Alternative Power and Green Practices in Wadi Rum

AQABA COMMUNITY and ECONOMIC DEVELOPMENT (ACED) PROGRAM

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ACED Program Frequently-Used Acronyms and Abbreviations

(Not all of the following will appear in every ACED Program document)

ACED Program	Aqaba Community and Economic Development Program (USAID)
ACT	Aqaba Container Terminal
ADC	Aqaba Development Corporation
ADS	Automated Directive Systems
AIDAR	USAID Acquisition Regulation
AIIE	Aqaba International Industrial Estate
ANREPCO	National Real Estate Projects Company
APC	Aqaba Ports Corporation
ASEZ	Aqaba Special Economic Zone
ASEZA	Aqaba Special Economic Zone Authority
ASRI	Aqaba Skills Readiness Index
ASYCUDA	Automated System for Customs Data
ATASP	Aqaba Technical Assistance Support Program (USAID)
AUC	Aqaba University College
AZEM	Aqaba Zone Economic Mobilization Project (USAID)
AGDTF	Aqaba Garment Development Task Force
BAFO	Best and Final Offer
BDC	Business Development Center
BDS	Business Development Services
CBO	Community-Based Organization
CO	Contracting/Contracts Officer
COB	Close of Business
COP	Chief of Party
CP	Cost Proposal
CRM	Customer Relationship Management
CSO	Civil Society Organization
CSR	Corporate Social Responsibility
CTO	Cognizant Technical Officer
D&G	Democracy and Governance
DCA	Development Credit Authority
EG	Economic Growth
EGRA	Early Grade Reading Assessment
EO	Economic Opportunities
EOI	Expression of Interest
EPC	Executive Privatization Commission
ERfKE	Education Reform for a Knowledge Economy (USAID)
EU	European Union
ETF	European Training Foundation
FAR	Federal Acquisition Regulation
FDI	Foreign Direct Investment
FTA	Free Trade Agreement
FTZ	Free Trade Zone
FZ	Free Zone
FZC	Free Zones Corporation
GCC	Gulf Cooperation Council

GDA	Global Development Alliance
GDP	Gross Domestic Product
GEM	Gender Entrepreneurship Markets
GIS	Geographic Information System
GOJ	Government of Jordan (the central governing entity of Jordan)
GPS	Global Positioning System
HR	Human Resources
ICDL	International Computer Driving License
ICT	Information and Communications Technology
INJAZ	Economic Opportunities for Jordanian Youth Program
IPR	Intellectual Property Rights
IQC	Indefinite Quantity Contract
ISP	Internet Service Provider
IS-ASEZA	Institutional Support to ASEZA (EU funded project)
IT	Information Technology
JD	Jordanian Dinar
JITOA	Jordan Inbound Tour Operators Association
JIB	Jordan Investment Board
JNA	Jordan National Agenda
JNCW	Jordanian National Commission for Women
JSCED	Jordan Standard Classifications of Education
JUSBP	Jordan-United States Business Partnership
JUSFTA	Jordan-United States Free Trade Agreement
KOJ	Kingdom of Jordan (the country within its physical boundaries)
KSA	Kingdom of Saudi Arabia
LCDD	Local Community Development Directorate (ASEZA)
LCL	Less than Container Load
LECP	Local Employee Compensation Plan
LOE	Level of Effort
LTTA	Long-Term Technical Assistance
M&E	Monitoring and Evaluation
MENA	Middle East and North Africa
MFI	Microfinance Institution
MIS	Management Information System
MOF	Ministry of Finance
MOL	Ministry of Labor
MOPIC	Ministry of Planning and International Cooperation
MOTA	Ministry of Tourism and Antiquities
MOU	Memorandum of Understanding
MSME	Micro, Small & Medium Enterprises
NCHRD	National Center for Human Resources Development
NDA	Neighborhood Development Activity
NDC	Neighborhood Development Committee
NET	Neighborhood Enhancement Team
NICRA	Negotiable Indirect Cost Rate
NGO	Non-Governmental Organization
NTS	National Tourism Strategy
PACE	Participatory Action for Community Enhancement
PMP	Performance Management Plan

PPP	Public Private Partnership
PR	Public Relations
PSD	Private Sector Development
R&D	Research and Development
QA	Quality Assurance
QC	Quality Control
RFP	Request for Proposal
RFQ	Request for Quotation
SABEQ	Sustainable Achievement of Business Expansion and Quality (USAID)
SEO	Search Engine Optimization
SIYAHA	The Tourism Project (USAID)
SFU	Satellite Factory Unit
SME	Small and Medium Enterprises
SOW	Scope of Work
STTA	Short-Term Technical Assistance
SWOT	Strength, Weakness, Opportunities and Threads
TA	Technical Assistance
TBD	To Be Determined
TO	Task Order
TOT	Training of Trainers
TP	Technical Proposal
TRIDE	Trilateral Industrial Development
TVET	Technical and Vocational Education and Training
USAID	United States Agency for International Development
USD	United States Dollar
VTC	Vocational Training Center
WAEDAT	Women's Access to Entrepreneurial Development and Training
WEPIA	Water Education and Public Information for Action
WTO	World Trade Organization
WTTP	Workforce Technical Transformation Program

CONTENTS

I. Executive Summary

This report introduces alternative green energy solutions to existing energy usage practices in Wadi Rum and Disi camps. Alternative energy serves to overcome the difficulties associated with the current practices. In order to fully map energy consumption, a detailed survey was designed and completed for all camps. Detailed energy end use models for all camps have been established, which map input energy to different energy consuming end uses. Alternative options have been proposed, designed, and discussed in this report. In addition, this report examines main barriers behind adopting renewable energy in camps. Lastly, current energy consumption and generation in the areas are highlighted and identified.

II. Introduction

Jordan is a small country in the north-western corner of Asia and is a non-oil producing country with limited natural resources and minerals. Its economy was based primarily on agriculture and farming; however, in recent decades the importance of the agricultural sector has declined both in terms of its contribution to the national income and as a main source of employment. The country has become more dependent on services and manufacturing sectors as well as on tourism and transport activities.

In recent years, concern about energy consumption in Jordan has increased. The continuous growth in energy demand has led to the increased dependence on imported crude oil, refined products and natural gas. At present, the country is importing crude oil and natural gas to sustain its present way of life. This leads to a significant hard-currency drain in the economy, with annual oil expenditures exceeding USD $3 billion, the equivalent of approximately 12% of the GDP, in 2009, and 42% of domestic exports and about 19% of total imports into the country. It is extremely difficult for a country such as Jordan to continue spending nearly half of its national income from exporting domestic commodities just to import needed oil for social and economic development.

Recently, not only energy use but also associated GHG emissions and their potential effects on the global climate change have been the worldwide concern. Carbon dioxide is the most important GHG, which is responsible for around 80% of the anthropogenic climate change and global warming effects. If the CO_2 emissions continue to increase at their current trend due to fossil fuel combustion, there is a possibility that at the end of this century, a massive climate change will occur and the coastal areas of the earth will be flooded. Therefore, the global greenhouse effect may be one of the greatest challenges ever to face humankind.

Tourism is one of the most important sectors in Jordan's economy. In 2010, 8 million tourists from various countries visited Jordan, with tourist receipts amounting to about USD 3.5 billion dollars. An additional USD 1 billion was earned through medical tourism to the kingdom. Its major tourist attractions include visiting historical sites, religious places, and natural locations.

Wadi Rum and Disi are desert and mountainous areas located in the south of Jordan. They are popular for their sights in addition to a variety of outdoor sports, such as rock-climbing and trekking. It is also known for its connection to Lawrence of Arabia. The area is now also one of Jordan's important tourist destinations and attracts an increasing number of foreign tourists, particularly trekkers and climbers, for camel and horse safaris or simply day-trips from Aqaba or Petra. The influx of tourists to this once isolated area has substantially increased the financial stability of the Bedouin people as they are heavily engaged in the local tourism sector as a source of income.

Camps in Wadi Rum and Disi currently depend on burning fossil fuel to meet their energy demands for lighting, cooking, heating, hot water and transportation purposes. In addition to environment problems, emissions and noise have an effect on the tourists' experience and the energy resources needed to operate the Bedouin camps are costly.

2.1 PROBLEM STATEMENT

Most camps in Wadi Rum and Disi regions depend heavily on non-renewable sources of energy that are non-environmentally friendly, costly, and not always easy to obtain. In addition, there are sub-optimal energy consumption practices in these camps. Therefore, it is desirable to explore alternative energy resources to replace the current energy usage practices.

2.2 SCOPE OF WORK

- Map existing energy generating practices at camps in Wadi Rum and Disi areas;
- Design and develop a proposal suggesting the most appropriate alternative method(s) to generate power for the remote camps. Proposed methods must address, at least, the investment cost, operational cost, environmental impact, socio-economic impact, supporting factors, limitations, and financial viability;
- Outline the maintenance challenges for each power generation system proposed including the availability and cost of replacement parts, system weaknesses, technical skills required to use and maintain the system, level of maintenance of the system required and level of 'day-to-day' management of the system required; and
- Prepare the technical specifications and the RFP (Request for Proposals) for the proposed options for the environmental friendly power generation.

2.3 REPORT STRUCTURE

This report is organized in four sections: introduction, methodology, analysis and one case study. The methodology, analysis, results and the conclusions of this study are presented in the next sections of the report. The report concludes with the design of the telescope room in Wadi Rum as a case study for solar energy applications in the Disi and Wadi Rum areas.

III. Methodology

In order to achieve the purposes and objectives of this study, the following research methodology has been used:

- **Establish an "energy balance" for each camp:** in order to evaluate the current energy uses practices and to formulate alternative solutions, an "energy balance model" for each camp is required. In order to establish these, the consultant visited all camps in the Wadi Rum and Disi regions and used a structured survey (shown in Appendix A). The survey has been constructed to evaluate all energy usage in terms of types and quantities in addition to challenges and barriers faced by camps owners to install alternative energy sources. In addition, several meetings with key persons in both areas have taken place to explore difficulties, challenges and limitations of adopting such alternative technologies.

- **Analyze the data:** the gathered data were analyzed to extract important findings to estimate the energy usage patterns for each camp.
- **Propose alternative solutions:** based on findings, options have been proposed with their advantages and disadvantages.

IV. Analysis, Results and Discussions

4.1 THE ENERGY BALANCE OF CAMPS

In order to determine the energy flow in each camp, the energy end use quantities of the camps were assessed. Since such detailed data and information was not available prior to this study, a detailed survey was conducted for all legally registered camps in Wadi Rum and Disi regions. This survey aimed at collecting relevant data that are necessary to complete this study, and to gain further insights into fuel and electrical energy consumption characteristics. The questionnaires covered the following aspects:

- Types of lighting lamps, the energy and working hours and the quantity used for each type.
- Types of water heaters, the energy and working hours for each type.
- Types of cookers, the energy and working hours for each type.

- Types of other appliances in use (such as refrigerator), the energy and working hours and the quantity used for each type.

To ensure the quality of the survey, each camp was surveyed by the researcher directly either by visiting all sites and or conducting the survey by phone. Tables 1 and 2 show the visited camps.

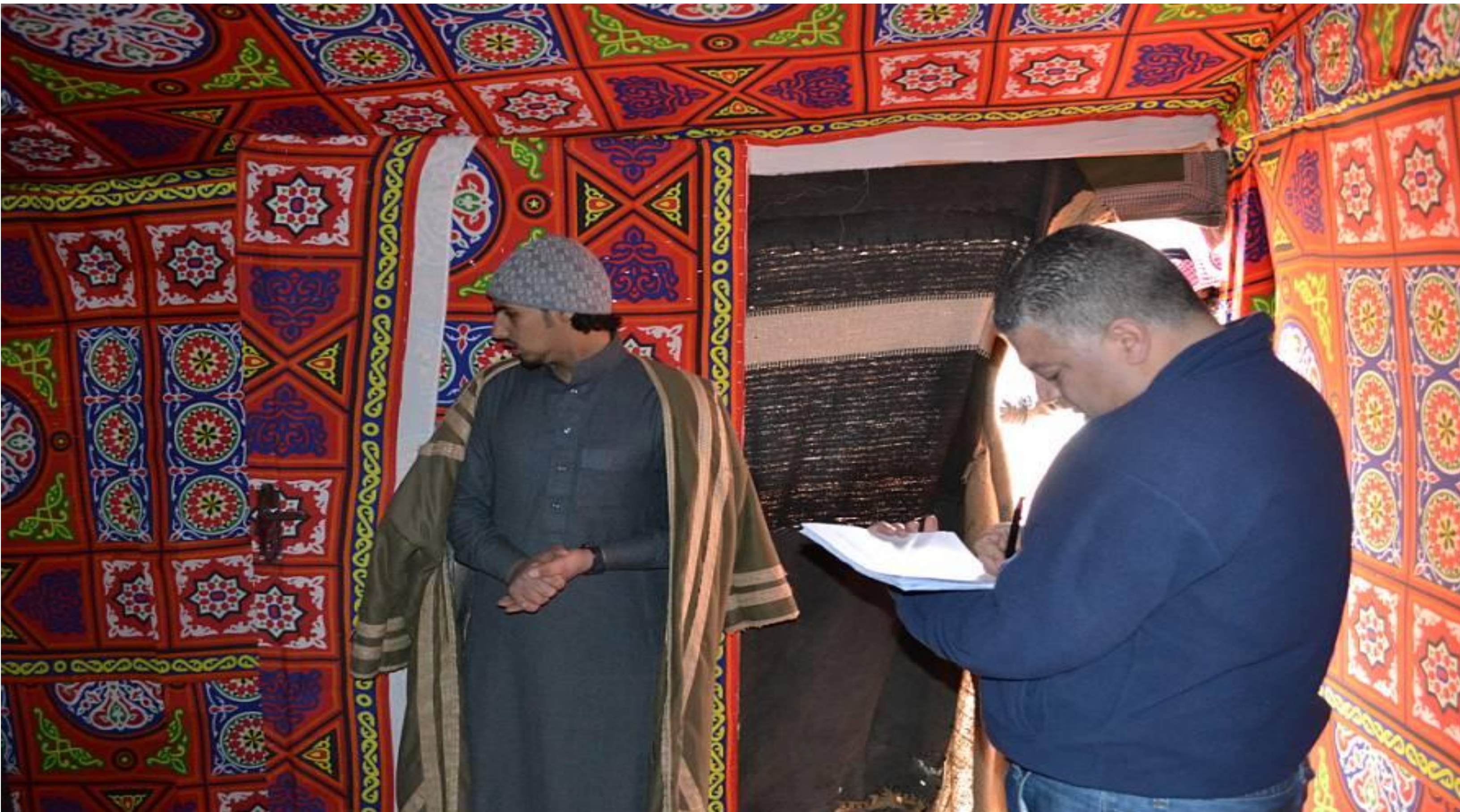


Table 1: Camps in Wadi Rum

Camp's Name	Owner's Name	Year Established	Current Capacity (Persons)	Code
SunSet Camp	Mohammad Sabbah Zalabiyah	1996	100	1-W
Khaled Camp	Khaled Sabbah	1998	60	2-W
Rainbow Camp	Suleiman Ghanem Zalabiyah	2000	80	3-W
Bedouin Camp	Zeidan Sabbah	1995	55	4-W
Wadi Rum Camp	Abdallah Awad Zalabiyah	1998	50	5-W
Bedouin Hams Camp	Odeh Abdallah Zalabiyah	2001	50	6-W
Bedouin Life Style Camp	Attallah Sami Blewi	2004	100	7-W
Khaza'ali Camp	Saleh Sawalheen	2002	35	8-W
Panaorama Camp	Zayed Helayel Jewan	1995	100	9-W
Mohammad Motlaq Camp	Salem Motalq	2000	45	10-W
Red Sand Camp	Abed Sabbah Etyieq	1993	50	11-W
Attallah Camp	Attallah Salem Zalabiyah	2000	60	12-W
Desert Moon Camp	Madallah Etyieq	2000	60	13-W
Mezyed Camp	Mezyed Etyieq Zalabiyah	1996	50	14-W
Bedouin Cave Camp	Mohamamd Etyieq Zalabiyah	1996	20	15-W
Bedouin Guides Camp	Mohammad Hamdan Zalabiyah	2006	100	16-W
Wadi Rum Friends Camp	Salem Mutlaq Zalabiyah	2001	35	17-W
SunRise Camp	Ali Hamad Zalabiyah	2002	20	18-W
Moving Sands Camp	Salem Eid Zalabiyah	1992	30	19-W
Wadi Rum Sunrise Camp	Hammad Hamdan Zalabiyah	2010	30	20-W
Badr Wadi Rum Camp	Yaser Mohammad Zalabiyah	2002	20	21-W
Bedouin Team Camp	Abdallah Ali Zalabiyah	2000	50	22-W
Sama Rum Camp	Abed Etyieq Zalabiyah	1996	50	23-W
Badia Tours Camp	Awad Hamdan Zalabiyah	2008	60	24-W
Desert Experience Camp	Sabbah Ali	2000	60	25-W
Bedouin Roads Camp	Eteiq Ali	2001	50	26-W
King Aretas Camp	Abdallah Hleil	2002	100	27-W

Table 2: Camps in Disi

Camp's Name	Owner's Name	Year Established	Current Capacity (Persons)	Code
Seiq Abu Awad Camp	Awad Radi Zawaydah	1995	50	1-D
8 Brothers Camp	AbdAlaziz Zawaydah	2004	40	2-D
Desert Quite	Abdallah Awad Zawaydah	2003	100	3-D
Desert Camp	AbdAlqader Ali Zawaydah	2000	50	4-D
Barrah Camp	Helal Salem Zawaydah	2004	30	5-D
Jabal Mtwaq Camp	Hasan Meznah	2003	28	6-D
Bedouin Life Camp	Edyd Naser Amamrah	2002	100	7-D
Abu Raed Camp	Mohammad Oqlah Zawaydah	2004	55	8-D
Desert Rose Camp	Abdallah Odah	2003	20	9-D
Salman Abdallah Camp	Salaman Abdallah Zawaydah	2005	25	10-D
Rahayeb Camp	Ali DeifAllah Zawaydah	2004	90	11-D
Ameleh Camp	AbdAlkareem Salem Zawaydah	2004	20	12-D
Seiq Um AlTawaqi Camp	Mahmoud Ebyd	2008	15	13-D

For each camp, an energy balance flow model has been established (as shown in Figure 1).

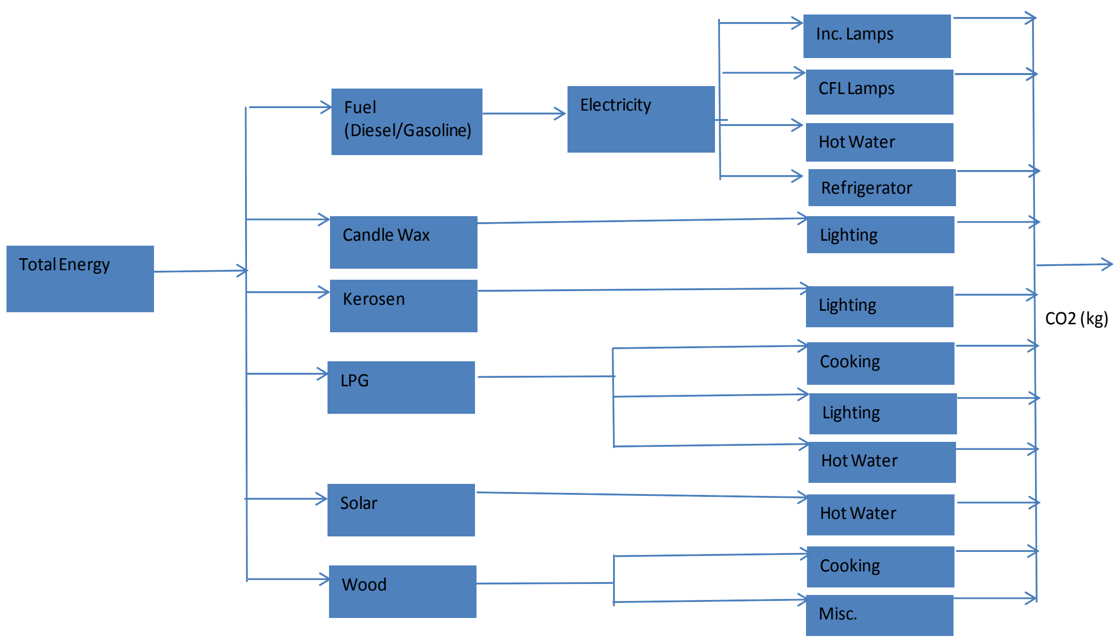
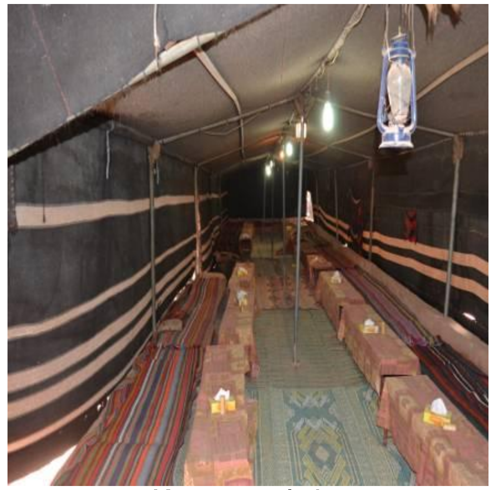


Figure 1: Energy Balance Model.

