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Energy Audit for Field Camp K220

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Contents

1 Introduction

To improve efficiency on field camps Antarctica New Zealand wants to introduce a guideline for researchers to help them organising their energy demands in the field. Therefore an energy audit was carried out at the field event K220 from 21 December to 29 December 2009. During the field camp 14 students and 5 supervisors from Gateway Antarctica, University of Canterbury, carried out different activities on the Ice to learn more about the continent, flora and fauna, research and history. This included trips to historic huts, geography at Castle Rock and seal census at Hutton Cliffs. The camp was run very basic to keep the energy demand low. As a result most of the energy was consumed for transportation and cooking.

In the following, the camp as well as the used equipment is described shortly. The energy demanding tools and vehicles are shown and the frequency of usage is presented. After discussing the individual fuel consumptions the total usage is summarized. Then, the energy demands of two other field activities will also be presented based on the gained experience at K220. Finally, they will be compared to each other to gain a better understanding for energy demands and distribution in Antarctic field camps.

2 General information

2.1 The campsite

The K220 field camp is located at Windless Bight on the Ross Ice Shelf 8.8km north of Scott Base in Antarctica. The site is shown in the map in Fig. 1. The coordinates are 77°47'S, 166°59'E. The total duration was 9 days from December 21 to December 29, 2009. The weather during this period was generally calm and mostly clouded. Temperature varied between -1°C and -13°C and wind did not exceed speeds above 8m/s with an average of 2.1m/s.

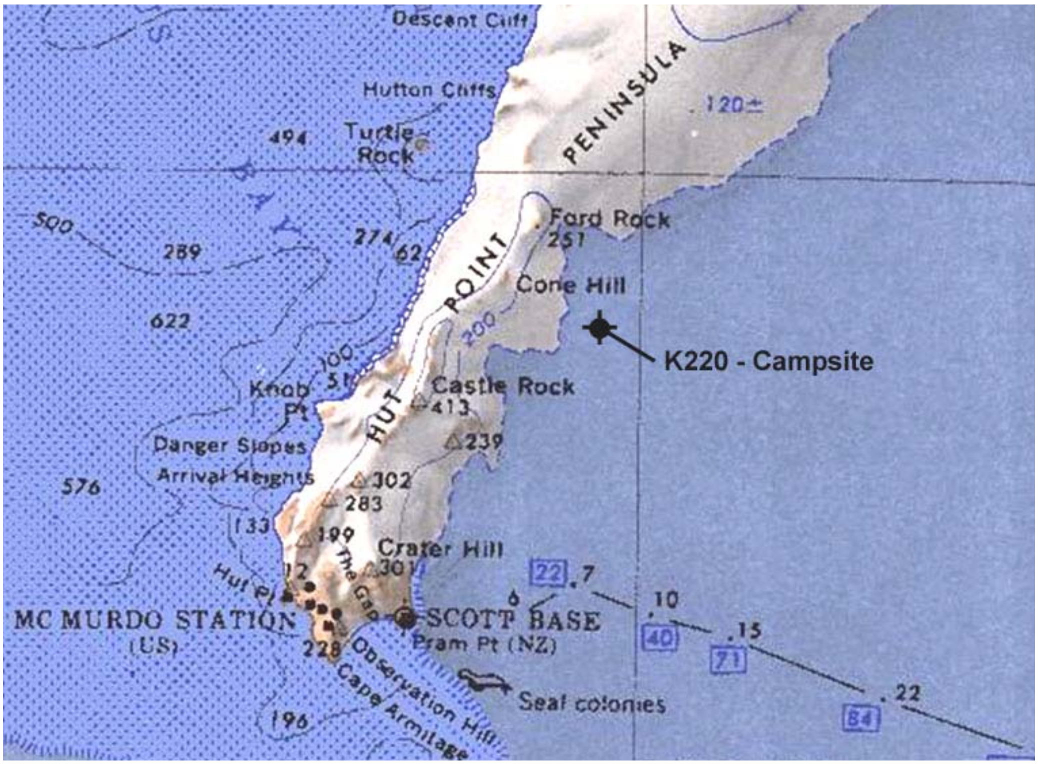

Fig.1 Map of Hut Point Peninsula with marked location of campsite K220 [9]

The campsite setup can be seen in Fig. 2. 19 People were living in ten polar tents arranged in a V-shape open to the north. Each tent could inhabit two persons and cooking groups were arranged in groups of four people with two neighbouring tents. Each group also dug out a sheltered toilet facility nearby their tents. The two groups on the top left shared one toilet.

The big Polar Haven tent was set up beforehand and was used for group meetings and equipment storage. Beside the tent, vehicles and sledges for towing the equipment were parked when not in use.

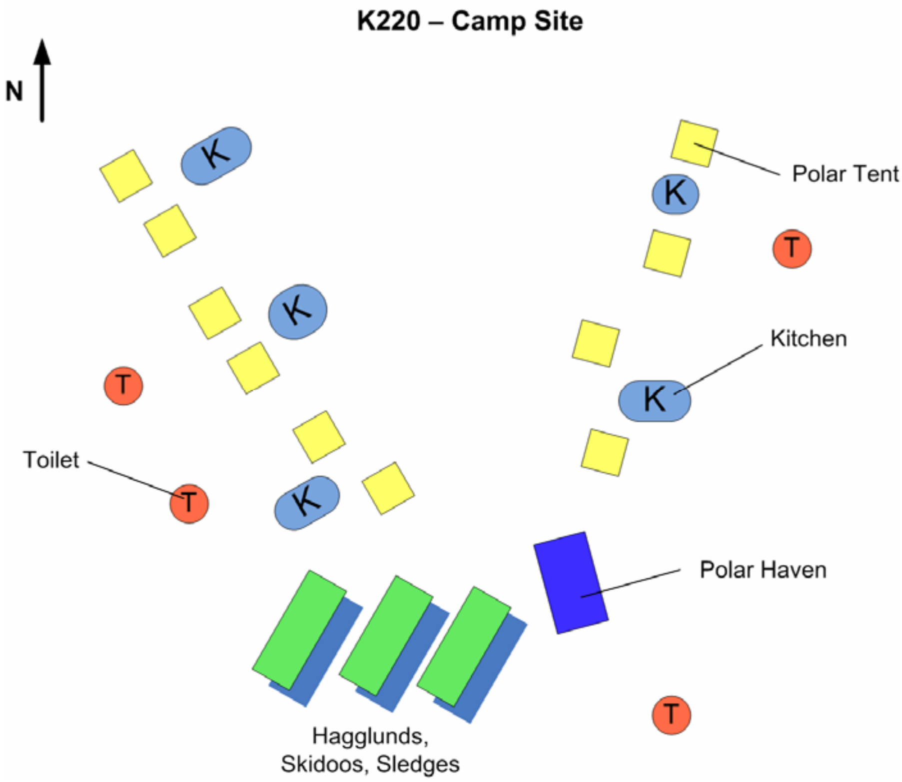

Fig. 2 Setup of K220 campsite on the Ross Ice Shelf

The main purpose of the K220 field campsite was to experience field work in Antarctica in one of the world's most remote and extreme environments. The activities included field safety training and various trips to do research activities and visit historic sites. A timetable about the accomplished activities is shown in Tab. 1.

21.12.2009	Arrival at Campsite, tent setup, building necessary facilities
22.12.2009	AFT (Antarctic Field Training)
23.12.2009	Trip to historic hut at Cape Evans
24.12.2009	Group 1: Trip to Castle Rock (geology), Group 2: Trip to Hutton Cliffs (seal census)
25.12.2009	Christmas Day: Day off at campsite
26.12.2009	Snow pits and ice coring at campsite (glaciology)
27.12.2009	Group 1: Trip to Hutton Cliffs (seal census), Group 2: Trip to Castle Rock (geology)
28.12.2009	Measuring and removing poles at snow stake farm at Windless Bight
29.12.2009	Leaving campsite, packing equipment, removal of all human remains

Tab. 1 Timetable of field activities during the field camp at Windless Bight

2.2 Equipment

In the following, the standard equipment for field camps in Antarctica will be introduced on basis of field camp K220. The use of the different parts is described and weights are given to get an overview over the total amount of equipment necessary for operating a field camp.

