The Manufacture of Briquettes using Forest Residue

By

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Declaration

I hereby certify that this material which I now submit for assessment on the programme of study leading to the award of M Sc (Research) is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work

Signed ____________ Date 1/2/94
Candidate

Date ____________

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ABSTARCT

The high cost of energy and the need for an environmentally sound and renewable source of fuel has led to the study of utilising alternative sources of energy One of these alternative sources of energy is the branches and needles left behind after commercial forest harvesting This post harvest residue is internationally known as slash Slash can be chipped and used directly in industry or it can be densified into briquettes and burnt as a domestic fuel

Once the particle size of slash chips has been reduced to less than 3mm and its moisture content brought down to less than 10% it is possible to produce a well structured briquette which has a calorific value of 4 380 Cal/g If a factory was established to manufacture these slash briquettes the most suitable location for the enterprise would be at Avonmore, Co Wicklow The surrounding forests would be capable of supplying a sustained yield of approximately 77,232 m^3/annum while proximity to the large Dublin market would help reduce haulage costs

If indeed this factory was located in Avonmore and designed to produce 800 000 units of briquettes (10kg per unit), the retail value of each unit sold would have to be £1 81 in order to breakeven This high figure can be partially attributed to the high cost of harvesting slash, £6 35/green tonne, and the cost of haulage £102 419/annum Market research has however shown that there is a potential market for a clean burning, convenient environmentally friendly fuel

The harmful impact on the forest site after the removal of slash, in terms of soil acidity and nutrient depletion means that only the most fertile sites can be harvested for slash This limiting factor coupled with the high cost of manufacturing this type of briquette probably prevents this new product from becoming a commercially viable enterprise in the short term

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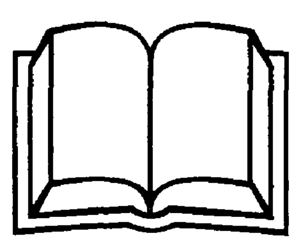
PART ONE

THE LITERATURE REVIEW



CHAPTER ONE

CHIPPING AND THE FUNDAMENTAL DESIGN OF CHIPPERS

1 1 THE CHIPPING OPERATION

This operation can take place either at the forest roadside (landing chipping) or alternatively at the stump (terrain chipping) It involves the breaking up of branches and/or small diameter stems into more manageable pieces or chips

1 1 1 Terrain Chipping

Terrain chipping involves chipping slash at the point where it was left behind on the forest floor after commercial harvesting This type of operation is characterised by light weight machinery, with a lower productivity than landing chipping (Mitchell, Hudson and Gardner (1), 1987) There are three main categories of terrain chippers,

1) Chipper harvesters the material is gathered chipped and blown into a separate adjacent container

2) Chipper forwarders, the material is chipped and extracted to the landing The chipping unit must be fed manually or by another machine which has a hydraulically operated grab

3) Chipper harvester forwarders, a self feeding system which forwards the chips to the landing

Terrain chippers must be easy to manoeuvre and limit damage to the soil and remaining trees Chipper harvester forwarders, which are the more popular system of terrain harvesting may be made up of a chipping unit mounted on a forwarder (eg Bruks 1001CT), (Bjorheden (2), 1990) Alternatively, it may be a specially designed unit specifically for harvesting, chipping and finally forwarding to the landing, (eg Lokomo 919/P 1000) The sort of production that one could expect from this system would be around 25 - 40 m^3/h depending of course on various factors like ground conditions and biomass density

With mobile chippers the chips are typically blown into a bin which would have a capacity of up to 20 m^3 This system of chipping due to its nature is sensitive to extraction distances over 300m (Mitchell Hudson and Gardner (3) 1987) Terrain chipping is also restricted to sites with good bearing capacity with a moderate slope and very few obstacles

1 1 2 Landing Chipping

Landing chipping takes place at the forest roadside after or as part of commercial harvesting Landing chipping is a much more productive system to operate than terrain chipping, but not necessarily the most cost effective (Richardson (4) 1986) It is the only option in many cases where the terrain is difficult There are two main categories of landing chippers Firstly there is the portable type which is a separate unit, usually powered by a tractor or it is self powered and mounted on a trailer Secondly there is the mobile type where the chipping unit is part of a truck or lorry Table 1

Category	Size	Machine Example	Output m^3/hr
Tractor Mounted (portable)	Medium Large	Junkkari HJ10 Erjo 204T	7 - 20 15 - 40
Lorry Mounted(Mobile)	Medium Large	Valmet TT1000L Valmet TT1000LP/LT	50 - 100 70 - 120

Table 1 Categories of Landing Chippers

Landing chipping can also be done using a chipper mounted on a forwarder This, however would not be an efficient system of chipping as it is designed for working on the terrain with frequent stoppages, (Richardson (4), 1986)

When chipping is taking place at the landing regardless of the output it is important to have a buffer stock to ensure that the machine is constantly working The more productive the machine the greater the buffer stock and hence the greater the space needed to store it This requirement would not be accommodated in the majority of Irish forest sites due to the fact that there is limited space at the landing Machinery capable of high outputs also requires a large quantity of accessible material to work with if economies of scale are to be taken advantage of

