm meals. Weather data on the amount of useful sunny days in a year (the backup ratio), have been derived by processing the data in the archives held by Vajra Foundation, see appendix 13.4.

None of the repair or maintenance processes requires more than labour or material. So, because no direct primary energy is being used, and data for production and transport of the materials already have been described in the previous paragraphs, no new data need to be presented.

Usage stage values	Value	Range	Unit	Sources	Comments
Backup ratio	45%	38% - 52%		(see appendix 13.4)	Value valid for all solar cooking alternatives.
Fuel use chula	2,25	1,5 - 3	Kg/average meal	Fieldtest (see appendix 13.3)	The used wood was Sissu, the range is large. But because of the fact that every refugee cooks in his own way, more certainty cannot be guaranteed.
Fuel use kerosene stove	0,21	0,18 – 0,23	l/average meal	Fieldtest (see appendix 13.3)	The provided stoves in the camps vary widely in quality due to bad housekeeping and reuse, but the values are close to original characteristics (0,215 l) of the stoves by the producer.
LHV wood (sal)	16,8		MJ/kg	Pokharel & Munankami 2003	Value is an average for the unsustainable wood consumption in Nepal
LHV kerosene	43,7		MJ/kg	IEA Statistics, without date from (Blok, 2002)	-

table 6: values for usage stage

5.1.5 Waste stage

Because no data has been found on the exact policy for dealing with waste materials, partly because of the uncertainty about the refugee situation ten years from now. It will therefore be assumed that none of the materials used will be reused or recycled, thus forming a worst case scenario. In the sensitivity analysis some other scenarios will be introduced to see how this would change the outcome.

5.2 CO_2 emission

The emission factors expressed in the table below are relevant for all the different stages in the lifecycle. Again, comments about the validity are being made where necessary. The value for crude oil will be used when including the sea transport in the sensitivity analysis. The values for CO_2 emission per primary energy use in Nepal and India have been included for the estimation of emission factors that could not be directly found (as shown in the comments of the table below).

	Value	Range	Unit	Sources	Comments
CO_2 EF Wood	83	-	Kg/GJ	Pokharel and Munankami, 2003	Value is an average for the wood consumption in Nepal
CO_2 EF Coal	95	-	Kg/GJ	IEA, 1997; Pokharel and Munankami, 2003	-
CO_2 EF Crude oil	75	-	Kg/GJ	Pokharel and Munankami, 2003	-
CO_2 EF Diesel	74		Kg/GJ	IEA, 1997; Pokharel and Munankami, 2003	-
CO_2 EF Kerosene	72	-	Kg/GJ	Pokharel and Munankami, 2003	-
CO_2 EF Kerosene production	0,48		Kg/kg	Ecoinvent2000, 2004	Directly linked to the extra primary energy use due to the production of kerosene.
CO_2 EF Natural gas	56	-	Kg/GJ	IEA, 1997	-
CO_2 EF Iron	1,8	1 - 2,6	Kg/kg	Mathiesen, 2002 Energetics Inc, 2000	Asian value extrapolated to iron production based on ratio for American iron and steel production.
CO_2 EF steel	2,4	1,3 – 3,5	Kg/kg	Mathiesen, 2002	BOF - Value for 'rest of Asia' (including India). Lower range is formed by the American value and the upper range has been extrapolated on base of the primary energy use.
CO_2 EF Cement	0,7		Kg/kg	Karwa (1998) from Schumacher	-
CO_2 EF Aluminium	11,7		Kg/kg	Ecoinvent2000, 2004	-
CO_2 EF Paint	2,4		Kg/kg	Ecoinvent2000, 2004	-
CO_2 EF electricity generation Europe	123	-	Kg/GJp	Blok, 2002 (energy analysis reader)	Only valid for European situation
Primary energy use electricity Nepal	0	-	Kg/GJp	IEA statistics, 2004	Nepal only uses hydro energy
Primary energy use electricity India	300	-	Kg/GJp	IEA statistics, 2004 Karwa, 1998	Fuel mix consists mainly out of coal (80%) and hydro energy and some other renewables 15%. An efficiency of 24,8 % is used for electricity generation by coal fired power plants

table 7: CO_2 emission factors

5.3 Deforestation

The amount of fuel wood (mostly dalbergia sissu) needed to prepare one meal has already been presented in the data input for the usage stage. As the nearest forests to the refugee camps consist mainly of dalbergia sissu, numbers on the maximal sustainable yield (MSY) and the maximal unsustainable yield (MUY) of this type of forest are useful indicators to make statements on the resulting deforestation. But the values found, should still be converted to kg's and therefore the density of sissu will be used, due to the fact that the precise value could not be found, based on the fact that the heaviest type of wood weights 1340 kg/m^3 (Encarta, 2002) and Dalbergia Sissu is a kind of heavy hardwood, a range between 800 kg/m^3 and 1000 kg/m^3 will be assumed (FAO, without date).

Data on Dalbergia Sissu forests (Duke, 1983)						
Forest age	10	20	30	40	50	60
MSY(m^3/ha/year)		5	7	7	7.5	7.5
MUY(m^3/ha)	10	100	210	280	370	460

table 8 Deforestation data

5.4 Costs

The financial analysis can be executed when the data of table 9 are combined with the data of the usage stage of the environmental effects. Most of these values have no uncertainty range, but as these are mainly current prices of services or devices and relatively easy to obtain, this is not really needed. The changes in values over time, however, are hard to predict and therefore these data should be handled with uttermost care.

The chosen inflation rates are the averages over the period 1990 – 2000. Even though the last few years, the economical situation in India improved and the situation in Nepal worsened. But as statistics over these last few years could not be found these were the most suitable values.

The interest rate applicable on the UNHCR has been determined based on a five year average (1997-2002). The document showed that most funds are invested in low risk projects or deposited at banks at average interest rates. Because of the uncertainty of predicting changes in interest rates over time, a range has been added of one percentage below and above the used average.

The exchange rate of the Euro and the NPR has changed enormously in the last years (FXhistory, 2004). And as the Euro was introduced a representative average is hard to determine. The current exchange rate has been used and will be changed over time according to the difference in the average inflation rate of the specific locations, as this seems the most likely scenario. The price of fuel is also uncertain, even though the current price is known. The Nepalese Oil company had announced price raise to equal the Indian price for fossil fuel, and as a result most recently the kerosene price rose to 36 NPR per liter. This price is still a little below the Indian price and due to that more price hikes have been announced, which makes it difficult to remain up to date.

A final remark should be placed for the price of the SK-14. The price has been derived from the proposal of VFN to the UNHCR, but has been divided into separate cost posts. The price for the cooker itself, the overhead costs and the personnel costs per year together form the total costs per cooker.

	Value	Range	Unit	Sources	Comments
Inflation rate India	8%	-	-	WDR2002, 2001 from Thirlwall, 2003	Ten Year Average (1990-2000)
Inflation rate Nepal	8%	-	-	WDR2002, 2001 from Thirlwall, 2003	Ten Year Average (1990-2000)
Inflation rate Europe	2%	1,5% -3%	-	WDR2002, 2001 from Thirlwall, 2003	Ten Year Average (1990-2000), the range has been introduced because of the fact that different countries within Europe have different inflation rate
Interest rate applicable on UNHCR	4%	3% - 5%	-	UN, 2002	Estimation based on the average from the last five years
VAT	18,5%	-	-	Flame of Life, 2004	From quotation Flame of Life
Current Exchange rate, Euro-NPR	94	-	-	Kathmandu Post, 2004	Average exchange rate of December 2004
Current exchange rate IR-NPR	1,6	-	-	Kathmandu Post, 2004	Fixed exchange rate
Price kerosene	36	28- 45	NPR	Gulf Oil, 2004	Price has increased rapidly over the past few years. At the beginning of Febraury 2005, the price was 36 rupees.
Price kerosene stove	250	250 -300	NPR	NRCS, 2004	The NRCS uses a set budget per stove when purchasing new stoves. Therefore the price paid is more or less the same every year.
Price SK-14	9700		NPR/ per cooker (includes a black cooking pot, a hay box and VAT)	VFN proposal for extension, 2004	Includes reflector plates (converted from € to NPR), but excludes costs for training etc.
Price SK-14 reflectorplates	55		€ /per set	VFN, 2004	This price includes the import taxes, and whereas the reflector plates are coming from Germany this value is given in euros.
Overhead costs per solar cooker	1450		NPR	VFN proposal for extension, 2004	-
Personnel costs Refugee incentive	300		NPR / year	VFN proposal for extension, 2004	-
Price firewood	240		NPR / 100 kg	CFC, 2004	Will be used in sensitivity analysis for sustainable forestry.

table 9: Values for economical calculation

5.5 Users Attitude

Three types of data are needed for executing the users' attitude analysis: aspects on which the alternatives differ from each other, scores of each alternative on each of those aspects, and the importance that a group of users have rated these aspects.

In box aside, the list of 12 aspects that have been determined by the screening of the alternatives on the four areas of theoretical importance is shown. According to the cooking profile theory indicators have been based on observation of the differences between the alternatives and been divided in the main areas. The argumentation of the effect scores will follow below.

<u>Cooking device ownership and reponsibility</u>
- Not having to make agreements on usage time
- Not having to make agreements on maintenance

<u>Preliminary conditions</u>
- Effort for obtaining fuel
- Effort for maintenance
- Cooking place (inside)

<u>Cooking process</u>
- Cooking duration
- Not to have effort in paying much attention during cooking

<u>Cooking process externalities</u>
- No Inconveniences because of smell
- No Inconveniences because of smoke
- No Inconveniences because of space required
- Possibility to use fuel for other purposes
- No Inconveniences because of reflection

A solar cooker has to be shared among two or more families, and thus there is a need to make agreements between cooks on when to cook and how to maintain. This is a disadvantage of solar cooking compared to the other alternatives, as those do not require such needs. When expressed on a binary scale, scores follow of 1 (firewood) – 1 (kerosene) – 0 (solar cooker). See table 10.

The scores on preliminary conditions can be derived equally easy. Only with a solar cooker it is not possible to cook both in- and outside (score 1 – 1 – 0). The effort for the refugees to obtain their two-weekly share of kerosene is very small, as they only have to pick it up at a central place in the camp. As less kerosene is needed in the solar cooker alternative the effort for obtaining it, will also be lower. For firewood presumably more effort is needed: the refugees have to go into the forest, and cut the logs into smaller parts. For these reasons, a score of 3– 2 – 1 can be assumed. The refugees usually make little attempts to maintain their kerosene stove properly, as they'll get a new stove provided every two years anyway (NRCS, 2004). A chula must be replastered every once in a while taking more effort, but this is required less often than a solar cooker must be cleansed. Even though, the questionnaire could not give certainty about the rank, scores of 2 – 1 – 3 will be used as we expect the cleaning more often is more important. However, if this would prove to make a difference, a 3-1-2 score will be used in the sensitivity analysis as well.

The effort during the cooking process is highest with wood: as the fire is an irregular source of heat, it should be watched continuously to prevent the food from burning. The solar cooker should be tracked once a quarter and for the kerosene only checking on the food is necessary. Score: 3 – 1 – 2. The cooking duration has been measured during field tests (see appendix 13.3), and showed average cooking times for firewood, kerosene and the solar cooker of respectively, 2 hours, 1,6 hours and 1,9 hours. But as the cooking time depends on lots of uncontrollable parameters like the amount of fuel added (including solar energy) only an ordinal range can be given with some certainty, whereas the testing showed relatively small differences. Kerosene is the quickest, followed by wood and solar cooker in second place (2 – 1 – 2).

Regarding the externalities, smoke is only caused by the chula, smell both by the chula and the kerosene stove and reflection only from the solar cooker. On a binary scale the scores on these aspects are thus obvious again. As both the chula and the kerosene stove are small compared to the solar cooker, the latter scores a 0 compared to a 1 for both the kerosene and the firewood alternative. Because kerosene can be sold in the marketplace, and is easy to use for lightning purposes as well, it scores best on the aspect of ‘possibilities to use fuel for other purposes’. Kerosene supplied as back-up for solar cooking might be used that way as well, a possibility that the firewood alternative lacks. So, the scores on this final aspect are 3 – 1 – 2.

Dimension	nr.	Indicator	Scale	Value alternatives (rank)		
				Fire wood	Kero sene	SK-14
Cooking devices ownership & responsibility	1	NOT to make agreements on usage time	Binary	1	1	0
	2	NOT to make agreements on maintenance	Binary	1	1	0
Preliminary conditions	3	Effort for obtaining fuel	Ordinal	3	2	1
	4	Effort for maintenance	ordinal	2	1	3
	5	Cooking place (inside)	Binary	1	1	0
Effort cooking process	6	Cooking duration	Ordinal	2	1	2
	7	NOT to have effort in paying much attention during cooking	Ordinal	3	1	2
Cooking externalities	8	NO Inconveniences because of smell	Binary	0	0	1
	9	NO Inconveniences because of smoke	Binary	0	1	1
	10	NO Inconveniences because of space required	Binary	1	1	0
	11	Fuel usage for other purposes	Ordinal	3	1	2
	12	NO Inconveniences because of reflection	Binary	1	1	0

table 10: Criterion scores per alternative

A questionnaire has been held in Beldangi-I in the last weekend of November 2004. 117 refugee cooks have filled out the questionnaire during the monthly meeting of the solar cooking user group of their sector, containing two parts, one to validate the effectscores and one to determine the importance of these aspects. Because everybody is obligated to attend these user groups, the questionnaire should give a representative random sample. In appendix 13.6 the frequencies of answers on the different questions are being presented.

For all aspects results have been obtained to validate whether the refugees actually perceived the difference, and if not, those aspects have been removed from the list. From the list of 12, only the criterion ‘not having to cook outside’ has been removed. This has been done because it turned out that the refugees actually seemed to like cooking outside as much as cooking inside. The questions about effort in maintenance, cooking duration and cooking effort in the questionnaire have not been answered properly, so it is not clear whether the refugees perceive difference on these aspects between the alternatives, but as the maintenance, the cooking duration and the cooking effort, showed reasonable differences during observation they have been left in the comparison.

For the importance of the aspects the results can be used of question 9a, in which the refugees were asked to rate the importance of the aspects on a scale of 1 to 5. The average scores of the aspects have been used to obtain a ranking of their importance, which will be presented in the next chapter.

6 Analysis

In this chapter the actual analysis on environmental effects, costs and users' attitude will be presented. After derivation of the so-called 'best guess'-values on each of those aspects, an over-all comparison will be executed using a MCA-approach. The significance of uncertainties in each of the sub analyses, as well as in the final comparison will be examined in the next chapter.

6.1.1 Primary energy use and CO_2 emissions

Firewood alternative
The only relevant energy use in the firewood alternative is the actual burning of firewood. The estimated average need of 2.25 kg of sissu wood (which LHV is 16.8 MJ/kg) per meal equals an energy use of 37.8 MJ/meal.

Firewood alternative			
	Lifecycle stage	Energy use (MJ/meal)	**CO_2** emission (kg/meal)
1	prod. half fabr.	0.0000	0.0000
2	Transport	0.0000	0.0000
3	Production	0.0000	0.0000
4	Transport	0.0000	0.0000
5	Usage	37.8000	3.1374
6	Waste	0.0000	0.0000
	Tot.	**37.8000**	**3.1374**

table 11: energy usage of the firewood alternative

The burning of firewood is the only process that causes CO_2 emissions as well. Multiplying the energy use by an emission factor of 83 kg/GJ results in a total emission of 3.137 kg/meal.

Kerosene alternative
Fuel use also accounts for the lion share of energy use in the kerosene alternative. If a value of 0.21 liter of kerosene per meal is being assumed, this implies an energy use of 7.34 MJ for every meal. The difference with the fire wood alternative is mainly caused by the higher efficiency of a kerosene stove compared to a chula.

For the production process of the kerosene stoves few more is needed than perforating and bending of the thin steel plates, most probably done manually, and its energy use can therefore be neglected. The production of its main component, steel, requires 35 MJ/kg, but as the mass of one stove is just 3 kg, the energy use due to steel production only accounts for a little part of the total energy use. (0.072 MJ/meal) When expressed per meal is the energy use for production of kerosene many times higher: 1.468 MJ.

The kerosene is being produced approximately 400 to 500 km from the refugee camps. The assumption that all of the tanker trucks will have to return empty means that even double this amount of kilometres must be attributed to the kerosene transport. Applying a fuel use of 4.64 MJ/tkm, a reduction in energy use for an empty truck of 50% results (given the same kerosene use per meal) in an energy use of 0.497 MJ/meal. This is somewhat smaller than the number mentioned in the table below, as that value is topped by a small energy use of stove transport.

Because of the reuse of old stove components, materials and therefore energy are being saved in the waste stage. Given that the components of four old stoves can be reassembled into one 'new' one, and the energetical costs of stove production, transport etc. as already calculated, it can be derived that as much as 0.0184MJ/meal is being saved. The rest of the materials will be recycled: 70% new material (low quality steel) can be made out of every 100% input, saving out 0.0377 MJ/meal. An overall primary energy use of 9.330 MJ/meal then follows from adding and subtracting of the energy uses mentioned.

Kerosene alternative			
	Lifecycle stage	energy use (MJ/meal)	**CO_2** emission (kg/meal)
1	prod. half fabr.	1.546	0.083
2	Transport	0.000	0.000
3	Production	0.000	0.000
4	Transport	0.498	0.037
5	Usage	7.342	0.543
6	Waste	-0.056	-0.004
	Tot.	**9.330**	**0.660**

table 12: Energy usage of the kerosene alternative

Multiplying the emission factor of kerosene (0.074 kg/MJ) to the amount of energy used per meal gives the CO_2 emission in the usage phase. This does (not surprisingly given the high use of energy) also account for the biggest part of the total CO_2 emissions.