The photos below are samples of each uses shown in figure 1

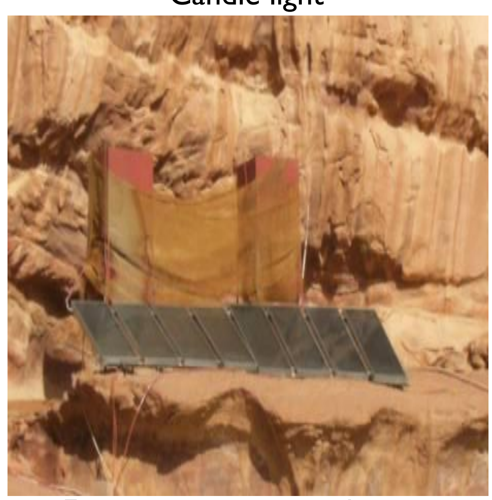

LPG light


Kerosene light


Candle Light

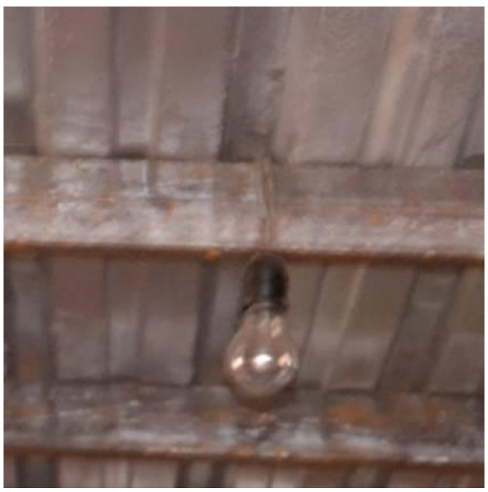

Candle light


Evacuated solar water heater


Flat plate solar water heater


Electrical water heater


LPG water heater


Incandescent lamp


Compact fluorescent lamp


Refrigerator

Fuel generator

LPG cooker

Figure 1 shows how the total energy is distributed and used for each end use. Also, it shows the carbon dioxide emissions resulted from using the energy in each camp. In order to establish figure 1 for each camp, all energy sources used are converted to common energy unit (here is kJ). Table 3 shows the equivalent heating value and emission factor for each energy source considered in this study.

Table 3: Heating and emission factors for energy sources considered in the study

Energy Source	Heating Value(KJ/kg)	Emissions Factor (kg CO2/kJ)
Diesel	42265	0.0000741
Gasoline	47394	0.0000693
Kerosene	46117	0.0000715
LPG	48500	0.0000631
Wood	21700	0.0001096
Candle Wax	43100	0.000442691

By compiling the data gathered from the survey from each camp and converted different sources of energy using Table 3, figures 2 and 3 show the weighted energy balance flow models for Wadi Rum and Disi camps respectively.

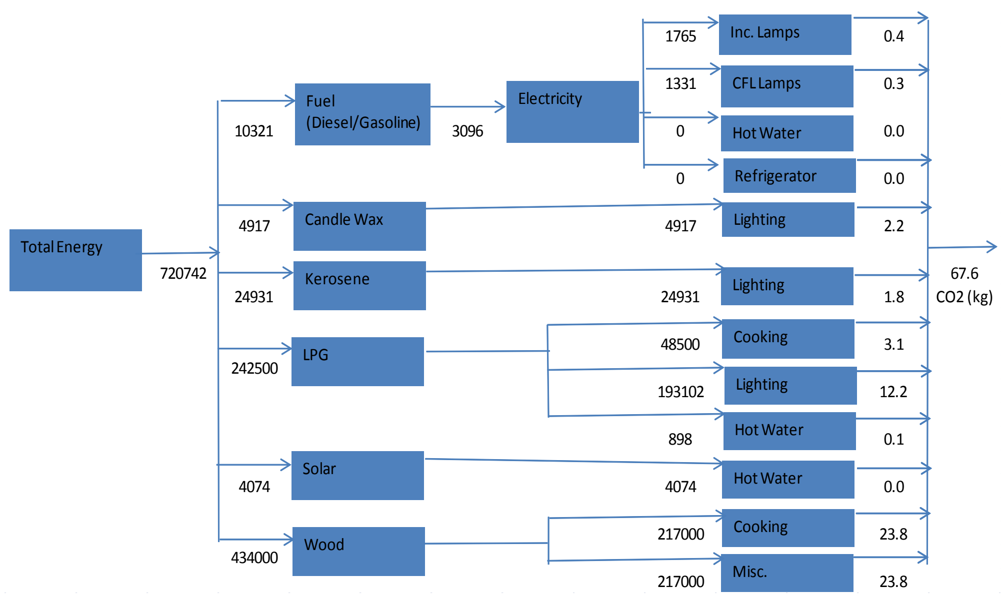


Figure 2: Weighted energy balance flow model for Wadi Rum camps (kJ/day).

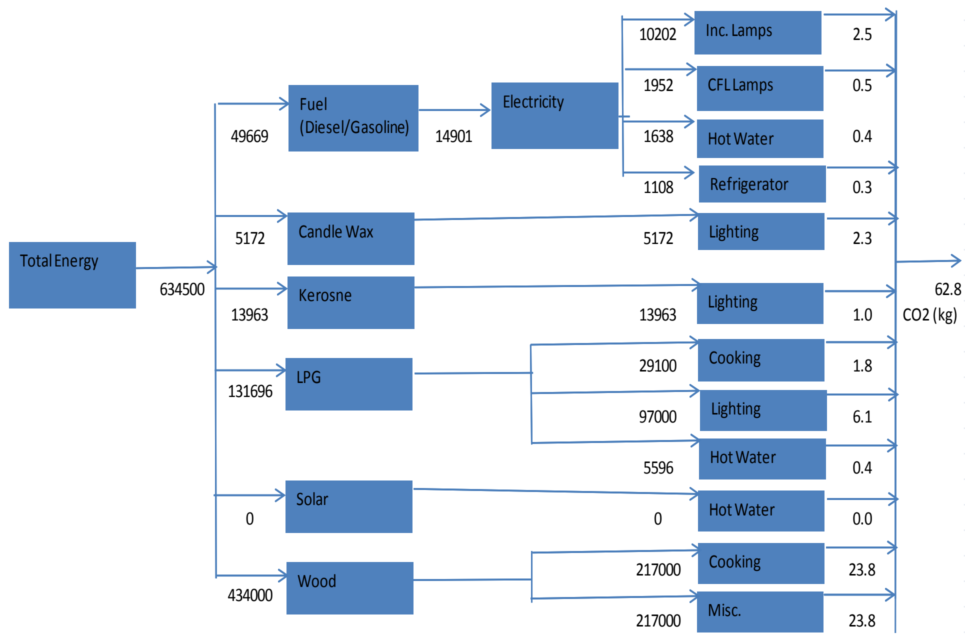


Figure 3: Weighted energy balance flow model for Disi camps (kJ/day).

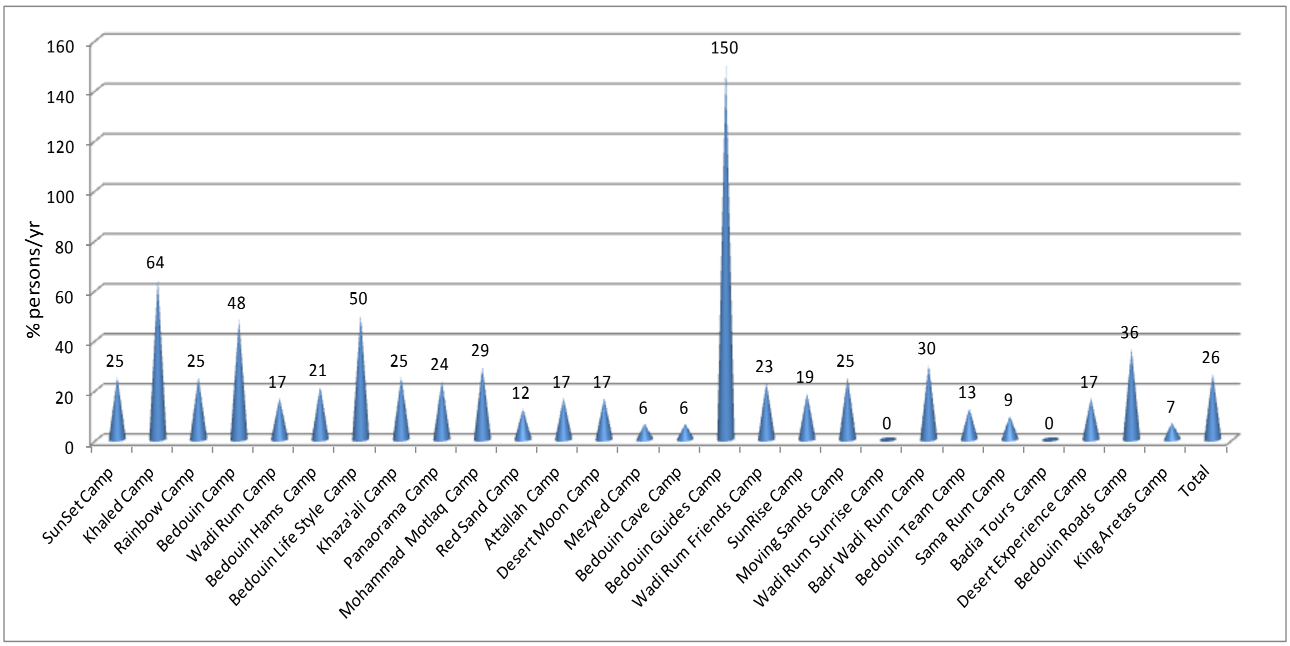
Detailed energy balance models for all camps are in Appendix B.

4.2 IMPORTANT FINDINGS

a. Annual growth of camps

Figures 4 and 5 shows the annual growth of Wadi Rum and Disi camps respectively. As seen from these figures, there are noticeable expansion of most camps in both areas and if the current trend suggests the need to replace the current energy practices by more efficient and sustainable energy sources.

Figure 4: Annual growth of Wadi Rum camps (% person/yr).



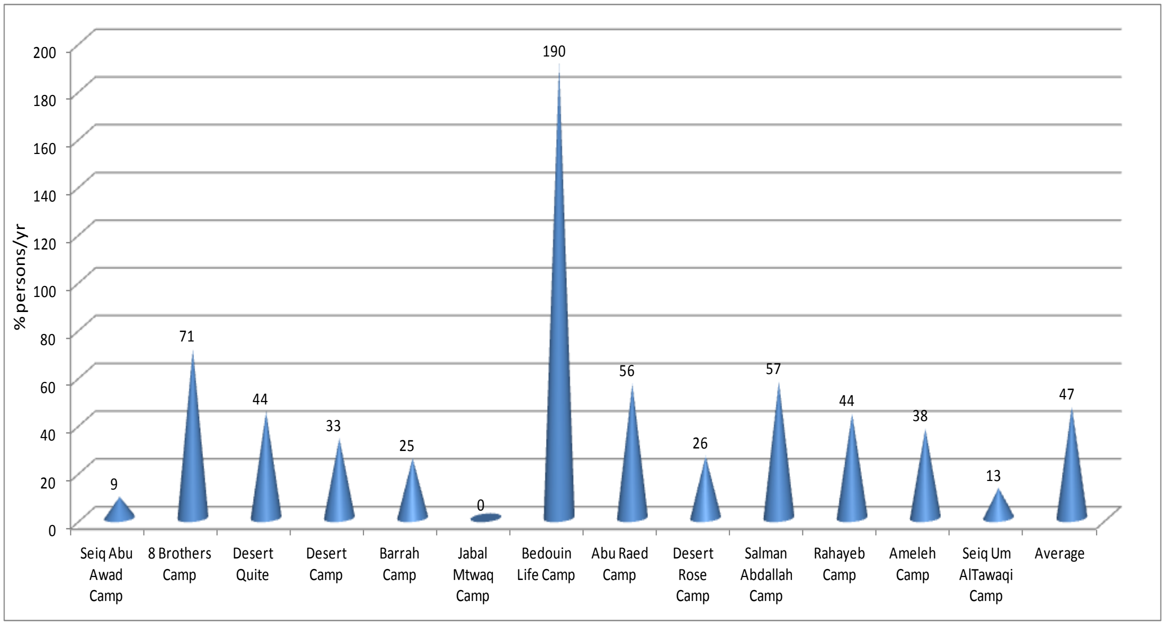


Figure 5: Annual growth of Disi camps (% person/yr).

b. Fuel Generators Uses

Figure 6 shows the percentage of fuel generators used in Wadi Rum and Disi camps.

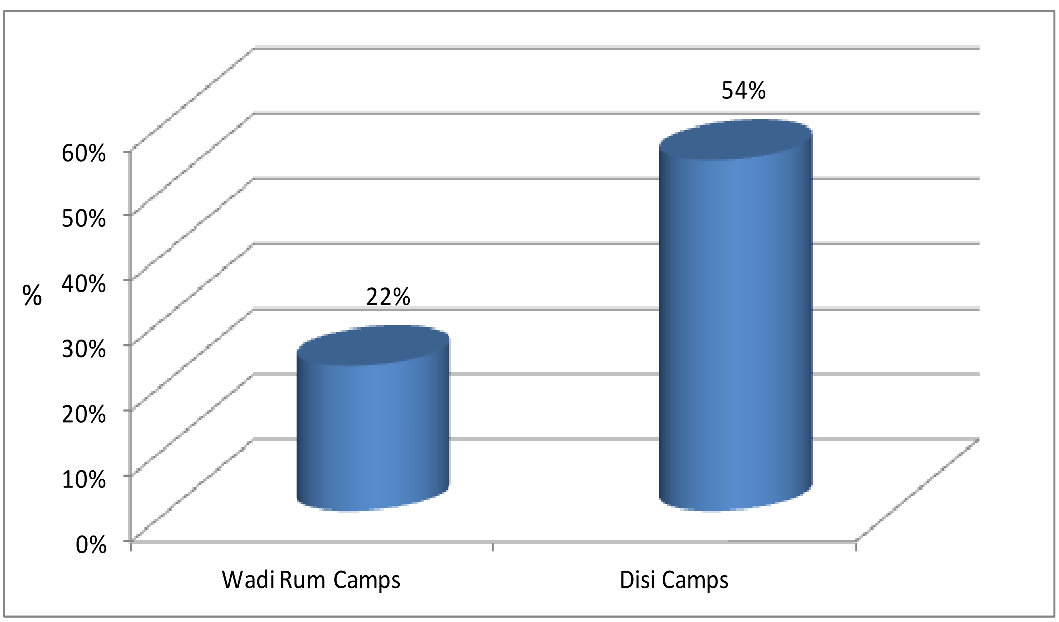


Figure 6: Fuel Generator uses comparison between Wadi Rum and Disi camps.

As can be seen clearly from this figure, Disi camps depend more on using fuel generators than Wadi Rum camps. One can expect that Wadi Rum camps are more environmentally friendly than those in Wadi Rum; however, this is not the case as can be seen from Figures 2 and 3. Both Figures 2 and 3 show that Wadi Rum camps consume more energy and hence emit more carbon dioxide emissions to the environment. This is mainly due to the fact that Wadi Rum camps depend heavily on LPG and kerosene for lighting purposes, which use high quality energy carriers to light places that can be achieved by more efficient ways. Therefore, it is not only camps with fuel generators that need to change their practices, but also those with LPG and kerosene lights should consider alternative sources of energy for lighting purposes.

Another interesting finding is that most of energy used and emitted carbon dioxide are due to burning wood for cooking and miscellaneous purposes (such as space heating and lighting). Therefore, policies and regulations should be directed to reduce wood uses as much as possible.

c. Current Barriers of Renewable energy application

The survey was designed to identify the main barriers that refrain camps owners from replacing the current energy sources by renewable energy; specifically, solar energy. This section discusses these barriers:

- **Cost**

  The main barrier that face camps owners is the initial cost of the solar system. As can be seen from figures 7 and 8, 100% and 92% of Wadi Rum and Disi camps owners respectively see the initial costs of solar systems as a main barrier that hinders solar energy applications in their camps. This barrier is valid since the payback period of such applications is still high compared with traditional energy sources in addition to relatively low cost of current energy sources.

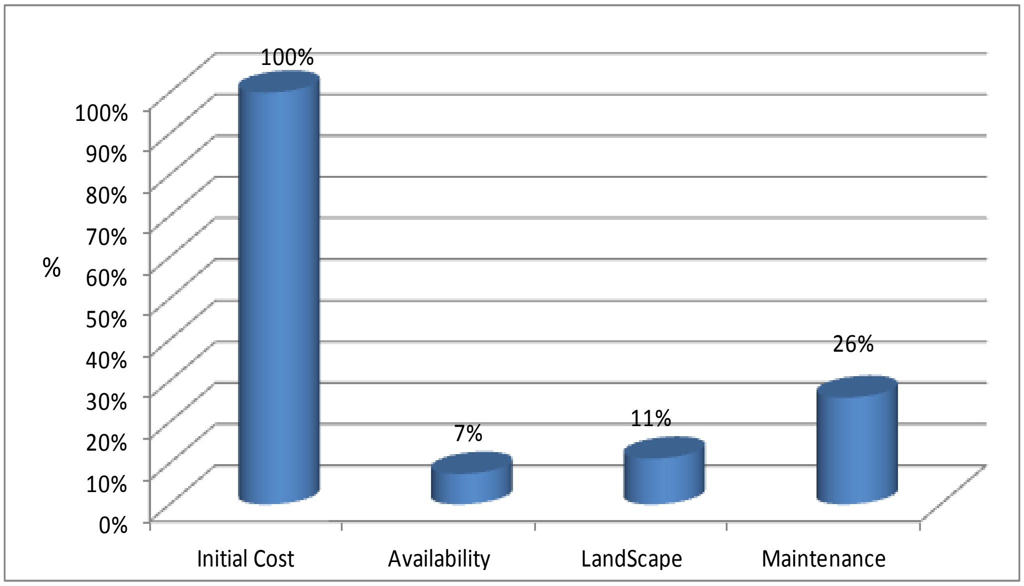


Figure 7: Barriers of implementing solar energy source in Wadi Rum camps.

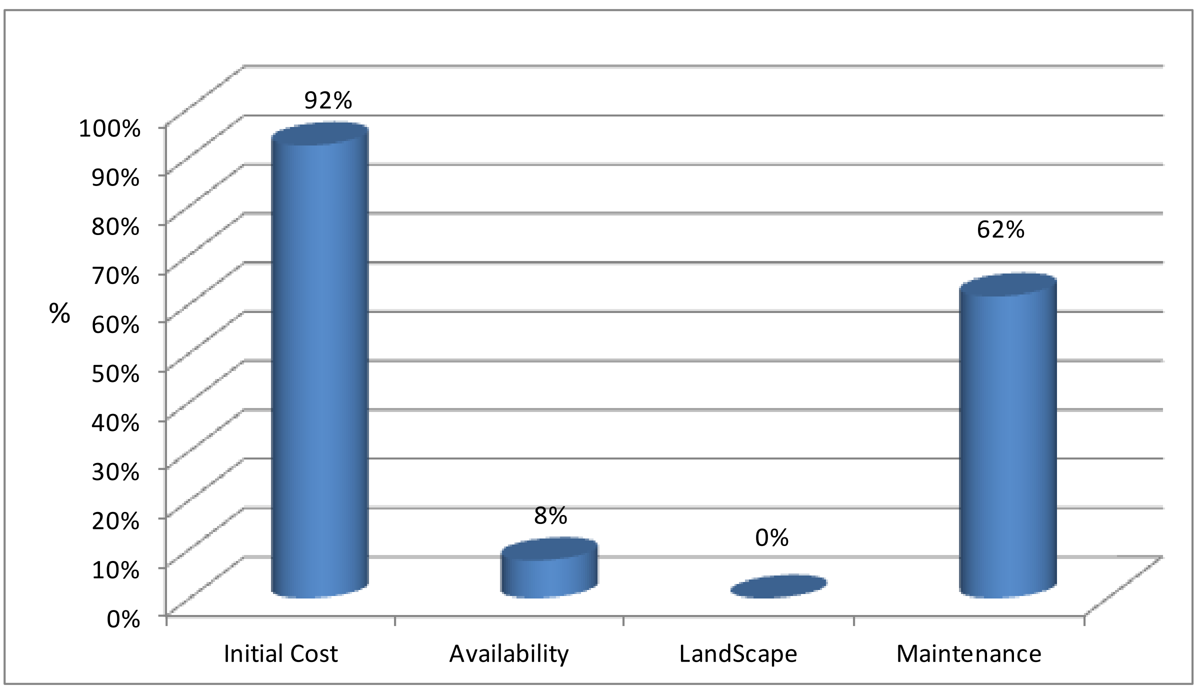


Figure 8: Barriers of implementing solar energy source in Wadi Rum camps.

- **Availability of solar systems**

  Most camps owners are aware of renewable energy sources and believe that they are available but not affordable. As can be seen from figures 7 and 8, only 7 and 8% of camps owners see that such systems are not available or not applicable in Jordan.

- **Landscape effect**

  Wadi Rum and Disi regions are characterized by natural scenes that attract tourist. Solar systems have benefits to both area which in turn may determine future tourists choices to visit these regions or not. However, as can be seen from figures 7 and 8, only 11% of camp owners in Wadi Rum see that this barrier will affect tourist choice or experience to visit their camps while all camp owners in Disi see that this barrier has no effect on tourists choice and experience. On the contrary, they believe that installing such technologies will add substantial benefits to their camps.

- **Maintenance**

  Solar photovoltaic systems are mainly categorized as on grid and off grid systems. The first one can be considered as free of maintenance system with long life; however, the second one, since it consists of batteries and inverters, requires more effort and maintenance to keep the system operating properly. Only the off grid systems can be considered in remote areas such as Wadi Rum and Disi camps. As can be seen from figures 7 and 8, 26% and 62% of Wadi Rum and Disi camps owners believe that the maintenance of such system will make them think twice before deciding installing such system. In order to avoid such barrier, each camp owner should be trained of how to use such systems and what actions need to be taken in case of system failure.

- **Location**

Solar photovoltaic panels ideally face south at an elevation of approximately 30° while arrays pointing east or west albeit at lower performance. In addition, systems should be in locations that are un-shaded at all times of day if possible. Mountains in Wadi Rum and Disi camps potentially shade the modules particularly in the early morning and early afternoon. The performance of the system will be affected even if a small part of it is shaded. Figures 9 and 10 show the suitability of camps locations in Wadi Rum and Disi regions.