Clothes and personnel

For travelling to Antarctica each participant got kitted out with a layering system of warm clothes, including two pair of boots for the cold conditions. The included extreme cold weather clothes (ECW) had to be worn during the flight. The approximate weight of all clothing is 8kg. Persons on the flight were estimated 114kg each including hand luggage and ECW. Other luggage was estimated to 34kg per person. With 19 participants the total weight for personnel, clothes and luggage sums up to 2,812kg. [3]

Tents and sleeping bags

To withstand worst weather conditions, the Polar Pyramid Tents are specially designed for the Antarctic conditions. In the case of a severe storm, it is possible to live and cook in the tent for several days. They are made to accommodate 2 people and got an inner ground area of 2.2m x 2.2m. Each tent weighs 42kg. For K220 field camp 10 tents were needed. [3,11]

The Polar Haven is a bigger tent with a surface area of 3m x 6m. With its wooden floor pallets, it is designed for working in the field. It weighs164kg and was used as a research equipment storage and meeting room. [3]

For sleeping in the cold environment every person got issued a four layer sleeping bag and a thick self inflating mattress. The sleeping bag includes an outer cover, a polar overshell made of synthetic insulation, a heavy down bag for extreme conditions and an inner fleece liner. The total weight of one sleeping kit is 11kg. [3,10]

Kitchen and food

Every four people were sharing a field kitchen box, an LPG 2 burner stove and a 9kg LPG bottle. The Kitchen box included all the needed dishes, pots, cups and cutlery necessary for cooking and eating. The box itself could be used as a cupboard having an additional tray. Its total weight with all the equipment is 19kg [3].

The LPG 2 burner stove from Coleman had additional foldable side flaps for a better wind shelter (see Fig. 3). The maximum cooking power of this stove is 11,000 BTU/h (equals 11.6MJ/h) per burner [8]. Each fully filled 9kg LPG bottle weighs about 20kg [3]. For the K220 field camp five kitchen sets were necessary.

Fig. 3 Coleman 2 burner stove used for cooking in field camps [8]

A standard field food box contains 20 days of easily prepared, highly nutritious food for one person [12]. Including the frozen items supplied in chilly bins the weight sums up to 33kg. At the 9 day field camp one food box was provided for every two persons. The needed water was melted out of ice from around the campsite.

Toilets

As no remains at all were allowed to be left on the ice shelf, toilet facilities had to be installed. Everyone was issued with a 1 litre pee bottle. At the toilets 20l barrels with funnels were used to collect the liquids including grey water. The toilet consisted out of a yellow bucket with a plastic bag on the inside and the outside and a removable plastic seat. At filled buckets plastic bags and buckets were sealed and returned to Scott Base. For disposal the sealed buckets are shipped to New Zealand. A toilet facility can be seen in Fig. 4. 19 pee bottles, 20 pee barrels and 11 field toilets were brought to the campsite having a total empty weight of 73kg [3].

Fig. 4 Established field toilet in Antarctica with a spare bucket and barrel at the top right

Transport

For transportation, snowmobiles and Hägglunds were used. Being a large group two Hägglunds were necessary to visit different sites during the field camp. The cargo was transported by two Hägglund sledges and a Maudheim sledge. For smaller goods, the box type sledges were used and pulled by the snowmobiles.

Hägglunds are amphibious personnel carriers and can carry up to 13 people. Two of those were used for moving people and cargo while one of them stayed at the camp permanently. The gross vehicle weight of the used Hägglunds is 6,200kg (including a load capacity of 2,250kg) [7]. It can additionally tow a load of about 2,500kg on a sledge. Fuel consumption is 1 litre per 1 km. Two Hägglund sledges were used for towing the equipment and stayed at the campside. The total carrying capacity of each sledge is 2,000kg. An additional Maudheim sledge was used to tow the Polar Haven tent to the campsite. [3,7,12]

For different tasks, two skandic snowmobiles were taken to the campsite. Each of them weighs 250kg and towed a box type sledge with a maximum carrying capacity of 450kg [3,12]. Fuel consumption of these snowmobiles is around 1 litre per 2.3km.

Research and safety gear for activities

Additional to the general equipment, safety gear like first aid kits and rescue had to be carried along at each trip. Radios were brought along for communication between groups within the camp and Scott Base. Furthermore climbing gear and different other equipment was necessary for some activities. Research equipment for weather observations and ice coring was also taken to the camp. The total weight of all additional equipment was 765kg [3].

3 Energy consumption

In the following chapter, the energy consumption during field camp K220 will be presented. The total energy usage can be split in three main topics: Living, Transportation and Research. These topics will be regarded separately and later combined and discussed in summary.

3.1 Living

In camp K220 two different energy appliances were used. The main energy supply needed was LPG gas for cooking. The other necessary equipment was the set of radios for communication when groups went away from campsite and for the obligatory contact to Scott Base twice a day. No heating for tents was used, but the different tent temperatures were recorded to obtain data about insulation and heating from sun radiation.

Cooking

The Coleman PerfectFlow™ InstaStart™ 2-burner stove with large and independently adjustable burners was used for cooking groups of four persons. Only one group shared a kitchen within three persons. The stove was also used for melting the necessary drinking water and had a maximum heat output of 23.2MJ/h. [8]

The LPG used for cooking was a propane (60%) and butane (40%) mix. Its energy density is 49.6MJ/kg [5]. The heating value, or also called calorific value, of LPG (46.1 MJ/kg) is better than the values of diesel (42.5 MJ/kg) and petrol (43.5 MJ/kg) [1]. The 9kg LPG gas bottles were weighed every day to measure the daily energy demand. Results are shown in Fig. 5. The red line describes the average usage of all cooking groups. Water for the arrival day was taken from Scott Base in private water bottles and energy demand for small meals in the evening are included in the second day’s measurements. Weights on 21 December 2009 are the original weights before using the burners.

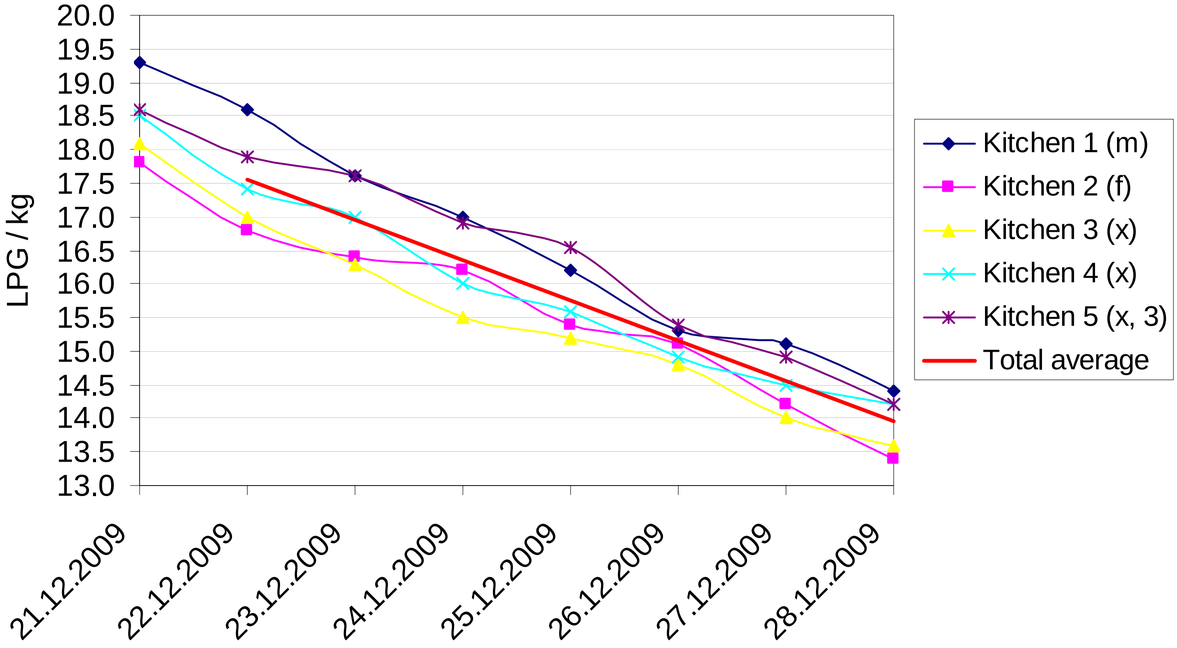

Fig. 5 LPG bottle weights each day for the five different kitchens and the total average of LPG gas usage (red)

It can be seen that kitchen 5 needs about the same amount of gas for cooking, although it was a group of only three people. Furthermore, there are no significant differences between female (f), male (m) and mixed (x) groups. Two missing persons at kitchen 2 on 26 December 2009 could be interpreted as a little decrease in consumption. However there are similar variations through all the different demands for the kitchens.

The energy consumption is also dependent on many other parameters like different cooking efforts for different dishes, wind and temperature outside, amount of water and food needed (dependent on activities). Overall an average of 0.60kg of LPG was needed for each cooking group on a full field day not regarding arrival and departure day (see red graph Fig. 5). This equals an energy demand of 7.8MJ per person per full day (0.16kg LPG). In total the K220 field camp used 22.5kg of LPG, equalling a total energy consumption of 1,116 MJ. The detailed information about the measurements is shown in Appendix A.