Solar cooker alternative

The most energy intensive parts of the solar cooker are the reflector plates. By adding the energy requirement of the anodizing process (48 kWh or 432 MJ_p for each cooker) to the GER of aluminium times the mass of aluminium needed, an energy need for the reflector plates follows of 609.3 MJ/cooker. With a set of reflector plates lasting for ten years, it can contribute to the cooking of as much as 10 * 365.25 * 2 meals a day = 14610 meals during its lifespan. Hence, when the energy requirement of the reflector plates is being expressed per meal, only a marginal value of 0.058 MJ/meal remains. Production of the iron parts of the cooker account for 0.031 MJ/meal, while the contribution of initial paint production is even smaller.

The transport of the reflector plates from Europe is to a large extent (0.023 MJ/meal) responsible for the value for 'transport' given in table 13. The energy for production and transport of the kerosene and the kerosene stove are included in the value for the usage phase. This has been done by multiplying the total usage of the kerosene alternative by the percentage of time that it is needed as a back-up for the solar cooker. Assuming that the solar cooker is able to cover 55 percent of the meals gives a back-up need of 45 percent, or 4.199 MJ/meal. Repair, and particularly repainting, accounts for the remaining energy use in this phase.

Because of the big uncertainties regarding the waste stage, no energy streams have been included in the waste stage. The implications of this choice will be examined in the sensitivity analysis.

Solar cooker alternative					
	Lifecycle stage	Primary Energy use (MJ/meal)	Primary energy use without kerosene (KJ/meal	**CO_2** emission (kg/meal)	**CO_2** emission without kerosene (g/meal)
1	prod. half fabr.	0,071	70,5	0,005	5,3
2	Transport	0,003	3,5	0,000	0,3
3	Production	0,030	29,6	0,004	3,6
4	Transport	0,025	24,5	0,002	1,7
5	Usage	4,204	0,5	0,298	0,7
6	Waste	-0,053	-53	-0,004	-3,7
	Tot.	**4,279**	**80,5**	**0,305**	**7,9**

table 13: energy usage of the solar cooker alternative

Like primary energy, most of the CO_2 emissions can be accredited to the usage stage, and thus the back-up need. When small additions for production and transport of the cooker are added a final emission can be derived of 0.305 kg/meal.

6.1.2 Deforestation

No direct deforestation is caused by either kerosene or solar cooker alternative. In the wood alternative, 2.25 kg of firewood is used per meal. This value can be directly taken as the contribution to deforestation of cooking one meal on firewood. An estimation of the effects of this demand for the surrounding forests can however give new insights.

2.25 kg of firewood comes down to a use of 0.0025 m^3 (2.5 dm^3) per meal, using a best guess value of 900 kg/m^3 for the density of the wood (sissu). Per year this need can then be calculated to be 36 m^3 for one family, or about 600,000 m^3 for the total amount of families in the seven camps. To put this in perspective, it might be compared to the maximum sustainable yield (5 m^3/ha/year) and the maximum usable yield (100m^3/ha) of a 20 year old sissu forest. In the latter case, 6000 acres of sissu forest would be wasted to cover one year of fuel supply for the refugees.

6.1.3 Costs

Firewood alternative
Due to the definition of costs used in this study, there are no costs for the firewood alternative to be considered. However, as wood generally is not free of costs when purchased legally, it is still interesting to calculate how much money would be needed if the UNHCR was to provide funds for fire wood.

There would still be no initial costs, as except for the clay and water made chula, no other devices are needed. The costs per meal thus totally come down to the fire wood usage. From the price mentioned by the community forest group near the Beldangi camps (2.4 NRS/kg) and the average fire wood use per meal (2.25 kg) it can be estimated that the fuel costs per meal for this alternative are 5.40 NRS or (using an exchange rate of 1:94) €0.057.

The change of some of the parameters over time has to be taken into account. The costs of firewood are assumed to increase along with the inflation in Nepal (8%/year). The exchange rate between euro and NRS is assumed to change with a pace equal to the difference in inflation between the two regions (8 – 2%). Given an interest rate of 4%, the costs of 10 years supplying firewood to the refugees can be estimated at 5.3 eurocents per meal. But these costs will only count when all firewood would be legally purchased and if the UNHCR would account for that costs.

Kerosene alternative
Supplying kerosene to the refugees involves both initial as recurring costs. Initially, each family has to be supplied with a kerosene stove, and afterwards this stove has to be replaced by a new one every two years. For the first purchase the current price of 275 rupees can be assumed, for the next purchases, interest, exchange and inflation rates again have to be taken into account. At t=2; the third year, when this second purchase has to be made, the price will probably have risen to 292 NRS, which, considered the interest rate, equals a present value of 270 NRS or €2.56. Four more of such expenses have to be taken into account, notably at t=4, 6 and 8.

Like all other prices is the kerosene price assumed to rise according to the inflation. The current fuel costs for one meal can be calculated by multiplying this price (36 NRS) to the amount of fuel needed (0.21 l), resulting in a value of 7.56 NRS or 8.0 eurocents per meal.

Costs kerosene alternative	NRS	PV (€)
Current costs of stoves	275	2.93
Costs of stoves at t = 8	509	2.50
PV all costs on stoves (per meal)	---	**0.19 ct**
Current fuel costs per meal	7.56	0.080
Fuel costs at t = 4	10.29	0.074
Fuel costs at t = 9	13.99	0.069
PV all costs on fuel (per meal)	---	**7.38 ct**
Maintenance costs at any t	---	---
PV all costs on maintenance (per meal)	---	**0.00 ct**
Total costs per meal	---	**7.57 ct**

table 14 Kerosene costs

The total costs per meal have ultimately been calculated by dividing the sum of the present values of all money streams involved (over ten years) by the amount of meals covered in that period.

Solar cooker alternative
For the solar cooker alternative the costs can be divided into four components: an initial investment on the solar cooker, multiple investments for kerosene stoves, costs on maintenance and costs on backup fuel. This alternative requires the biggest initial investment compared to the other alternatives as both a solar cooker and a stove have to be bought. The solar cooker can last for whole of the period of ten years, but the two[6] kerosene stoves still have to be replaced a few times. Due to the fact that it is less frequently (about a factor-2) used in this alternative, it has been assumed that the stove will last twice as long as in the kerosene alternative. So, at t=4 and t=8 new kerosene stoves have to be bought, for 748 and 1018 NRS respectively (present values of €5.41and €5.01).

Because the costs for the UNHCR are being calculated, the amount needed as an initial investment can be directly derived form the extension proposal (and quotation) that Vajra Foundation has sent to the UNHCR. Besides the costs of production and transport of the solar

[6] If a solar cooker would be shared by two families, two kerosene stoves have to be bought for backing up one solar cooker. But, because two families cook twice as much meals this makes no difference in costs per meal (compared to the costs on a stove in the kerosene alternative).

cooker, this value of 11150 also include costs that, according to Vajra, are directly needed for a successful implementation of solar cookers. In the sensitivity analysis it will be examined what would be the effect of stripping this value for the final results.

In the current situation, the refugees themselves are responsible for proper maintenance of the cooker, which includes paying the costs for repair and repainting. To allow such a regulation to work, however, hiring some personnel is needed. These costs have to be allocated to the solar cooker, and as the UNHCR would have to pay, these costs have been included in the analysis. It accounts for all of the costs mentioned as ‘maintenance costs’, as the other costs don’t have to be paid by the UNHCR. Vajra Foundation estimates the costs for supervising all camps at 1622400 NRS/year, equalling (when 6250 cookers would be placed) 260 NRS per cooker per year, or 0.18 NRS/meal. At t=9, these costs are expected to be at 0.36 NRS/meal, both amounts contributing marginal when expressed in eurocents of PV (0.2 ct).

A solar cooker does not require any fuel, and as such, thus no fuel costs have been taken into account. However, when the kerosene backup is needed, fuel costs arise, which will be referred to as ‘backup costs’. Given a yearly constant backup ratio of 45%, and the fuel costs as calculated above, these costs can be calculated to be of a present value of 3.6 eurocents per meal.

Costs solar cooker alternative	NRS	PV (€)
Current price of cookers	11,150	118.62
PV all costs on cookers (per meal)	**---**	**0.81 ct**
Maintenance costs at t = 0	120	2.76
Maintenance costs at t = 9		2.32
PV all costs on maintenance (pm)	**---**	**0.08 ct**
Costs on kerosene stoves at t=8	1,018	0.501
PV all costs on kerosene stoves (pm)	---	**0.11 ct**
Costs on backup fuel at t = 0	3.40	0.036
Costs on backup fuel at t = 9	6.80	0.030
PV all costs on backup fuel (pm)	---	**3.32 ct**
PV Total costs per meal	---	**4.32 ct**

table 15 Solar cooker costs

6.1.4 Users attitude

By comparing the average scores of the eleven aspects considered, a ranking could be derived of their relative importance. This ranking is shown intable 16, along with the according weighting factors, which have been derived by applying the expected value method. No two aspects have the same score, as there is always a difference in average score, even though this difference is sometimes very small.

Before applying the method of weighted summation, the scores had to be standardised. For the criteria using a binary scale this has been done on basis of a maximum standardisation,in which a value of 1 has been attributed to the best score, a value of 0.89 to the second best and 0.61 to the third. If two alternatives score even, their scores have been calculated by dividing the sum of their scores of the places they share by two. After this step, final scores for each criterion can be derived by multiplying the standardised values by their weighting factors. Summation of all criterion scores then gives a final score for each alternative.

Indicator	Rank	Average score	According Weight	Standardised values			Score alternatives		
				F	K	SK-14	F	K	SK-14
NOT to make agreements on usage time	6	3,72	0,070	0,95	0,95	0,61	0,06	0,06	0,04
NOT to make agreements on maintenance	4	3,83	0,110	0,95	0,95	0,61	0,10	0,10	0,07
Effort for obtaining fuel	10	2,77	0,017	0,61	0,89	1	0,01	0,02	0,02
Effort for maintenance	9	3,02	0,027	0,89	1	0,61	0,02	0,03	0,02
Cooking duration	7	3,63	0,052	0,75	1	0,75	0,04	0,05	0,04
NOT to have effort in paying much attention during cooking	5	3,78	0,086	0,61	0,95	0,95	0,05	0,08	0,08
NO Inconveniences because of smell	2	4,35	0,183	0,75	0,75	1	0,14	0,14	0,18
NO Inconveniences because of smoke	1	4,56	0,275	0,75	0,75	1	0,17	0,26	0,26
NO Inconveniences because of space required	8	3,35	0,039	0,95	0,95	0,61	0,04	0,04	0,02
Fuel usage for other purposes	3	3,85	0,138	0,89	1	0,61	0,12	0,14	0,08
No inconveniences because of reflection	11	2,73	0,008	0,95	0,95	0,61	0,01	0,01	0,01
Total score							0,76	0,92	0,82

table 16: steps in the MCA on users' attitude

It shows that the kerosene alternative has an advantage over the other two, and can therefore be considered the alternative of the users' preference. Solar cooking scores second place, leaving the refugees' traditional way of cooking on firewood a third place.

Making agreements and thus sharing a solar cooker is a significant disadvantage of solar cooking in this project against the other alternatives, as the refugees consider this an important issue. The efforts for obtaining fuel and maintenance are not considered very important, and thus little difference is made in this category. The effort during the cooking process is of medium importance and as wood scores worst on both aspects and kerosene best, significant differences in the final score are being made here.

The most important aspects concern externalities, and as wood once more scores worst on the important issues it cannot compete with the other two alternatives. The most important advantages of kerosene over the SK-14 in this category is the possibility of using the fuel for other purposes: this aspect accounts for half of the difference between solar cooking and kerosene. But as this difference is evened out by the inconvenience of the kerosene smell the small advantage of kerosene in this category is caused by the size of the cooking device. Finalizing it can be stated that using these indicators, as kerosene scores only first or second places on all the issues and as firewood does not score first on any issue, the chances of changes by using different weight sets are relatively small.

6.1.5 Multi Criteria Analysis

Input of Multi Criteria Analysis					
	Primary energy use (MJ/meal)	CO_2 emissions (kg/meal)	De-forestation (kg/meal)	Costs for the UNHCR (€/meal)	Users attitude (rel. score)
Cooking on wood / chula	37.8	3.14	2.25	0	0.83
Cooking on kerosene / stove	8.97	0.64	0	7.6 ct	1.00
Cooking on a SK-14 solar cooker	4.17	0.31	0	4.4 ct	0.89

table 17 Input data for the MCA based on the performed analyses on firewood, kerosene and the SK-14

The input for the final comparison, being the output of the previous analyses, is shown in table 17. Before these results could be summated, weighting factors had to be applied. All analyzed criteria have proven to be highly important aspects of implementing cooking technology in the Bhutanese refugee camps. Nevertheless, the history of the project showed it likely that some aspects are of bigger importance than others.

First of all, from the fact that the UNHCR is willing to invest in reducing environmental impact (otherwise they would never have started supplying cooking facilities), it can be derived that environmental effects must, at least, be slightly more important than costs.

Next to that, costs (and thus environmental effects as well), can be considered more important than the users' attitude, for the reason that users' attitude is merely a conditional criterion. After all, the UNHCR supplies the refugees without charging them. Even if the refugees do not like a cooking technology best, this does not necessarily mean they will object against others. Especially not, because one of the criteria for selecting a technology is the feasibility of fully covering the refugees basic cooking needs.

All aspects have proved to be important, and therefore none is assumed to be more important than the other two combined. In addition, the seperate environmental effects are not thought to be important enough to exceed the importance of costs or the users attitude on their own. From these assumptions a logical set of weighting factors can be derived: environmental effects 0.15 per sub criterion, costs 0.35 and users attitude 0.2. In the sensitivity analysis, the effect of other weight sets will be examined.

Subsequently the results are presented below. Considering these weights, the solar cooker alternative comes out best. The magnitude of the advantage might best be understood by studying the effect of removing one of the criteria: only in one case one of the other alternatives tops the solar cooker (in case deforestation would be left out of consideration, the solar cooker would lose by the tiny margin of 0.01). In none such cases would the kerosene stove win.

MCA Weighted Summation Best Guess Scenario											
			Input data			Standardized			Final Scores		
		Weights	FW	K	S	FW	K	S	FW	K	S
Environmental	Deforestation	0.15	-2.25	0	0	0	1	1	0	0.15	0.15
	CO_2 emission	0.15	-3.14	-0.64	-0.31	0	0.80	0.90	0	0.12	0.14
	Primary energy use	0.15	-37.8	-8.97	-4.18	0	0.76	0.89	0	0.11	0.13
Costs		0.35	0	-7.6	-4.3	1	0	0.43	0.35	0	0.15
Users attutide		0.20				0.83	1	0.89	0.17	0.2	0.18
Total		**1**							**0.52**	**0.58**	**0.76**

table 18 Results of the MCA for firewood, kerosene and the SK-14

table 18 furthermore uncovers the main reason why the solar cooker outdoes its competitors: it receives points on each criterion, whereas firewood does not receive any points on the environmental criteria and kerosene lacks points on the cost criterion.

7 Sensitivity analyses

7.1 Sensitivity analysis on sub-analyses

For each criterion a sensitivity analysis has been performed to see what the impact of different variations is on the outcome per criteria.

7.1.1 Environmental effects

The high contribution of fuel use in the total environmental effects of the alternatives has been one of the main findings of the analysis. Because of this high contribution, changes in the parameters concerned are likely to have a much bigger influence than is the case for any parameter in other parts of the lifecycle. Therefore only variation in the usage stage values will be used when constructing an upper and lower range for the final outcome of each alternative.

Uncertainties regarding data
The amount of kerosene and firewood used for preparing one meal indeed accounts for the biggest range of final outcome. This is not only due to their high contribution on final outcome, but also due to the big range. It proved however impossible to derive a smaller range, as these parameters are depending on numerous uncontrollable variables like good housekeeping of the refugees.

For constructing the worst and best case scenario of wood only the amount of wood used per meal and the LHV are interesting. Together they are resulting in range of between 22,5 – 54 MJ/meal. In terms of CO_2-emission factor a range of 10% has been applied which would change the total range in terms of the worst and the best case scenario for CO_2 emission to 1,694 – 5,062 kg CO_2/meal.

For kerosene the best and worst case scenario are ruled by the kerosene usage per meal and the ERE of kerosene, which set the range to 7,25 – 10,15 MJ / meal. Besides the range in kerosene usage per meal, the ERE also varies within a relative big range, but as it is depending on location more certainty could not be given. In terms of CO_2 usage this leads to the following range 0,545 – 0,704 kg CO_2/ meal.

As for the solar cooker the only fuel needed is kerosene, changes in the lower and upper range are directly being linked to changes in the assumptions for the kerosene alternative. For the SK-14 the range depends largely on changing the amount of kerosene per meal, the backup ratio, and once more the ERE of kerosene. Combining these factors leads to a range of 2,82 – 5,42 MJ / meal in terms of primary energy and to a range of 0,212 – 0,376 kg CO_2 / meal in terms of CO_2 emission.

Comparing these results shows that none of the alternatives comes within range of the other when incalculating the biggest possible changes in data-input. Therefore, the original ranking of the alternatives on environmental effects is solid.

Uncertainties in alternative outlook
Within the environmental effects assumptions have been made on the way of intercontinental transport, the waste stage of the SK-14 and the deforestation resulting from firewood usage. The analysis showed that changes in transport and the waste stage have little impact compared to the difference with kerosene and firewood. Therefore it is not useful to assess them any further.