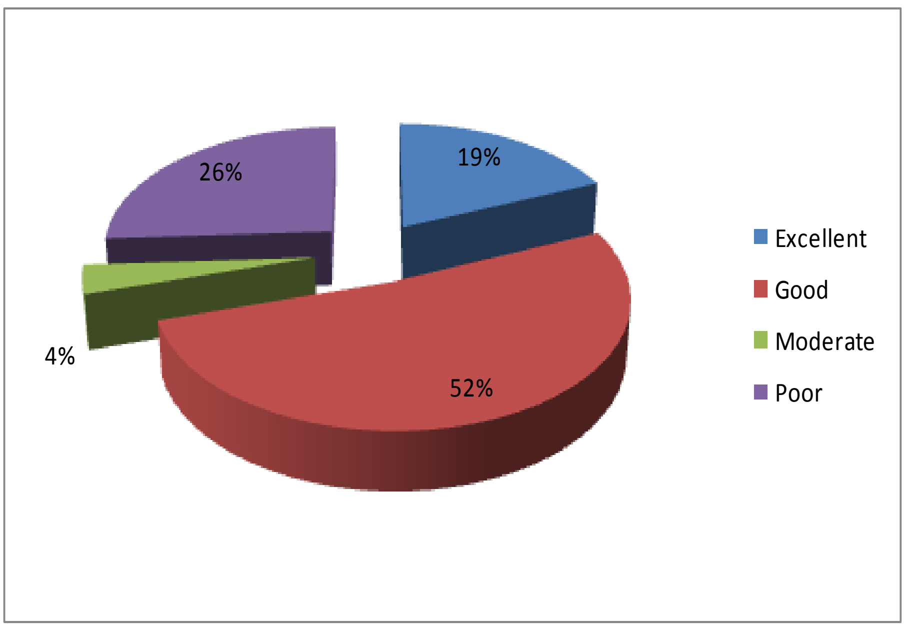


Figure 9: Suitability of locations in Wadi Rum

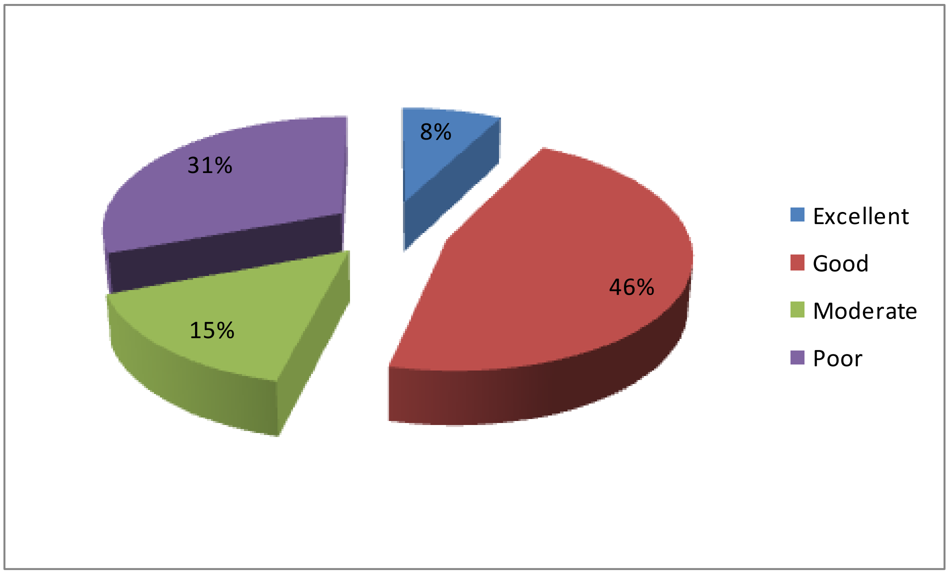
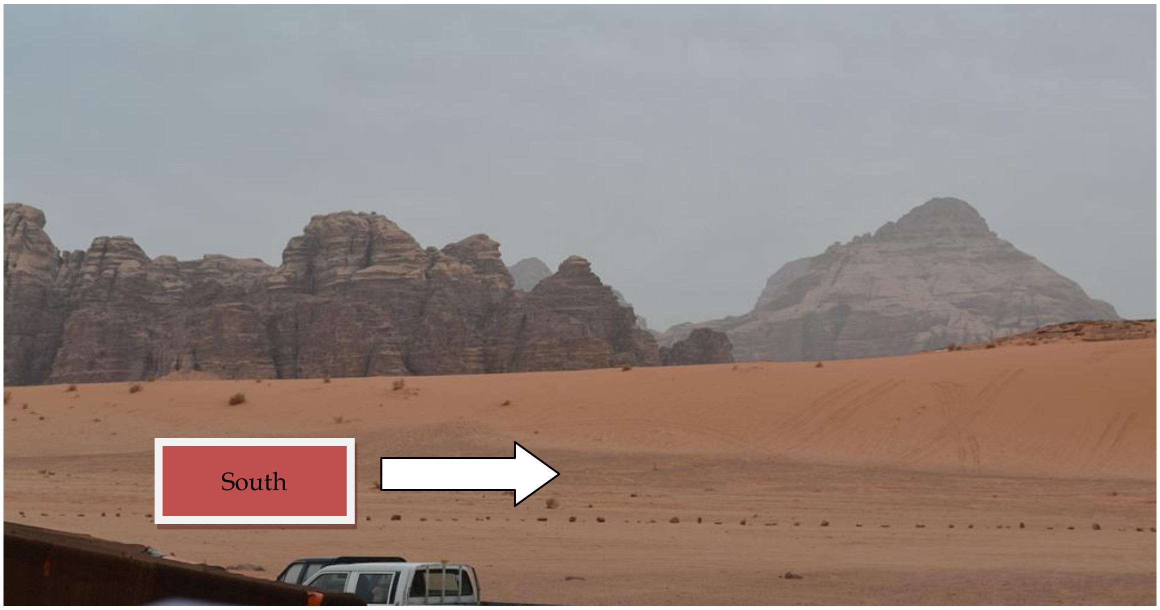


Figure 10: Suitability of locations in Disi.

In figures 9 and 10, excellent location means that the camp is directly facing south and the location is ideal for solar system installation, while good means that the system performance will be affected by 10-20% of its performance due to shading. On the other hand, moderate means that 40-50% of system performance will be lost due to shading and poor means that the solar system is almost shaded during the day and not suitable for solar system application. As can be seen from figures 9 and 10, considerable percentage of camps in both areas are affected by shading that will reduce the performance of solar systems. In order to overcome this problem, the size of solar system needs to be oversized or installed far away from the camp to ensure sun rays to reach arrays. Photos below show examples of excellent and poor locations.



Excellent location

Poor location

d. Domestic hot water

Hot water is required in camps for washing hands and taking showers. However, most camps do not have means of water heating although camps owners believe that hot water should be available especially during winter season. It is found that 23.1 and 18.5%

of Wadi Rum and Disi camps respectively afford hot water to tourists. Figure 11 shows the percentage of water heating means used in both camps.

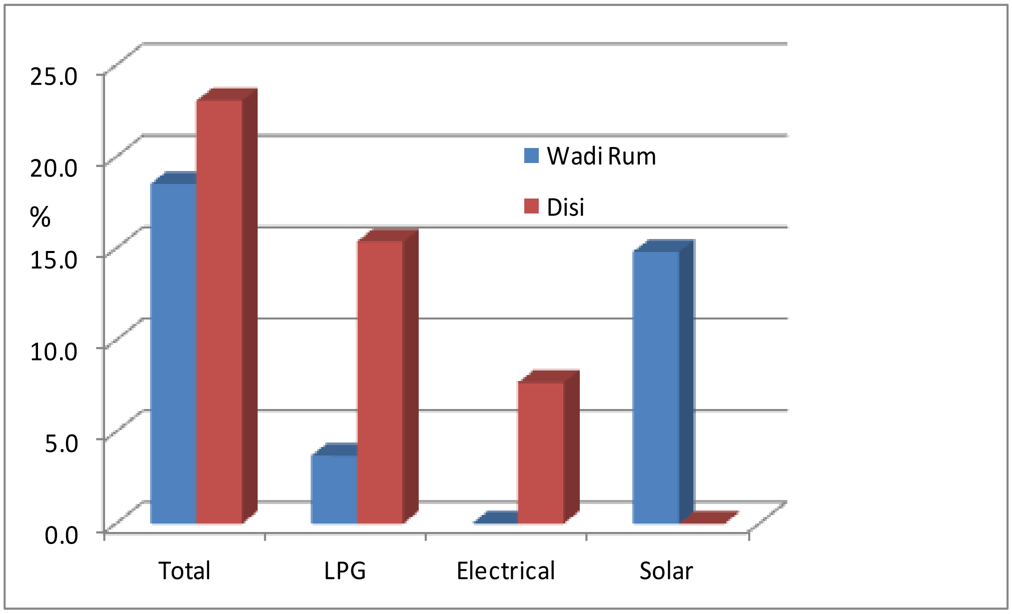


Figure 11: Water heater means distribution in Wadi Rum and Disi camps.

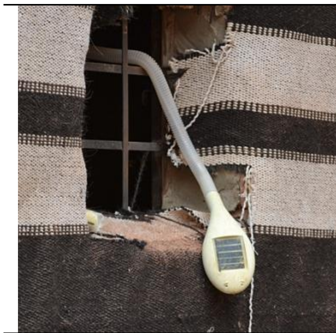
As shown in figure 11, most of hot water produced in Wadi Rum camps is through solar energy, which reflects the lack of solar energy awareness among people in Wadi Rum camps. However, the total percentages of using hot water in both camps are low.

e. Miscellaneous findings

Some camps owners tried to design and fabricate wind turbines to produce electricity and hence overcome the current energy supply and cost problems. Although these trials failed, it is a direct indication that the energy supply and cost are serious problems to them. The photo below shows one of these turbines.

Some of camps owners use different means of solar energy sources for lighting purposes. Photos below show samples of these types. Again, such usages are direct indication of the current energy supply and cost problems.

	This types is used for external lighting (garden solar lights). It converts solar energy into chemical energy during the day that is stored in small batteries that can be converted into electrical energy to provide lighting during the night.
 	This type is used for internal lighting. It converts solar energy into chemical energy during the day that is stored in small batteries that can be converted into electrical energy to provide lighting during the night. It is occupied with motion sensor that allows the light to be on only when there is someone inside, otherwise, it turns light off.

	This type is used for internal lights. It consists of transparent pipe that contains small LED lamps. Solar energy is converted into chemical energy that is stored in small batteries that can be converted into electrical energy to provide lighting. The pipe can be extended in more than one place (suitable for bathrooms).
 	This type is a typical stand alone solar system. The photovoltaic panel converts solar energy into DC electricity that is then stored in batteries. The DC electricity is then converted into AC electricity using converter. The system also includes solar charge controller that regulates electricity flow into/from batteries. This type can be used internally or externally to provide lighting.

f. *Poor practices of energy use.*

The descriptions of photos below summarize some of poor practices of energy use in Wadi Rum and Disi camps.

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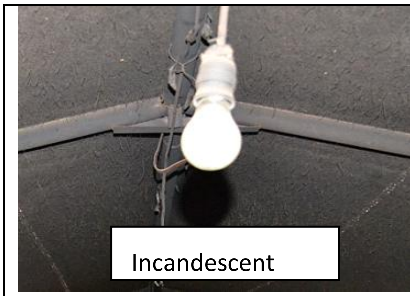
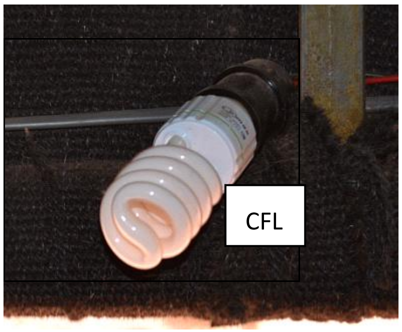
<tr>
<td>


</td>
<td>Most of camps that use fuel generators have incandescent lamps which can be considered inefficient lamps that can be replaced by CFL lamps that can provide same level of illumination but can save 75 to 80% of energy compared to incandescent lamps.

In addition, CFL lamps have longer life (8 times) than incandescent lamps.</td>
</tr>
<tr>
<td></td>
<td>Some camps charge batteries from the car and use them during the night. The battery is directly connected to the light and no protection is in between. The protection is important to avoid full discharge. Full discharge substantially reduces the battery life.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</table>

g. Tourist survey

In order to paint a complete picture of existing energy usage patterns and actual requirements of energy needed by the camps, a well-designed survey has been constructed and 100 tourists from different camps in Wadi Rum and Disi areas have been interviewed and surveyed. The following questions have been covered in the survey:

1- Do you think that the current type of energy source should be replaced by another alternative?
2- Do you think replacing current energy sources by renewable energy sources will add significant benefits to camps?
3- Do you think light level in camps is enough?
4- Do you think that hot water should be available in camps?
5- Do you think that cold water for drinking purposes should be available in camps?

Table 4: Summary of tourists survey for current energy consumption

	Totally Agree	Agree	Neutral	Disagree	Totally disagree
Q1	35	50	10	5	0
Q2	50	40	5	5	0
Q3	20	50	27	2	1
Q4	37	45	8	10	0
Q5	9	14	12	45	20

From the table above, several conclusions can be drawn:

1- The current energy pattern should be replaced by an alternative source. Most of tourists who encourage this were in camps that use fuel generators.

2- Most of tourists see that using renewable energy sources will add benefits to the camps.

3- The current light level seems to be adequate for most tourists. Therefore, when designing the alternative solution, the current light level should be maintained.

4- Hot water is essential to most of tourists.

5- Cold water is not essential to most of tourists.

4.3 ALTERNATIVES SOLUTIONS

It was found that a typical camp in Wadi Rum and Disi areas has 13 tents/guest accommodations, five bathrooms, one kitchen, one sitting room, and an external sitting area. The analysis hereafter will be based on these numbers. Tables 5, and 6 summarize the assumptions used in the followings analysis.

Table 5: Suggested Appliances for a typical camp.

Appliance	*Location*	*Number*	*Power Rating (W)*	*Operational Hours (hrs)*
CFL	Kitchen	1	18	5
CFL	Sitting	4	11	5
CFL	Bathrooms	8	8	3
CFL	Bedrooms	13	8	3
CFL	outdoor	2	11	3
Mobile Charger	Misc.	3	17	3
Refrigerator	Kitchen	1	180	8
Water Cooler	Sitting	1	100	3

Table 6: Assumptions used in analysis

Charger Efficiency	*0.98*
Inverter Efficiency	0.90
Wire Losses	0.03
System trip losses	0.85
Battery Discharge	0.80
Autonomy Days	2
Irradiance Level (kWh/m^2.day)	3.0
Safety Factor	1.15
System Voltage	24
Wp cost	1.0
Diesel Price	0.66
AH cost (12 V)	1.30

a. Stand alone photovoltaic system for base loads (option 1).

Stand-alone PV (photovoltaic) systems are used when it is impractical to connect to the utility grid. The design criteria for stand-alone systems are generally more complex than the design criteria for utility interactive systems, where most of the critical system components are incorporated in the design.

The PV modules must supply all the energy required. The DC electricity produced by the solar panel or module(s) is used to charge batteries via a solar charge controller. The *AC* appliances are powered via an inverter connected to batteries or charge controller. Most stand-alone PV systems need to be managed properly. Users need to know the limitations of a system and tailor energy consumption according to how sunny it is and the state of charge (SOC) of the battery.

The schematic diagram below (Figure 12) shows the design for standalone PV system that covers the base appliances that should exist in a typical camp (appliances shown in Table 5 except refrigerator and water cooler).

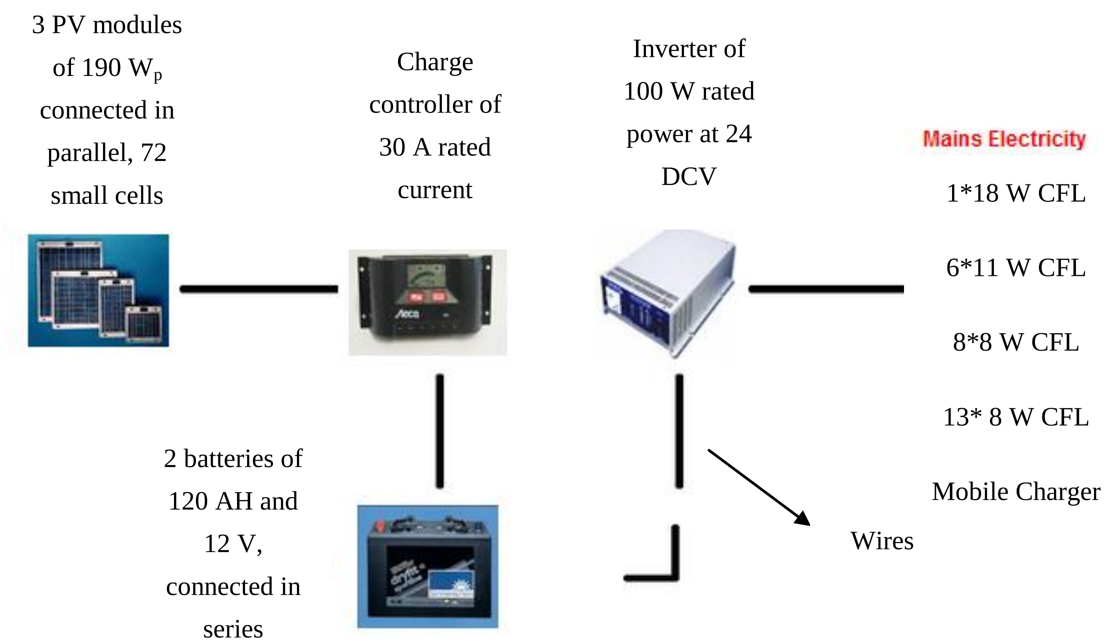


Figure 12: Main components of standalone PV system (option 1).

The solar panels need to be configured to match the system, which is determined by the battery. System voltages are typically, 12V DC and 24V DC, larger systems will operate at 48V DC. In our case, the system voltage is 24 V. The operating voltage of a solar panel in a stand-alone system must be high enough to charge the batteries. The solar panel must be able to deliver this voltage to the battery after power losses and voltage drop in the cables and charge controller and in conditions in which the solar cells operate at a high temperature.

A charge controller is designed to protect the battery and ensure it has a long working life without impairing the system efficiency. Batteries should not be overcharged and the function of the charge controller is to ensure that the battery is not over charged.

Charge controllers are designed to function as follows:

- Protect the battery from over-discharge, normally referred to as low voltage disconnect (LVD) that disconnects the battery from the load when the battery reaches a certain depth of discharge (DOD).
- Protect the battery from over-charging by limiting the charging voltage. It is usually referred to as high voltage disconnect (HVD).
- Prevent current flowing back into the solar panel during the night, so called reverse current.
- The power requirements of standalone PV systems rarely match with the battery charging. Appliances and loads need to be powered when there is sufficient solar radiation, during overcast weather and during the night. Bad weather may last for several days and the daily charging and discharging of the batteries takes its toll on them. In our design, two "autonomy days" are included.
- The inverter is used to convert DC electricity into AC electricity so it can be used by different AC appliances. The inverter should have high efficiency to reduce the losses from the system.

- Cables need to be UV resistant and suitable for outdoor applications. It is very important to keep power losses and voltage drop in the cable to a minimum. It is recommended that this be less than 3%. .

Table 7: Economical analysis of option 1 system.

Item	*Cost in JD*
Modules Cost (3 modules of 190 W_p)	570 JD
Batteries cost (2 batteries of 120 Ah, 12 V)	312 JD
Inverter cost (100 rated power at 24 DCV)	150 JD
Charge controller (30 A rated current)	80 JD
Appliances cost	100 JD
Installation cost	400 JD
Investment (System cost)	1612 JD
Payback period (years)	19

b. Stand alone photovoltaic system for all loads (option 2).

This system is the same as option 1 except that refrigerator and water cooler are added. The schematic diagram below (Figure 13) shows the design for standalone PV system that covers all appliances shown in Table 5.

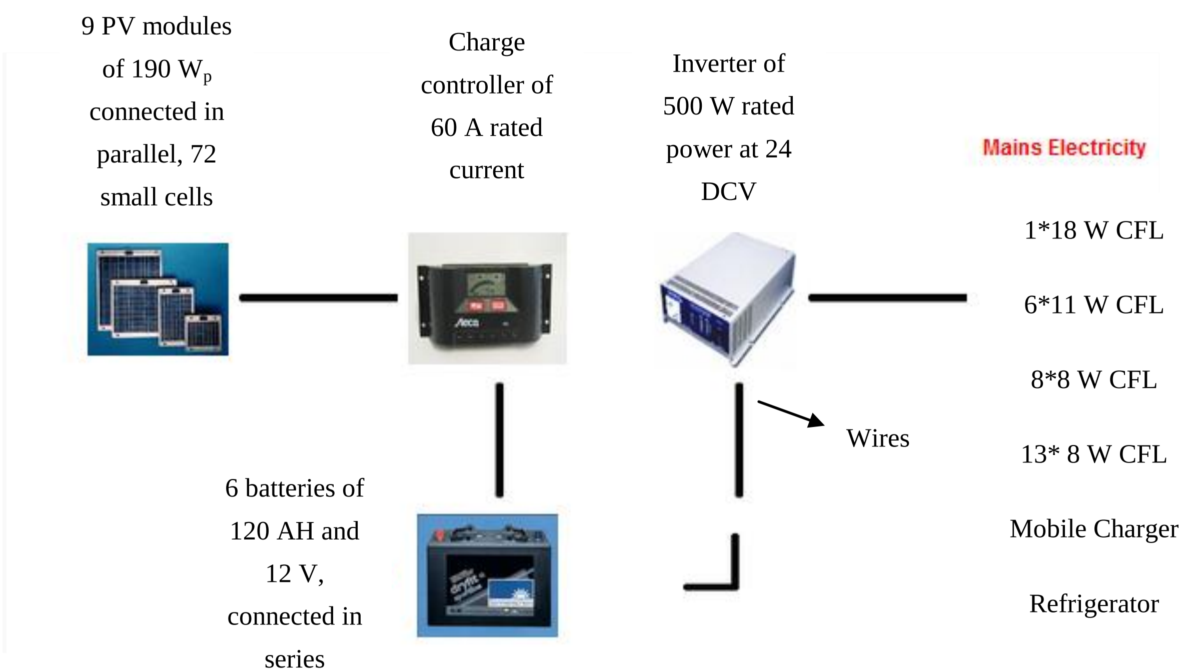


Figure 13: Main components of standalone PV system (option 2).