Downsizing groups would lower the efficiency and increase the daily energy demand per person. Bigger group sizes of six or more people cannot be recommended as pots and dishes are too small to handle bigger servings. As the pots are most suitable for the cooker, sizes cannot be increased. Therefore cooking groups of four people and the current cooking equipment are a very efficient way of cooking in the field. As the total number of participants in a field camp is usually smaller, the effort of implementing a big field kitchen for large groups cannot be justified.

Radio transmission

For communication between groups leaving the campsite and the two daily control calls to Scott Base, 5 Motorola GP328 radios with additional 5 spare batteries (NiCd, 7.5V, 1500mAh) were available. The battery life is between 8 and 10 hours dependent on the settings [6].

The battery charge was maintained by 2 Motorola chargers (15.3W) each powered by 2 Soltec-M1136 (12V output) solar panels (see Fig. 6). The radiation at late evenings on a cloudy day was still high enough to charge the NiCd batteries. On 23 December 2009 at 22:30 cloud coverage was 100%. The radiation measured was still around 130W/m². Both solar panels had a power output of 1.2W at a voltage of 9.3V. Solar radiation only dropped below this value for about 1 to 6 hours each night, depending on cloud coverage and thickness. Radiation and cloud coverage diagrams are shown in Appendix A.

Fig. 6 Two Soltec-M1136 solar panels for powering the battery chargers of the Motorola GP328 radios

Due to the good performance, all radio batteries could be charged and maintained by these two solar chargers. With enough spare batteries and a low self discharging rate, no additional backup systems were necessary. Estimating an average usage of about 1h daily at the 9 days of field camp, a total amount of 46kJ was used.

Insulation and heating

In field camp K220 no additional heating was used. Nevertheless, temperatures inside the tents were recorded to gain information about insulation and heating by radiation. Three types of tents were used at the campsite:

- The Polar Haven tent (see Fig. 7a) has got a ground surface of 3m x 6m. The floor surface is insulated by a wooden pallet floor against the snow and the fly consists of two thick layers of canvas sewed together. A blue outer layer and a grey inner layer are held by a stable pole structure and anchored to the ground by several ropes. The doors (two at each side) are closed by zippers and additionally sealed by Velcro.
- The standard Polar Pyramid Tent (see Fig. 7b) has got a ground surface of 2.2m x 2.2m. It consists of a thick waterproof floor and a two layer fly - a very though outer canvas (yellow) and a thin inner nylon layer creating an air gap of about 10cm in between each other. The tunnel door entry can be closed by ties. Additionally the tent had two ventilation pipes for fresh air supply. The ground part of the fly was covered with ice and snow to achieve a good insulation against the wind.
- The difference of the new Polar Pyramid Tent (see Fig. 7c) compared to the standard Polar Tent was only the slightly darker colour of the outer fly and the lightweight multipart aluminium poles for better transportation. The floor, the two layer system of the fly and the size were designed equally.

(a)  (b)  (c) 

Fig. 7 Three tent types used at field camp K220: a) Polar Haven, b) standard Polar Pyramid Tent, c) new Polar Pyramid Tent

Fig. 8 shows the tent temperatures compared to the outside air temperature (green). The temperature in the Polar Tents (red) is about 5 to 15 degrees warmer than the outside temperature at any time of the day. Regarding the new Polar Tent (orange) and its slightly darker colour, heating by radiation was slightly improved in comparison to the standard Polar

Tent. The temperature in the Polar Haven tent (blue) is very similar to the other tents. The increase of temperature by body heat due to long group meetings in the tent can be clearly seen in the diagram. The peaks are marked by arrows.

The dependency of the temperature from radiation values can be verified the grey temperature graph recorded outside with the probe not being covered against the sun. The records show a higher temperature on sunny days compared to the real temperature. This can be validated by the cloud coverage diagram in Fig. 9. On sunny days the tent temperature increases more than 15 degrees over the outside temperature during the day. In sunny nights heating of about 8 degrees was achieved.

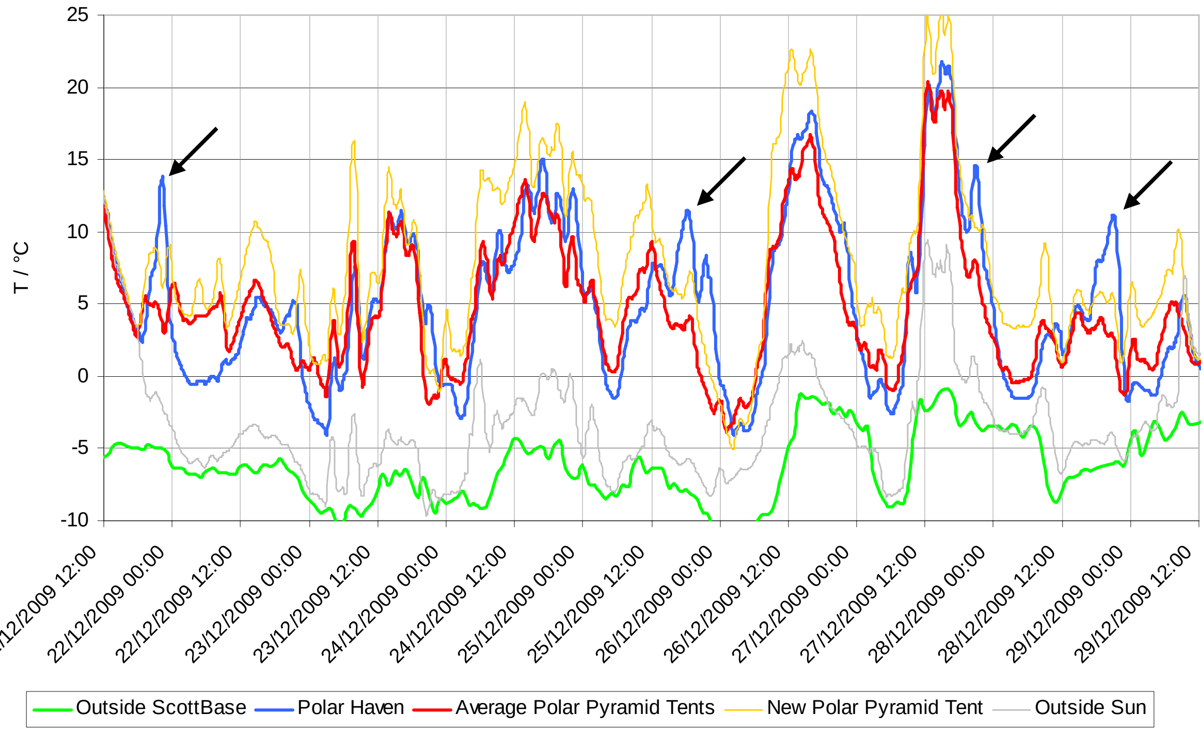

Fig. 8 Temperatures at field camp K220 outside and inside the different tents

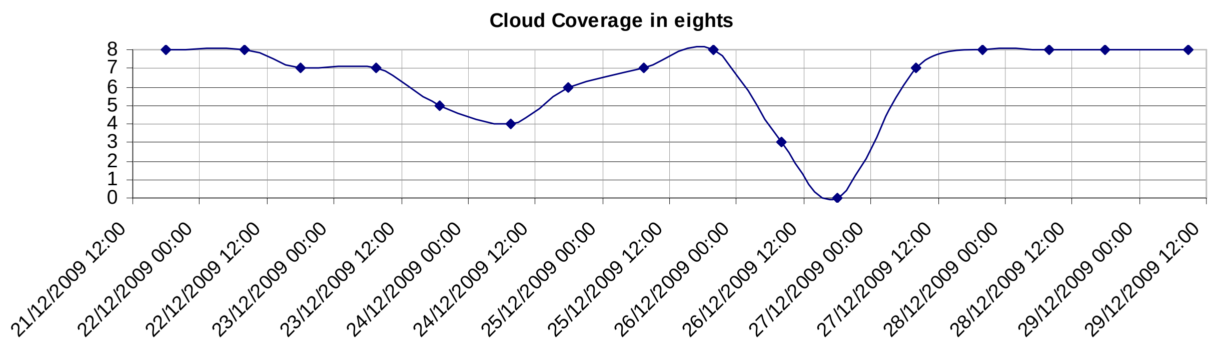

Fig. 9 Cloud coverage in eights during field camp K220 recorded twice a day

Although an increase of temperature by body heat was expected in the Pyramid Tents, no significant change between empty tents, one person tents and fully inhabited tents could be measured. Some tents were empty for some nights while the same temperature as in other fully inhabited tents was recorded in them. Therefore most of the body heat must be kept in the sleeping bags. This approves a very good insulation of the sleeping bags and the suitability for extreme conditions.