Deforestation is resulting from firewood usage and as this is only the case in the firewood alternative changes in this value is irrelevant to the total outcome on this criterion. It will only influence the outcome if less wood is used than the average yield of the surroundings. But than collecting firewood should be controlled, and wood should be coming from sustainable forestry, which would link it directly to the costs criteria.

7.1.2 Costs

In this analysis some results and chosen ways of varying parameters require a further explanation. The discussion will be divided in two sections: uncertainties regarding data and uncertainties in alternative outlook.

Uncertainties regarding data
To assess the impact of the exchange rate, a gradual increase per year has been used to assess the sensitivity of the chosen method (linking the exchange rate to the difference in inflation). In terms of euro's the changes are noteworthy, but it should nonetheless be remembered that in NPR this would make no difference.

As the cookers, provided in Beldangi-I about 7 years ago, are still working properly, this lower range is not very likely to be realistic. And as the reflector plates are most expensive and vulnerable to bad maintenance, replacement of the reflector plates once during the life span seems sufficient for covering this.

Furthermore, it should be stated that as the SK-14 is the cheapest option under the current assumption, changing some assumptions at the same time could lead to a different conclusion. The worst case scenario would include the highest backup ratio, the highest usage of kerosene per meal and the replacement of the reflector plates once during the lifespan. And for the best case scenario it would include the lowest backup ratio, the lowest amount of kerosene per meal. This leads to the results of €0,033 - €0,055 per meal.[7] Due to the fact that the higher boundary is for a large extent dependent on the kerosene usage per meal, this value is directly related to the higher boundary of kerosene itself. In fact, the higher the kerosene usage per meal, the bigger the absolute difference will become, when placing multiple solar cookers.

The both scenarios for kerosene are to a large extent influenced by the amount of kerosene used per meal and leave the actual value to vary between the boundaries of €0,065 and €0,082. Firewood scores 0 on the cost criteria, but a change in the system boundaries could be influential and will therefore be discussed in the next paragraph along with other changes in system boundaries.

[7] Parameters equally influencing all the alternatives (like the interest rate, inflation rates and exchange rate) have been left out of consideration.

Uncertainties in alternative outlook
The uncertainties in alternative outlook are discussed here to assess their impact on the cost criteria. If they prove relevant they will be included in the final sensitivity analysis of the MCA to assess their influence on the final outcome of the comparison

The current price of firewood of 240 NPR per 100 kg (CFC, 2004) has been incorporated in the complete sensitivity analysis to assess how the costs for providing wood would be compared to the other alternatives if the UNHCR would buy the wood. For firewood, the only parameter influencing the costs is the amount of firewood used and this leaves a range of €0,035 - €0,07 per meal.

In the table only a lower price range of the SK-14 has been included because in the first place the price of the SK-14 is not likely to rise. Secondly, the lower range has been included to assess the impact per meal of providing a stripped solar cooker, without cooking pots, without hay box and without services like training etc. Depending on the situation some benefits can be obtained, but as the hay box and training have proven crucial for the success of the project, trying to save out on these costs is not smart. This will therefore not further be examined in this study.

Even though, the technical lifespan of the solar cooker is at least 7 years an economical lifespan of 3 years has been included to see what would happen with the price if the refugees are allowed to repatriate to Bhutan at that time. It would mean a price increase of 50 % per meal, which would make it a less feasible solution. Nevertheless, one should consider that if the refugees can return home, the cookers can be sold or put to use elsewhere, which would lower the costs per meal again.

7.1.3 Users attitude

The outcome of the users attitude analysis is subject to three types of uncertainties: uncertainties regarding the method by which the criteria have been given a weighting factor, uncertainties in the data-input and uncertainties regarding which criteria should have been taken into account. For each of these uncertainties it has been examined whether they influence the relative scores of the alternatives. (A score of 0.92 thus implies that the end score of the alternative concerned is 92% of the highest scoring alternative, and not that the score has changed by that percentage)

Uncertainties in methods used
The weighting factors have been derived by converting the outcome of the questionnaire into a ranking of the importance of the criteria, after which the expected value method has been applied to calculate weighting factors. Both steps could have been executed in other ways, and therefore the implications of using two other methods have been examined.

First of all: the applicability of the expected value method is arbitrary because the uniform, non-linear distribution of the importance of the criteria cannot be proved. The effect of assuming a linear distribution instead has been examined by applying method 2 as described in chapter 3. Besides the effect of taking small differences into account by method 3 will assessed. Of the selected alternative ways of deriving weighting factors, no significant change occurred compared to the first method and thus kerosene remains the first choice of the refugees, the solar cooker the second and firewood the third.

Uncertainties regarding the data
As the criteria have been designed to represent all differences between the alternatives, there is not very much doubt about the values on each criterion. Furthermore, when there were any doubts, the values proposed have been checked by means of the questionnaire. However, on some points the questionnaire or its results were not totally clear either, and in such cases the possible varieties in input should still be examined.

One such unclearness is the interpretation of the criterion ‘possibility of using fuel for other purposes’. Originally it has been included as an advantage of kerosene over cooking on solar energy and firewood, as kerosene can also be used for lighting, and (presumably even more important) to sell outside the camp. However, people using a solar cooker can also be assumed to save more kerosene than people using only kerosene. Seen in this light, a score of 3-2-1 should have been applied in stead of 2-1-3. This changes the final outcome in favour of the solar cooking alternative, but there remains a little preference for the kerosene alternative (0,96).

There have been some claims that using a kerosene stove, like using a chula, would result in inconveniences because of smoke. As the cooking sessions attended this was not the case, a score of 0-1-1 has been applied on this criterion. However, when a score of 3-2-1 would have been used, this would have resulted in a relative score of the solar cooker of 0.92, while the other relative scores would become 0.84 and 1.

Uncertainties regarding the criteria used
Leaving the criterion of ‘possibility of using fuel for other purposes’ out at all (which is reasonable because of the different interpretations) would close the gap between kerosene and solar cooker from 0.90 to 0.95.

Shortly after the questionnaire had been held, some irregularities in the kerosene distribution occurred due to problems of the Nepal Oil Corporation and the political situation in Nepal. The reliability of kerosene distribution has been subject of (harsh) discussions since, which makes a case for including this aspect in the list of criteria. When assumed to be of 3rd most importance to the refugees, kerosene loses much of its advantage, but still wins over its competitors. By combining this step with the uncertainty in “using fuel for other purposes”, which is relevant as the unreliability could reinforce the perceived position on this topic of the solar cooker. Under these conditions, the solar cooker achieves a first place, followed closely behind by kerosene. Still, as both changes include some uncertainty, it leaves ample room for discussion.

Concluding remarks
As firewood never takes over the second place from the solar cooker, it can be concluded, that given the outcome of the questionnaire, the outcome of firewood on a third place is stable. The solar cooker alternative however showed the capability of outpacing kerosene when “reliability” is included, also meaning a continued precarious situation in Nepal, and fuel usage for other purposes is interpreted differently. But this would only be possible under precarious circumstances and as none of the uncertainties mentioned could on its own change the outcome of kerosene as the alternative to which the users are most keen, so under normal circumstances, kerosene will take a first and the solar cooker a second place.

7.2 Sensitivity analysis on MCA

No matter what MCA, the chosen set of weighting factors is always subject to discussion. Therefore, no MCA is finished before the effect of applying alternative sets of weighting factors has been assessed. Next to this, the effect of varying the input data over their upper and lower range will be examined. Finally, some analysis will be done on changes in alternative outlook. In this last section some attention will be paid to using sustainable wood , instead of taking wood into account as a worst case scenario, and changing the time span.

Uncertainties regarding weighting factors
In appendix 13.7 the results of varying the weights and the data within their uncertainty range are depicted. Using the best guess data range shows that varying weights hardly influences the final outcome as now the solar cooker wins in 5 out of 6 cases. In the case that environmental aspects would be considered least important, and costs most important, firewood wins, but as the initial goal of funding kerosene was saving the environment, this is the least likely weight set. In all cases that costs are considered less important than environmental effects, kerosene ends up second, but never outpaces the solar cooker.

Uncertainties regarding data
Now the effect of the weight sets is clear on the best guess scenario, the effect of the uncertainty in the data should be assessed. In the same appendix the worst and best case scenarios have been constructed based on the ranges derived from the analysis per criterion.
These results show that the solar cooker is indicated as best alternative in 29 of 36 cases. Once again firewood comes out best in the other cases, but five of these cases are under the assumption that the cost are more important than both the environmental effects and the users attitude, which was the most unlikely weight set. The other two cases are one best case of firewood and the worst case of the SK-14 under ranking costs second and environmental effects third. Furthermore, firewood and kerosene seem to switch position whenever changes in the rank of environmental effects are considered.

Varying the time span
The first variation to assess in alternative outlook is changing the time span. If it would be the case that the refugees can return home before the technical lifespan of the solar cooker ended , a shorter economical lifespan should be taken into account. It will be assumed this will only involve changing the costs, as it is unlikely to assume that the solar cookers will be thrown away after repatriation and loses it environmental benefits. Thus changing the time span does not change the solar cooker being the best alternative, followed by respectively kerosene and wood, considering the best guess data range and the ECU weight set.

Sustainable forestry
The results of the sensitivity analysis so far showed that firewood in some cases (of varied weights or data), outdoes the kerosene alternative. This does however not directly mean providing the refugees of firewood is a feasible alternative to substitute kerosene. It has to be noted that the firewood alternative has been included in this comparison as a scenario in which the UNHCR would stop their supplies at all. Thus, no costs for the UNHCR are being involved, and thus it is not even the worst alternative given some weights and data.

In case the UNHCR would provide the wood, this would not come for free in financial terms, which would mean an altered score on costs. Likewise, the scores on environmental effects would be different, as the UNHCR is more likely to use sustainable forestry compared to the situation that the refugees would go into the woods by themselves. This makes it difficult to apply the data of this analysis to the option of sustainable forestry. In table 39 of the appendix, it is shown that using the best guess data ranges and the weight set ECU results in kerosene finishing last, firewood second and the solar cooker first, using both the three and ten year time span.

So, finalizing it can be stated that the weight set used and the uncertainty in data are hardly of influence for the final position of the solar cooker, but they do influence the position of firewood at the cost of kerosene or other way around. Changing the alternative outlook in terms of time span, does not change the final outcome under the ECU weight set and best guess data ranges. Introducing sustainable forestry leads to different conclusions. Using firewood coming from sustainable forestry firewood seems under the given conditions a better alternative than kerosene, but less than the solar cooker. In practice not all wood bought is certainly coming from sustainable forestry and scenarios, in which firewood costs money and has negative environmental effects are possible. Examining this was due to timing not possible , and should be further examined by others.

8 Assessment of alternative solar cooking techniques

8.1 The F1400 solar cooker

The F1400 is a parabolic cooker considered by Vajra as a possible improved design over the currently used SK-14. The F1400 differs from the SK-14 both in material and design. The reflector plates consist of polypropylene with an aluminium coating, while the framework is made out of galvanized steel. Main differences in design are the tripod shaped stand and the way that the cooker must be adjusted and set. In contrast to the SK-14, the F1400 is not a widely known type of solar cooker, nor is it produced on a commercial scale.

If larger scale production would take place this would, on request of the designer, be done in Almelo, Holland, after which the cooker would be transported to Nepal by plane and truck. Another by the producer mentioned, but still highly uncertain possibility, is total production in India. The framework requires some welding, which (like for the SK-14) can be neglected in the comparison. The reflector plates are coated by squeezing the aluminium on the polypropylene, which requires neglectable energy compared to the GER values (Flame of life, 2005).

Working on the same principles, the way of usage does not differ very much compared to that of the SK-14. A field test (see attachment …) has shown that the performance is somewhat less though, and tracking and adjusting is certainly more difficult. Although slower, a F1400 must be able to cover four meals a day like the SK-14, and it can therefore be assumed that the use of the back-up system is equal to that of the SK-14. Maintenance is comparatively easy, as no repainting is required, and little risk of making scratches exists. Due to the experimental stage of the F1400, no official lifespan can be stated. The easy replaceable reflector plates can be expected to last for two (guaranteed by the producer) to four years and lose reflectivity under influence of UV radiation (Flame of Life, 2004). The framework made out of galvanized steel can be expected to last longer. It will be assumed that for maintenance one would require 10% of the frames weight in spare parts per 2 years; they are likely to be produced in Patna, India. For the waste stage, two scenarios can be assumed: either the reflector plates will be burned and the frame reused, or both will find a second useful task.

In terms of costs, the ‘additional’ costs of training and personnel can be considered equal to those of the SK-14. Money streams that do differ are the initial investment of frame and reflectors, and the recurring replacement costs of the latter. Back-up costs might slightly vary to that of the SK-14, as the difference in performance might cause a more frequent need to use the kerosene stove.

Properties F1400
Size: 1.4 m^2 diameter
reflective area 1.5 m^2
Material balance:
6 kg galvanized steel
1.5 kg PP/al (1.4 / 0.1) laminate
Expected life span:
reflector plates 2-4 years
frame 15 – 20 years
Power: unknown
Test results have shown ability to cook 1 l of water in 25 min

8.2 Comparison of the F1400 solar cooker

Some additional data is needed to calculate the primary energy use, CO_2 emission factors and costs of the F1400. European GER-values can be used for galvanised steel and propylene. The main costs can be calculated from a quotation of Flame of Life, the producing company.

Extra data needed for comparison of F1400					
Variable	**Value**	**Range**	**Unit**	**Source**	**Comment**
Galvanised steel	45	38-60	MJ/kg	Energetics, 2000; Lawson 1996; UNHCS,1991	All the galvanized steel is produced in Europe, and not the highest quality is used
Poly propylene	63,2	60-63,2	MJ/kg	Worrell et al., 1994. Gielen, 2003	All produced in Europe as well
CO_2 EF GS	1,5		Kg/kg	Energetics Inc, 2000	The GS is coming from Europe where a same emission factor is valid
CO_2 EF PP	7,9		Kg/kg	NW&I, 2003	
Price F1400	99	99-139	€/ per cooker	Flame of life quotation, 2004	The bulk price excluding VAT is the most likely price to be paid by the VFN.
Reflectors F1400	39	39-59	€/ per set	Flame of life quotation, 2004	The bulk price excluding VAT is the most likely price to be paid by the VFN.

table 19 Inputdata for the analysis of the F1400 alternative

Environmental effects

table 20 shows the calculated primary energy use and CO_2 emission of the F1400 alternative. When the values are expressed per meal, it shows that using a F1400 when sunny has considerable environmental benefits over full kerosene usage (which had a primary energy use of 9.33 MJ). The totals of the F1400 furthermore turn out not to be so much different to those of the SK-14, which is due to the back-up system being responsible for most of the total in either alternative. In order to take a closer look on the differences between the solar cookers, also values expressed in KJ per meal, disregarding the back-up system, are being shown.

F1400 solar cooker					
	Lifecycle stage	Primary Energy use (MJ/meal)	Primary energy use without kerosene (KJ/meal)	**CO_2** emission (kg/meal)	**CO_2** emission without kerosene (g/meal)
1	prod. half fabr.	0.0250	25.8	0.0015	1.5
2	Transport	0.0004	0.6	0	0
3	Production	0	0	0	0
4	Transport	0.0605	60.5	0.0041	4.1
5	Usage	4.2463	47.9	0.3004	3.6
6	Waste	-0.0121	-12.1	0.0001	0.1
	Tot.	**4.320**	**122.7**	**0.3061**	**9.4**

table 20 Primary energy use and CO_2 emission of the F1400 alternative

The final transport stage and the usage stage make up the biggest part of the primary energy use and CO_2 emission per meal. The transport is accountable for almost fifty percent, more than 60 KJ and 4.1 gram per meal, of the value without kerosene usage: this is mainly due to the assumption that the complete cooker must be transported from Europe. The values of 47.9 KJ and 3.6 g per meal in the usage stage are mainly caused by the need for replacement of the reflector plates once in 3 years. Finally, for the waste stage the galvanized steel has been assumed to be transported to India and fully recycled, and the reflector plates being half used for other non-attributable purposes and half being burned without generating useful heat or electricity. Due to this, a small netto CO_2 emission takes place in this stage. Adding up the totals leaves a best guess score directly attributable to the F1400 of 122.7 KJ/meal and 9.4 g/meal.

Changing one or more assumptions on the production, distribution or the lifespan of the F1400 can have significant influence on the final outcome. How long the reflector plates can last is still highly uncertain, and varying this parameter gives a range of 103-169 KJ/meal. It has been assumed that the total cooker would be produced in Europe, although the producing company mentioned also a small possibility of total Indian production. If that would be the case, both primary energy use and CO_2 emissions would drop to values under those of the SK-14.

When all intercontinental transport would be done over sea rather than through air, reductions are possible that prove very beneficial for the outcome of the F1400. If Vajra would change its policy to ordering boat transport instead of air transport, this would alter the energy use for the F1400 to a relatively low 43 KJ/meal compared to 58 KJ/meal for the SK-14.

Change on original assumptions	Pr. energy use SK-14	CO_2 emission SK-14	Pr. energy use F1400	CO_2 emission F1400
Best Guess	**80.44**	**7.88**	**122.74**	**9.36**
Transporting the cookers by boat in stead of by plane	57.65	6.34	42.96	3.95
Production of the frame in India in stead of Europe	80.44	7.88	76.06	6.07
50% empty return trips	82.34	8.08	124.08	9.45
5-year lifespan of the reflectors	80.44	7.88	103.12	7.68
2-year lifespan of the reflectors	80.44	7.88	161.98	12.71

table 21 Results of sensitivity analysis of the F1400 solar cooker

Costs

Back-up and maintenance costs are the same as for the SK-14. The difference is made by the initial investment and the replacement of the reflector plates. The initial investment is NPR 14289, at the same side costs as calculated for the SK-14 and including VAT. When the reflector plates are assumed to be replaced at t = 3 and t = 6, this equals a present value of 0.56 eurocents per meal over a ten year period. In total, all costs add up to 5.22 €ct per meal.