Table 8: Economical analysis of option 2 system.

Item	*Cost in JD*
Modules Cost (9 modules of 190 W_p)	1710 JD
Batteries cost (6 batteries of 120 Ah, 12 V)	936 JD
Inverter cost (500 rated power at 24 DCV)	350 JD
Charge controller (60 A rated current)	200 JD
Appliances cost	650 JD
Installation cost	600 JD
Investment (System cost)	4446 JD
Payback period (years)	19

c. Hybrid system for base loads (option 3).

In areas where winter sunlight is significantly less than summer sunlight, if sufficient PV is deployed to meet winter needs (as options 1 and 2), then the system produces excess power for many months of the year. If this power is not used, then the additional capacity of the system is wasted. Thus, for such cases, it often makes sense to size the PV system to completely meet the system needs during the month(s) with the most sunlight, and then provide backup generation of another type, such as a gasoline/diesel generator, to provide the difference in energy during the remaining months. In this option, the generator charges the batteries through battery charger when sunlight is not enough. Also, the system can only be based on generator when necessary by the transfer switch shown in the diagram below (Figure 14).

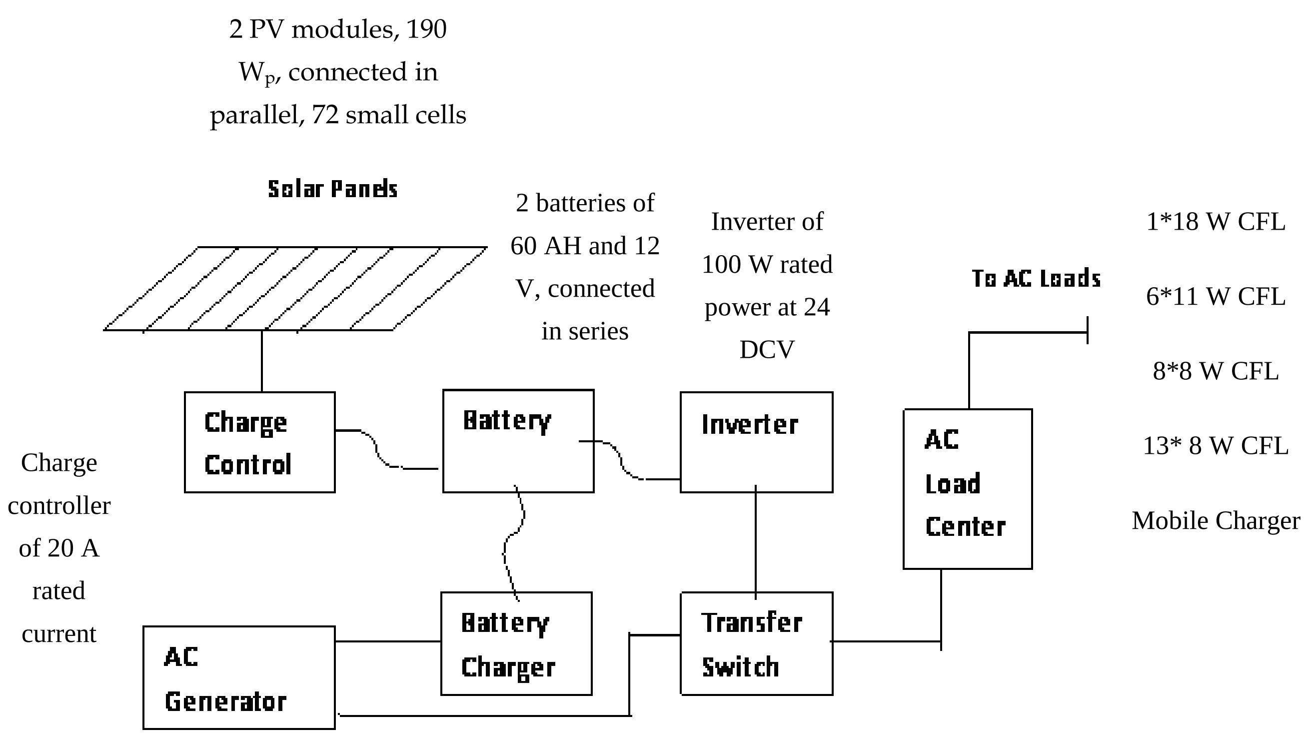


Figure 14: A schematic of standalone hybrid PV system (option 3).

Table 9: Economical analysis of option 3 system.

Item	*Cost in JD*
Modules Cost (2 modules of 190 W_p)	380 JD
Batteries cost (2 batteries of 60 Ah, 12 V)	156 JD
Inverter cost (100 rated power at 24 DCV)	150 JD
Charge controller (20 A rated current)	50 JD
Battery charger	100 JD
Transfer Switch	50 JD
Appliances cost	100 JD
Installation cost	400 JD
Investment (System cost)	1386 JD
Fuel Cost	35 JD
Payback period (years)	16

b. Hybrid system for all loads (option 4).

The system here is the same as option 3 except that refrigerator and water cooler are added. The schematic diagram below (Figure 15) shows the design for standalone PV system that covers all appliances shown in Table 5.

Table 10: Economical analysis of option 4 system.

Item	*Cost in JD*
Modules Cost (5 modules of 190 W_p)	950 JD
Batteries cost (6 batteries of 120 Ah, 12 V)	624 JD
Inverter cost (500 rated power at 24 DCV)	350 JD
Charge controller (40 A rated current)	150 JD
Battery charger	200 JD
Transfer Switch	100 JD
Appliances cost	650 JD
Installation cost	600 JD
Investment (System cost)	3624 JD
Fuel Cost	90 JD
Payback period (years)	16

c. *Mobile solar energy equipment (option 5).*

In camps where location is a barrier, mobile solar kits can be used. The solar kit is easy to move to a place where sunrays are available to charge it and use it during the night. There are several types of solar kits but the most common one is the camping light that can be used indoor or outdoor (as shown in the photo below).

Solar camping light

The camping light is occupied with LED lights that have long life (approximately 40,000 hours), it has multi-modes of charging: by car charger, adapter and solar panel.

Table 11: Economical analysis of option 5 system.

Camping light cost (28 kits)	*1400 JD*
Payback period (years)	16.5

d. Comparison of different options

Table 12 shows the main aspects of comparison between the different solutions considered in this study as alternatives to current energy generation patterns.

Table 12: Comparison between the different solutions considered in this study.

Aspect	*Standalone*	*Hybrid*	*Mobile kits*
Cost	high	Low	Moderate
Life	Life is limited to battery life (maximum of 5 years)	Life is limited to battery life (maximum of 5 years)	Life is limited to battery life (maximum of 5 years)
Maintenance	Moderate	High	Low
Flexibility	Low	Moderate	High
Availability in local market	High	High	Low
Landscape effect	High	High	Low
Spare parts cost	High	High	Low
Installation difficulty	High (skilled person)	High (skilled person	Low
Environment impact	Low	High	Low

4.4 SOLAR WATER HEATERS

Water heaters are major energy consumers for domestic hot water applications. It was found that five camps in Wadi Rum and three Disi areas use water heaters to provide hot water to tourists. Four camps and one camp in Wadi Rum use solar water heater and LPG heater respectively while two camps and one camp in Disi use LPG heater and electrical heater respectively. The percentages of affording hot water in camps are 18.5 and 23.1% in

Wadi Rum and Disi areas respectively; this low percentages are not acceptable to the camp owners and tourists. The main barrier behind not affording hot water is the cost of such systems and the cost of energy needed to operate such systems.

Solar water heaters can operate in any climate and their performance varies depending on the amount of solar energy available and the coldness of the water coming into the system. The amount of hot water a solar water heater produces depends on the type and size of the system, the amount of sun available at the site, proper installation, and the angle and orientation of the collectors. In order to improve the service quality provided to tourists, it is highly recommended to install solar water heaters in camps where location is not a barrier.

The design of solar water heaters for camps in Wadi Rum and Disi is based on providing avergae quantity of 225 liters of hot water at 35 ^{o}C temperature difference. To provide this quantity, the following material is required:

The material of this solar water heater:

- Inner tank: Galvanized steel with thickness: 1.8 mm.
- Vacuum tube: Three target tube, 58 X 1800 mm.
- Outer tank: powder coated steel : 0.4 mm.
- Insulation: polyurethane 50mm thickness.
- Frame: powder coated color steel 1.25 mm.
- Number of tubes: 20 tubes.
- Cylinder capacity : 180 Liters.
- Magnesium rod.
- Size : 1750 X 1620 X 1680 mm.
- Feeder tank size : 1000 X 1000 X 1000 mm.
- Feeder tank Material: Galvanized steel with thickness 1.3 mm
- Feeder tank base height 1800 mm.

V. Telescope Room

One of the scopes for the current project is to design a proper solar system for the telescope room. This system will serve the following appliances (Table 13):

Table 13: Appliances and operational hours the solar system should serve.

Appliance	*Power (W)*	*Number*	*Operational Hours (Hrs/day)*
LED 3 W	3	23	16
LED 5 W (exit sign)	5	1	24
DC motor	400	1	2
Telescope	50	1	4

In order to meet the requiremets shown in Table 13, the solar system should include the followings (the design is based on two cloudy days):

1- Four panels of 190 W_p each, 72 monocrystalline small cells.

2- Four batteries of 150 AH each at 12 V.

3- Charge controller of 20 A.

4- Inverter at rated power of 750 W and 24 V.

The estimated cost of this system is 2500 JD. Figures 16 and 17 illustrate the design.

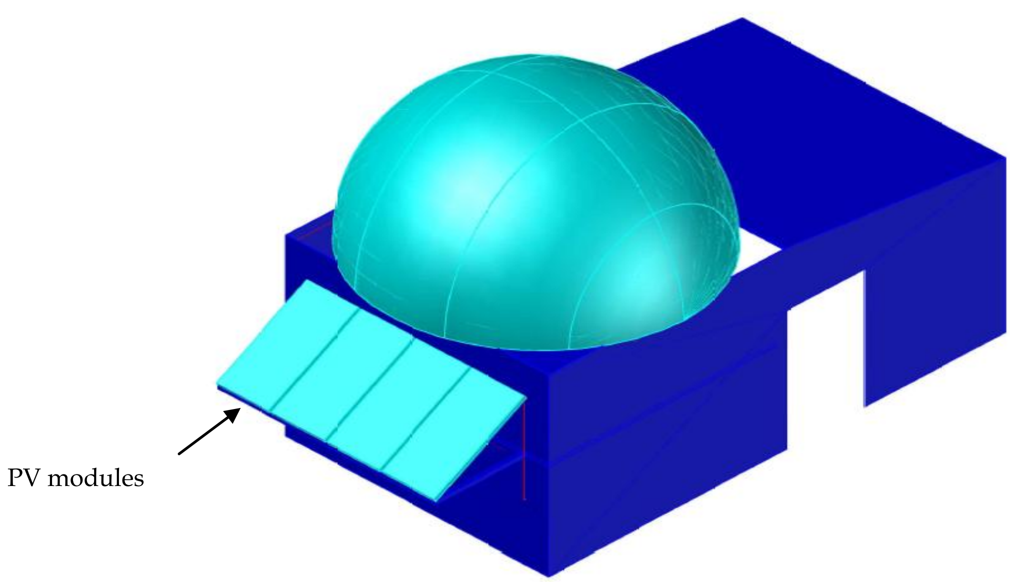


Figure 16: Schematic sketch of PV location.

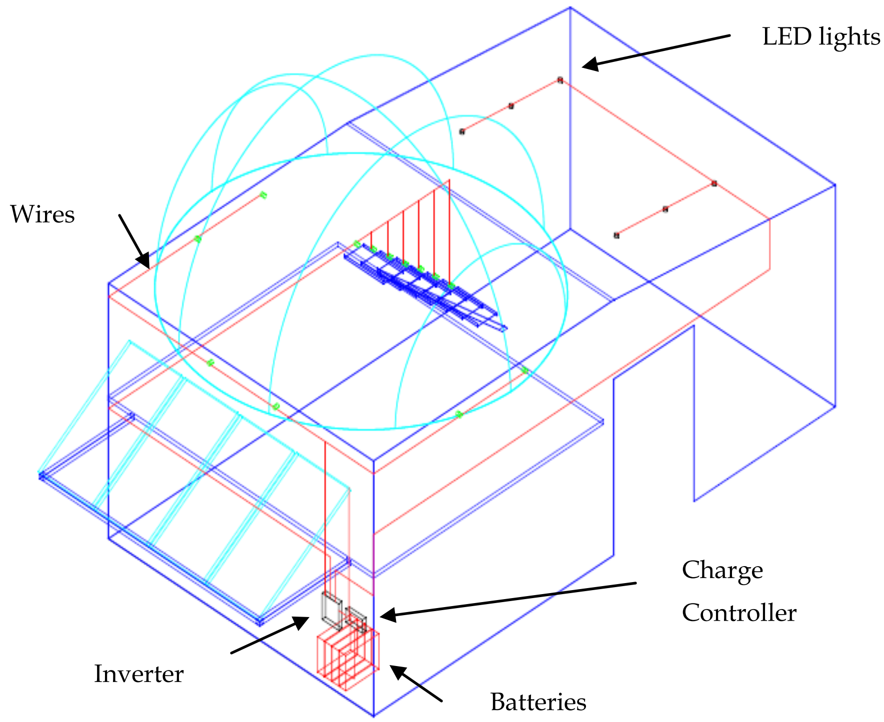


Figure 17: Schematic diagram of solar system installation

VI. Appendix A

Camps Survey

Camp Name and Location	Capacity (persons)	Contact Person (Name and Phone Number)

Months of High season	
Months of Low season	
Unoccupied Months	

Appliance	Quantity	Power Rating (W)	Operational Hours (hrs)	Location	Served Area (m^2)	Notes

<u>Consuming Electricity Equipments:</u>

Have you considered before any alternative energy sources to replace the existing fuel generator (if exist)?

If yes, what are these alternatives?

Limitations of renewable energy applications:

1- Initial Cost:

2- Availability of such systems:

3- Landscape effect:

4- System Maintenance :

5- Others:

Are you willing to install the alternative solution totally at your expense?

If no, if the donor offers to support the initial cost, are you willing to install it?

VII Appendix B

End use models for camps in Wadi Rum and Disi areas

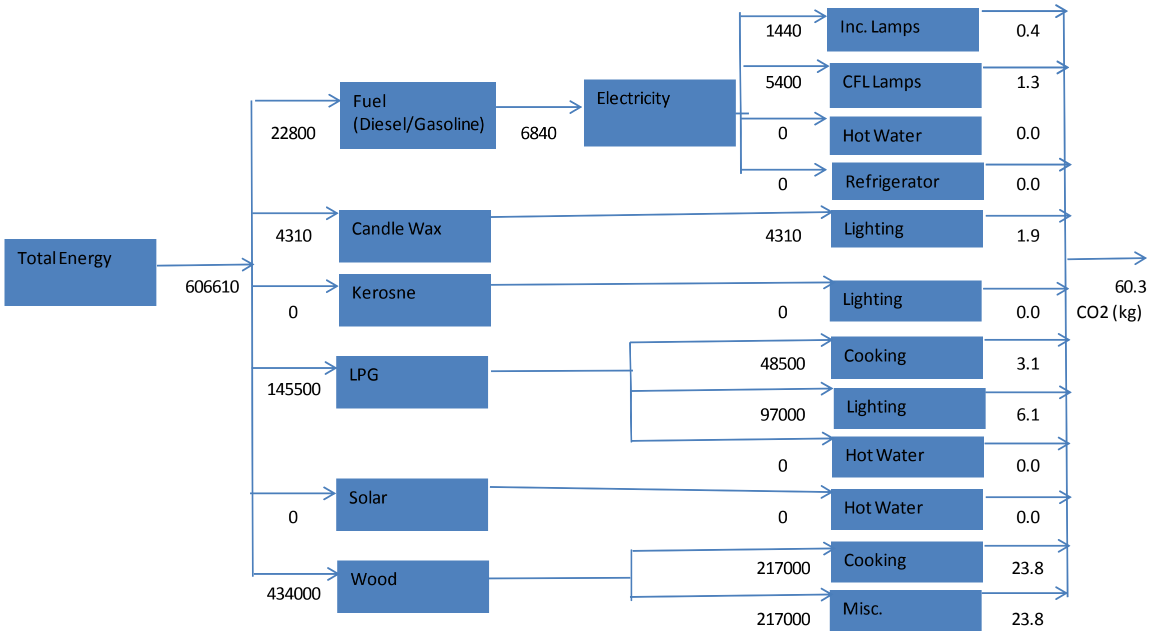


Figure B1: Energy end use model for 1-W.

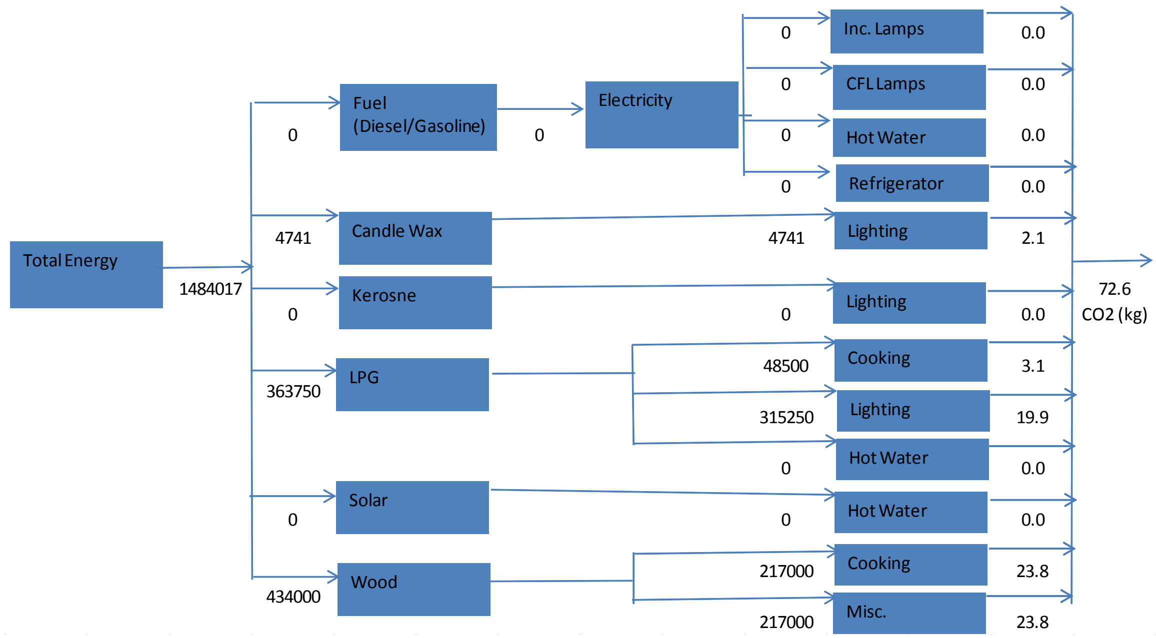


Figure B2: Energy end use model for 2-W.

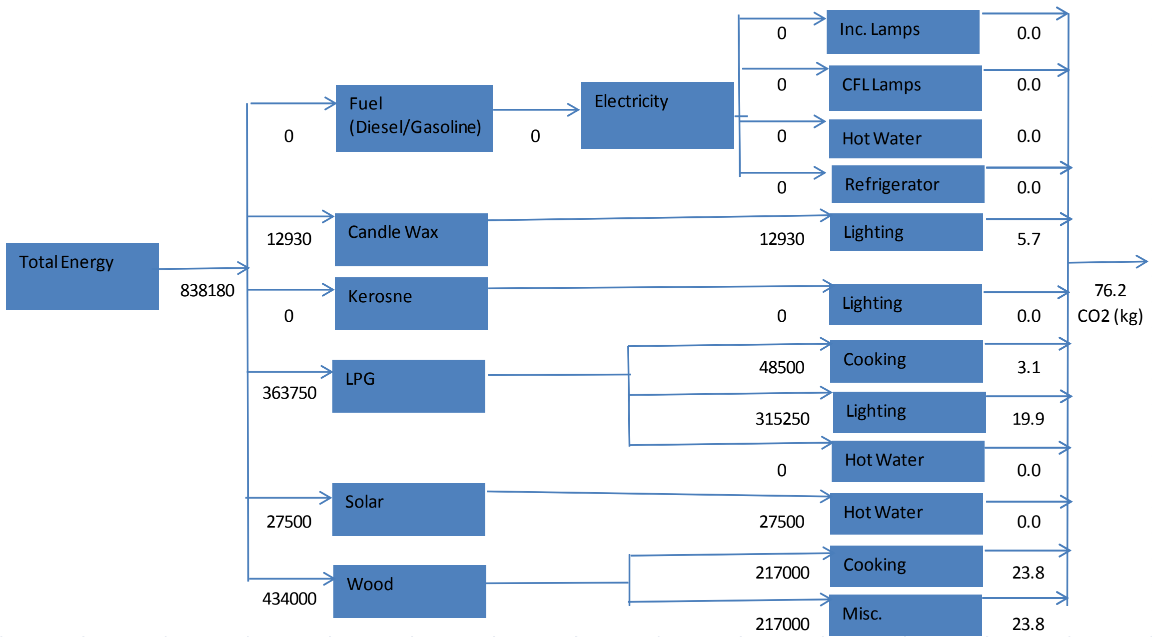


Figure B3: Energy end use model for 3-W.