3.2 Transportation

Having already described the different vehicle types used, this chapter covers the fuel usage for different trips made during the field camp. The Hägglunds were mainly used to carry the equipment for setting up the campsite and to move big groups of people to the different locations. As emergency kits for every person had to be carried along to every location, two Hägglunds were necessary to move the whole group of 19 people and a field assistant from Scott Base. Snowmobiles were used for smaller tasks and were kept at the campsite for emergency reasons. The tables with all the vehicle specific trips are shown in Appendix B. In the following, the trips and hence the individual energy consumptions are split in five different groups:

- **Training:** To be allowed and able to handle a vehicle type around Scott Base, the driver had to undertake a special driver's training for Antarctic conditions. This was also necessary to learn how to interact with traffic on marked routes.
- **Transportation to the campsite:** This category includes the rides for moving all the gear to the campsite as well as returning it to Scott Base. It also covers the rides of the field assistant from Scott Base to support the group at some activities.
- **Scheduled and research:** All trips which were planned to be made in Antarctica are covered under this topic. Transports necessary for research activities are included as well.
- **Recreational:** All unplanned trips for recreational purposes are listed in this section
- **Emergencies:** Unexpected trips being carried out for emergency reason are included in this section.

Tab. 2 shows the trips and the driven kilometres for each topic. The vehicle type is specified for each activity. (h) stands for Hägglund and (s) stands for snowmobile transportation. For each section the total fuel consumption is calculated and presented.

	Activity	km	vehilce
Training			
	Skidoos	28.4	(s)
	Hägglunds	16.1	(h)
	Total:	28.4 km - 12.3 l	(s)
		16.1 km - 16.1 l	(h)
Transportation to campsite			
	Arrival	17.6	(s)
		44.0	(h)
	Departure	17.6	(s)
		44.0	(h)
	Support peronnel for activities	87.4	(h)
	Total:	35.2 km - 15.3 l	(s)
		175.4 km - 175.4 l	(h)
Scheduled and research			
	Castle Rock	32.0	(h)
	Hutton Cliffs	67.0	(h)
	Cape Evans	148.4	(h)
	Ablation Stakes	58.0	(h)
	Weather and Glaciology	51.0	(s)
	Total:	51.0 km - 22.2 l	(s)
		305.4 km - 305.4 l	(h)
Recreational			
	Room with a view	60.0	(s)
	Total:	60.0 km - 26.1 l	(s)
Emergencies			
	To Scott Base and back	17.4	(h)
	Total:	17.4 km - 17.4 l	(h)
Total:	Hägglunds (1 l/km)	514.3 km	514.3 l diesel
	Snowmobiles (0.43 l/km)	174.6 km	75.9 l petrol

Tab. 2 Different trips and travelled distances with Hägglunds and snowmobiles during field camp K220

Regarding the average fuel consumption of diesel (1l/km) for Hägglunds and petrol (0.43l/km) for snowmobiles, a total amount of 514.3 litres diesel and 75.9 litres petrol was needed. The vehicles have been refuelled at Scott Base and from 20l fuel barrels during trips. Each Hägglund carried 2 spare fuel barrels at all activities. The average consumption values were gained at Scott Base through long time experience in operation under Antarctic conditions.

The energy density of the fuels is 34.2MJ/l for petrol and 38.6MJ/l for diesel [5]. This results in a total energy consumption of 22,448 MJ. The percentage of energy demand in each transport section is shown in Fig. 10. Over half of the total energy demand (56%) was consumed by the intended activities. 8% of the energy was used for essentials (Emergencies and Training) and only 4% were used for recreational purposes. The rest of the total demand (32%) was needed to establish and remove the campsite with all equipment and participants.

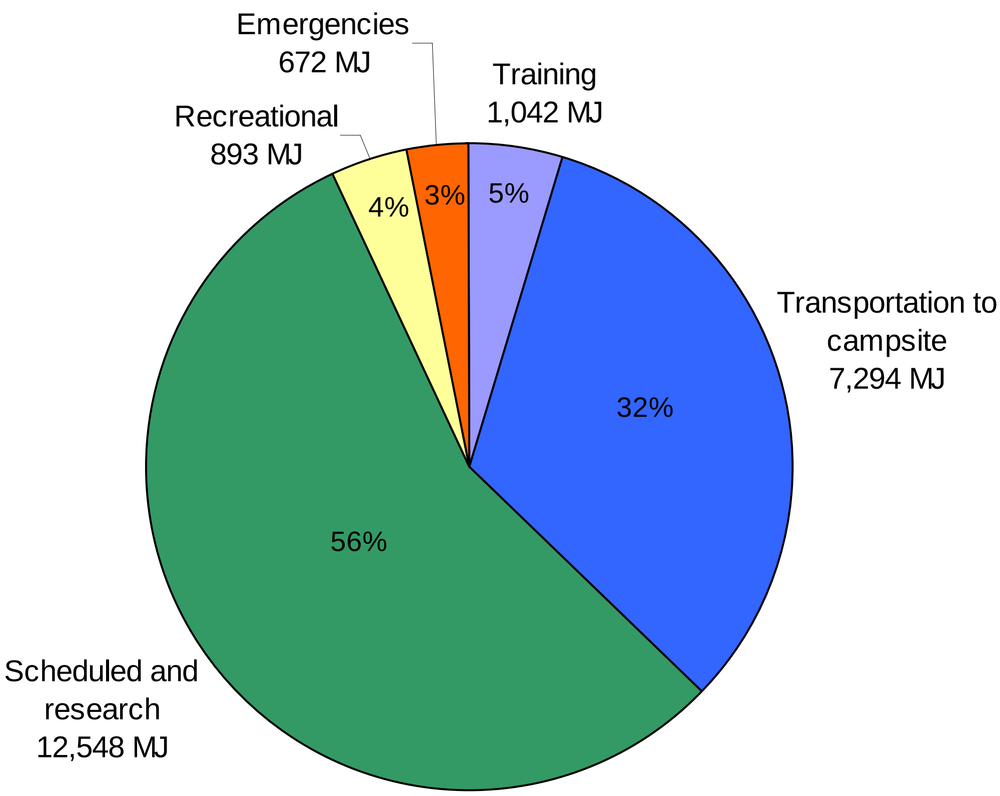

Fig. 10 Fuel consumption in different sectors of transportation at K220

Considering the proportions of the different sectors the camp has been run efficiently. As in field camp K220 the “scheduled and research” sector should obtain the highest percentage possible. The energy consumption in other sectors has to be kept low. Recreation should not be regarded as an unnecessary component as it supports the whole team dynamics. Nevertheless, energy consumption for recreation should be kept as low as possible. Only being one short trip for the leaders at field camp K220 the amount of energy used can be accepted.

One third of the total fuel consumption is used for transportation and setup of the campsite. To check the sector’s efficiency vehicle choice and number of trips has to be considered. Carrying an amount of 2,270kg of equipment and additionally 19 participants with luggage (estimated 2,812kg) to the campsite three Hägglund rides are acceptable. Although the weight could have been carried by two Hägglunds, the effort of fixing the often bulky luggage to only two vehicles and thereby risking the loss or damage of equipment is too big. Snowmobiles had to be driven to the campsite as they were necessary for some activities.

Concerning the regular need of one additional staff member for activities, energy demand could have been reduced by 15% (3,374MJ less energy consumption) if the field assistant would have stayed at the field camp. Simultaneously the second Hägglund would have had to be available permanently for the K220 event. With this energy reduction the “transportation to campsite”-sector would only need 21% of the total transportation demand. However, the possibility has to be questioned as the Hägglund and the field assistant may have been needed on base during the K220 field camp period.

3.3 Research

For the field camp K220, a lot of different equipment was taken along to work on different projects. The gear using power was needed for weather observation and glaciology. In Tab. 3 all energy consuming gear is presented. Most of the equipment was powered by non rechargeable batteries and therefore only used an insignificant amount of energy. Most energy was consumed by the combustion engine driving the ice corer.

During the use of the ice corer drive for receiving about 6m of ice core, 0.3l of petrol were needed which equals an energy demand of 10.3MJ. The laptop for weather observation was recharged by a gel cell battery which was trickle charged by a flexible solar panel (USF-11). Total energy consumption for that was at about 146kJ. A 1kW generator was available for backup at the field camp but was not used at any time. The total amount of energy used for the research equipment can be estimated as 11MJ.