Costs F1400 alternative	NRS	PV (€)
Current price of cookers	14289	167.43
PV all costs on cookers (per meal)	**---**	**1.15 ct**
Price of reflector plates on t=3	5440	43.34
Price of reflector plates on t=6	6478	38.75
PV all costs on reflectorplates (pm)	---	**0.56 ct**
PV all costs on maintenance (pm)	**---**	**0.08 ct**
PV all costs on kerosene stoves (pm)	---	**0.11 ct**
PV all costs on backup fuel (pm)	---	**3.32 ct**
PV Total costs per meal	---	**5.22 ct**
(Payback time: 3.3 yrs)		

table 22 F1400 costs

This means the costs per meal are higher than for the SK-14 (4.32 ct). Some cost reduction might be possible if the production of the frame would be done in India instead of Europe. Local production seems the only way to come near the price of the SK-14, as even with the upper range of the reflector plates' lifespan, the F1400 is the more expensive cooker in costs per meal. The payback time of the F1400 is with 3,3 years comparatively high to that of the SK-14.

Users' attitude
Compared to the conventional ways of cooking, the users' attitude towards the F1400 can be expected not to differ much from that of the SK-14: the principal working of the two devices is the same. In practice however, every user would perceive differences in comfort and performance. The limited precision by which the F1400 can be tracked is a problem: there is no indicator on the frame, and fixation is only possible in a limited amount of positions. Another problem is that the stand of the cooking pot is positioned in a way that it absorbs a lot of the concentrated solar radiation meant for the cooking pot. This results not only in the frame getting red hot, but also in efficiency losses. Both are likely to affect the users' attitude in a negative way, the latter since lower efficiency means longer cooking time. However, the producing company proposed solutions to these problems in the form of a new design, which has not been compared in practice to the SK-14 so far. Even if, as a solution to the heat loss problem, the material is changed, this would still leave the stand near or in the focus point, thereby still intercepting light meant for the cooking pot. After installing a more precise tracking mechanism, the users' attitude on this point will probably not differ from the SK-14s.

The materials used in the F1400 are likely to be positively valuated by the refugees. Maintenance of the galvanised steel does not require repainting- regular cleaning is enough, as the risk of corrosion is much smaller than for iron. It is hard to say whether the refugees would prefer to have multiple distributions of the more vulnerable F1400 reflector plates, or a single distribution of the anodized aluminium ones (of the SK-14). Cleaning of the laminate is easier, however, than cleaning of the aluminium plates: the F1400 does not have sharp edges, and does not get scratched too easily.

8.3 Concluding remarks on utility F1400

In environmental terms, the F1400 is as suitable as the SK-14 to substitute kerosene. The difference in primary energy use and CO_2 emission becomes clear only when the options are being examined without taking the back-up system into account. Under the given conditions, the SK-14 comes out as the better alternative, but if the production of the frame of the F1400 would be moved to India instead of Europe, or when the mode of transport would be changed, it can score a little better than the SK-14, mainly due to the exchange of highly energy requiring aluminium plates for the less consuming but shorter life-spanned laminate plates. Nevertheless, the difference between the two will never be significant compared to the difference of one of the solar cookers to kerosene usage.

The F1400 is more expensive than the SK-14, and even if it would be produced in India or in Nepal, it is highly uncertain whether it would outdo the SK-14, because solely the replacement of the reflector plates twice in ten years, using the current quotations' price, is more expensive than the initial investment for a complete SK-14. Besides that is the price of a F1400 already 50% more expensive than that of the SK-14. While the SK-14 has a payback time suitable to the (officially) temporary refugee situation, the F1400's might be somewhat too high.

Users most probably would also prefer the SK-14 compared to the first F1400 design, because of its better tracking, stability and performance. Improvement of the design might close this gap. It should be clear by now that the F1400 is not yet a mature design of solar cooker. Besides that, the shorter life span of the reflector plates can be considered a major disadvantage: that was one of the reasons to swap the box cooker for the SK-14 in 1997.

Switching to the F1400 would mean a need for extra effort for improving it to the current level of the SK-14 in all the terms of comparison, while the potentials of significant final benefits, over the currently used SK-14, to the project can be considered small. However, especially in environmental terms, the usage of aluminium laminate as reflector plates instead of the full aluminium plates is worth further examination. For now, the costs of the reflector plates should be reduced and their lifespan increased.

8.4 A two-dish solar kitchen

Properties of solar kitchen
Number of dishes: 2
Dish size: 9.6 m^2
Materials used per dish:
steel 150 kg
mirror glass 24 kg
(panels size varies between 10x15 and 60x 60 cm)
Receiver: 0,5 m^2 anodized aluminium
Efficiency at focus: 50%
Estimated lifespan: 12–20 years

A solar kitchen is a large device that uses solar energy for cooking purposes much in the way a solar cooker does on a smaller scale. The best documented and most widely spread type of solar kitchen is of the so-called Scheffler-type, named after Austrian Wolfgang Scheffler who has designed and promoted the design since the mid-eighties. Since the original, designs have mostly differed in their size, in the way they track the sun, and in how the heat is being transferred into the cooking pot. The potential of the currently standard type of solar kitchen[8] will be examined here: larger-scale plants that produce steam, such as the ones proven to be successful at Brahma Kumaris will not be considered because involving a steam system would make the system technically much more complicated and would require additional safety measures. As in Nepal high qualified personnel is more scarce, from a development economics point of view, implementing this more advanced solar technology is likely to be less suited.

A solar kitchen like the one described here can be expected to cook two meals a day for as much as 100 to 120 people (Gadhia, 2004). The current cooks will thus have to cook in shifts, cooking one day a lot for many people, but on other days not having to cook at all (and able to pick up a meal). Using a solar kitchen induces the need for bigger cooking pots, but as the cooking pots for the SK-14 fell outside the system boundaries, they will not be included here as well. It has been assumed that the refugees are still being supplied with kerosene and stoves, so that they can take care for their own meals when the solar kitchen cannot be used due to weather conditions.

[8] A more detailed description of the solar kitchen concerned can be found in Scheffler and Oehler, 1995. However, on dish size and tracking device the kitchen considered here differs, representing latest insights according to Golo Pilz and Deepak Gadhia, the two experts considered.

The main parts of the kitchen are two 9.6 m^2 reflectors, of oval, parabolic-like shape standing on two painted steel stands. The reflecting material is mirror glass, which is attached to a steel oval shaped framework on top of the stand. If properly tracked, the shape of the reflectors causes the solar radiation to reflect onto an anodized aluminium secondary receiver, which is placed half in, half outside a kitchen building. Tracking can probably best be done by using a wiper motor, to which both reflectors are connected by a horizontal and a vertical axis. More sophisticated tracking systems are available, but proved practically less suitable for the Indian situation, because of the desired involvement in the technology of local people. Extrapolating to the Nepalese situation, using the most sophisticated tracking device, will thus also prove unsuitable under the assumption that local people should be involved if a project is to succeed.

Globally, there is not a big market for solar kitchens, and only a few companies are active on the subcontinent. An Indian company will most likely be involved in placing solar kitchens in the refugee camps, at least for the technical support. While the materials will be coming from either Patna or Biratnagar by truck, construction is most likely in or near the camps. Like the reflector plates of the SK-14, the secondary receiver should be brought in from Germany.

Broken mirrors…
In Nepal, half a dozen solar kitchens have been placed during the last couple of years, most of which were successful for a while, but as much of them have fallen out of order after a period of bad maintenance.

After placement, a solar kitchen requires some maintenance of repainting the steel components and replacing damaged mirrors. The amount of mirrors broken each year is highly dependent on the weather and the number of playing children and (especially) animals that come close to the reflectors. Therefore, the producer advices to take replacement of all mirrors into account, for every 5 years of usage. Furthermore, it should be taken into account that a solar kitchen needs daily labour, as in morning time the dish should be placed at a starting position and during daytime tracking should be checked and adjusted if necessary. As for this job some technical knowledge is needed, some refugees should be trained and given an incentive to execute this maintenance task.

The technical lifespan of a solar kitchen is expected to be 12 to 20 years, depending on the lasting of the framework. During its lifespan, besides the initial investment, maintenance costs on personnel and mirror replacements can be expected, while as much back-up costs are involved as for the SK-14.

Extra needed data input
For the comparison between the conventional and the SK-14 alternative already data input has been given. Much of this is useful for the comparison between the comparison of these solar alternatives as well. However, some additional data is needed.

Extra data needed for comparison of the solar kitchen

Variable	Value	Range	Unit	Source	Comment
Stainless Steel	100	80-120	MJ/kg	UNHCS, 1991	Value for developing countries
Solar collecting glass	45	-	MJ/kg	Ecoinvent 2000	Because of the fact that the glass is should be more durable and highly reflectable a much higher GER is used than for ordinary glass
CO_2 EF Solar glass	2,5		Kg/kg	Ecoinvent2000, 2004	

CO_2 EF SS	5,0		Kg/kg		Asian value extrapolated to stainless steel production based on ratio of primary energy use.
Solar kitchen	65000		Indian Rupee / 9,6 m^3dish	Gadhia, 2004	Ordering one dish at Gadhia Solar costs in total about INR 65000
Current price Reflecting Mirrors	24580		Indian Rupees / 9,6 m^3 dish	Pilz, 2004	Costs reflector plates Mt Abu.
Placement costs	20800		Indian Rupee / 9,6 m^3 dish	Pilz, 2004	10% overhead costs are assumed
Maintenance costs	14760		NPR	Assumption based on the personnel costs per refugee incentive worker (VFN, 2004)	Based on the amount of personnel needed in Mount Abu and as the kitchen will be smaller one person per kitchen is sufficient

table 23 Input data for the analysis of the solar kitchen alternative

8.5 Results comparing the solar kitchen

In the table below the results for the solar kitchen are given. Like for the other solar alternatives the scores on both environmental indicators are mainly caused by the kerosene usage. Leaving the backup system out of consideration, a relative high input of 96.4 KJ/meal in basic materials shows, which makes up two third of the primary energy use. Little energy is being consumed for transport and production, this is because the mainly manual labour needed in construction, and the need to construct locally (due to the reflector size). The usage stage makes up for the remaining part of the CO_2 emission: energy use is caused primarily by the total replacement of the mirror glass once in five years. Transporting the used steel to the place of recycling and using it for new steel can be expected to save out 51 KJ/meal and 3.3 g CO_2/meal on the final primary energy use. In total, final primary energy use and CO_2 emission will cost respectively 96.1 KJ/meal and 6.3 g CO_2/meal. Taking the uncertainty in data into account leaves a range of 68.4 – 95.0 KJ/meal and for CO_2 emission between 4.5 – 6.0 g CO_2/meal.

Solar kitchen				
Lifecycle stage	Primary Energy use (MJ/meal)	Primary energy use without kerosene (KJ/meal)	**CO_2** emission (kg/meal)	**CO_2** emission without kerosene (g/meal)
Prod. half fabr.	0,0964	96,4	0,0062	6,2
Transport	0,0048	0,5	0,0004	0,4
Production	0,0059	5,9	0,0007	0,7
Transport	0,0016	1,6	0,0001	0,1
Usage	4,2113	20,8	0,2968	1,4
Waste	-0,0509	-50,9	-0,0033	-3,4
Tot.	**4,2772**	**78,7**	**0,3021**	**5,4**

table 24 Primary energy and CO_2 emission of the solar kitchen alternative

As some uncertainty existed about the difference in GER values between western countries and India, these values have been used to create a lower boundary. The upper range is formed by using a value for developing countries from the beginning of the nineties. Taking these aspects in data into account leaves a range of 68.4 – 95.0 KJ/meal and for CO_2 emission between 4.5 – 6.0 g CO_2/meal. Furthermore, the table shows that taking empty return trips into account hardly makes any difference, but that importing the aluminium reflector plates by ship instead of plane could change the balance in favour of the SK-14.

Changes in en consumption	Pr. energy use SK-14	CO_2 emission SK-14	Pr. energy use solar kitchen	CO_2 emission solar kitchen
Best guess	**80,44**	**7,88**	**78,72**	**5,33**
GER higher range Indian values	82,87	8,51	94,97	6,03
GER lower range Indian values	76,23	7,22	68,36	4,51
BOAT transport from Europe	57,65	6,34	77,85	5,30
Empty return trip 50%	82,34	8,08	81,94	5,65

table 25 Results of the sensitivity analysis for the solar kitchen

In financial terms the solar kitchen will cost, when expressed in the present value using a ten year time span, 6.23 €ct per meal, of which 3.43 €ct can be directly attributed to kerosene usage. The cost for hiring maintenance staff, one person per kitchen, comes down to 0.99 €ct per meal and the latter 1.80 €ct is needed for buying the total solar kitchen dish initially and replacing all the reflector plates after 5 years. By addressing the savings on kerosene expenditure as benefits and the initial investment and the maintenance on reflector plates as costs, a breakeven point of 4.3 years has been calculated.

Solar kitchen alternative	NRS	PV (€)
Current price of solar kitchen	208000	2212.77
Overhead costs	20800	1191.49
PV all costs on cookers (per meal)	**---**	**1.66 ct**
Price of reflector plates on t=5	24850	
PV all costs on reflectorplates (pm)	---	**0.14 ct**
PV all costs on maintenance (pm)	**---**	**0.99 ct**
PV all costs on kerosene stoves (pm)	---	**0.11 ct**
PV all costs on backup fuel (pm)	---	**3.32 ct**
PV Total costs per meal	**---**	**6.23 ct**
(Paybacktime: 4.3 yrs)		

table 26 Solar kitchen costs

If solar kitchens are to be used in the camps, the refugees would not have to cook for themselves any longer: a dramatic alteration of the refugees' cooking profile. This makes other issues not only less important, but some even irrelevant. In the questionnaire a special section was devoted to the solar kitchen, by which it could be determined how this small group of refugees thought of not having/being able to cook for themselves anymore. It showed that about 54% of the refugees did explicitly not like a facility like this, 25% seemed to like it just as much as the current situation, and only 21 % would like it better. Results showed furthermore sharing a cooking device with different castes was not the problem as 87% did not mind that. But it came out that the ability to cook for themselves was ranked 4.3 on the importance scale, indicating that the refugees want to keep their cooking for themselves.

Utility solar kitchen

When kerosene usage is taken into account, the difference in environmental terms between a solar kitchen and a solar cooker is very small. If not, the solar kitchen has a slight advantage in terms of environmental benefits compared to the SK-14. That is, given the assumption that the reflector plates will be transported by air cargo. In any case, the CO_2 emissions remain below those of the SK-14, due to the high energy consumption for making the SK-14 reflector plates SK-14.

The solar kitchen is more expensive than the SK-14. Besides that, the size of a solar kitchen makes it almost impossible to replace the kitchen if the refugees would be allowed to repatriate. As a result, implementing a solar kitchen would mean increasing the financial risk as well.

In terms of users' attitude, it is very likely to be less popular than the SK-14: more than 50% of the refugees would not like it if they were not able to cook for themselves. In fact, as cooking is almost the only thing they are allowed to do, taking this away would require major changes in their cooking profile and could eventually even take away their self esteem.

So, it can be concluded, that though some environmental benefits could be obtained, the solar kitchen is both in terms of costs and in terms of users attitude a less feasible solution for the refugee camps.

9 Assessment of changes in cooker design or production

9.1 Changes in solar cooker design

Changes in frame design
Since the introduction of parabolic cookers in Beldangi-I in 1998, most changes in design have been made on the framework. Broadly speaking, more material is being used, but production has been made fairly easy, as has the tracking and further usage. The possibility to rotate and flip-over the reflector showed to be a major advantage over, for example, the F1400, and is likely to have a positive influence on the lifespan of the reflector plates.

The material currently used, iron, is of relative low quality compared to the framework used in other parabolic solar cookers. The F1400 has a framework of galvanized steel, and the standard type of frame offered by EG Solar is also made out of stainless steel. However, using iron has the advantage over these other materials, that it is more cheaply available (VFN, 2004).

Compared with the above mentioned designs, the amount of material currently used in the frame is relatively high. Reducing this amount could lead to benefits in terms of costs and primary energy use. However, as the use of iron only accounts for small percentages of both, the benefits might not weigh up to possible losses on strength and stability of the cooker. This could be overcome by using stronger material like galvanized steel or stainless steel. For assessing changes in the frame in terms of costs and on environmental impact the following indication can be used for comparison. In environmental terms it can be used that 5,4 kg of stainless steel or 9 kg of galvanized steel (both produced in India) would be more or less equal in GER terms to the currently used amount of iron (and paint). As stainless steel costs 2,70US$ /kg and galvanized steel costs 0,80 US$ /kg (Mesteel, 2005) each kg of these materials respectively equals at least 5,2 and 1,6 kg of iron, assuming a price of 0,50US$ /kg in cost terms. So, when changing the frame these indicating numbers should be taken into account to make sure changes in the material of the frame have a positive influence on the overall performance, but as the required reduction in material use is relatively high chances are small for obtaining benefits.