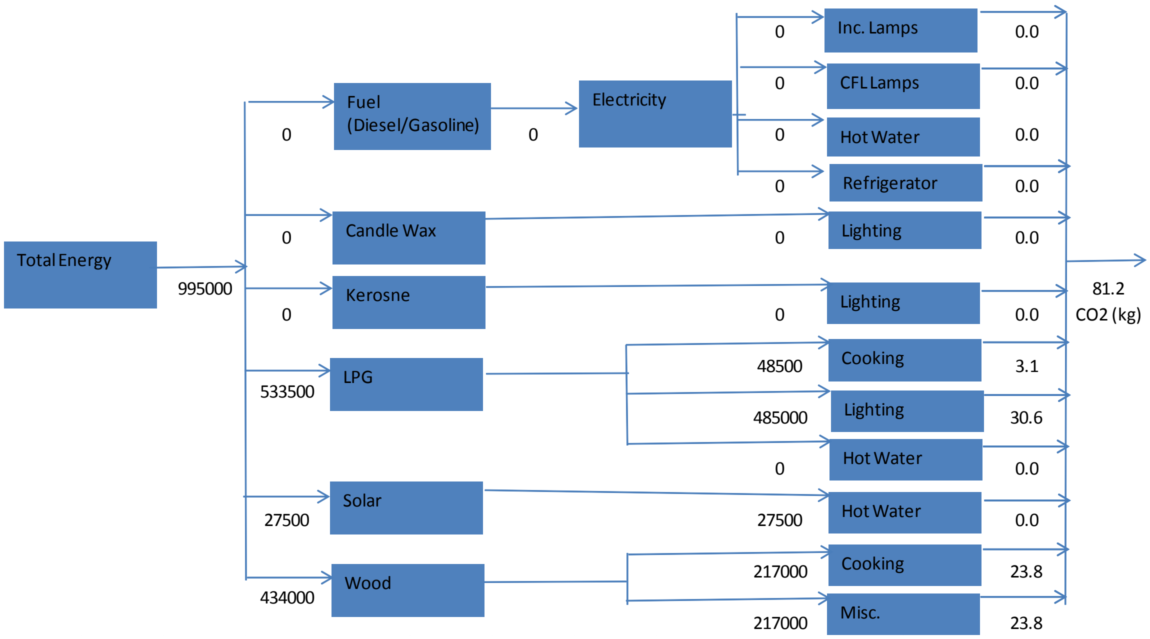


Figure B4: Energy end use model for 4-W.

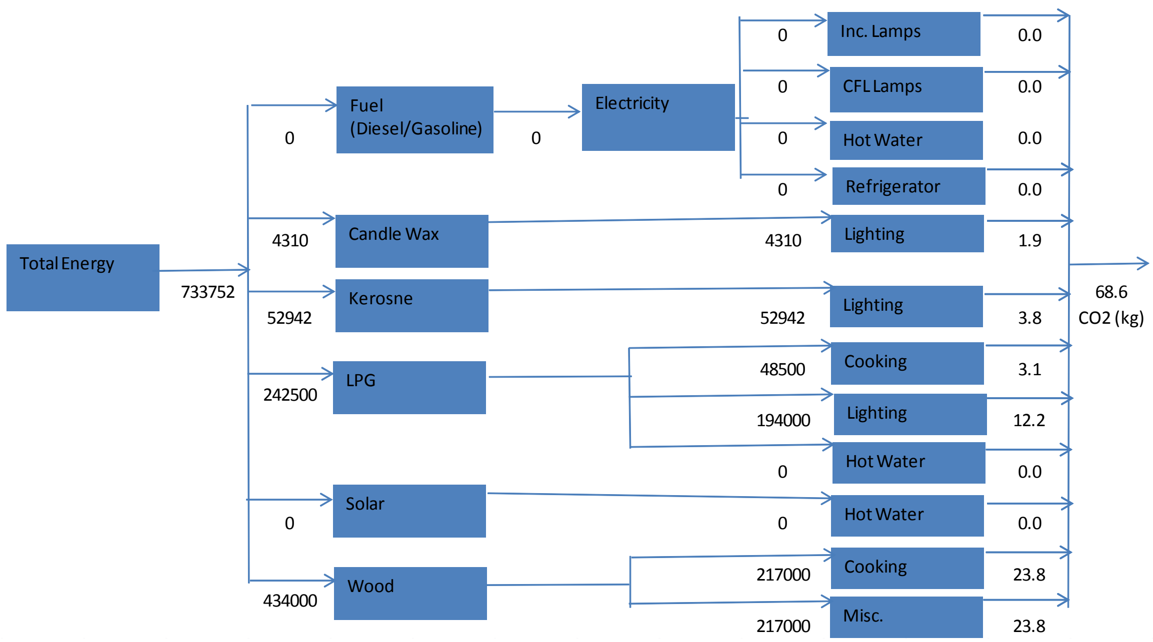


Figure B5: Energy end use model for 5-W.

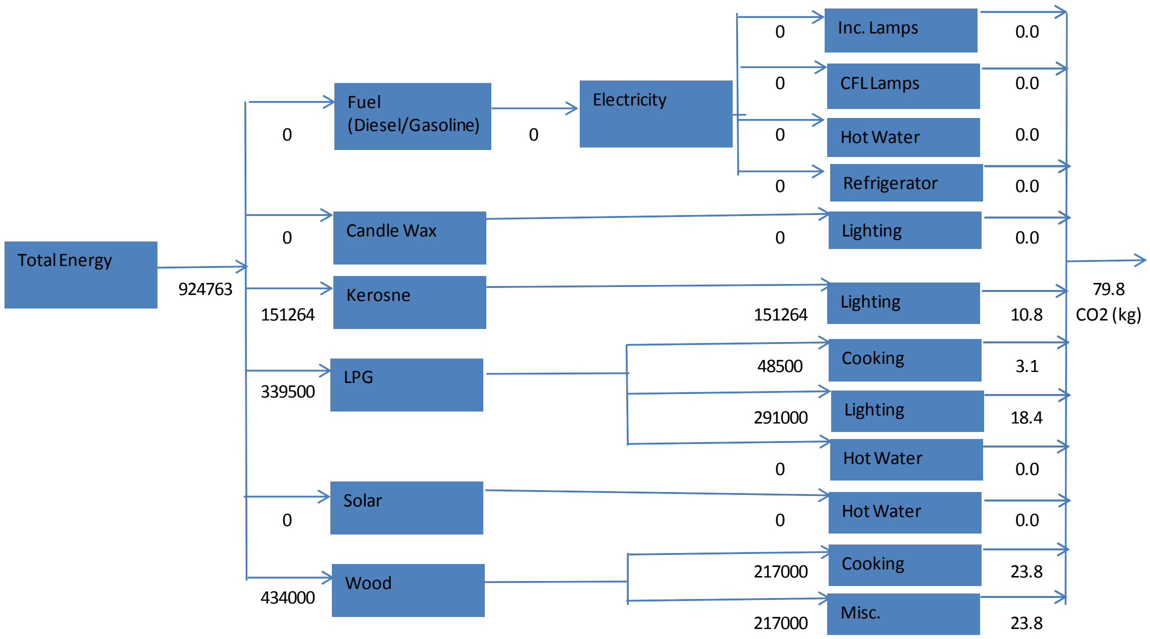


Figure B6: Energy end use model for 6-W.

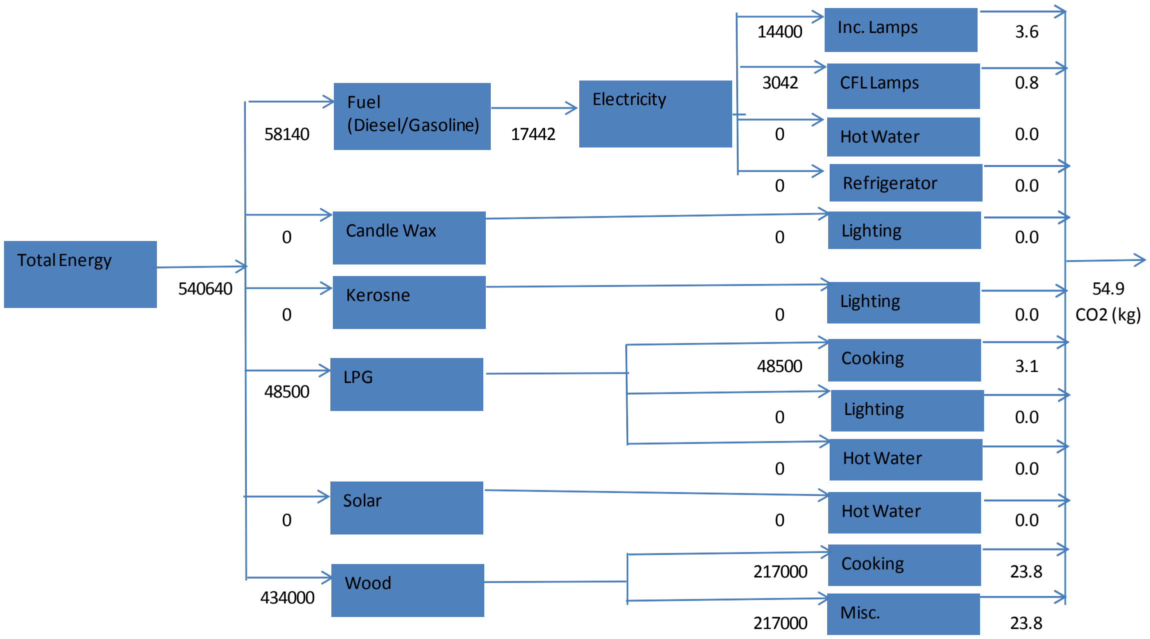


Figure B7: Energy end use model for 7-W.

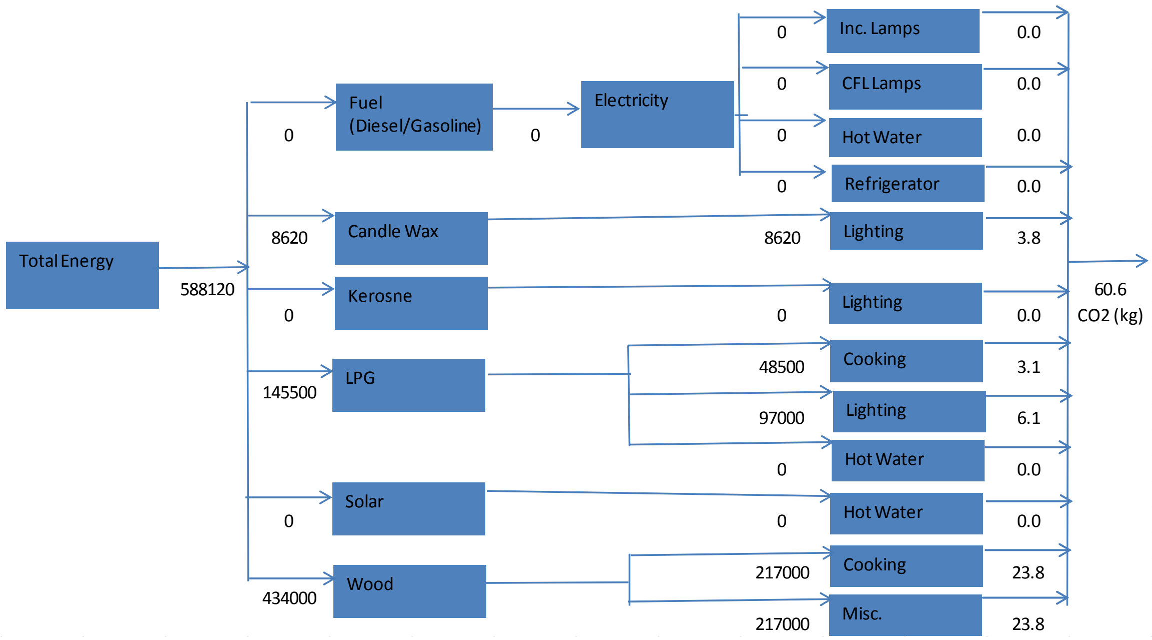


Figure B8: Energy end use model for 8-W.

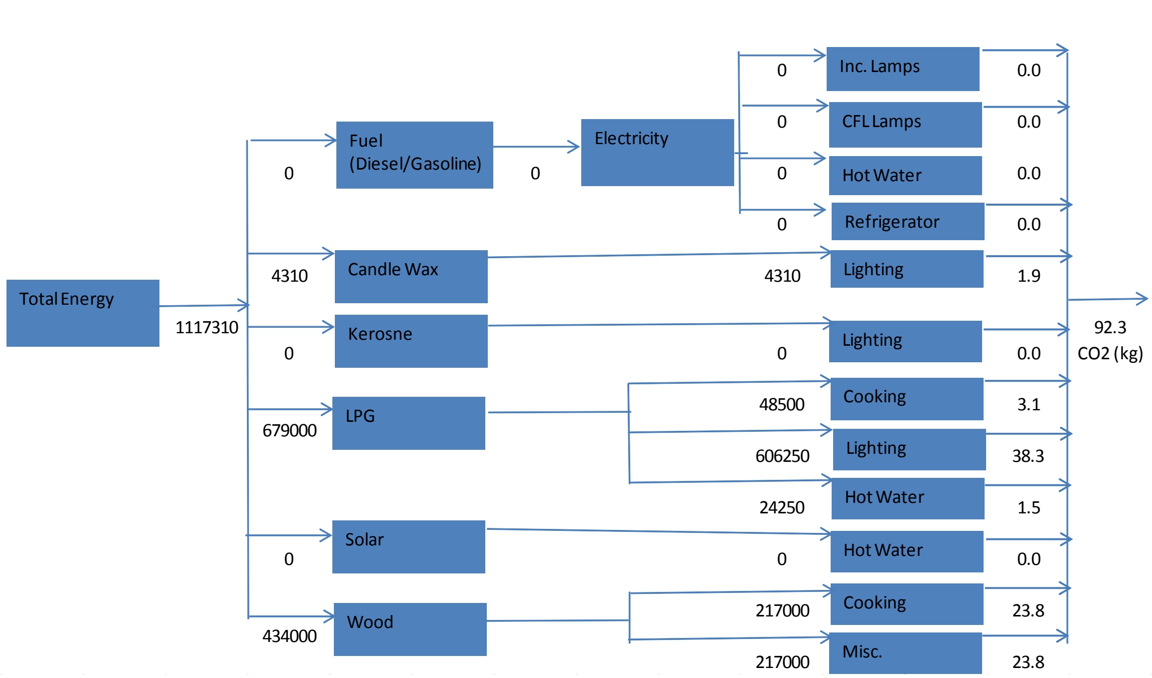


Figure B9: Energy end use model for 9-W.

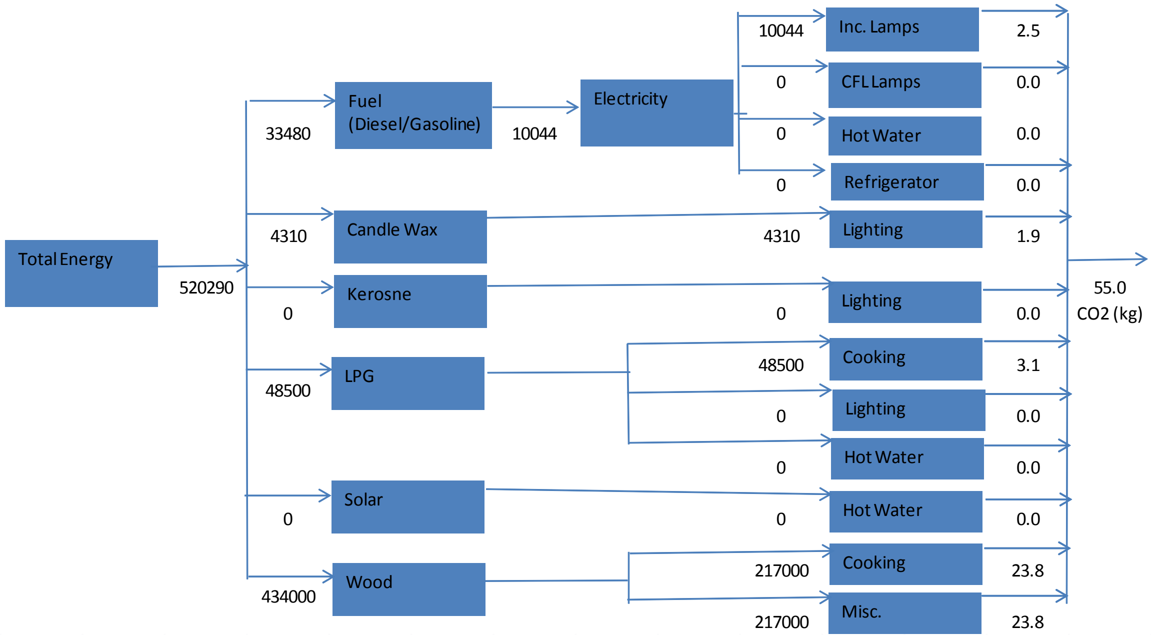


Figure B10: Energy end use model for 10-W.

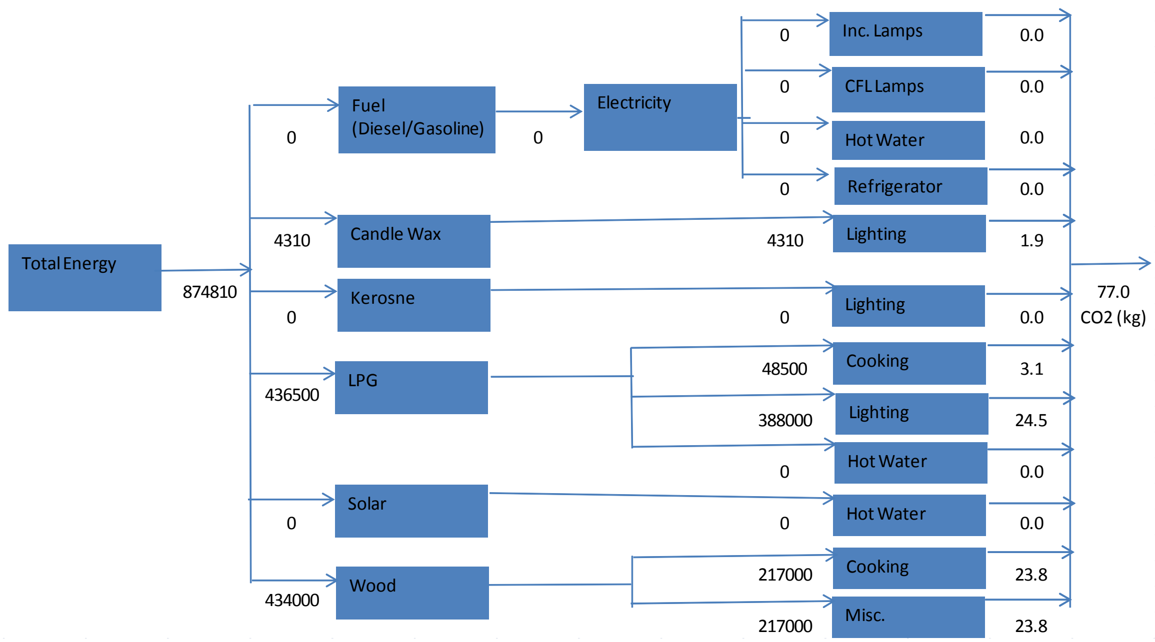


Figure B11: Energy end use model for 11-W.

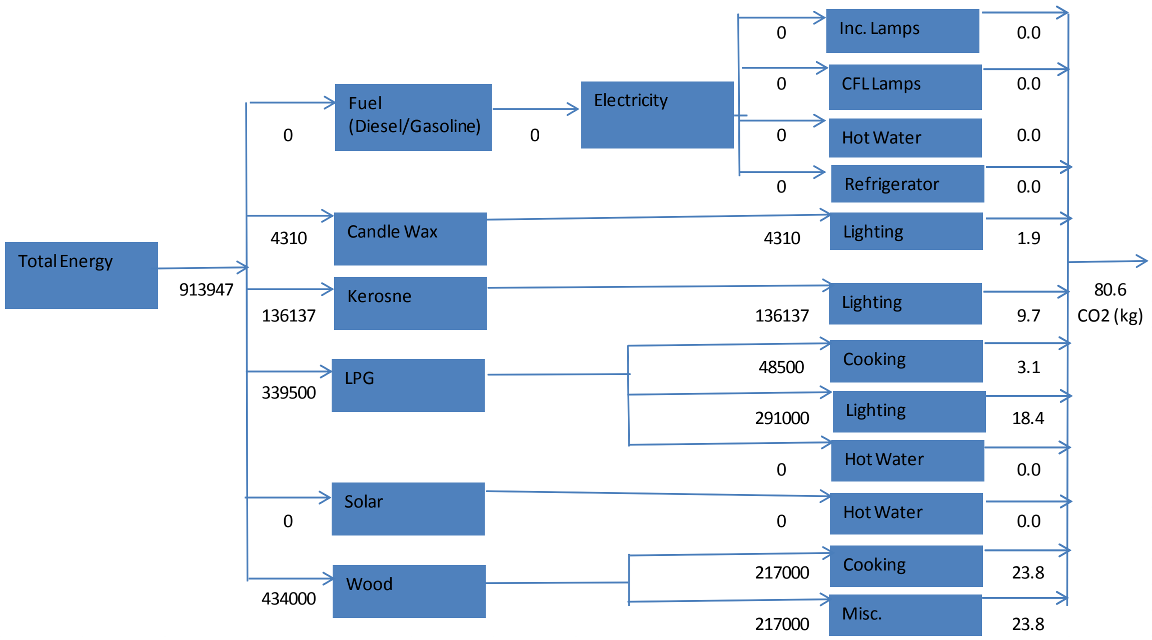


Figure B12: Energy end use model for 12-W.