Qty	Euqipment	Brand	Power Supply	Bat. Life	Runtime	Energy use
1	Automatic Weather Station	HOBO	4x AA batteries	1a	6 days	
1	Laptop	Panasonic Toughbook	10.65V, 5.7Ah Li-Ion battery	9h	6h	146kJ
1	Laptop Charger	Panasonic Inverter	12V, 7Ah gel battery			
1	Solar Panel for laptop charger	USF-11	12V, 11W			
1	Radiosonde		6x AA batteries		3h	
1	Radiosonde Receiver		12V, 7Ah gel battery		3h	
1	Radar		2x 12V, 7Ah gel bat.		not in use	-
2	GPS handheld		2x AA batteries		2h each	
1	Drive for KOVEX Corer	EH035 (1.16kW)	Petrol (0.65l tank)		0.5h (0.3l petrol)	10.3MJ
1	Generator (backup)	Honda EU10i	1kW, petrol (2.3l tank)	8h	not in use	-

Tab. 3 Energy consuming research equipment used at field camp K220

3.4 Summary

The three main topics have shown the energy consumption in each field of interest. In total, an amount of 23,575MJ has been needed in field camp K220. Comparing these three sectors over 95% of the total energy were needed for transportation (see Fig. 11). 4.7% were needed for living and only a very small amount of 11MJ (equals 0.04%) was used for research equipment.

An amount of 0.2MJ was provided by renewable energy. In K220 this energy was provided by solar panels. The rest was provided by fossil fuels. 22.5kg (1,116MJ) of LPG gas was used for cooking and living. A total of 437.2kg (514.3l, 19,852MJ) of diesel and 54.9kg (76,2l, 2,606MJ) of petrol were used for transportation and research. This adds up to the total amount of 514.6kg of fossil fuels.

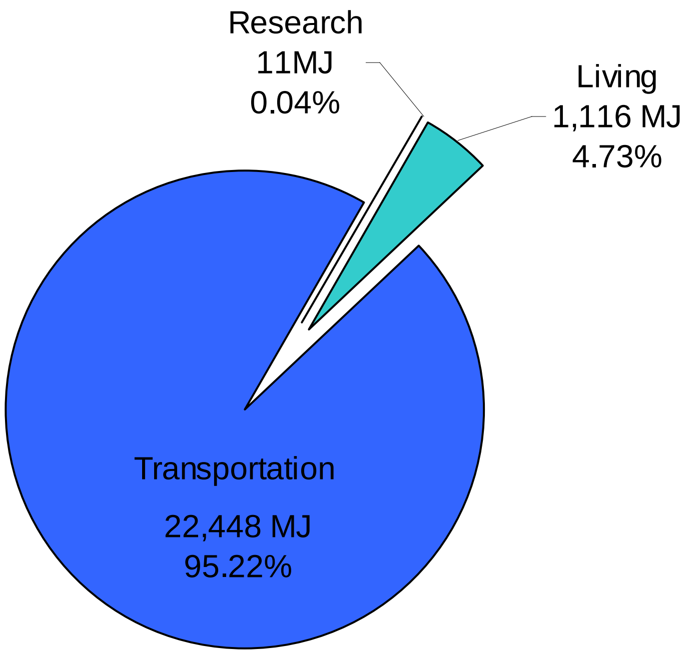

Fig. 11 The total energy consumption of 23,575MJ at field camp K220 split up in the introduced three main sectors

The diagram in Fig. 11 shows the energy demand strictly divided into the different topics introduced in this chapter above. Therefore, transportation necessary to accomplish research was not regarded as a part of research. To achieve a more meaningful arrangement of sections, the transportation sector has to be divided and included in the appropriate sections.

In Fig. 12 all the energy demand needed for the actual purpose of the camp – this means planned trips and transportation to sites for research – is included in one section "research and planned trips". The section "living" includes all necessary applications at the campsite as cooking and the daily radio schedule. Transportation of participants and equipment to the campsite, the necessary logistics for departure and campsite removal as well as the obligatory training lessons for drivers were included in the section "logistics and training". The other minor or unexpected energy demands like recreational trips and emergencies were covered in the section "others".

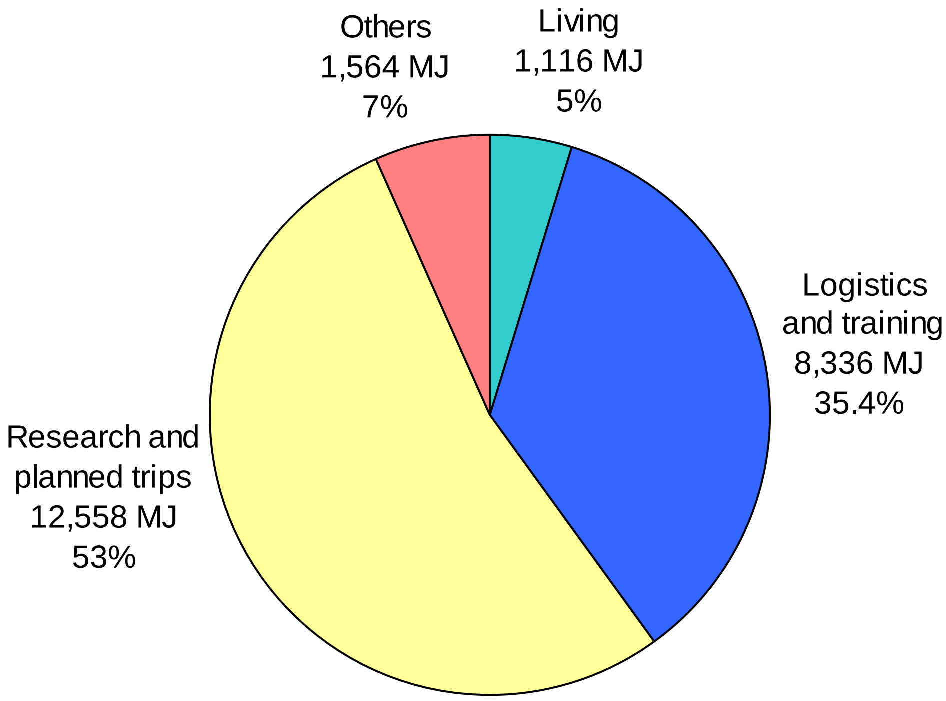

Fig. 12 Distribution of the total energy demand at field camp K220 with the integration of related transportation demands in the corresponding sector

It can be seen that the actual purpose of the trip consumed more than half of the energy. The other main section of over one third is transportation for setting up the campsite. Only 11.3% of the total demand was used for living and non purpose related activities.

Generally the campsite was run economically. A minimum amount of energy was used for living and only necessary equipment was taken along. Due to the number of people participating at field camp K220, the number of rides could not be reduced. In total an amount of 1,240MJ per person was needed for the whole trip, equalling an amount of 32 litres of diesel. Regarding this amount which includes everything from living to activities and transportation for 9 days the camp was run very efficient and can be taken as an example for low energy field camps in Antarctica.

4 Other field camps

In the following, two other field camps will be presented and then compared to field camp K220. The information was obtained by interviews with Professor Bryan Storey and Dr. Wolfgang Rack from Gateway Antarctica at the University of Canterbury. Necessary assumptions about the amount of energy needed were made with the experience from field camp K220. In future, further field camps can also be easily revised with this existing data.

4.1 Field camp – K053

Field camp K053 was undertaken from 1 November until 10 November 2008 to install ablation stakes at two sites L1 and L2. A four day field camp was carried out at site L2, 40km away from Scott Base, while the researchers were living at Scott Base to install snow stakes at the site L1, only 15km away. The team consisted of three researchers and one field assistant on the first day to set up the camp. All energy demands for living in the field and transportation are regarded for this field camp. Daily trips from Scott Base to site L1 are included in the corresponding research section. The energy for living at Scott Base is not included. A detailed table of trips and energy demanding activities is shown in Appendix C.