But as reducing the amount of material will also decrease the cookers weight, and will thus result in an even more positive refugee attitude as moving a cooker into the sun will become a less heavy task. Using galvanized steel or stainless steel would also decrease the possibility on corrosion, especially to the stand. But on the other hand, the current policy of making the refugees aware of this problem and asking them to place the cookers on a stone or cement platform and to paint the cooker once a year also seems to work. The last years, in terms of users' comfort a lot of improvements already have taken place, of which the implementation of an extra vertical rotation axis for easier tracking is the most visible. Besides this a small cooking rack could be installed down in the corner of the frame, which gives the refugees the opportunity to put their spoons there, instead of on the lid of the cooking pot or on the reflector plates, reducing the chance of damaging the reflector plates when falling off.

Changes in reflector design
The current material, anodized aluminium, is one of few materials especially designed for solar cooking applications. The anodizing process costs as much as 1 GJ per set, and reduces

the reflectivity of the material by 4%, but still is very feasible as it increases the durability of the material enormously. Still, the comparison of the SK-14 to the F1400 showed that laminate could prove to be a fierce competitor.

The usefulness of alternative materials for the reflector plates can be considered largely dependent on their costs, environmental impact and (presumably most important) reflectivity[9]. Materials with a slightly lower reflectivity still can be worthy alternatives, but this will change rapidly with decreasing reflectivity. If too low quality of reflective material would be used, the added value of distributing parabolic cookers instead of box cookers would to a large extent vanish.

Metal	Visible Light Reflected from a Polished Surface
Silver	95%
Aluminum	90%
Tin	70%
Gold	61%
Chromium	61%
Iron	58%
Nickel	50%
Stainless steel	49%

table 27 Reflectivity of different metals. (Zahner, 2004)

table 27 shows the reflectivity of different metals, which also illustrates that aluminium is one of the best reflecting metals, only outpaced by silver. Even though these values can be subject to further processing of the materials, the difference between aluminium and other metals shows that a material should be a lot cheaper when even considering a change of material. But as aluminium is also available as very cheap foil, focusing on aluminium laminate seems the only option worth of consideration.

Changes in complementary devices

The hey box in itself can be seen as a complementary cooking device. Therefore improvements in this device could also result in lower costs, better users' attitude and higher environmental benefits as the time needed to prepare one meal by solar cooker might be decreased by optimizing the hey box in itself. Besides that it has the opportunity to save out other cooking methods, like using kerosene, as well.

Different types of these cooking devices are available in the market, from insulating sacks to insulating boxes, which can all be used for the same purpose, and mainly varying in their insulating capacity. The insulating capacity of the currently used hay box seems not optimal as the cooking time of this box is 1 hour for 1,23 kg's of rice (with 2 liters of water) and a different type, the wondersack, has reached cooking 2,5 kg of rice within 40 minutes (sources). This device should be constructed out of a jute bag, plastic sheet and hay, it has the potential of being much cheaper than the currently used box as the market price of the all the needed material in India was 172 INR (275 NPR) in 1997 and the currently used box costs

[9] Commonly, a distinction is being made between the initial reflectivity and the longer-term reflectivity (e.g. the reflectivity after 3 years). The longer-term reflectivity determines to a large extent the durability of the material.

750 NPR per piece (VFN, 2004). All together, this indicates that possibilities exist for reaching higher performance at lower costs and improving the users attitude by changing the design or the type of hay box used.

The properties of the pot used are an equally important determinant for cooking efficiency and time as the properties of the cooking device. A cooking pot must be fully capable to absorb the heat from the concentrated solar radiation but at the same time not be losing too much heat to the environment by conduction and convection.

As mentioned in the solar cooking guide, decreasing the size, and the thickness have a positive influence on the overall performance besides the color (SCI, 1994). Other ways for increasing the performance could however prove beneficial too. If the pot is divided into multiple sections as it could be used for cooking on gas or kerosene (PRCA, 2004), might enable cooking multiple components of a meal at once. Horizontal division would lead to smaller space in the cooking pot, and is therefore most suitable for cooking small amounts of food (so for smaller families). Vertical division of the cooking pot, by the usage of a steamer (two cooking pots piled up, with small holes in the uppers' bottom) might be possible for bigger quantities. In the lower pot water for tea or rice can be boiled, while heating up other food or steaming vegetables can take place at the same time in the higher pot.

Measure	Possible benefits	Applicability
Changing the material of the stand	Reduces chance on corrosion	Might not be necessary as the costless measures currently taken also seem to work
Reducing the amount of material used in frame	Small cost reduction, environmental benefits	First the risk of possible losses on the stability and strength of the frame must be assessed.
Trying other types of hay boxes or insulation materials	Other designs are claimed to have a far better performance	Easy
Using a thicker cooking pot or insulating the cooking pot	Fewer heat losses during cooking	Easy, but might result in costs increasing
Division of the cooking pot	Cooking multiple items at the same time	Scanning the market for pot dividers and testing

table 28 Possible changes in solar cooking design

9.2 Assessment of changes in cooker production, assembly & distribution

Changes in cooker production

Theory illustrates that by applying process innovations two main goals can be achieved, improvements in process design and enlarging the process control. Given the used parameters for the projects performance improvements in process design give only little opportunities for improvements due to interventions made by Vajra Foundation. The, in terms of costs and environmental effects, expensive reflector plates are being produced by EG Solar and thus. the only way to influence the costs and environmental effects for the reflector plates by Vajra Foundation is by choosing another type of reflector plate which has already been discussed in paragraph 9.1. Transporting the reflector plates in from Germany is accountable for a large share of the primary energy use per meal and small share of the costs per meal. So, choosing a local producer would lead to benefits in both parameters. At this moment, there is however no company on the Indian subcontinent that is able to produce suitable plates on its own (Brugman and Hart, 2004; Gadhia, 2004), but as no information about the Chinese market was available for this research alternatives might be found in China.

The frame of the solar cooker is almost completely manually produced in a local workshop and induces hardly any environmental effects. In terms of costs the potential benefits of changes are considerable: the construction of the frame including acquiring basic materials takes 2300 NPR per cooker. If reduction is to be made by improvements in process design it should happen by increasing the production capacity relatively more than increasing the labour costs. Hence, the employees should work more effectively. Methods for reaching this can be found in innovation theory; the most suitable ways for this project are, training the labour force or giving them incentives to work more efficiently (Tidd, 2001).

Besides a reduction in costs for producing the frame, benefits by increasing the production capacity might also be obtained from an environmental point of view. Indirectly, each extra cooker produced per month would reduce primary energy use and CO_2 emission from kerosene usage by respectively 1080 MJ and 76 kg CO_2 to 504 MJ and 37,2 kg CO_2 for two families. However, nowadays the production happens according to irregular incoming funds and distribution happens only after all the funded cookers (for a certain period) have been produced. Waiting until 100 cookers are finished, while distribution can start after 20, is therefore inefficient. Including a fixed number of cookers, after which distribution starts, in the distribution policy is an easily feasible solution for this.

The second type of goal to be achieved by implementing process innovation is increasing the quality of the process and thus the final product. A first big step was taken in 2003 as it was discovered that many of the cookers produced at that time did not follow the original design plans, their output therefore being reduced. To solve this problem, a mould has been made on which frames of equal and optimal shape can be produced (Brugman and Hart, 2004). However, to improve the control on the quality of the cookers structurally, one should have a reference of the desired quality, a threshold value, and methods to test whether the new cookers are of this desired quality. A low cost method for measuring solar insulation is a pyranometer (available for between 10 and 20US$), by which it will become possible to compare the performance of the cookers over time (Paudyal & Shrestha, without date).

Transport

During the transport of the frames from the workshop to the camp half of the cookers was slightly bend, and thus the quality of the cooker had decreased after the trip. To prevent this from happening, one could make transport policy in which the optimal amount of cookers to be transported at once is determined, or one could make a transport mould by which the cookers can be piled safely and effectively. Besides the higher quality it could also safe costs as the tractor will have to drive less often, which is also better from an environmental point of view.

Assembly

It showed that during the assembly the reflector plates could be watched more carefully. The plates are provided by EG Solar with a covering foil to protect the anodized layer as this is what makes the reflector plates suitable. At assembly however, this foil is removed before the plates are attached to the cooker and as it requires some effort to fit the plates in the frame, many plates already contain some scratches before they are actually used. One should

consider to remove the foil after assembly as the holes in the foil make it possible to attach the plates without removing the foil, even though it has already been tried.
Another point of attention combines the maintenance with the assembly. Many cookers that have been reassembled and painted have the reflector plates attached in a different order. This causes a loss of reflectivity, as the edges of the plates covered by another plate, are damaged more rapidly. Placing these damaged edges on top leaves thus a smaller high reflecting area in the reassembled cooker. To prevent this, numbering the plates during assembly could prove to be a solution.

Measure	Possible benefits	Applicability
Purchasing the reflector plates from a local company instead of importing them from Germany	Environmental benefits, as less transport is involved. Financial benefits as well: labour is much cheaper than in Europe.	Currently no company nearby is able to produce the plates but this should be closely watched. If changed, the plates' quality should be thoroughly examined.
Incentives for increased labour efficiency	More capacity at same or lower labour costs	Take the attitude of the employees into consideration
Fixing the produced amount of cookers to the distributed amount	Lower waiting time, thus benefits mainly environmental in nature	Easy, just setting regulation
Structuralized quality control after production	Small net performance gains of the solar cookers and reducing the amount of defects and effective learning mechanism.	Possibly more personnel needed
Packaging the frame of the cookers during transport	Less defects due to transport	Can also be solved by changing the place of the workshop
Leaving the covering foil on the reflector plates during assembly	Prevention of scratches	Easily applicable
Numbering the plates	Maintaining reflectivity at the edges of the plates	Easily applicable

table 29 Possible changes in solar cooking production

9.3 Assessment of changes in energy usage

For cooking on a solar cooker, minimizing energy use might not seem very useful at first sight (no primary energy use is being used anyway), but in case cooking time can be saved, it is possible to cook more food on the solar cooker, thus replacing primary energy otherwise used on a kerosene stove.

A number of simple measures that have been widely documented (PRCA, without date) can help significantly for reducing cooking time. Cooking with a lower water to compound ratio and soaking food before cooking are famous examples that work disregarding the type of cooking device used. For a solar cooker specifically, time can be saved by more accurate or more frequent tracking. Maintaining the high reflectivity of the dish, by proper cleaning and prevention of scratches can also save cooking time in the long run. The potential of these options is determined by the willingness and discipline of the cooks, but as good housekeeping is estimated to reduce up to 30 percent of fuel usage when cooking on kerosene or gas (PRCA, without date) benefits will be substantial.

Another way to reduce cooking time is by better usage of the hay box, which is now gladly being accepted by the refugees as a device for keeping their food warm, but that they less commonly use for finishing-off the cooking. The ability of the hay box to keep their food warm till diner time might have a positive influence on the acceptance of the solar cooker, but has no direct benefits in cooking time and fuel use. Saving cooking fuel and time is possible though, exactly by using the other ability (further cooking of the food) that the hay box has. How good this works, depends besides the quality of the hay box, mainly on the initial heating time, and the quantity of water used.

It is generally understood that when boiling starts it is the best moment to take the cooking pot off the solar cooker (Cleovoulou, without date). Not only is this the best identifiable point within the cooking process; from then on adding more heat just causes further evaporation, and no additional heat transfer to the food. (PCRA, unknown) The time a solar cooker is needed for cooking rice for six persons would be reduced from 35 to 25 minutes when using 2 litres of water. After one hour of 'cooking' within the hay box, all water should be evaporated. The one hour term fits neatly in the refugees' scheme of cooking rice-vegetables-lentils: rice and lentils are ready at the same time.

For finishing-off the cooking process in the hay box, usage of 2 litres of water (a ratio of 1:1.63) turned out to be better than 2.5 litres, which took 1 hour 15 minutes, and better than 1.5 litres as the rice remained hard. A 1:2 ratio already indicates a relative low usage of water: (Cleovoulou, without date) for example addresses ratios of 1:3 and 1:4. The difference merely lies in cooking method: dry cooking or pouring out rest water. When a hey box is used, dry cooking always is the better method of the two, because this requires less time. Using a hey box, the difference in cooking time can be made up for by utilization of the rest water for other purposes like sterilizing water, cooking other food, or making tea).

Spreading energy saving measures

The potentials of the options presented in this chapter are subject to whether the cooks would really apply them, whether the cooks themselves are dedicated to the search for an optimal way of usage, and whether they would experiment on their own use. Being supplied of a vast two-weekly amount of kerosene, there is no direct need for the refugees to think of energy saving measures. On the other hand, saving on kerosene can give them financial benefits, as they can sell their surplus on the local market. It has been rumoured that a lot of refugees use this way of generating a second income. So, it can be assumed that at least some of the refugees are trying to save out kerosene. And, because of the possible financial benefits, it should not be necessary to make the refugees more dedicated, nor hard to make them willing to apply most of the measures they know of.

The easiest way for Vajra to increase the knowledge of the refugees on fuel saving measures would be through their monthly meetings. By discussing on rules of thumb for example, like a certain compound to water ratio, the refugees can be given a starting point. Exchange of experiences among users could help the learning process of the refugees.

By simultaneously working on the environmental awareness of the refugees, additional impulses for these and other environmental measures could be stimulated.

Measure	Possible benefits	Applicability
Finishing-off the cooking process in the hay box after the water starts boiling *	10 min savings on the cooking of rice for six persons, disregarding the type of cooking device used.	The refugees must become aware of this, which can be done by discussing and perhaps demonstrating in the monthly held user group meetings
Mix of pre-cooking preparations like soaking rice and cutting vegetables or lentils into smaller pieces. *	Savings on cooking time	Cook has to be personally motivated.
Using specially designed solar absorption paint	Higher absorption and thus efficiency.	Extra costs for refugees probably don't weigh up against benefits in absorption.
Educating the refugees on ways to reduce energy	Refugees to take share in search for reduction of energy usage; encouraging them to apply the above mentioned measures	Easy through user group meetings; other meetings or demonstrations possible as well

table 30 Possible changes in energy usage

The *-marked measures are applicable to cooking on a kerosene stove or chula as well, and might therefore have a greater impact.

9.4 Assessment of changes in project management

Current and future key-issues

The solar cooking project has been growing steadily in the first years of existence, now having reached the point that the cooking demand in Beldangi-I is almost entirely covered. If not yet started, the project should reach the learning or reinnovation stage of the implementation cycle by Tidd. Optimally, this stage consists of structural reflection, conceptualizing, experimenting and honest capture of experience. Failing to learn can cause an organization to carry on with inefficient or counter-productive practices, to get locked-in, to miss opportunities, and to set unrealistic targets. Enabling learning should now thus be a key issue for a successful continuation of the project. By doing so, obtaining environmental and cost benefits will be assured for the future as well.

For extension of the project, new markets must be found now Beldangi-I is entirely covered, the most logical being the six remaining refugee camps. Vajra has halfway 2004 made the decision not only to ask permission to the UNHCR for placing cookers in the other camps, but also to ask the UNHCR to raise the funds. Because the UNHCR and Vajra have not yet reached an agreement over the proposal, Vajra could turning its attention to other projects in the meantime, even though the project should be continuously watched to assure progress.

Factors of Gow and Morss

The halting progress of the project involves a risk regarding the problem area of sustaining project benefits. Further development of the project is now being thought of as totally dependent on approval of the UNHCR and the Nepalese Government. Waiting for the UNHCR to provide funds on top of approval, is useful for spreading solar cooking, but should not lead to the end of the project. Therefore it is important that new ways keep being explored continuously.

The most critical of the 'notorious nine'

1. political, economic and environmental constraints
2. ***institutional realities***
3. ***host country personnel limitations***
4. technical assistance shortcomings
5. decentralization and participation
6. timing
7. ***information systems***
8. differing agendas
9. ***sustaining project benefits***

Vajra turning more and more of its attention away from the project, can result in problems that combine multiple factors of Gow and Morss. Initiating too many new projects can result in acute personnel shortage and have detrimental consequences for all projects initiated, as practices in Kenia have pointed out. (Gow & Morss, 1983). Increased pressure on available personnel for the solar cooking project is not unlikely to result in just carrying out the tasks that need to be done, putting less effort in creating and maintaining institutional strength. The relatively small number of people and time that is currently involved in the project rises the chance of being confronted with institutional realities in a latter stage.

Learning being crucial in this phase of the project is another reason for paying extra attention to the organizations institutional capabilities. To stimulate learning locally, and especially to perform structural reflection and to capture and spread knowledge and competencies, a properly functioning information system can be very helpful.

Possibilities for learning and effective continuation of the project

For overcoming the threat of being faced with institutional realities, a flexible process-oriented approach is needed. For Vajra, the information flow from field to head office is being hindered by the long distance from Beldangi-I to Kathmandu, and the absence of periodically meetings within the own organization. The placement of a representative of the Vajra board in Damak could help improving the information flow as well as general project overview. Moreover, continuous supervision opens doors for better ways of evaluating the project and for screening for opportunities and threats. Last of all, opening an office in Damak (if equipped with an archive) can lead to better capturing of knowledge.

The big risk for every small organisation is that if one of the driving forces, so-called key individuals retire or retreat from the organisation, their knowledge and skills are hard to replace. Especially in the situation of skilled personnel scarcity, a small organisation should focus on ways to store knowledge and practices within the organisation. The early involvement and training of junior personnel can prove an even more durable solution.