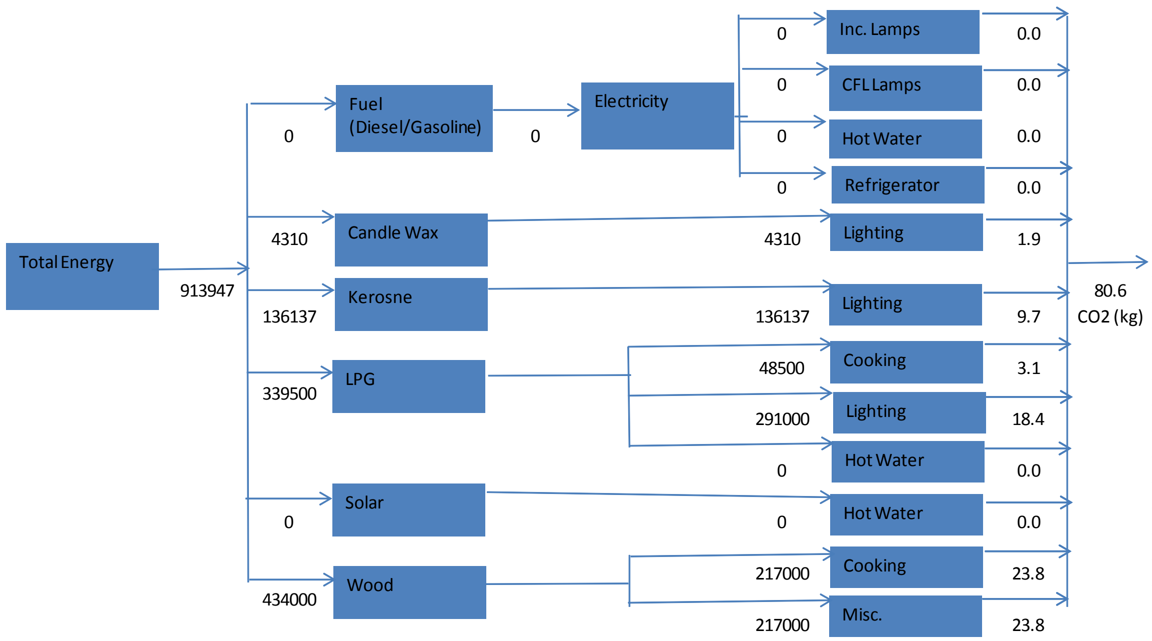


Figure B13: Energy end use model for 13-W.

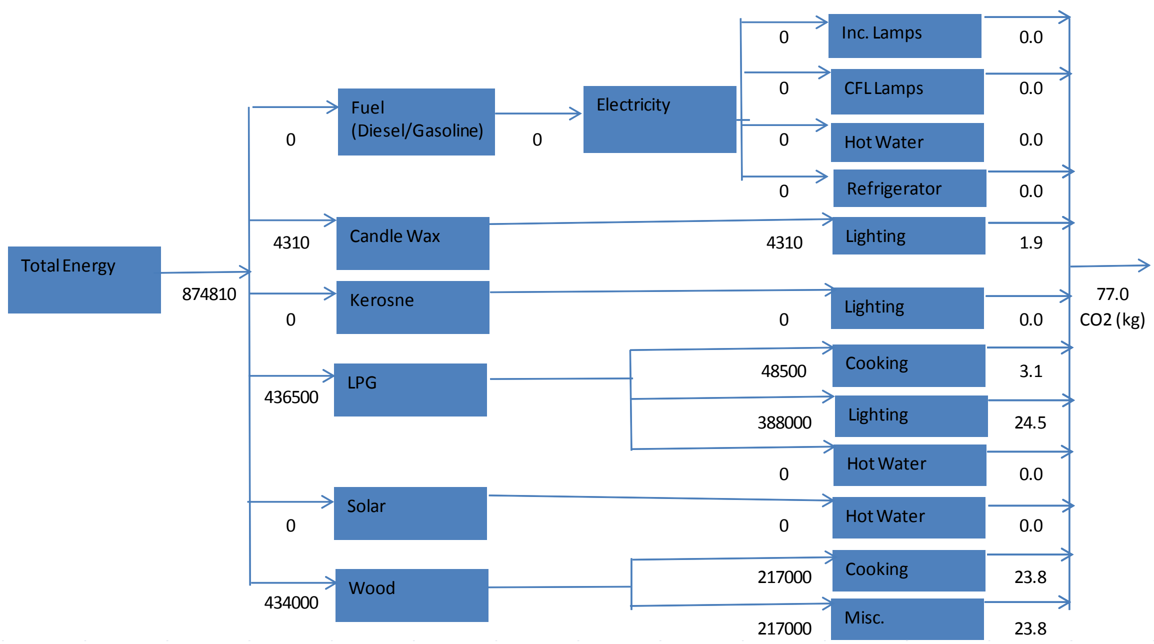


Figure B14: Energy end use model for 14-W.

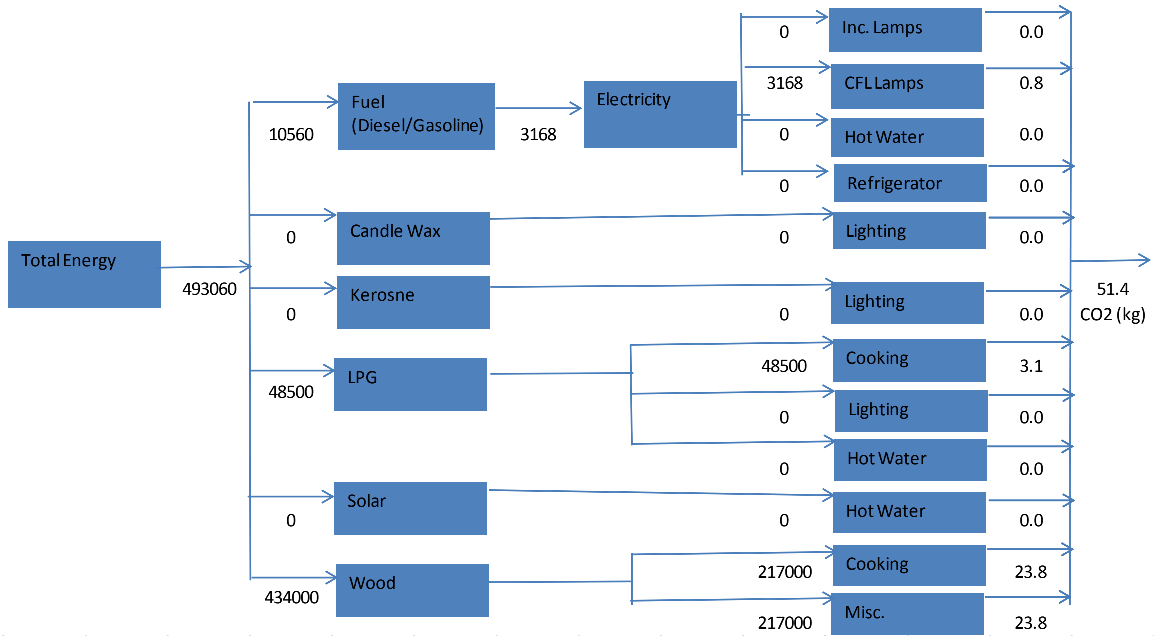


Figure B15: Energy end use model for 15-W.

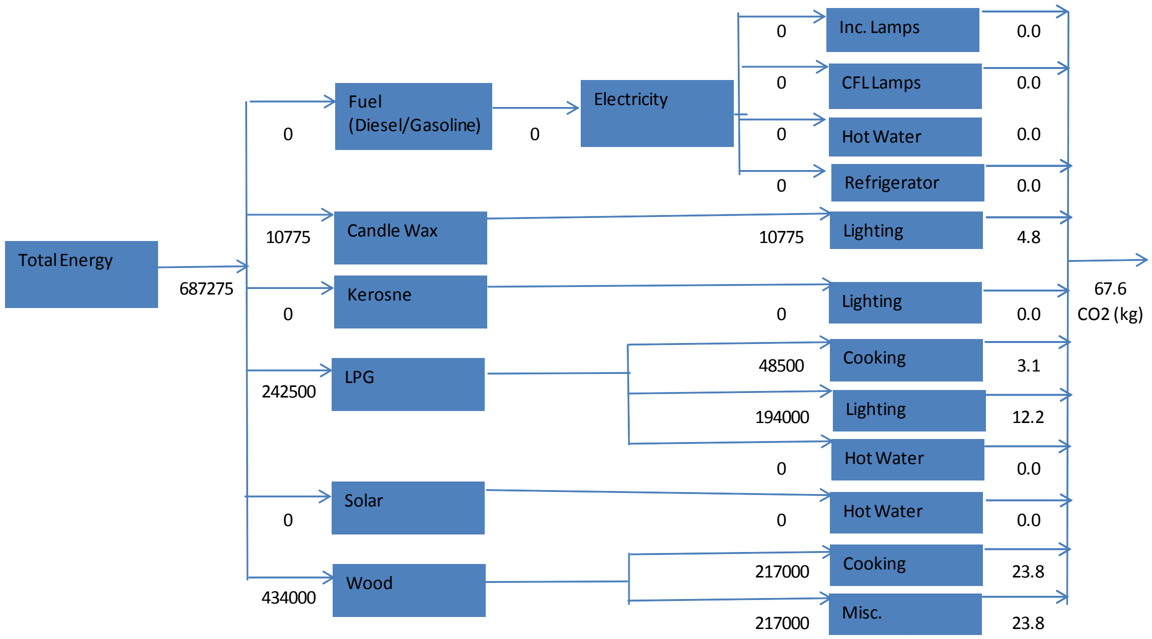


Figure B16: Energy end use model for 16-W.

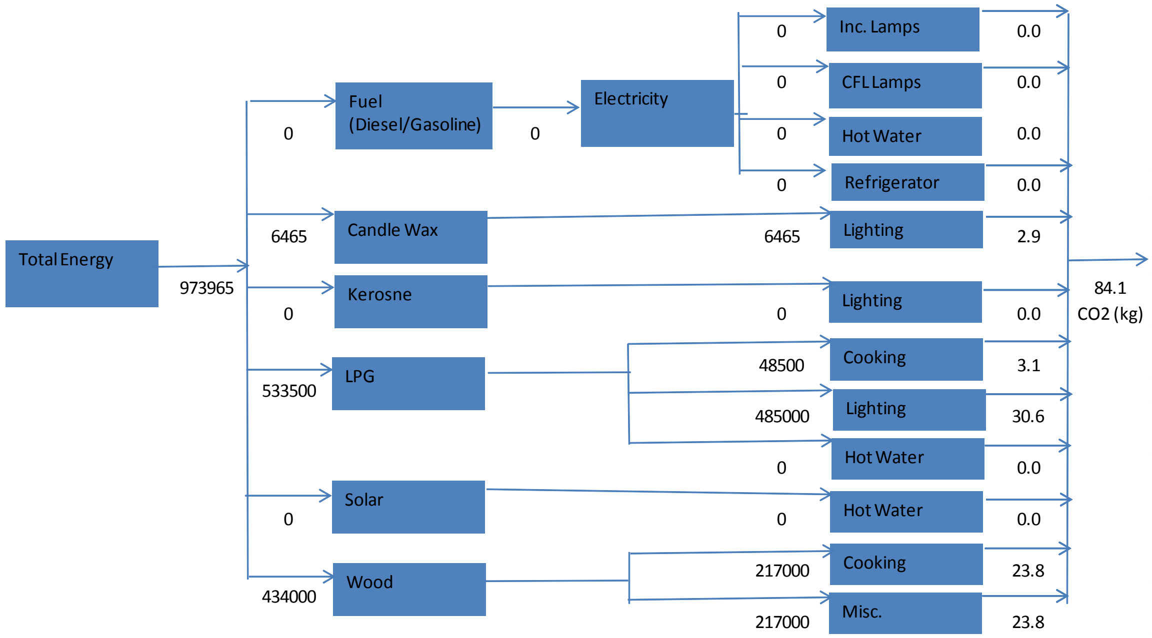


Figure B17: Energy end use model for 17-W.

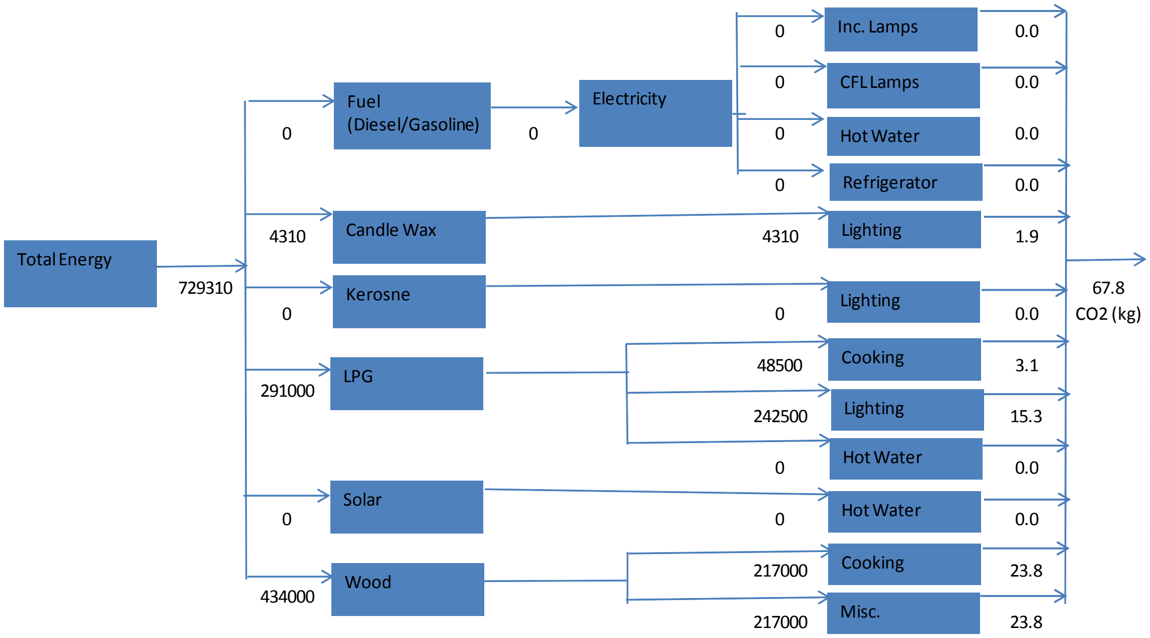


Figure B18: Energy end use model for 18-W.

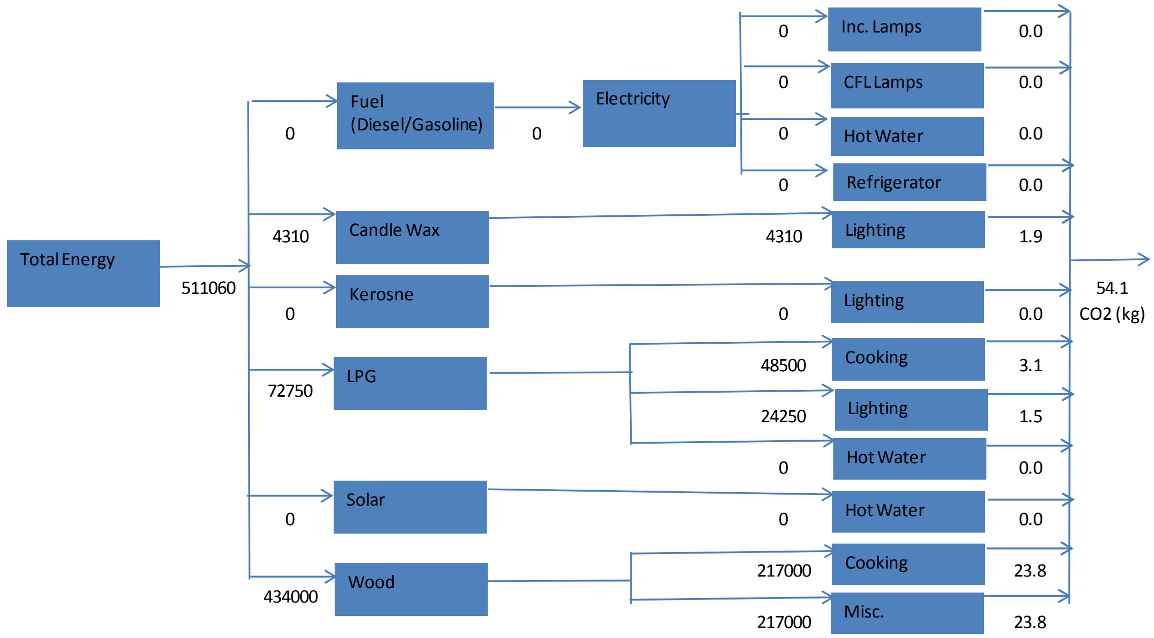


Figure B19: Energy end use model for 19-W.

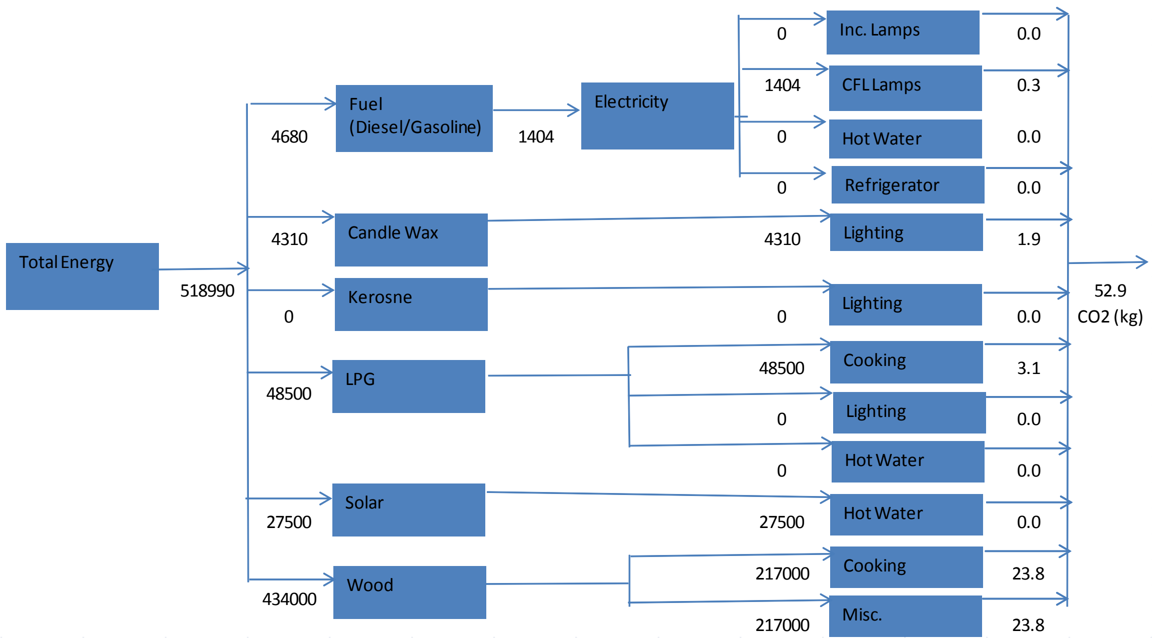


Figure B20: Energy end use model for 20-W.

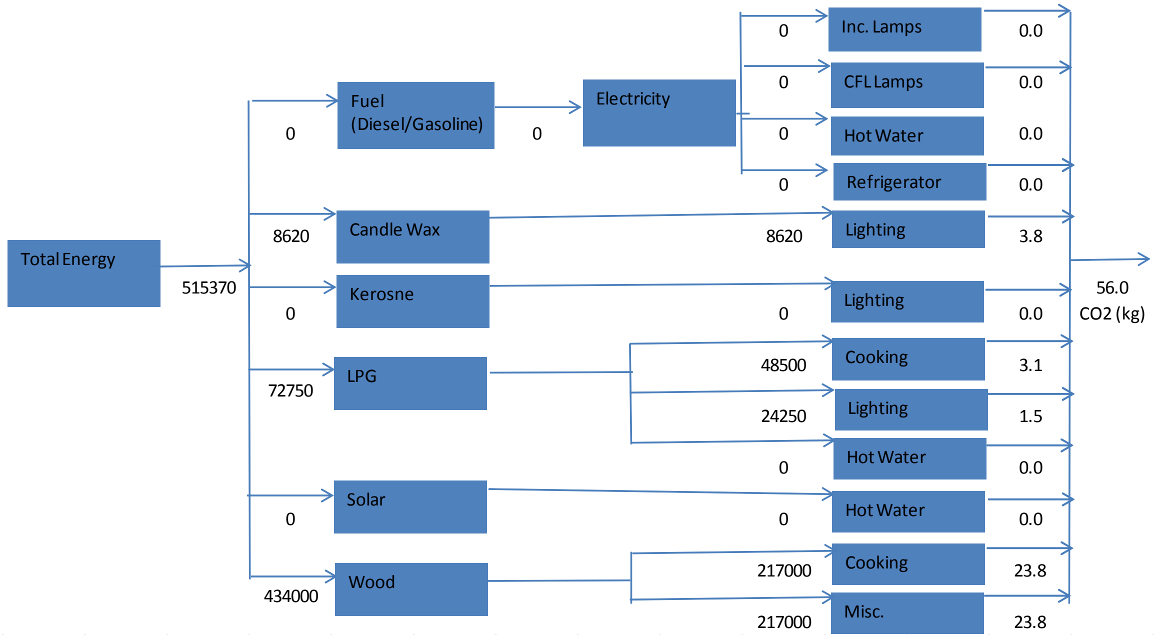


Figure B21: Energy end use model for 20-W.

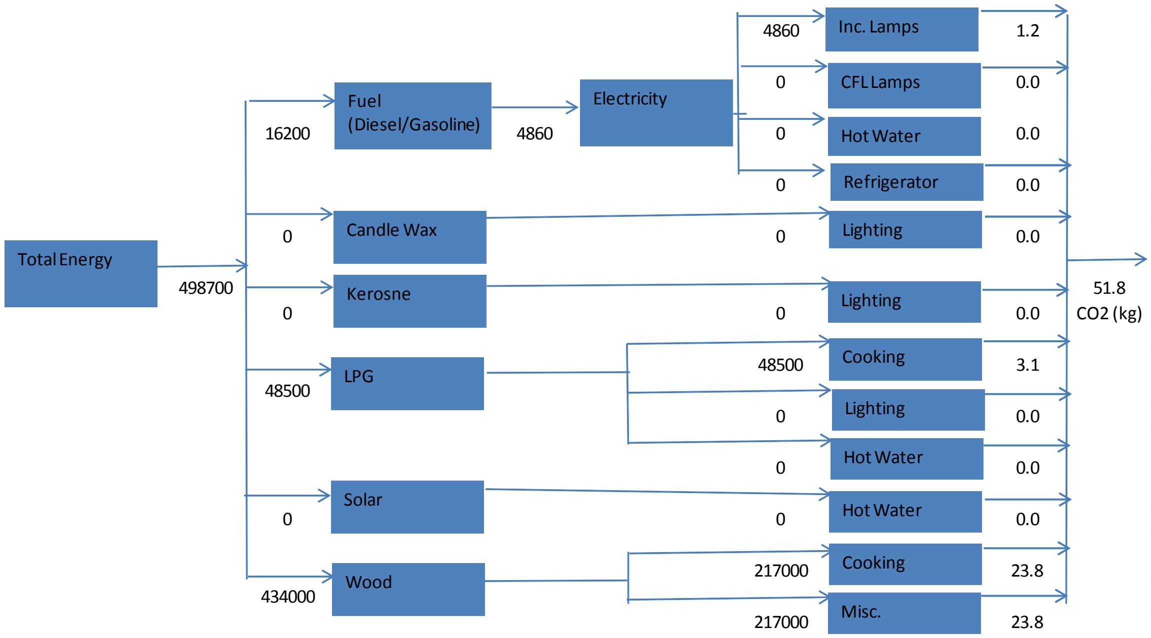


Figure B22: Energy end use model for 21-W.