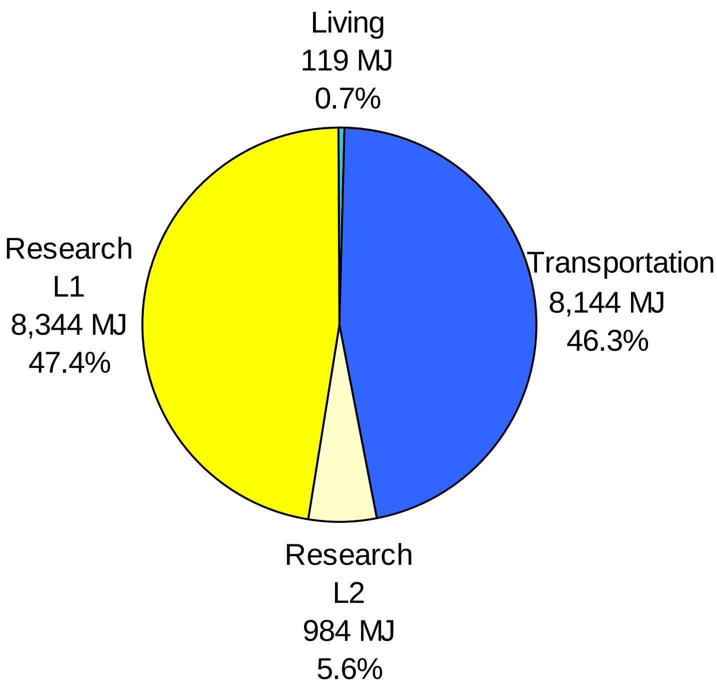

Fig. 13 Distribution of the total energy demand in field camp K053

The total energy demand of activity K053 was around 17,600 MJ. The distribution in the different sectors is shown in Fig. 13. Research has been divided into two groups “Research L1” and “Research L2” as L2 was run from a field camp and L1 was run from Scott Base. Transportation therefore relates to the field camp setup for research at L2. The daily trips from Scott Base to site L1 were included in “Research L1” for being research related transports. These travels to site L1 needed about 7,100MJ and consequently most of the energy of this section. Establishing a field camp at site L1 with the same transportation means (one Hägglund, four snowmobiles) as for site L2 could have saved an energy amount of about 4,300MJ, equalling 110 litres of diesel. This would have been almost 25% of the total energy consumption in K053.

4.2 Field Camp – K056

Field camp K056 was located at Lake Wellman in the Darwin-Hatherton glaciers region. The camp was located at 79°55’ south, 156°55’ east at a distance of about 310km to Scott Base. It was run from 3 December to 15 December 2007. The team included eight participants and one field assistant from Antarctica New Zealand. The camp was established by two Twin Otter (DHC-6) flights and removed by 4 helicopter flights. Helicopter transport is usually carried out by Bell 212 helicopters stationed at McMurdo. The average fuel consumptions for the aircrafts is about 1.1kg/km of Jet fuel for the Twin Otter and about 1.7kg/km of Jet fuel for the Bell212 [4]. At McMurdo, the aircrafts are fuelled with Jet fuel JP-6 being a Jet fuel designed for low temperature use. Its energy density is 42.6MJ/kg [2]. Additionally to the main flights the team had one helicopter support for research during its stay. Apart from that research was carried out locally without any further transportation. Detailed information about energy demands can be found in Appendix C.

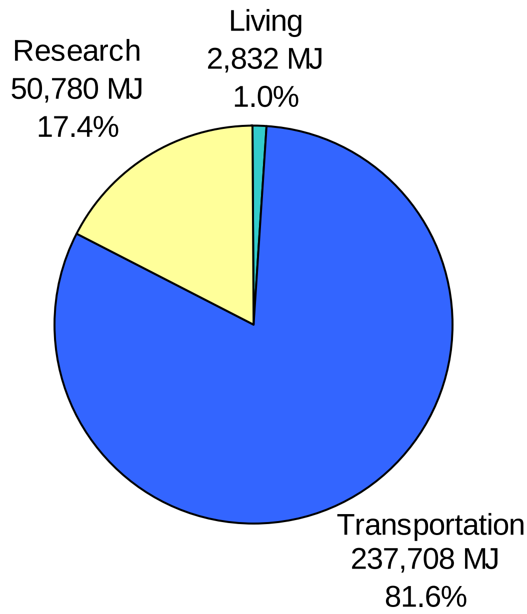

Fig. 14 Distribution of the total energy demand in field camp K056

Due to the remote location, field camp K056 had a high energy demand of 291,300MJ in total. Although a heater was used for living, most of the energy was consumed for transportation (see Fig. 14). One helicopter flight needs about 50GJ worth of fuel which equals around 17% of the total energy consumption. Other than for the return to Scott Base, more efficient Twin Otters have been used for establishing the campsite. Using another two Twin Otter flights for returning to Scott Base instead of the four helicopter flights would have saved more than 120GJ of energy being more than 40% of the total energy demand for the event. However, transportation is also dependent on weather conditions and availability of aircrafts. It is easier to land a helicopter on site than a Twin Otter which needs a flat area as a runway. Nevertheless, landing at site K056 should have been possible as transport there has already been carried out from a Twin Otter in first place.

5 Comparisons

Comparing the three different field camps with each other, K056 clearly needed most of the energy followed by K220 and then K053 (see Fig. 15). The reason for this high energy demand is the remote location of K056. The other two camps were very close to Scott Base and could be established by ground vehicles. K056 had to be established by aircrafts demanding a high amount of energy.

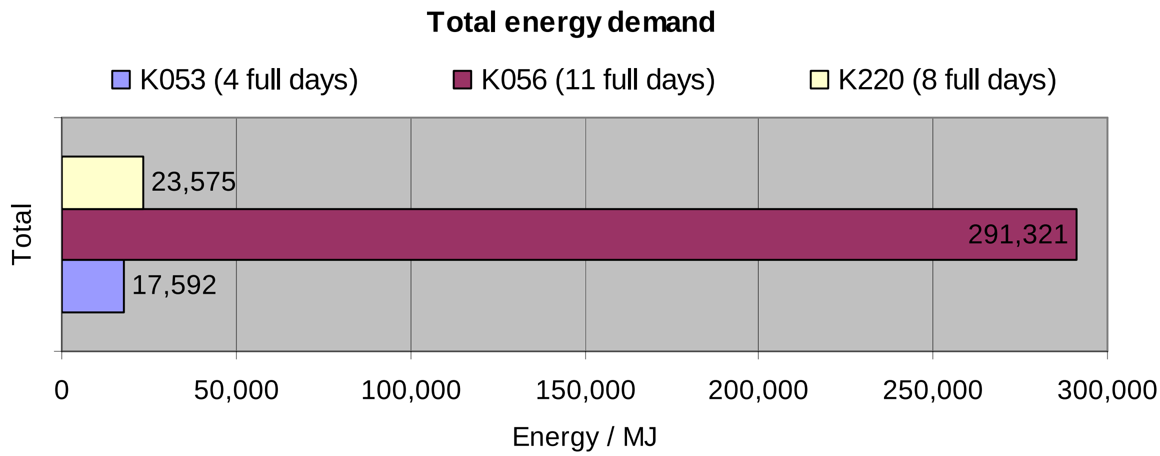

Fig. 15 Comparison of the total energy demand at the three field camps

For a better comparison of each sector of the different field camps, the energy demands were divided by participants and duration in full days. The diagram in Fig. 16 shows the energy demand per person per day for each sector. It can be seen that energy for transportation at K056 is by far the most. Furthermore, living in K056 has the highest demand due to the use of a diesel heater. Efficiency in K220 was slightly better than in K053 as cooking groups of four people can work more efficient than only cooking in a group of three people.

The reason for the highest energy demand for research in K053 is the use of vehicles for research and the daily travelled distance from Scott Base for establishing ablation stakes at site L1. In K056, only one helicopter support was used within the whole research period in the field. The equipment used at K053 was also consuming more energy and had to be recharged more frequently.

All in all, the comparison confirms the high efficiency of event K220. Although an energy demand for other activities than research and living was recorded, the camp still was run most efficient in all main sectors. The very low transportation demand also results from being the closest camp to Scott Base and simultaneously having the highest number of participants.