Appropriate attention towards information flows and information capturing should ultimately (that is: when the information system is properly designed) result in learning. According to Gow and Morss, one condition necessary is what they call improved planning capacity: a focus on target setting and periodically evaluating the project along those targets. Currently this evaluation mechanism is mainly in Dutch hands and could improve if Vajra Nepal would periodically set clear targets in terms of (for example) technical progress, cooker distribution and fund raising as well. This would both enable and encourage local learning. Simultaneously giving a new Damak agent, or the current refugee supervisors the explicit task to experiment on the solar cooker and ways of usage, could speed up the learning process. If being executed by Nepali embedded in the organization, this also makes Vajra less dependent on technical assistance from Dutch volunteers.

If the approval of the UNHCR would not yet come, screening of extension opportunities might prevent the project from halting. Especially in such a lock-in situation, options for independent progress should be explored. It is thus very useful that some other options for in the camps are still open, but distributing cookers to the local people outside the camps could prove just as good a market in the long term. By doing so, Vajra would show its eye for a growing social problem, and although follow-up would be more difficult (the local people are not as well organised as the refugees), Vajra should have enough experience to cope with that under more peaceful circumstances.

Gow and Morss point out that self-sustainability of a project often depends on the ability to be financially self-sustaining. The past has shown the project to be stopped periodically, when foreign aid was not sufficiently available. Generating and saving of money are the two obvious ways to deal with such problems. A way for saving money might be by utilizing the recently Nepalese authorization on the Clean Development Mechanism, and approaching Western companies for trade in CO_2 emission reductions. Furthermore, it might be possible to generate money in the long term by setting-up a company in solar cooking, but only if the situation in Nepal would calm down. GTZ has had good experiences in a project in which South African villagers could try-out solar cookers, and afterwards pay for them with a loan. Even when assessed unfeasible giving the current political situation in Nepal, such options should not be forgotten.

Measure	Possible benefits	Applicability
Having a representative in Damak, even when there are no direct activities needed.	Strengthened links and faster information flows within the organisation, as well as with other organisations and users	Costly
On a structural basis gathering solar cooker literature, news and contacts by the Nepali people involved.	Makes the project more self-sustaining: reduces the need for and dependence on Dutch volunteers for technical knowledge input.	Easy applicable
Ook taken doorgeven aan junior personeel (rotation). Rekening houden dat een key individual weg kan vallen	More stability within organisation, capturing competencies and better focus for long-term growth.	Might in the long run even be costs-saving, as junior personnel is generally speaking cheaper than senior personnel.
Introducing a local evaluation mechanism	Makes it easier to quantify the benefits of the project, and thus to better define new targets. Furthermore, it enables organisational learning.	It is not really in the Nepalese culture, and could therefore prove very hard.
Looking beyond the UNHCR and the refugee camps for possibilities of project extension in the long term	Is a more direct way to serve the goal of spreading solar cooking.	At the moment difficult due to the political circumstances.

table 31 Possible changes in project management

10 Conclusion

Comparison

In order to find out to what extent solar cooking technology can contribute to the relief assistance in the camps, the usage of a SK-14 solar cooker has been compared to alternatives in which all cooking would be done on firewood and kerosene respectively. For the SK-14 it has been assumed that in the time it can not be used due to whether conditions, kerosene would be used as a back-up.

The alternatives have been compared on the topics of primary energy usage, CO_2 emission, deforestation, costs and users' attitude. In table 32, the outcomes of these subanalyses are being presented.

	Primary energy use (MJ/meal)	CO_2 emissions (kg/meal)	De-forestation (kg/meal)	Costs for the UNHCR (€/meal)	Users attitude (rel. score)
Cooking on wood / chula	37.8	3.14	2.25	0	0.83
Cooking on kerosene / stove	8.97	0.64	0	7.6 ct	1.00
Cooking on a SK-14 solar cooker	4.17	0.31	0	4.4 ct	0.89

table 32 Input data for the MCA based on the performed analyses on firewood, kerosene and the SK-14

The SK-14 can reduce about half the environmental impact (in primary energy use and CO_2 emission compared to the kerosene stove. In fact, most of the energy use of the solar cooker can be attributed to the back-up need: the usage of kerosene when the solar cooker cannot be used due to bad weather conditions.

Cooking on a solar cooker turns out to be financially attractive as well: costs per meal have been estimated to be 4.4 €ct, while cooking on kerosene costs 7.6 €ct. For the firewood scenario, no costs for the UNHCR have been assumed: the refugees would cut or buy for themselves. If these costs would not be neglected, costs for the firewood alternative will be 5.3 €ct per meal. The payback time of investing in a solar cooker has in the current situation been estimated at 1.3 years, compared to the current situation of kerosene provision.

A Multi Criteria Analysis based on weighted summation has shown that given the 5 criteria considered and the data from the table, the solar cooker can be considered the best alternative of the three. Only when the most unlikely of six weight sets is being picked, the solar cooker finishes second best. So, it can be concluded that supplying the refugees of a SK-14 with some kerosene as back-up is a more than reasonable alternative to the current ways of aid relief.

Improvements

The project has been structurally screened for possible improvements. At first, it has been examined whether two alternate solar cooking devices might suit the project better than the currently used SK-14: the F1400 parabolic cooker and a standard-type solar kitchen.

The differences are relatively small when comparing on environmental effects. The results show that the F1400 can be considered somewhat less environmental friendly. However, relocating production from the Netherlands to India, would make the F1400 use a little less primary energy and cause less CO_2 emissions than the SK-14. Costwise, a pay back period of 3.3 years has been calculated: which is long compared to 1.8 years of the SK-14. It can be concluded that in the F1400s current stage of maturization, it is not yet worth the effort to switch from SK-14 to F1400.

The solar kitchen and the SK-14 score equal in environmental terms, but a meal prepared by the solar kitchen costs 6.23 €ct/meal and the device has as a result a longer payback period of 4.3 years. If the refugees would repatriate before this break-even point is reached, the kitchen cannot be used anymore, because relocating is impossible. The solar kitchen scores is thought to score worse on users attitude: the refugees in Beldangi-I rated having the ability to cook food by themselves (which is impossible when using the solar kitchen) very high. Therefore can the solar kitchen only be considered as a possible solution if there is too little space for placing multiple SK-14s in certain areas in the camp.

Even though, the SK-14 proves to be a good cooker, changes in the design of the frame, reflector plates and complementary devices could increase its benefits even further. Best possibilities for improving the frame lie within decreasing the amount of iron used. Switching to stainless or galvanized steel can only decrease the environmental pressure and costs if much less material is used. The reflector plates are relatively expensive, both in terms of costs and environmental impact. So, switching to aluminium laminate might be an improvement as this material already proved to cause less environmental pressure. It would furthermore be very beneficial if opportunities for production in the Indian or Chinese industry could be found.

In addition to the above mentioned points of attention, it will prove beneficial determining aspects on production, transport and assembly of the cookers in a policy. For the production both gains could be obtained by implementing quality control mechanisms for the cookers and rewarding the workshop employees when working more efficiently. Only after implementing quality control, it can become a habit to structurally improve the process without help of foreign technical assistance. To decrease the defect in the cookers due to transport, using packaging material seems an easy solution, but nevertheless determining the maximum amount of cookers to be transported per shipment in policy should be the main focus as this takes away the source of the problem.

Providing the refugees with environmentally sound technology obviously helps saving the environment, but creating environmental awareness amongst them could prove a more sustainable solution. Starting to stimulate standard cooking fuel saving measures like using the hay box for finishing off the rice cooking, using less water and soaking lentils could already decrease cooking time significantly. Besides that, especially because the refugees are already organized in monthly meeting users groups, only little effort will be needed for turning these meetings into environmental awareness meetings, dealing, besides the solar cooker, with other environmental issues as well.

Changes in project management are likely not to have directly measurable influence on the project at once. However, strengthening the institutional realities by creating an extensive solar cooking archive, building evaluation mechanisms and addressing more human resources to the project will in the long run pay off in sustaining project benefits. The focus should be on sustaining the projects benefits, just as the solar cooking technology is focussed on sustaining the environment.

11 Epilogue

Even though, the situation was not stabile when we arrived in Nepal, during the first four months this situation had little impact on the progress of the report. Still, it deprived our eagerness to travel to the more distant camps. In the final stage the situation contributed significantly to delay in work progress as communication with the university was impossible for over a week. This, in the end led to a situation in which we did not receive any comments before leaving for the Netherlands.

Refugee politics influenced the working process significantly. Our permission for visiting the camps had to be granted by both the UNHCR and the Nepalese government. And besides that Vajra Foundation Nepal acquired permission of the same organisations for the placement of the cookers in Beldangi-I, due to this some topics were better left alone as they could jeopardize our research and the project as a whole. So, while the refugee were afraid of loosing some of their kerosene, talking about exchanging kerosene for a solar cooker could spread rumours on kerosene cut and finally result in riots, which could then be blamed on VFN. Therefore, indications on the by the refugee preferred cooking technology, could not be acquired directly and had to be acquired indirectly by combining the questionnaire with our observations.

As it was an internship in a rapidly changing and precarious situation, it was very important to keep the practical purposes of the project in mind. The first part, the evaluation of solar cooking technology besides kerosene and firewood and the second comparison were clearly defined in both theoretical and practical terms. But because of the rapidly changing situation, we decided to define the second part, on project improvements, less precise in advance in order to remain flexible. In first it was our intention to hand over this comparison after finishing our total report, but as the project supervisor of the UNHCR would leave Nepal in January, it seemed best to write a preliminary report for answering their main questions on the technology. However, in the end this resulted in less time for assessing the project improvements, which resulted in a practical relevant, but academically not completely sound final part on project improvements.

The language barrier played a role in our access to information too, most people we had to have official contact with, were pretty fluent in English. Especially, the contact with the refugees surprised us in a positive way as all the younger refugees were fluent in English and could translate when contact with the older refugees was needed. Still, using a questionnaire was fiddly business as the questionnaire had to be translated to Nepali and we had not realized until start, that most of the refugee elder women, the cooks, were illiterate. Fortunately, many younger refugees were willing to help as translators, but the many translation stages nevertheless raised some questions about the uncertainty of some parts of the acquired questionnaire data. To overcome this, we had to rely on our observations once again and on the useful parts of the acquired data. Besides that, it was practically impossible to have a useful conversation with the employees of the workshop as they worked on irregular base and spoke no English at all, which resulted in new ideas for process improvement based only on observation and discussion with the foundations supervisor.

Finalizing it can be stated, that even though, it is much more difficult to write an academic report in Nepal than it is in the Netherlands, mainly because of politics involved, the language barrier and the lesser facilities, nevertheless many of the occurring problems have been overcome in a reasonable way by improvising. According to Gow and Morss, development aid is more art than science, let’s hope this report proves once again that academic work can contribute to the development of underprivileged regions.

Finalizing, we are both very grateful for the opportunity of conducting this research in Nepal, and being of a help to thousands of refugees.
Therefore we would like to thank the following organisations and /or persons for their support and/or cooperation without whom, this project would not have been possible:

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References

- Bergler, H., Biermann, E. Grupp, M. Jones, M., Palmer, R., 1999 , *Moving ahead with solar cookers. Acceptance and introduction to the market,* GTZ GmbH

- Blok, K. *et al.*, 2000. *Reader Energie-analyse,* Utrecht University, Department of Science, Technology and Society

- Brealey R.A., Myers S.C., 2000, Principles of Corporate Finance, Sixth Edition, McGrawHill,

- Brugman, G., Hart, P., 2004. *Focus on the Sun,* Vajra Foundation and TH Rijswijk.

- CFC, 2004. Interview with the board of the Community Forest Committee Beldangi in Jhapa, Nepal on December 1st.

- Czech S., 2004. Email correspondence with Stephan Czech of EG solar.

- Cleovoulou, M., without date. *Introducing fuel-saving cooking methods in southern Tamil Nadu*. http://www.cleovoulou.com/fuelsave.htm Visited January 5th, 2005.

- Duke, J.A., 1983. *Handbook of Energy Crops*. Unpublished

- Ecoinvent 2000, 2000. For more information, please contact Wilfried van Sark; w.g.j.h.m.vansark@chem.uu.nl

- EG Solar, 2004. www.eg-solar.de, as visited on November 5th 2004.

- Energetics Inc., 2000, Energy and Environmental Profile of the US iron and steel industry, DOE/EE - 0229.

- Engelenburg, van B.C.W, Rossum, van T.F.M., Blok, K., Vringer, K., 1994. *Calculating the energy requirements of household purchases – a practical step by step method.* Energy Policy, 22, pp. 648-656.

- Flame of life, 2004. E-mail correspondence with Frank van den Bovenkamp

- FXHistory, 2004: *historical currency exchange rates conversion* Table: NPR to EUR (Interbank rate 2001-2003) http://www.oanda.com/convert Visited November 26 2004.

- Gielen, D.J., 2003.

- Gielen, D.J. and Moriguchi, Y., 2003. Technological potentials for CO_2 emission reduction in the iron and steel industry. International Journal of Environmental Technology and Policy 1, no. 3. pp. 229-249.

- Gow, D.D. and Morss, E.R., 1988. *The Notourious Nine: Critical Problems in Project Implementation.* World Development. Vol. 16. No. 12. pp. 1399-1418

- Gulf Oil, 2004. Press release November 2004.

- Hellendoorn, J.C. (red), 2000. *Evaluatiemethoden ex ante (selectie uit).* Ministerie van Financiën, Den Haag.

- IEA Statistics, 2004, IEA Energy statistics for India and Nepal 2001, http://data.iea.org/ieastore/statslisting.asp

- Karwa, D.V., J. Sathaye, A. Gadgil, M. Mukhopadhyay, 1998: *Energy Efficiency and Environmental Management Options in the Indian Cement Industry,* ADB Technical Assistance Project (TA:2403-IND), Forest Knolls, Calif.: ERI.

- Kathmandu Post, 2004. *Exchange rates*. As published on December 17th, 2004

- Koudijs,P. Dutilh, H.G. 1993, *Milieu-analyse rapport: onderzoek voor de produktgroepen broodsmeerbeleg olie saus en azijn*, CE.

- Kundapur A, 1998. *Review of the solar cooking technology*, TIDE, Vol 8, No. 1, March, Page 1-37

- Lawson, B., 1996 *Building materials, energy and the environment: Towards ecologically sustainable development.* RAIA, Canberra

- Levine, M., Martin, N., Price, L. and Worrell, E. without date. *Efficient use of energy utilizing high technology: an assessment of energy use in industry and buildings- summary on findings*

- Mathiesen, L. and Maestad, O., 2002. *Climate policy and the steel industry: achieving global emission reductions by an incomplete climate agreement.* Discussion paper.

- Moed, 2000, Minimisation Opportunities Environmental Diagnosis, Ministry of the Environment Spain, Spain.

- NASA, 2004, *NASA Surface meteorology and Solar Energy (At Latitude 26 and Longitude 87),* Document generated on Sat Nov 20 07:01:55 EST 2004, http://eosweb.larc.nasa.gov /cgi-bin/sse/sse.cgi?ralph_lindeboom@hotmail.com

- NMSU, 2002. *ASAE Standard: ASAE X580*, revised by P. Funk on 04/03/2002, http://web.nmsu.edu/~pfunk/X580.htm.

- Oehler U. and Scheffler W., 1994, The use of indigenous materials for solar conversion, Solar Energy Materials and Solar Cells 379-387, Elsevier.

- Olthof, 2004. Meetings with Maarten Olthof preliminairy to our departure

- Owen M., Stone D., Davey C. and Petersen M., December 2002, *Cooking options in Refugee Situations: A handbook of experiences in Energy Conservation and Alternative Fuels.* Environment Unit, Engineering and Environmental Services Section, UNHCR Geneva.

- Paudyal B.B. & Shrestha J.N. without date, *Low Cost Method for Solar Radiation Monitoring, from Renewable Energy Technology for rural development*.

- Phylipsen and Alsema, 1995. *Environmental life-cycle assessment of multicrystalline silicon solar cell modules.* Utrecht University, Department of Science, Technology and Society.

- Pilz G., 2004. Interview held on 28 september 2004 with mr. Pilz, supervisor of the Brahma Kumaris solar kitchen project at Mt Abu, India.

- Pokharel G.R. and Munakami R., 2003, Renewable energy technologies and avoidance cost of CO_2 in Nepal, University of Flensburg, Germany and IWM-Program, Centre for Rural technology, Nepal.

- PRCA, without date. Tips for fuelsaving, http://www.pcra.org/newgasandkerosene2.html date 29 november 17.45

- Reddy, A.K.N., Anand, Y.P. and D'Sa, A., 2000. *Energy for a sustainable road/rail transport system in India.* Energy for Sustainable Development. Volume IV, no. 1.

- Rogers, E.M.1995. *Diffusion of Innovations*. New York, Free Press.

- Scheffler W., Hoedt H., 1998, Evaluation Report: On Scheffler Reflector Technology Transfer to RIIC, Kanye.

- Solar Cookers International SCI, 1994. *Spreading solar cooking Leaders Guide, Sacramento USA.*

- Schapendonk, 1999. *'The sun is free' Verslag introductie zonneovens in de vluchtelingenkampen in Nepal.* Vajra Foundation.

- Schippers, W.A.J., 2000. *Structure and applicability of quality tools,* Eindhoven Technical University

- Schumacher, K. and Sathaye, J., 1999. *India's Cement Industry: Productivity, Energy Efficiency and Carbon Emissions.* Ernest Orlando Lawrence Berkely National Laboratory, Environmentel Energy Technologies Division.

- Shakya I., 2003, RETs for sustainable development: the gender persective. RONAST, Kathmandu, Nepal.

- Szirmai, A., 2003. *The Dynamics of Socio-economic Development: An introduction.* TU Eindhoven.

- Thirlwall, A.P., 2003. *Growth & development With special reference to developing countries*. 7th edition. PalgraveMacmillan. New York.