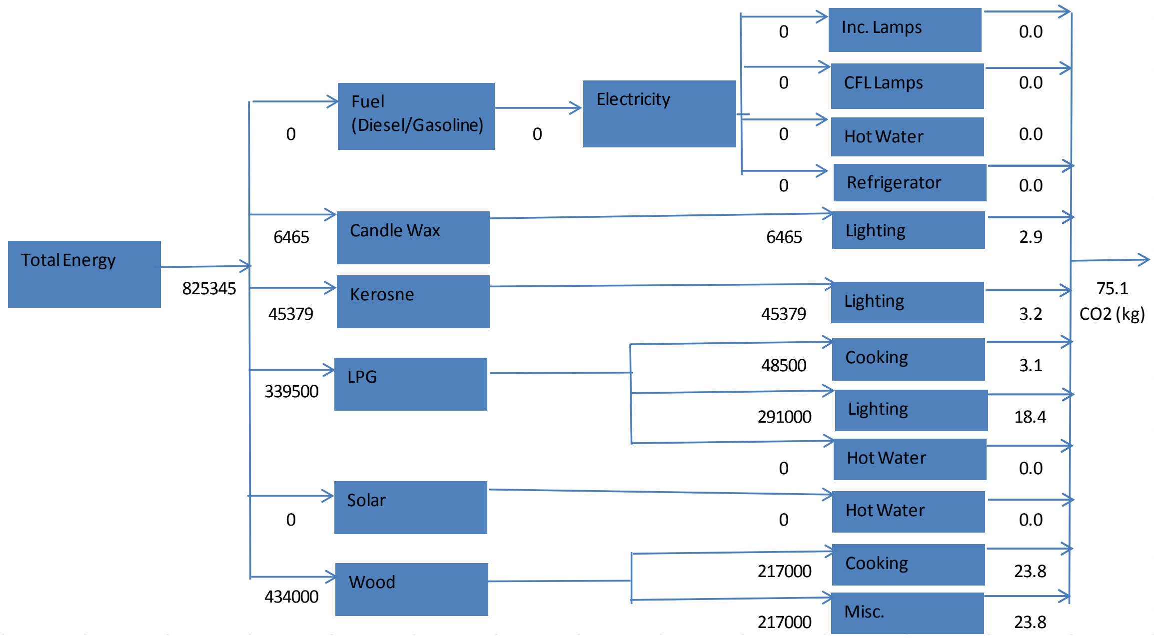


Figure B23: Energy end use model for 23-W.

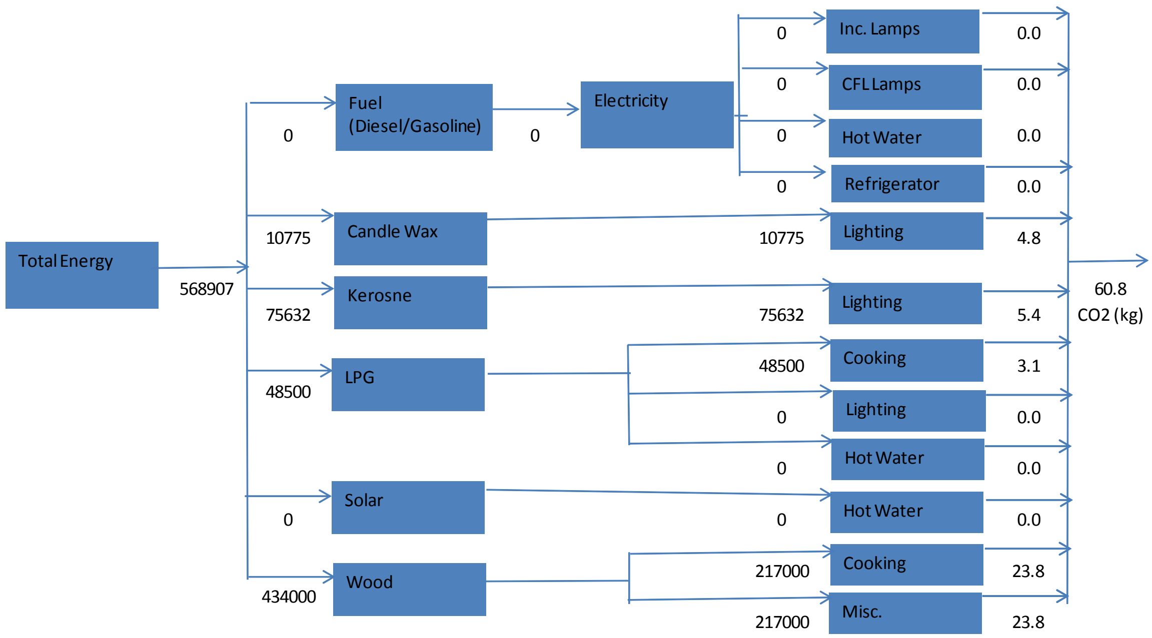


Figure B24: Energy end use model for 24-W.

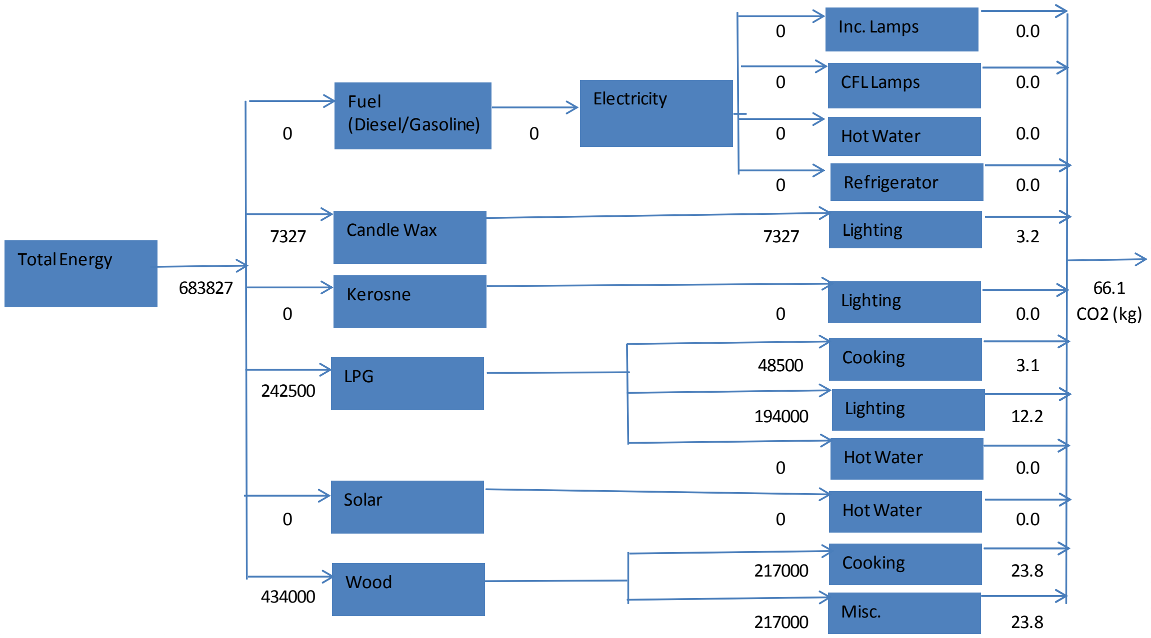


Figure B25: Energy end use model for 25-W.

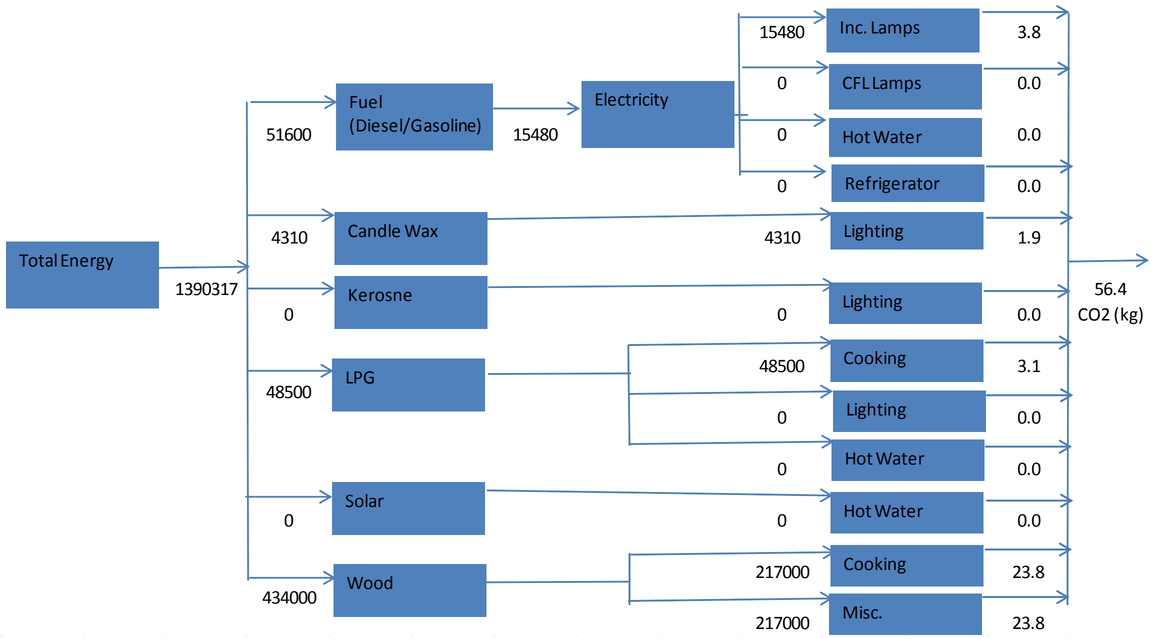


Figure B26: Energy end use model for 26-W.

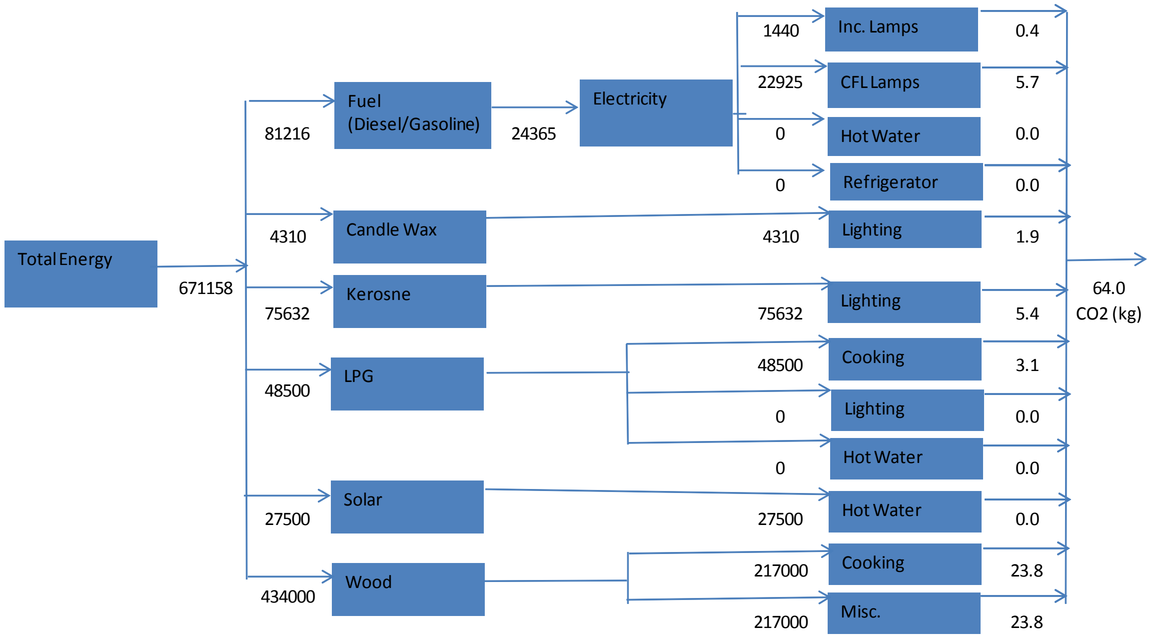


Figure B27: Energy end use model for 27-W.

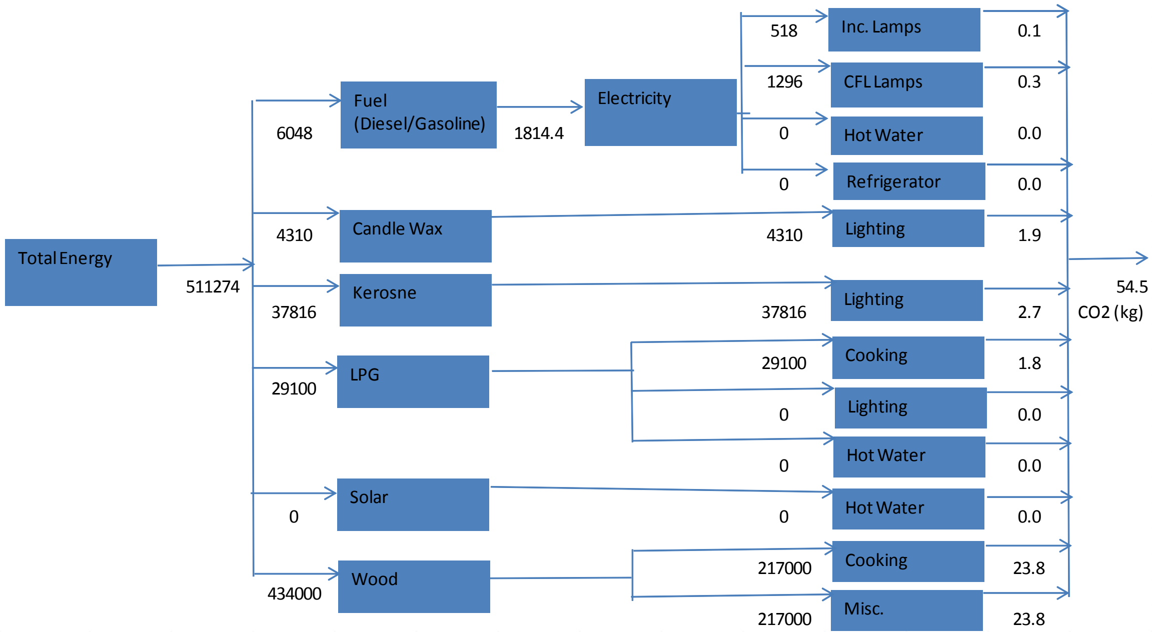


Figure B28: Energy end use model for 1-D.

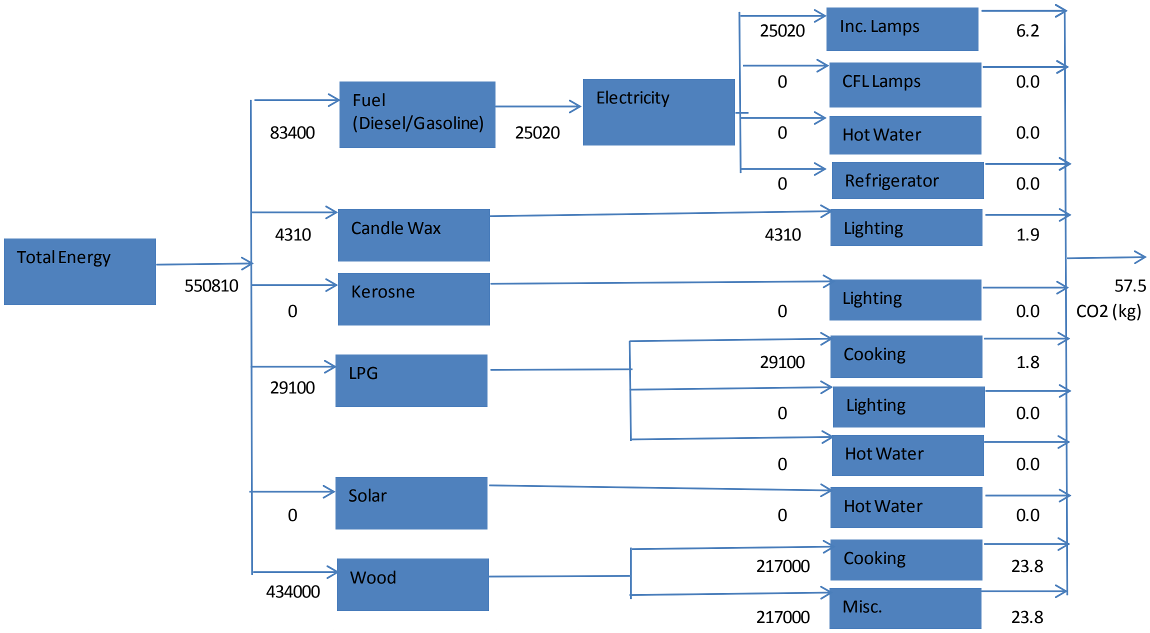


Figure B29: Energy end use model for 2-D.

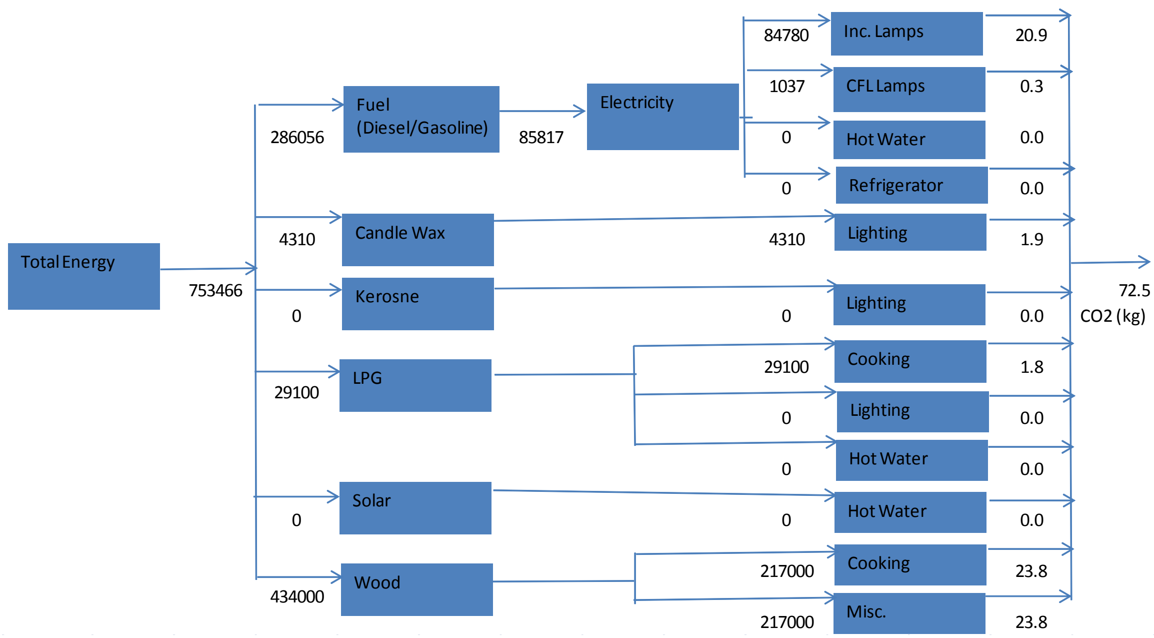


Figure B30: Energy end use model for 3-D.

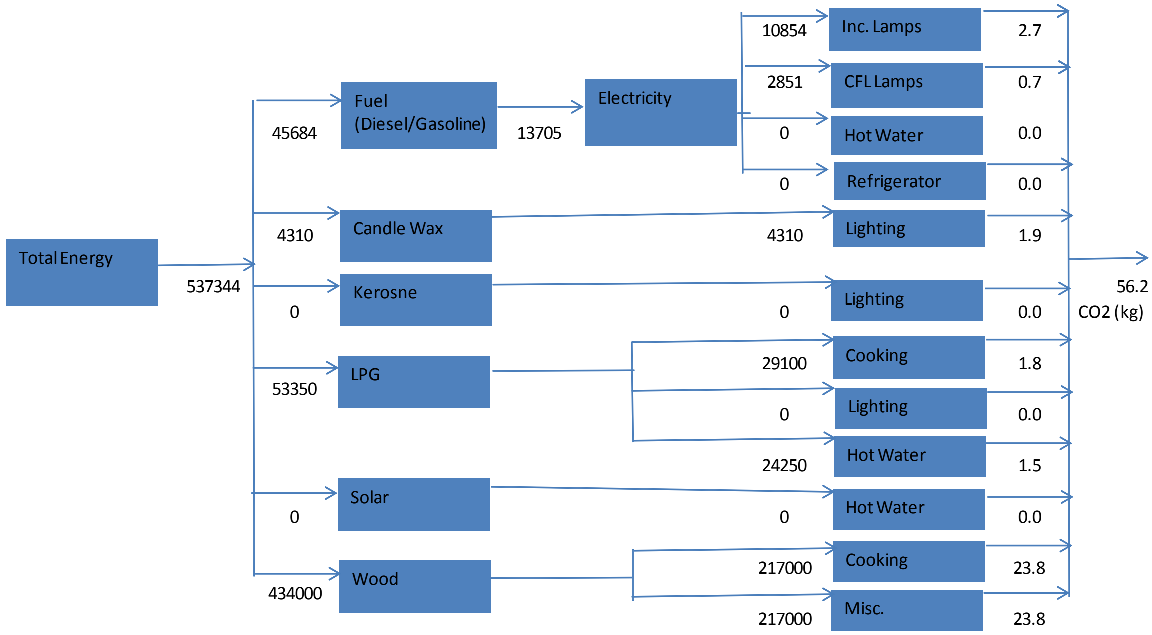


Figure B31: Energy end use model for 4-D.