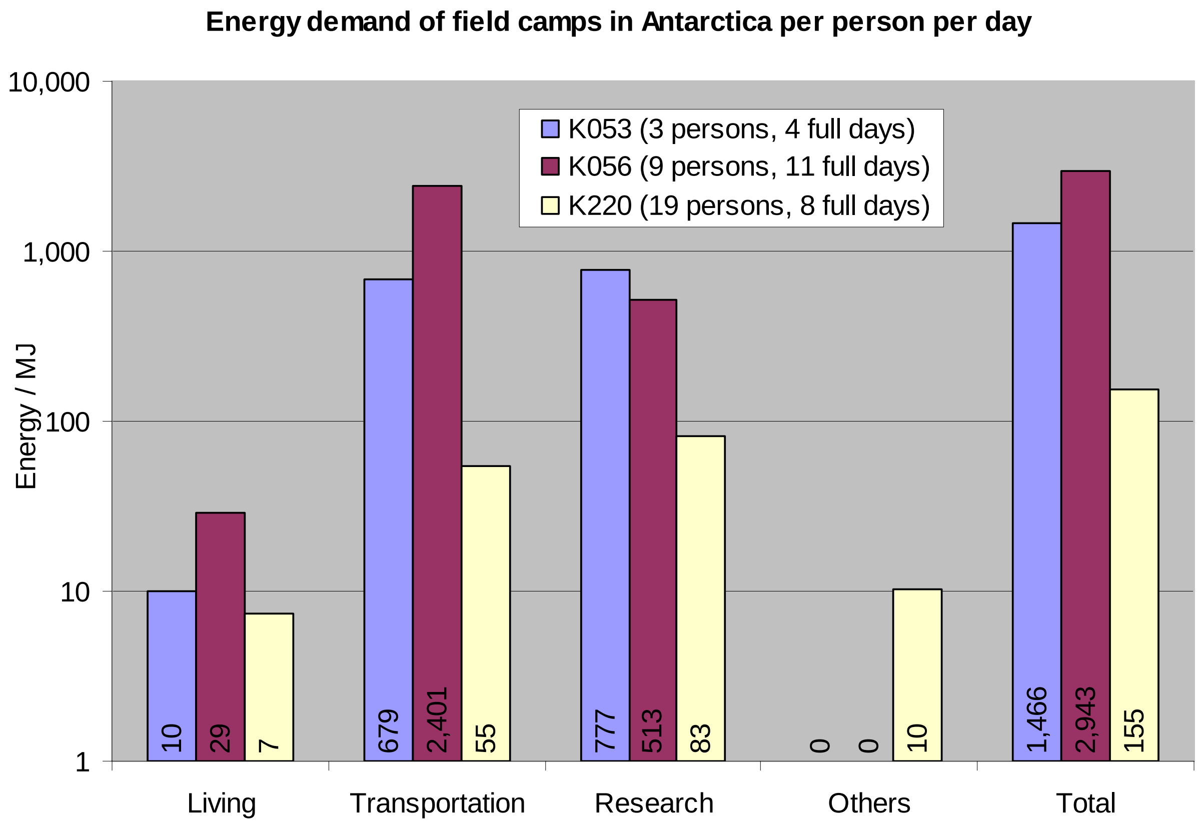

Fig. 16 Comparison of the energy demand of the three field camps in the different sectors per person per day

6 Conclusion

The comparison of field camp K220 to the two other field events has not only proved its efficiency, but also showed that the most varying energy demand at field camps is in the transportation sector. Establishing and removing the campsite and transportation of participants consumes a lot of energy. Furthermore, energy for transportation in research can vary heavily. It is important to choose the right vehicle depending on distance, participants and equipment. Correct evaluation of the planned activity to make the right choice of vehicle is the main possibility to save energy.

For close research sites, it has to be considered if a field camp is reasonable or living at Scott Base is less effort. This decision is not only a matter of energy consumption, but also depends on other circumstances like weather forecasts and the experience of the team. Permanent availability of equipment also can affect the decision for a field camp.

Altogether the efficiency of the different field camps examined is good regarding the extreme conditions in Antarctica. The standard in the camps is kept basic and is orientated to provide a high degree of safety. The main energy demand is used for all kind of transportation. Choosing the vehicle type differently in K056 and setting up another field camp in K053 could have saved some more energy at these events. However, further improvements in the transportation sector are hard to achieve as the occupied heavy terrain ground vehicles are necessary in Antarctica. Using aircrafts for more remote camps is often the only possibility to reach the determined area.

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Appendix

Appendix A

Energy densities used for calculations

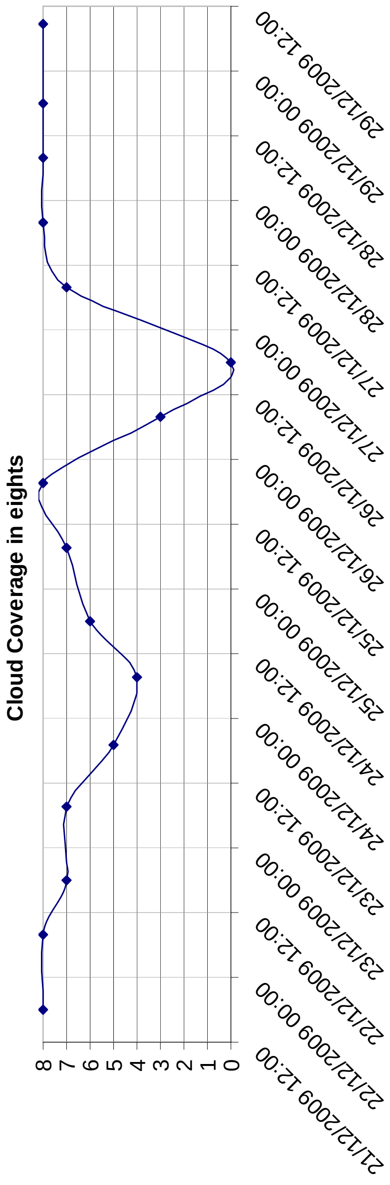
	Petrol	Diesel	LPG	JP-6
MJ / l	34.2	38.6		
MJ / kg	47.5	45.41	49.6	42.6 *

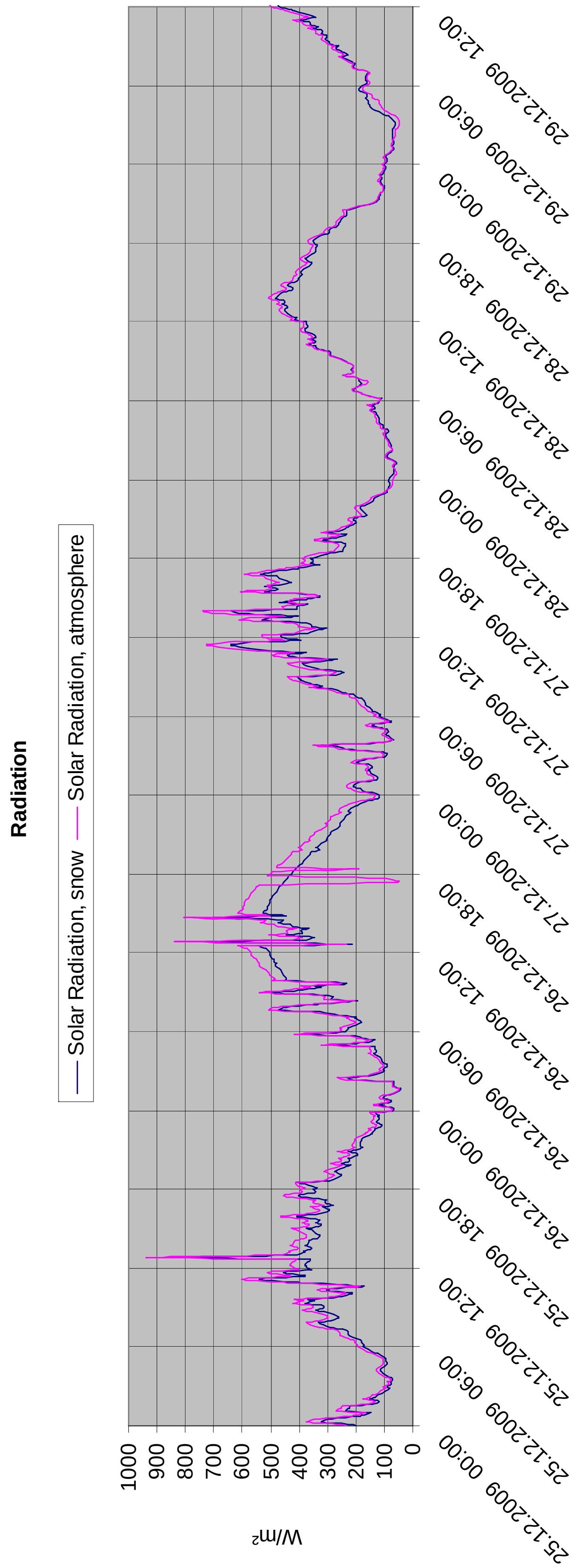
Fuel Energy Density, Energy Conversion Factors, IOR Energy Pty Ltd, Brisbane, 2010
* Elert, G., Energy Density of Aviation Fuel, The Physics Textbook, Brooklyn College, Brooklyn, 2010