- Tidd, J., J. Bessant, K. Pavitt. 2001. *Managing Innovation.* Chichester, Wiley.

- United Nations, 2002. *Voluntary funds administered by the UNHCR*, report of the executive committee of the HC program.

- UNHCR, 2004a. interview with Mr. T Moriyama, held on 29 October 2004 in the UNHCR office in Damak.

- UNHCR, 2004b. Camp profiles for implementation partners as published by the UNHCR. Update August 28th, 2004.

- UNHCS, 1991. Energy Efficiency in Housing Construction and Domestic use in Developing Countries. HS/218/91/E, Nairobi.

- VFN, 2004. *Annual Progress Report (17 July 2003- 16 July 2004)*, Planning and reporting section Vajra Foundation Nepal, Kathmandu.

- Vajra Foundation, 2004. *Study Assignment.*

- Worldbank, 2001 World Development Report 2002, Oxford University Press. From: Thirlwall, 2003 Growth & Development chapter 14.

- WEC (World Energy Council), 1995. Energy Efficiency improvements Utilizing high technology, London : from: Reader OEM *Research Methods for energy and resources, Utrecht University 2002-2003.

- Weidema & Wesnaess, without date. Environmental Assessment of Products, chapter 5 LCA to Z, TEK, Helsinki from: Reader OEM *Research Methods for energy and resources, Utrecht University 2002-2003.

- Worrel, E. 1994. *Potentials for improved use of industrial energy and materials*, Utrecht: Universiteit Utrecht, Faculteit Scheikunde.

- Zahner, L.W. 2004. *Architectural Metal Surfaces,* chapter 1. John Wiley and Sons.

12 Appendices

12.1 List of abbreviations

- Acre = 100 m by 100 m
- BOF = Blast Oxygen Furnace
- CO_2 EF = Carbon dioxide Emission Factor
- Dal Bhaat = Nepalese name for lentils and rice
- ECU weight set = weight set in which Environmental impact is weighted as 0.45, Costs is weighted as 0,35 and Users attitude is weighted as 0,20.
- ERE = Energy Requirement …?
- GER = Gross Energy Requirement, amount of primary energy needed to construct a material
- kJ and MJ = kilojoule and megajoule
- kWh = kilo Watt hour = 3,6 MJ
- LCA = Life Cycle Analysis, a method by which one can determine environmental impact of a product from ground material to dustbin.
- LHV = Lower Heating Value
- MCA = Multi Criteria Analysis, a method by which alternatives can be compared on different criteria
- MSY = Maximum sustainable yield
- MUY = Maximum unsustainable yield
- NRCS = Nepalese Red Cross Society for Refugees
- Pm = per meal
- PP = Polypropylene
- PV = Present Value
- TA = Technical Assistance
- tkm = tonne kilometre
- UNHCR = United Nation High Commisioner
- VAT = .. Tax ?
- VFN = Vajra Foundation Nepal

12.2 Clarification on MCA method

Cost and benefits
When using a multi-criteria method it is essential to make a distinction between cost and benefit-criteria. In principle all criteria on which a higher score is worse, like acidification or deforestation, are addressed as negative by putting a “minus” in front of the score. All positive effects, for which a higher score is better, like users happiness, are indicated by a positive sign.

Standardization
As comparing multiple criteria most likely involves multiple score ranges, it is necessary to standardize all scores on a range between 0 and 1 or -1 and 0. To accomplish this various methods are described: maximum-standardization, interval standardization, S-shaped standardization, concave-standardization and convex-standardization.
In this report only maximum standardization is used, by which one should divide the alternatives score by the score of the highest alternative for benefits and for the costs divide an alternatives score by the highest score and adding up 1 afterwards. The advantage of this method is that the original scores remain proportional to each other, which is not always the case for other standardization methods. But this method is only applicable if the scores have a natural minimum like costs or temperature.

Weighted summation
This method is fairly simple but can only be used for quantitative scores and includes five steps:

1. The scores on each criteria should be standardized
2. The weights should be determined manually
3. Multiplying the results of step 1 and step 2
4. Add the scores on the different alternatives up
5. Determine the final rank of each alternative

Expected value method
The main difference between this method and the weighted summation method lies in the fact that both quantitative and qualitative scores can be included. Both the qualitative criterion scores and the weights are determined based on their rank (among all alternatives). If it is only known, that A1 scores better than A2, and A2 scores better than A3 scores should be addressed accordingly. For this the Expected value method matrix is used, which can be calculated by using the following formulas:

Number of alternatives	A1	A2	A3	A4
1	1,00			
2	1,00	0,75		
3	1,00	0,89	0,61	
4	1,00	0,94	0,79	0,52

table 33

Number of criteria	W1	W2	W3	W4
1	1,00			
2	0.75	0,25		
3	0,61	0,28	0,11	
4	0,52	0,27	0,15	0,06

table 34

If two weights or criteria are of same importance or score, their additional places are added up and divided by their amount. So assuming three criteria, and the first placed is shared both will acquire the score of (0,61+ 0,28 / 2)= 0.445.

12.3 Field test on the refugees' cooking profile

The average meal
From former reports of the Vajra Foundation it has been determined that normally cooking is done for a complete family which lives in one hut. Therefore it was important to determine the average family size. From the camp profiles published by the UNHCR the average family size has been determined on 6 persons. So, the amount of people to be cooked for will now be set at 6 persons. The amount of food needed for this has also been derived of the camp profiles of Beldangi I by dividing the distributed amount of food per person per day/week/month through the number of meals to be eaten in that time. An average meal for 6 persons consists now of:

- Rice
    - 1230 grams of rice
- Curry
    - 120 grams of pulses
- Vegetables
    - 129 grams of green banana or pumpkin or cabbage (skin included)[10]
    - 129 grams of potatoe (skin included)
    - 25 grams of onion

Because of the low quantities and the variety in the amount of spices used in cooking, we have not included set amounts of spices in our definition of the average meal. We gave the cooks the opportunity to decide by themselves how much of the commonly used spices curry, salt and ginger they wanted to include in the meal. They could also decide freely on how much vegetable oil they used: this did not differ very much.

Inventory List

- SK-14 (few months old), chula (just replastered) and a kerosene stove (1,5 years old)
- A number of cooking pots distributed by the Vajra Foundation for cooking on the SK14. These are all painted black and have a diameter of 30 cm. Other cooking pots that will be used are made out of the same material, are also painted black, but will have a different size.
- A few measuring cups for measuring the amount of kerosene and water.
- A mass balance (accuracy of 100 grams)
- A stopwatch
- 1 litre of kerosene
- 4 kg of sissu fire wood
- About 20 litres of water

Data Collection & Results
The following data were obtained on October 14th 2004. The location of the test was sector A of Bhutanese refugee camp Beldangi I, near to Damak, Nepal. The weather conditions were sunny, a total clear day until a quarter to 4 PM, when some small clouds appeared. Originally the test was scheduled a day before, but because of the bad weather conditions that day (rapidly changing from cloudy to a little bit sunny and back), the test was postponed by one day. Table 35Table 36 show the collected data of the solar cookers.

[10] We were told that it is currently the green banana season, so green banana will be used in the test.

Table 35: data on field test #1a Duration of cooking an average meal by solar cooking during the day

Cooker no.; action no.	Cooking item	Starting time	Time finished	Duration (h./m./s.)	Comments
1a; 1	Rice	08.08 AM	08.55 AM	0h48m30s	Water boiled much faster, but the rice had to cook dry
1a; 2	Vegetables	09.09 AM	09.29 AM	0h19m30s	Frying
1a; 3	Curry	09.39 AM	10.18 AM	0h37m00s	Pulses for eating
1a; 4	Rice	10.22 AM	10.57 AM	0h35m00s	Water boiled after 25 minutes
1a; 5	Vegetables	11.19 AM	11.38 AM	0h19m00s	Frying
1a; 6	Curry	11.45 AM	12:46 PM	1h01m00s	Pulses were boiled longer, because soup was being made
1a; 7	Rice	13.00 PM	13.40 PM	0h40m30s	
1a; 8	Vegetables	14.01 PM	14.13 PM	0h17m00s	
1a; 9	Curry	14.27 PM	15.23 PM	0h56m30s	
1a; 10	Rice*	15.33	-	-	Because the refugees said that it would be of no use trying another meal, one litre of water was put up, but this also didn't work out. Up until 10 minutes the boiling went normal (the pot was hot, and small bubbles were shaped), but after 25 minutes (15 minutes later) the water still had not boiled

Table 36: results on field test #1b | Reference Solar cooking schedule for 1 litre of water

Cooker no.; action no.	Cooking item	Starting time	Time finished	Duration (h./m./s.)	Comments
2; 1b	Water 1,0 litre	08.08 AM	08.24 AM	0h16m30s	Starting time exactly same as starting time of cooking rice (action 1, cooker 1) , water showed small bubbles after 10 minutes. The cook agreed to check on the boiling, but the water probably boiled a few minutes before she checked. After this all the other measurements were checked by ourselves.
2; 2b	Water 1,0 litre	09.09 AM	09.26 AM	0h16m30s	
2; 3b	Water 1,0 litre	09.39 AM	09.55 AM	0h15m30s	
2; 4b	Water 1,0 litre	10.22 AM	10.37 AM	0h15m00s	
2; 5b	Water 1,0 litre	11.19 AM	11.30 AM	0h11m00s[11]	
2; 6b	Water 1,0 litre	11.45 AM	12:01 PM	0h16m00s	
2; 7b	Water 1,0 litre	13.00 PM	13.15 PM	0h16m30s	
2; 8b	Water 1,0 litre	14.01 PM		0	Suddenly the cooker was in use by the owner, whom was boiling pulses.

[11] This value has been excluded because it shows too much difference with the other measurements.

					Therefore boiling could not start at the right time, making measuring of little use.
2: 9b	Water 1,0 litre	14.27 PM	14.42 PM	0h15m00s	
2: 10b	Water 1,0 litre	15.33 PM	-	-	See Table 35 1;10 comments

Table 37 shows the results of the test on the kerosene stove, while Table 38 shows the chula results.

Table 37: Results on field test #1c | Duration and needed amount of kerosene needed for cooking an average meal

Cooker no.; action no.	Cooking item	Starting time	Time finished	Duration (h./m./s.)	Amount of kerosene left[12]	Comments
					1 l	
3; 1	Rice	13.00 PM	13.49 PM	0h49m00s		The kerosene can be smelled throughout the hut
3; 2	Vegetables	14.01 PM	14.17 PM	0h16m00s		Fire should be watched regularly
3; 3	Curry (soup-like)	14.27 PM	15.23 PM	0h56m00s	0,818l	**0.182 l used**

Table 38: Results on field test #1d | Duration and needed amount of firewood for cooking an average meal

Cooker no.; action no.	Cooking item	Starting time	Time finished	Duration (h./m./s.)	Amount of wood left	Comments
					4,0 kg	
4; 1	Rice	09.09 AM	09.44 AM	0h35m00s	3,0 kg [13]	After a while there was very much smoke inside the hut.
4; 2	Vegetables	09.45 AM	09.58 AM	0h13m00s	2,7 kg	Cooking on firewood is more intensive, the fire should be watched all the time.
4; 3	Curry (soup-like)	09.59 AM	11.12 AM	1h13m00s	1,6 kg	**2,4 kg used**

This fourth test was cancelled on the testing day, because of bad scheduling it was becoming too late for preparing a complete meal. Therefore the cooking on the firewood was tested October 15th at the same location. But because the weather condition could not influence this test, this was not a problem.

[12] Due to timing it was impossible to check the amount of kerosene in between, because than the stove should cool down first, before it would be possible to measure the amount of kerosene left.
[13] Approximation of the wood used; because the different pieces were all measured solely. Measuring in between was impossible as an abrupt break of the cooking process would be unfair for the comparison.

12.4 Derivation of Backup ratio

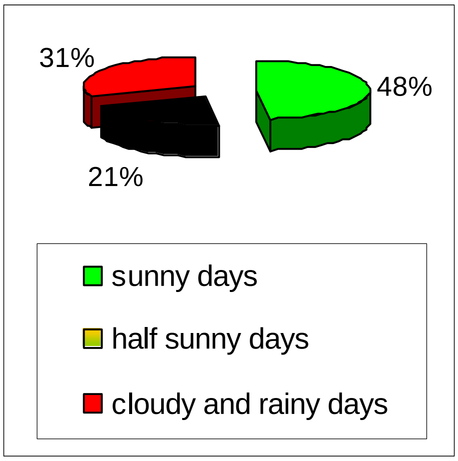
To calculate the potential savings of introducing solar cooking technology, it should be determined how many meals can be cooked on one day, as well as how often a backup system is needed (which will be referred to as the backup ratio[14]). This first number could easily be derived by field tests. On a sunny day in October it has proved very possible to cook 4 average meals for 6 persons. So, on a sunny day, it is possible to save the amount of kerosene normally used to prepare 4 meals.

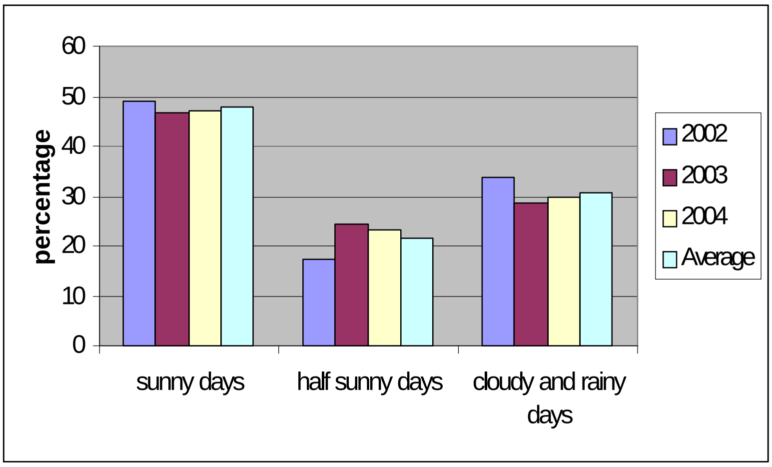
To quantify the benefits (savings ratio) of their project has Vajra Foundation Nepal been archiving the amount of days solar cookers could be used in Beldangi-I since 2002. They have classified each day in one of the following categories:

1. Sunny days; a day in which solar cooking can be used for the full length of the day
2. Cloudy and rainy days; on which no use of the solar cooker could be made at all
3. Half sunny days; a day in which the solar cooker could only partly be used[15]

Their records (see Figure 3) show that over the last three years on average 48% of the days could be fully used for solar cooking, while on average 31% of the days were useless for solar cooking. The half sunny days amounted on average 21 % of the days (VFN, 2004).

Figure 3 Annual percentage of day type in Jhapa, Nepal[16]





These findings are supported by the Surface meteorology and Solar Energy database of the NASA, as on this location, over a ten year range, 53% of the days per year have had a solar radiation of more than 4.74 kWh/day: the clear sky insulation in November in Jhapa district (NASA, 2004), when it has also proven possible to prepare four meals on the solar cooker on a sunny day.

[14] Its counter-equivalent will be referred to as the savings ratio, being the percentage of time in a year the kerosene is not needed.

[15]The amount of meals to be prepared by solar energy amounts 4 on a full sunny day and therefore the amount of meals to be cooked on a half sunny day will be at most 3.

[16] The data referred to as '2002' in fact covers the data of august 2001 until July 2002. The same is the case for '2003' and '2004'.