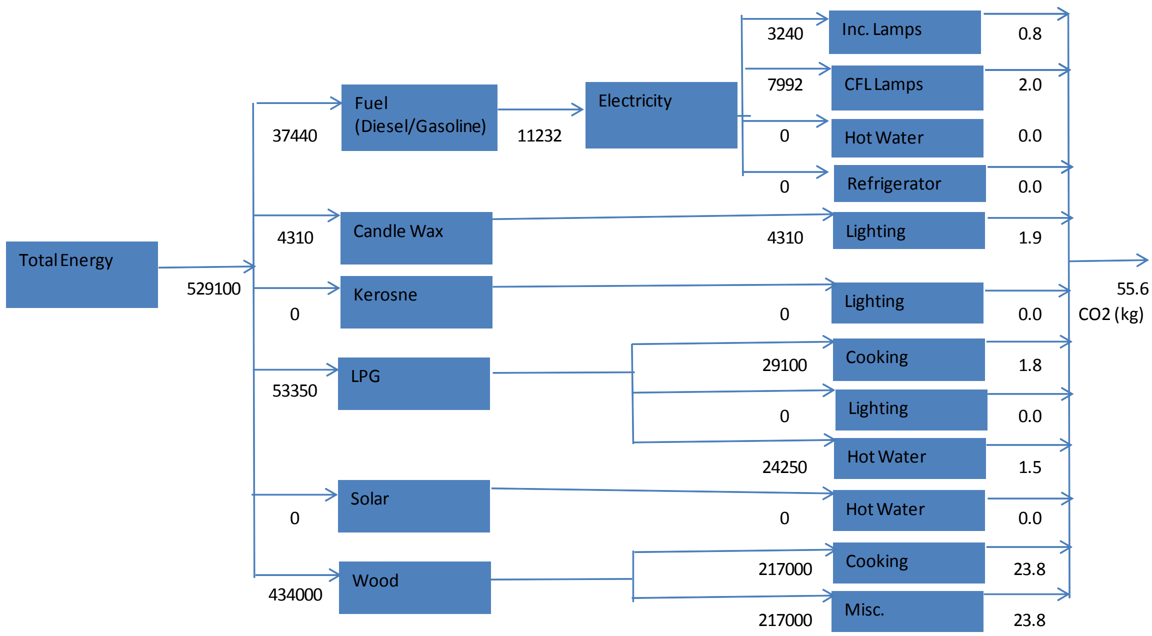


Figure B32: Energy end use model for 5-D.

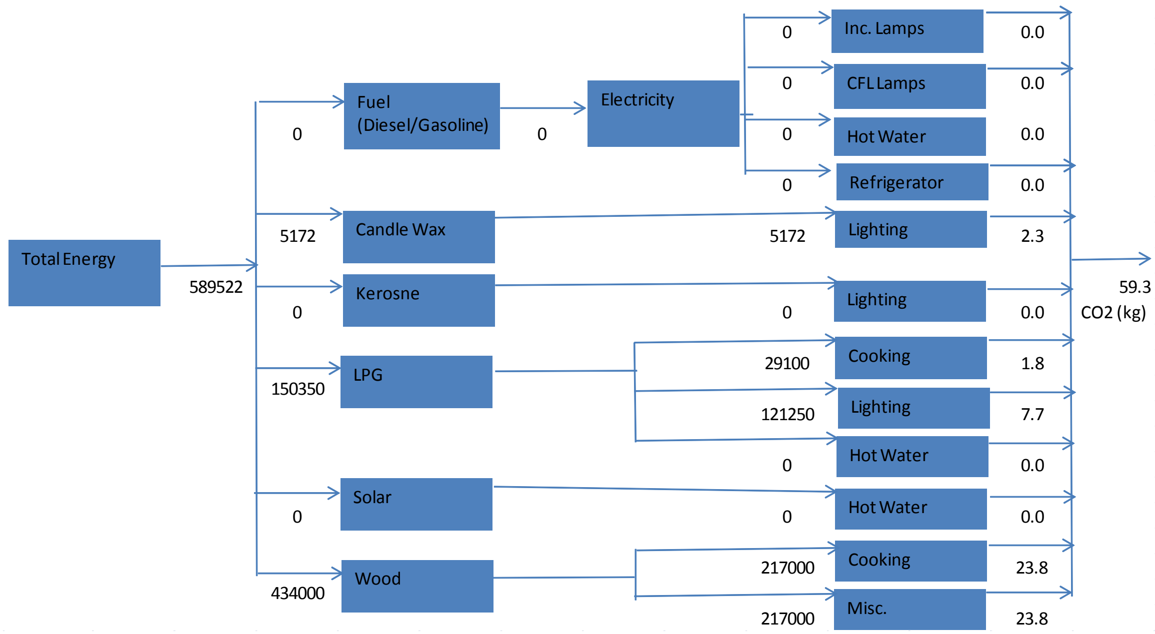


Figure B33: Energy end use model for 6-D.

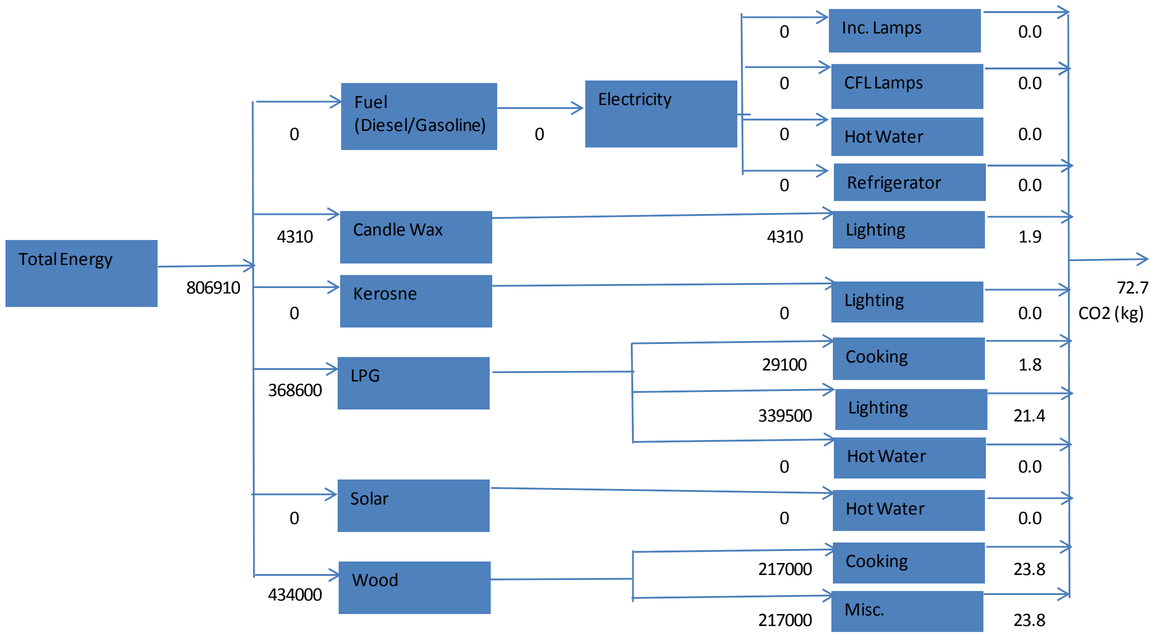


Figure B34: Energy end use model for 7-D.

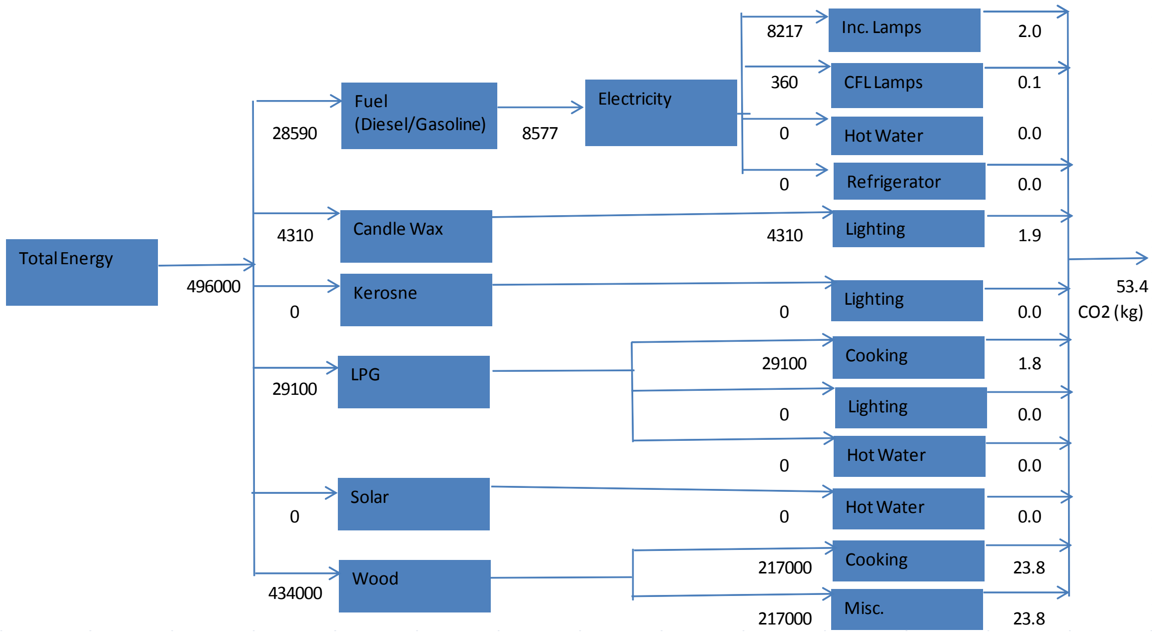


Figure B35: Energy end use model for 8-D.

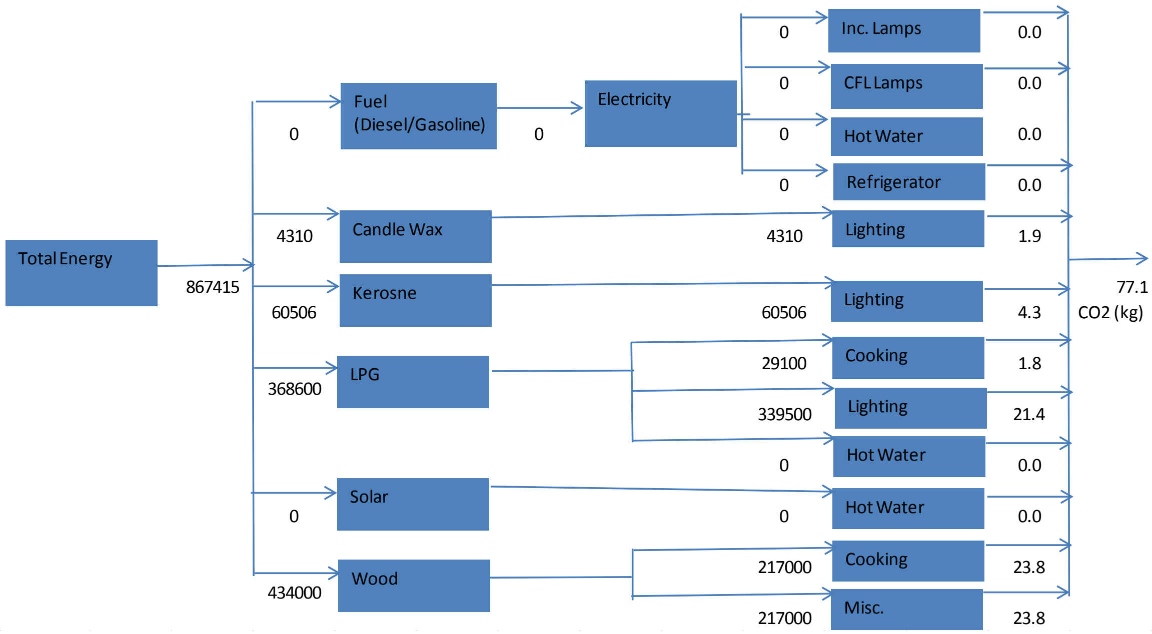


Figure B36: Energy end use model for 9-D.

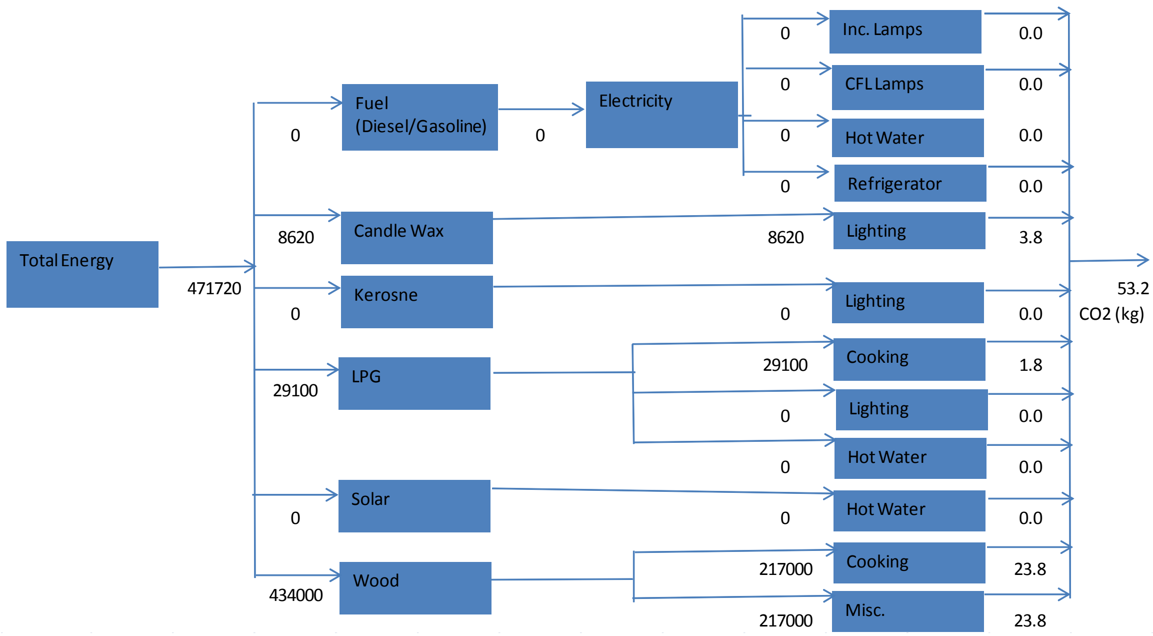


Figure B37: Energy end use model for 10-D.

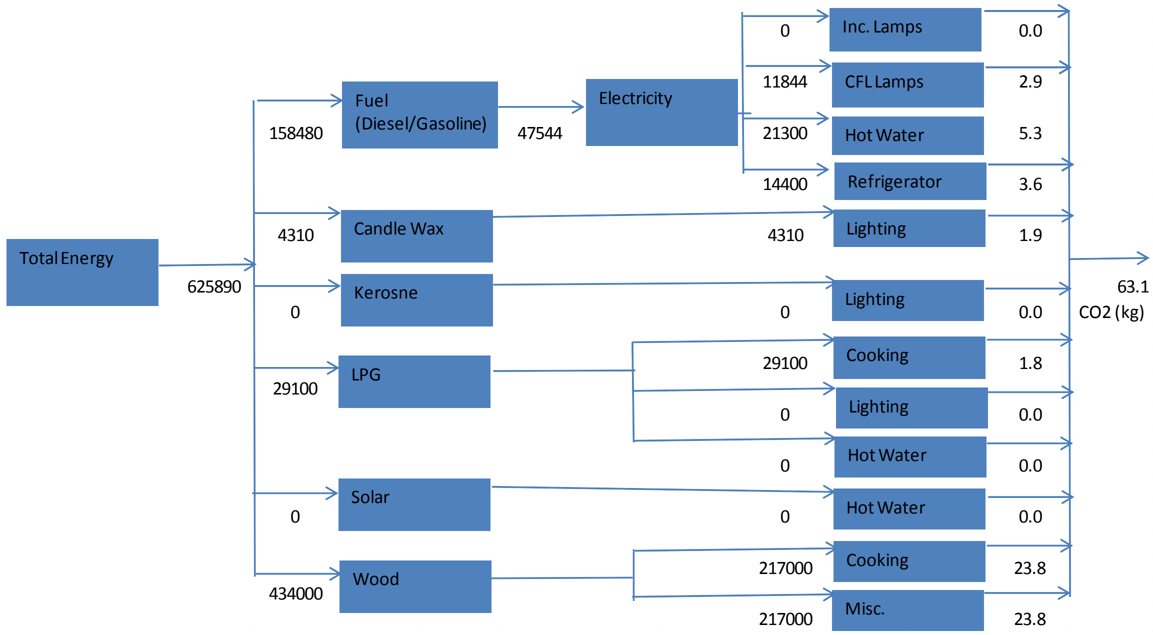


Figure B38: Energy end use model for 11-D.

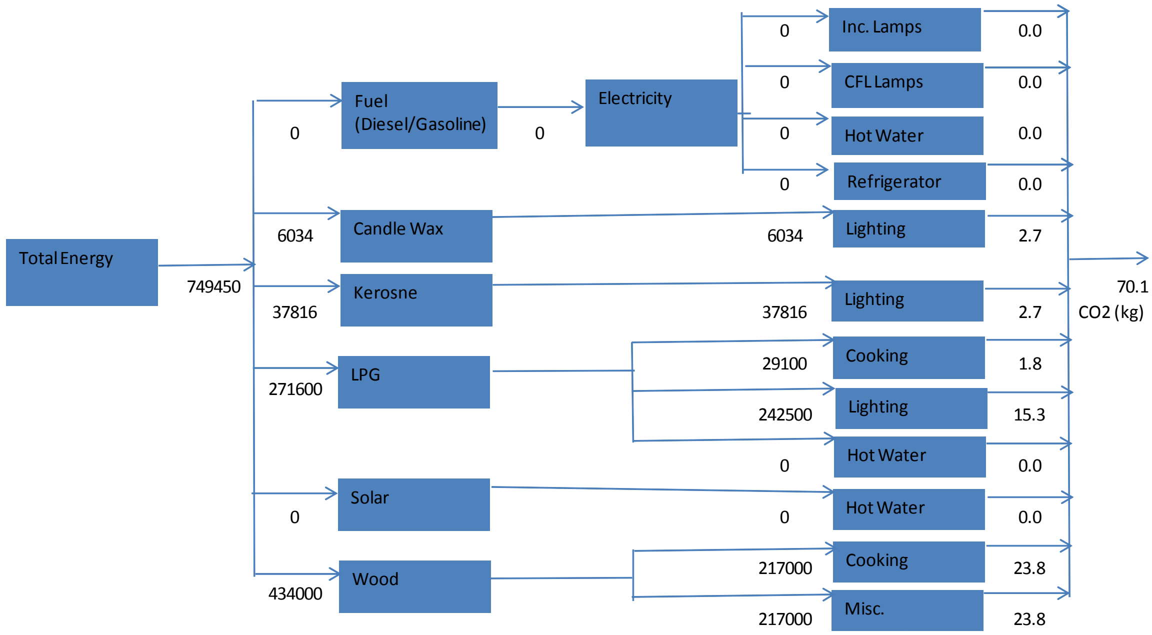


Figure B39: Energy end use model for 12-D.

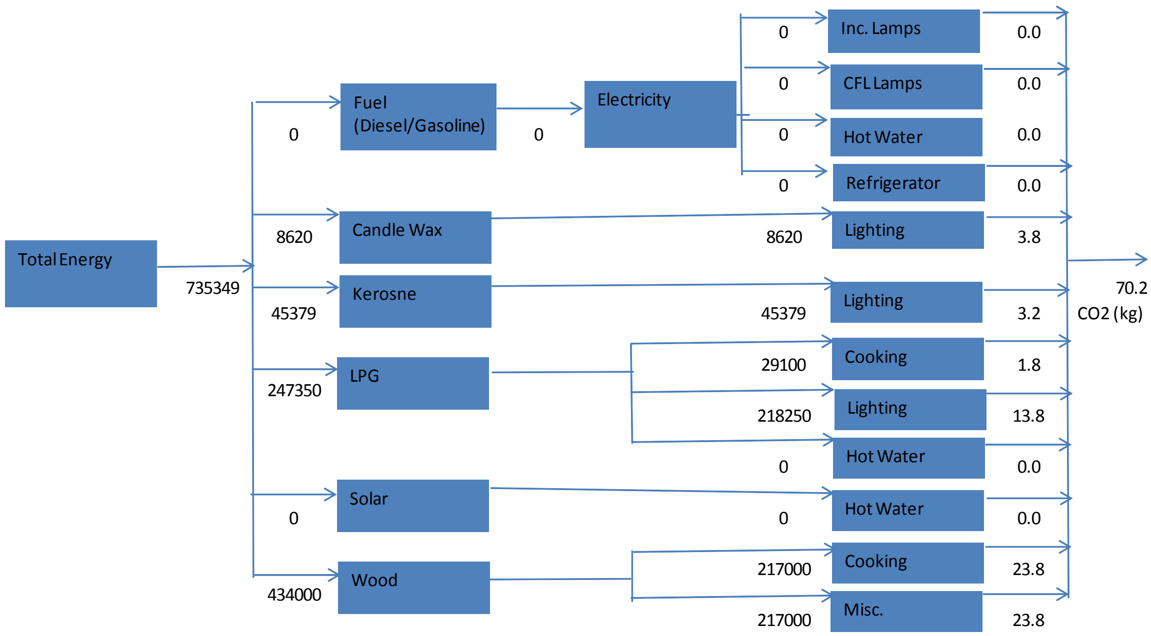


Figure B40: Energy end use model for 13-D.