LPG bottle weight during field event K220

weight in kg		before use								
Bottle	**Date:**	21.12.2009	22.12.2009	23.12.2009	24.12.2009	25.12.2009	26.12.2009	27.12.2009	28.12.2009	**total**
Kitchen 1 (m)	1	19.3	18.6	17.6	17	16.2	15.3	15.1	14.4	4.2
Kitchen 2 (f)	2	17.8	16.8	16.4	16.2	15.4	15.1	14.2	13.4	3.4
Kitchen 3 (x)	3	18.1	17	16.3	15.5	15.2	14.8	14	13.6	3.4
Kitchen 4 (x)	4	18.5	17.4	17	16	15.6	14.9	14.5	14.2	3.2
Kitchen 5 (x,3)	5	18.6	17.9	17.6	16.9	16.55	15.4	14.9	14.2	3.7
	average	18.46	17.54	16.98	16.32	15.79	15.1	14.54	13.96	3.58
										Check:
	usage per day		0.92	0.56	0.66	0.53	0.69	0.56	0.58	**0.597**
			including first dinner 21.12.							good
							average per day:		**0.597**	

Cloud coverage and radiation during field event K220





Appendix B

Transportation data field camp K220

Hagglund H5 based at Scott Base
consumption: 1l/1km
Scott Base: SB
Camp K220

Trip	Date	Start time	From	End time	To	Distance (km)	Comments	odm
1	21.12.2009	10:30	SB	11:30	Camp	8.80		
2	21.12.2009	18:00	Camp	18:45	SB	8.80		
3	22.12.2009	08:48	SB	09:15	Camp	8.80		
4	22.12.2009	10:00	Camp		Castle Rock		Skidoo/Hagglund Lessons	
5			Castle Rock	17:50	Camp	16.10		
6	22.12.2009	17:31	Camp	18:02	SB	8.80		42.6
7	23.12.2009	07:44	SB	08:15	Camp	8.80		51.4
8	23.12.2009	08:30	Camp		Cape Evans			
9			Cape Evans	05:30	Camp	74.20		134.4
10	23.12.2009	18:00	Camp	18:30	SB	8.70		143.1
11	24.12.2009	08:00	SB	08:32	Camp	8.70		151.8
12	24.12.2009	09:00	Camp		Hutton Cliffs			
13			Hutton Cliffs	17:00	Camp	33.40		185.2
14	24.12.2009	17:30	Camp	18:00	SB	8.70	(~130km other use)	
15	27.12.2009	08:00	SB	08:30	Camp	8.70		329.7
16	27.12.2009	09:00	Camp		Hutton Cliffs			
17			Hutton Cliffs	17:00	Camp	33.60		
18	27.12.2009	17:30	Camp	18:00	SB	8.70		372
19	29.12.2009	10:00	SB	10:30	Camp	8.70	Get Polar Haven	
20	29.12.2009	11:00	Camp	12:00	SB	9.00		389.7
					Total km:	**262.50**		

Hagglund H4 based at Camp Site
consumption: 1l/1km
Scott Base: SB
Camp K220

Trip	Date	Start time	From	End time	To	Distance (km)	
1	21.12.2009	10:30	SB	11:30	Camp	8.80	
2	23.12.2009	08:30	Camp		Cape Evans		
3			Cape Evans	05:30	Camp	74.20	
4	24.12.2009	10:00	Camp		Castle Rock		
5			Castle Rock	17:30	Camp	16.00	
6	25.12.2009	18:00	Camp	18:45	SB	8.70	Chrissie to base
7	26.12.2009	18:00	SB	18:45	Camp	8.70	Return
8	27.12.2009	10:00	Camp		Castle Rock		
9			Castle Rock	17:30	Camp	16.00	
10	28.12.2009	10:00	Camp		Ablation Stake Farm		
11			Ablation Stake Farm	16:30	Camp	29.00	
12	29.12.2009	11:00	Camp	12:00	SB	8.80	
					Total km:	**170.20**	

Hagglund H6 based at Scott Base
consumption: 1l/1km
Scott Base: SB
Camp K220

Trip	Date	Start time	From	End time	To	Distance (km)	Comments
1			SB		Camp	8.80	Install Polar Haven
2			Camp		SB	8.80	
3	28.12.2009	09:00	SB	09:30	Camp	8.80	
4	28.12.2009	10:00	Camp		Ablation Stake Farm		
5			Ablation Stake Farm	16:30	Camp	29.00	
6	28.12.2009	17:00	Camp	17:30	SB	8.80	
7	29.12.2009	08:30	SB	09:00	Camp	8.70	
8	29.12.2009	11:00	Camp	12:00	SB	8.70	
					Total km:	**81.60**	

Hagglunds total kms: 514.30 equals diesel consumption in litres

Skidoo SWT09
fuel consumption: 2.3 km/l makes 0.435 l/km

Trip	Date	Start time	From	End time	To	Distance (km)	Comments
1	21.12.2009	10:30	SB	11:30	Camp	23.00	including Skidoo lessons
2	22.12.2009	12:00	Camp		SB		weather gear
3			SB	18:00	Camp	17	
4	25.12.2009	22:30	Camp		Room with a view		
5			Room with a view	01:15	Camp	30	
6	29.12.2009	11:00	Camp	12:00	SB	8.8	
					Total km:	**78.80**	

Skidoo SWT05
fuel consumption: 2.3 km/l makes 0.435 l/km

Trip	Date	Start time	From	End time	To	Distance (km)	Comments
1	21.12.2009	10:30	SB	11:30	Camp	23.00	including Skidoo lessons
2	24.12.2009	12:00	Camp		SB		get weather gear
3			SB	18:00	Camp	17	
4	25.12.2009	22:30	Camp		Room with a view		
5			Room with a view	01:15	Camp	30	
6	29.12.2009	11:00	Camp	12:00	SB	8.8	
7	31.12.2009	12:00	SB		Camp		get weather gear back
8			Camp	18:00	SB	17	
					Total km:	**95.80**	

Total kms Skidoos:	**174.60**	**equals fuel in litres: 75.91**

Appendix C

Field Camp - K053 – Energy demands

	Petrol	Diesel	LPG
MJ/l	34.2	38.6	
MJ/kg	47.5	45.41	49.6

Duration: 1/11/2008 - 10/11/2008, with 4 days field camp
Participants: 3 + guide first day **Location:** McMurdo Ice Shelf

	Vehicle/Equipment	***Purpose***	***Usage***		***Fuel***		***Type***	***Energy (MJ)***
Living	(at stake farm L2)							
	Coleman 2-burner stove	Cooking	4	days	2.4	kg	LPG	119.0
	Vhf radios (GP328)	Comunication	4	days	Solar Power		0.02	
							Total:	119.1
Transportation								
	4 Skidoos	Training	20	km	8.7	l	Petrol	297.4
	1 Hägglund	Carry equipment	80	km	80	l	Diesel	3088.0
	4 Skidoos	Carry equipment/participants)	320	km	139.1	l	Petrol	4758.3
							Total:	8,143.7
Research L2	(40km from Scott Base)							
	3 Skidoos	Mount ablation stakes in 1x1km square	45	km	19.6	l	Petrol	669.1
	1kV Generator (2.3l tank)	Recharge radar, drill	4	nights	9.2	l	Petrol	314.6
							Total:	983.8
Research L1	(15km from Scott Base)							
	4 Skidoos	Mount ablation stakes in 1x1km square	60	km	26.1	l	Petrol	892.2
	Recharged at Scott Base	Recharge radar, drill						314.6
	4 Skidoos	Travel each day (15km one way)	480	km	208.7	l	Petrol	7137.4
							Total:	8,344.2
		Total energy demand for field camp K053						**17,590.7**

Field Camp - K056 – Energy demands

	Petrol	Diesel	LPG	JP-6
MJ/l	34.2	38.6		
MJ/kg	47.5	45.41	49.6	42.6

Bell 212	1.7	kg/km
Twin-Otter	1.1	kg/km

Duration: 3/12/2007-15/12/2007 (11 full days)
Participants: 8 + guide first day
Location: Lake Wellman and Darwin-Hatherton Glaciers, 79°55'S 156°55'E (310km one way)

	Vehicle/Equipment	*Purpose*	*Usage*		*Fuel*		*Type*	*Energy (MJ)*
Living								
	2 Coleman 2-burner stoves	Cooking	11	days	14.3	kg	LPG	709.3
	Vhf radios (GP328)	Comunication	11	days	Solar Power			0.06
	Diesel heater (1l/h)	Heating	11	days (5h daily)	55	l	Diesel	2123.00
							Total:	2,832.3
Transportation								
	Twin Otter	Flight arrival (2 flights)	2x 620	km	1364	kg	JP-6	58106.4
	Bell212 helicopter	Flight return (4 flights)	4x 620	km	4216	kg	JP-6	179601.6
							Total:	237,708.0
Research	(only walking at research areas)							
	2x 1kV Generator (2.3l tank)	Recharge equipment	5	h	2.5	l	Petrol	85.5
	1 Helicopter support	Change locations	700	km	1190	kg	JP-6	50694.0
							Total:	5,0779.5

Total energy demand for field camp K056	**291,319.8**