12.5 Questionnaire

Vajra Foundation is extremely interested in your cooking experiences, because it might help us improving the quality of the solar cooker supply as well as the solar cookers themselves. Thank you very much for taking the time to fill out this questionnaire!
representing Vajra Foundation, Ralph Lindeboom & René Goverde

1. ABOUT YOU

What is your gender?	woman / man*
In which sector do you live?	sector … …
How often do you cook?	… times per day / times per week
How often do you use the hay box?	… times per day / times per week
For how long have you (approximately) been using a solar cooker?	for …..… years / months*
For how long have you been using the hay box?	for …..… years / months*

2. SHARING OF THE SOLAR COOKER

You are sharing a solar cooker with three other families. Did you (or someone of your family) make agreements with those other families on…	
… the maintenance of the solar cooker?	yes / no*
… the times that the solar cooker can be used by each family?	yes / no *

3. COOKING IN OR OUTSIDE

Do you like cooking outside (next to or in front of your hut) more, less or just as much as cooking inside your hut?	more / less / just as much*
Do you always cook inside your hut and never outside, when using a kerosene stove, or do you sometimes also cook outside the hut on a kerosene stove?	never outside / sometimes outside*

4. FUEL

Do you think picking up kerosene at the weekly distribution is more convenient, less convenient or just as convenient a way of obtaining fuel as gathering fire wood in the surroundings of the camp?	more convenient / less convenient / just as convenient*

5. MAINTENANCE

Do you think the maintenance of a solar cooker requires more, less or just as much work as the maintenance of a kerosene stove?	more work / less work / just as much work*
Do you think the maintenance of a solar cooker requires more, less or just as much work as the maintenance of a chula?	more work / less work / just as much work*
Do you think the maintenance of a chula requires more, less or just as much work as the maintenance of a kerosene stove?	more work / less work / just as much work*

6. COOKING DURATION

Do you think cooking a meal with a solar cooker on a sunny day is slower, quicker, or just as quick as cooking on a kerosene stove?	slower / quicker / just as quick*
Do you think cooking a meal with a solar cooker on a sunny day is slower, quicker, or just as quick as cooking on a chula?	slower / quicker / just as quick*
Do you think cooking a meal on a chula is slower, quicker, or just as quick as cooking on a kerosene stove?	slower / quicker / just as quick*

7. EFFORT FOR THE COOKING PROCESS

Do you think cooking on a solar cooker requires more, less or just as much attention during cooking than cooking on a kerosene stove?	more / less / just as much*
Do you think cooking on a solar cooker requires more, less or just as much attention during cooking than cooking on a chula?	more / less / just as much*
Do you think cooking on a chula requires more, less or just as much attention during cooking than cooking on a kerosene stove?	more / less / just as much*

8. SMELL, SMOKE AND REFLECTION

Do you sometimes observe the (burning of the) kerosene, while cooking on a kerosene stove?	yes / no*
If yes, does this bother you?	yes / no*
Do you sometimes observe the burning of the firewood while cooking on a chula?	yes / no*
If yes, does this bother you?	yes / no
Do you sometimes observe smoke, while cooking on a chula?	yes / no*
If yes, does this bother you?	yes / no*
Does the solar radiation sometimes hit your eye while cooking on a solar cooker?	yes / no*
If yes, does this bother you?	yes / no*
Does the solar cooker sometimes block the path?	yes / no
If yes, does this bother you?	yes / no

9. WHAT YOU THINK OF AS IMPORTANT

How important do you consider the following aspects of cooking? (1=least important, 5 = most important)

1.	… being able to cook fast?	1	2	3	4	5
2.	… being able to make your own food?	1	2	3	4	5
3.	… being able to cook inside the hut?	1	2	3	4	5
4.	… being able to use the cooking fuel for other purposes as well?	1	2	3	4	5
5.	… **not** to have much effort in obtaining fuel for cooking?	1	2	3	4	5
6.	… not to have much effort in maintaining a cooking device?	1	2	3	4	5
7.	… **not** to have to make agreements with your neighbours on the times that each family can use a cooking device?	1	2	3	4	5
8.	… **not** to have to make agreements with your neighbours on the maintenance of a cooking device?	1	2	3	4	5
9.	… **not** to have much effort in cooking itself?	1	2	3	4	5
10.	… **not** to need much space for the cooking device	1	2	3	4	5
11.	… **no** smells due to the burning of fuel during the cooking?	1	2	3	4	5
12.	… **no** smoke due to the burning of fuel during the cooking?	1	2	3	4	5
13.	… **no** reflections in the eye because of the use of a cooking device?	1	2	3	4	5

10. SHARED KITCHEN FOR ABOUT 100 PERSONS

Imagine a situation in which a kitchen facility would be centrally placed in your sector, where would be cooked for around 100 people.

Would you like picking up a prepared meal once a day at a shared kitchen better, worse or just as much as cooking yourself twice a day? better / worse / just as much*

Would you like picking up a prepared meal twice a day at a shared kitchen better, worse or just as much as cooking yourself twice a day? better / worse / just as much*

Would you mind someone else of the same cast being responsible for preparing your families meals? yes/no*

Would you mind sharing a kitchen/or cooking device with different casts? yes/no*

Would you mind sharing responsibility with other residents of the camp for the maintenance of a shared kitchen? yes/no*

11. SUGGESTIONS?

Do you have any suggestions to Vajra or your fellow users of a solar cookers on how the solar cooker can be improved or better used?

Can you express your satisfaction regarding your solar cooker on a scale of 1 to 10 (1= very unsatisfied, 10= very satisfied

0 1 2 3 4 5 6 7 8 9 10

Do you have any suggestions to Vajra or your fellow users of how the hay box can be improved or better used?

Can you express your satisfaction regarding your hay box on a scale of 1 to 10 (1= very unsatisfied, 10= very satisfied)

0 1 2 3 4 5 6 7 8 9 10

12.6 Appendix (Answers questionnaire)

USER GROUP QUESTIONNAIRE DATA

number of respondents	117

Question	1a	1b	1c	1d	1e	2a	2b	3a	3b	4	5a	5b	5c
Labels	1 = woman 2= man 93 = missing	1 = sector E 2 = sector E	calculated per week (max = 14)	nog naar kijk voorlopig maar in hele	1= < 1 year 2= 1-2 yrs 3= 2-3 yrs 4= 3-4 yrs 5= >4 years	1 = yes 0 = no	1 = yes 0 = no	1 = more 2 = less 3 = just as much	1 = never 2= sometim	1 = more 2= less 3= just as mu	1 = more 2 = less 3 = just as mu	1 = more 2= less 3= just as mu	1 = more 2 = less 3 = just as mu
DATA table	1a	1b	1c	1d	1e	2a	2b	3a	3b	4	5a	5b	5c
resp. nr.	gender	sector	freq cook	FB since	SC since	agree main	agree time	out > in	outside	conv fuel	maint 3>K	maint S>C	maint C>K
	1a	1b	1c	1d	1e	2a	2b	3a	3b	4	5a	5b	5c
total	116	116	117	92	55,00	111	29	112	111	115	114	110	109
missing (93)	1	0	0	2	2,00	5	86	4	4	2	3	7	8
missing (other)	0	1	0	23	60,00	1	2	1	2	0	0	0	0
total percentage	99 1%	99 1%	100,0%	1	0,47	94,9%	24,8%	95,7%	94,9%	98,3%	97,4%	94,0%	93,2%
frequency percentage (exc	woman 93 80 2%	A 15 12 9%	mean 1 1 2 6	1 17 18%	< 1 year 14,00 25%	no 10 9,0%	no 1 3,4%	more 47 42,0%	never 72 64,9%	more 88 76,5%	more 41 36,0%	more 34 30,9%	more 46 42,2%
frequency percentage (exc	man 23 19 8%	B 20 17 2%		2 16 17%	1-2 yrs 16,00 29%	yes 101 91,0%	yes 28 96,6%	less 1 0,9%	sometimes 39 35,1%	less 10 8,7%	less 30 26,3%	less 35 31,8%	less 33 30,3%
		C 20 17 2%		3 16 17%	2-3 yrs 19,00 35%			just as much 64 57,1%		just as much 17 14,8%	just as much 43 37,7%	just as much 41 37,3%	just as much 30 27,5%
		D 20 17 2%		4 6 7%	3-4 years 3,00 5%								
		E 15 12 9%		4 5 - 5.4 3 3%	4 years or more 3,00 5%								
		F 12 10 3%		<0.5 34 37%									
		G 14 12 1%											

6a	6b	6c	7a	7b	7c	8a	8b	8c	8d	8e	8f	8g	8h	8i	8j
1 = faster	1 = faster	1 = faster	1 = more	1 = more	1 = more	1 = yes	1 = yes	1 = yes	1 = yes	1 = yes	1 = yes	1 = yes	1 = yes	1 = yes	1 = yes
2 = slower	2 = slower	2 = slower	2 = less	2 = less	2 = less	0 = no	0 = no	0 = no	0 = no	0 = no	0 = no	0 = no	0 = no	0 = no	0 = no
3 = just as fas	3 = just as fas	3 = just as fas	3 = just as mu	3 = just as mu	3 = just as much										
6a	6b	6c	7a	7b	7c	8a	8b	8c	8d	8e	8f	8g	8h	8i	8j
durat S>K	durat S>C	durat C>K	effort S>K	effort S>C	effort C > K	ker smell	bth ker smell	chula smell	bth chul smell	chul smoke	bth chul smoke	SC radiation	bth radiation	SC block path	bth block path
6a	6b	6c	7a	7b	7c	8a	8b	8c	8d	8e	8f	8g	8h	8i	8j
114	113	113	115	116	117	117	116	117	116	116	116	117	114	117	116
3	4	4	1	1	0	0	1	0	1	0	1	0	3	0	1
0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
97,4%	96,6%	96,6%	98,3%	99,1%	100,0%	100,0%	99,1%	100,0%	99,1%	99,1%	99,1%	100,0%	97,4%	100,0%	99,1%
slower	slower	slower	more	more	more	no	no	no	no	no	no	no	no	no	no
63	42	65	79	23	43	27	27	1	3	5	1	9	34	97	100
55,3%	37,2%	57,5%	68,7%	19,8%	36,8%	23,1%	23,3%	0,9%	2,6%	4,3%	0,9%	7,7%	29,8%	82,9%	86,2%
quicker	quicker	quicker	less	less	less	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
8	22	18	11	35	53	90	89	116	113	111	115	108	80	20	16
7,0%	19,5%	15,9%	9,6%	30,2%	45,3%	76,9%	76,7%	99,1%	97,4%	95,7%	99,1%	92,3%	70,2%	17,1%	13,8%
just as quick	just as quick	just as quick	just as much	just as much	just as much										
43	49	30	25	58	21										
37,7%	43,4%	26,5%	21,7%	50,0%	17,9%										

	9,1	9,2	9,3	9,4	9,5	9,6	9,7	9,8	9,9	9,10	9,11	9,12	9,13
	importance on a scale 1-5	importance on a scale 1-5	importance on a scale 1-5	importance on a scale 1-5	importance on a scale 1-5	importance on a scale 1-5	importance on a scale 1-5	importance on a scale 1-5	importance on a scale 1-5	importance on a scale 1-5	importance on a scale 1-5	importance on a scale 1-5	importance on a scale 1-5
	9,1	9,2	9,3	9,4	9,5	9,6	9,7	9,8	9,9	9,10	9,11	9,12	9,13
	cook fast	self food	cook inside	other purposes	not effort fuel	not effort maint	not agree times	not agree maint	not effort cooking	not need space	no smells	no smoke	no reflection
	9,1	9,2	9,3	9,4	9,5	9,6	9,7	9,8	9,9	9,1	9,11	9,12	9,13
	116	114	109	114	114	116	116	115	115	113	116	114	117
	1	3	7	3	3	1	1	2	2	4	1	3	0
	0	0	1	0	0	0	0	0	0	0	0	0	0
	99,1%	97,4%	93,2%	97,4%	97,4%	99,1%	99,1%	98,3%	98,3%	96,6%	99,1%	97,4%	100,0%
	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	2	91	12	31	17	16	20	9	17	10	4	32
	2,6%	1,8%	83,5%	10,5%	27,2%	14,7%	13,8%	17,4%	7,8%	15,0%	8,6%	3,5%	27,4%
	2	2	2	2	2	2	2	2	2	2	2	2	2
	13	6	4	13	17	15	12	13	10	7	2	2	31
	11,2%	5,3%	3,7%	11,4%	14,9%	12,9%	10,3%	11,3%	8,7%	6,2%	1,7%	1,8%	26,5%
	3	3	3	3	3	3	3	3	3	3	3	3	3
	34	17	11	11	29	47	18	3	25	32	5	10	14
	29,3%	14,9%	10,1%	9,6%	25,4%	40,5%	15,5%	2,6%	21,7%	28,3%	4,3%	8,8%	12,0%
	4	4	4	4	4	4	4	4	4	4	4	4	4
	40	23	2	22	21	23	12	10	24	33	19	8	17
	34,5%	20,2%	1,8%	19,3%	18,4%	19,8%	10,3%	8,7%	20,9%	29,2%	16,4%	7,0%	14,5%
	5	5	5	5	5	5	5	5	5	5	5	5	5
	26	66	1	56	16	14	58	69	47	24	80	90	23
	22,4%	57,9%	0,9%	49,1%	14,0%	12,1%	50,0%	60,0%	40,9%	21,2%	69,0%	78,9%	19,7%
GEMIDDELDE	3,6	4,3	1,3	3,9	2,8	3,0	3,7	3,8	3,8	3,4	4,4	4,6	2,7
RANGORDE	8	3	13	4	11	10	7	5	6	9	2	1	12

10a	10b	10c	10d	10e	11a	11b
1 = better	1 = better	1 = yes	1 = yes	1 = yes	satisf SC	satisf hey box
2 = worse	2 = worse	0 = no	0 = no	0 = no	1-10	1-10
3 = just as much	3 = just as much					
10a	10b	10c	10d	10e	11a	11b
1x kitchen>self	2x kitchen>self	mind same caste	mind other caste	mind responsibility	satisf SC	satisf hey box
10a	10b	10c	10d	10e	11a	11b
114	115	116	113	116	116	117
0	0	0	4	1	1	0
3	2	1	0	0	0	0
97,4%	98,3%	99,1%	96,6%	99,1%	99,1%	100,0%
better	better	no	no	no	1	1
18	31	54	98	109	0	1
15,8%	27,0%	46,6%	86,7%	94,0%	0,0%	0,9%
worse	worse	yes	yes	yes	2	2
70	53	62	15	7	0	0
61,4%	46,1%	53,4%	13,3%	6,0%	0,0%	0,0%
just as much	just as much				3	3
26	31				1	1
22,8%	27,0%				0,9%	0,9%
					4	4
					5	2
					4,3%	1,7%
					5	5
					17	7
					14,7%	6,0%
					6	6
					10	3
					8,6%	2,6%
					7	7
					10	10
					8,6%	8,5%
					8	8
					19	11
					16,4%	9,4%
					9	9
					18	13
					15,5%	11,1%
					10	10
					36	69
					31,0%	59,0%
			MEAN		7,862069	8,803418803

12.7 Outcome MCA at varying weighting sets

In this appendix the name of the weight set is the order of importance of the different criteria, in which the C stands for Costs, U for Users Attitude and E for environmental effects.

Weights equal

	Final score		
change in:	FW	K	S
best guess	0,62	0,62	0,75
Firewood data			
worst case	0,61	0,63	0,79
best case	0,64	0,58	0,72
Kerosene data			
worst case	0,64	0,61	0,78
best case	0,61	0,63	0,75
SK14 data			
worst case	0,64	0,61	0,70
best case	0,61	0,62	0,81

Weight set CUE

	Final score		
change in:	FW	K	S
best guess	0,75	0,53	0,70
Firewood data			
worst case	0,74	0,54	0,73
best case	0,77	0,51	0,68
Kerosene data			
worst case	0,77	0,53	0,73
best case	0,74	0,53	0,69
SK14 data			
worst case	0,77	0,53	0,64
best case	0,74	0,53	0,76

Weight set EUC

	Final score		
change in:	FW	K	S
best guess	0,50	0,73	0,82
Firewood data			
worst case	0,49	0,76	0,86
best case	0,52	0,68	0,78
Kerosene data			
worst case	0,52	0,73	0,84
best case	0,49	0,75	0,82
SK14 data			
worst case	0,52	0,73	0,78
best case	0,49	0,74	0,87

Weight set UEC

	Final score		
change in:	FW	K	S
best guess	0,58	0,76	0,82
Firewood data			
worst case	0,57	0,77	0,86
best case	0,61	0,72	0,79
Kerosene data			
worst case	0,61	0,75	0,85
best case	0,58	0,76	0,82
SK14 data			
worst case	0,61	0,75	0,78
best case	0,57	0,76	0,88

Weight set CEU

	Final score		
change in:	FW	K	S
best guess	0,62	0,51	0,70
Firewood data			
worst case	0,61	0,52	0,73
best case	0,63	0,47	0,68
Kerosene data			
worst case	0,63	0,50	0,72
best case	0,62	0,51	0,70
SK14 data			
worst case	0,63	0,50	0,65
best case	0,61	0,51	0,75

Weight set UCE

	Final score		
change in:	FW	K	S
best guess	0,73	0,63	0,75
Firewood data			
worst case	0,72	0,64	0,79
best case	0,76	0,61	0,72
Kerosene data			
worst case	0,76	0,63	0,78
best case	0,73	0,63	0,74
SK14 data			
worst case	0,76	0,63	0,69
best case	0,72	0,63	0,81

12.8 Sensitivity analysis on sustainable forestry inclusion

MCA Weighted Summation Best Guess Scenario Firewood (sustainable)											
		weights	FW	K	S	FW	K	S	FW	K	S
environmental	deforestation	0,15	0	0	0	1	1	1	0,15	0,15	0,15
	CO_2 emission	0,15	0	-0,64	-0,31	1	0	0,52	0,15	0	0,08
	primary energy use	0,15	-37,8	-8,97	-4,18	0	0,76	0,89	0	0,11	0,13
Costs		0,35	-5,3	-7,6	-4,3	0,30	0	0,43	0,11	0	0,15
users attutide		0,20				0,85	1	0,9	0,17	0,2	0,18
Total		**1**							**0,58**	**0,46**	**0,69**

MCA Weighted Summation Best Guess Scenario Time span 3 years Firewood (sustainable)											
		weights	FW	K	S	FW	K	S	FW	K	S
environmental	deforestation	0,15	0	0	0	1	1	1	0,15	0,15	0,15
	CO_2 emission	0,15	0	-0,64	-0,31	1	0	0,52	0,15	0	0,08
	primary energy use	0,15	-37,8	-8,97	-4,18	0	0,76	0,89	0	0,11	0,13
Costs		0,35	-5,67	-8,15	-6,4	0,30	0	0,21	0,11	0	0,08
users attutide		0,20				0,85	1	0,9	0,17	0,2	0,18
Total		**1**							**0,58**	**0,46**	**0,62**

MCA Weighted Summation Best Guess Scenario Time span 3 years Firewood											
		weights	FW	K	S	FW	K	S	FW	K	S
environmental	deforestation	0,15	2,25	0	0	0	1	1	0	0,15	0,15
	CO_2 emission	0,15	-3,14	-0,64	-0,31	0	0,80	0,90	0	0,12	0,14
	primary energy use	0,15	-37,8	-8,97	-4,18	0	0,76	0,89	0	0,11	0,13
Costs		0,35	0	-8,15	-6,4	1	0	0,21	0,35	0	0,08
users attutide		0,20				0,85	1	0,9	0,17	0,2	0,18
Total		**1**							**0,52**	**0,58**	**0,67**

table 39