One of the advantages of the less productive units is the fact that a smaller landing space is required A further advantage of the smaller systems is the reduced capital outlay, and the availability of these machines eg farm tractors

1 2 DESIGN CHARACTERISTCS OF CHIPPERS

1 2 1 Processing Types

There are three main types of processors that do the job of comminuting timber These are as follows (Houldershaw (5) 1991)

1) Drum chippers are similar to head planers and would typically have four blades covering

the width of the horizontal drum This provides a well balanced cutting unit which tends to be quite noisy with poor control over chip quality

2) Disc chippers are again noisy but chips are of better quality and consistency Smaller chippers may have a disc diameter of 630mm having two or four knives fitted onto it The larger chipping machines would have a disc diameter in the region of 1070mm with the same number of knives

3) Screw chippers draw material in against a rotating screw whose sharpened threads cut the timber against an anvil mounted on the casing Unlike drum or disc chippers that utilise replaceable blades, the entire thread of the screw must be sharpened This requires a certain degree of skill to achieve a consistent edge

The maximum timber diameter a chipper can comminute depends on the chipper design The Junkarri HJ6 can chip a log of a maximum diameter of 15cm, whereas the Junkarri HJ30 could manage a log of diameter 30cm

1 2 2 Feed Types

Gravity feed entails dropping or pushing material into the chipper by hand or crane Screw chippers then pull in material while drum chippers "snatch" the material, (Hartler (6), 1986) The alternative system of hydraulic-feed rollers provides greater control over the process

The material itself can be fed from the side as in the majority of cases or from the top It is more practical to feed from the side particularly when the machine is hand fed

The feed system can operate in the oposite direction in order to allow blockages to be speedily cleared and are generally regarded as being safer In the case of drum chippers they prevent material being thrown back at the operator and there is less potential for machine straining This may occur where an over long heavy piece of timber is fed in

1 2 3 Safety Aspects and Other Features

Manually fed chippers are exceptionally dangerous It is imperative therefore that the feed chute should be sufficiently deep as to eliminate this danger However as a precautionary measure an automatic shut off bar should be fitted It should be accessible and situated at the mouth of the feed chute

The feed table should be at a comfortable workıng heıght to make the job of feedıng easıer In addıtıon to thıs the dıscharge chute should also be easılv turned ın order to blow the chıps ın dıfferent dırectıons Noıse generated from chıppıng machınes can be consıderable Where the noıse level reaches 85 dB (A), ear protectors should be worn bv the operators (Shesgreen (7), 1991)

The machıne casıngs of chıppers should be strong enough to protect agaınst the rough and tumble of forestry lıfe yet allow for easv access for servıcıng The machıne housıng should also provıde some degree of protectıon ın the lıkelıhood of say a blade comıng lose and flyıng out of the machıne

CHAPTER TWO

HARVESTING WOOD FOR FUEL

2.1 INTRODUCTION

There are many different systems of harvesting wood products available to contractors and foresters today Ground conditions harvesting costs and the products harvested determine which one is most suitable Within the scope of chipping three systems of harvesting can be identified These are as follows

i) Whole Tree Harvesting
ii) Integrated Harvesting
iii) Post Harvest recovery of Residue

2.2 WHOLE TREE CHIPPING

Harvesting early thinnings is a silviculturally desirable practice but a financially poor one The problem with early thinnings is the cost of harvesting and the low value of the products harvested In order to improve the value of the product and make the thinning operation a more financially viable one, thinnings are delayed for a number of years The consequences of this is the increased risk of windthrow[1], (Gardner (8), 1991) Whole tree chipping offers an attractive solution to the problems of harvesting low value products, (Minamikata (9), 1986) With this system of harvesting, the most laborious and costly work phase of harvesting timber is avoided ie delimbing The result is that almost the entire above ground biomass is processed which could be utilised to manufacture briquettes

In the case of terrain chipping the most popular system in Sweden is to use a chipper forwarder like the Bruks 1001 CT, or a Silvatec (Bjorheden (4) 1990) This system is sensitive to excessive extraction distances so where extraction distances are long, a chip forwarder shuttle may be used to maximise chipper utilisation The chipper, when its bin becomes full simply empties its load into the shuttles bin The limitations of this system is the fact that ground conditions need to be reasonably good

With ground conditions prevailing, this system of harvesting used in conjunction with a mechanical feller buncher would be the most efficient system to employ for harvesting early thinnings (Mitchell et al (1) 1987) The feller buncher can reduce the cost of producing chips by up to 30% by concentrating material in a given area

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[1]Windthrow refers to the levelling of trees by the wind

Landing chipping of whole trees would be more suitable for larger stems occurring in later thinnings or in a premature clearfell The larger stems could be processed more efficiently using the more powerful and productive machinery mentioned earlier Stands felled prematurely would normally consist of very poor quality timber with little or no commercial assortments

Extraction to the roadside can be done by skidder[2] or forwarder[3] Stems which have been skidded to the landing are more likely to become contaminated with dirt The dirt can blunt the blades of the chipper and hence reduce its productivity, (Savage and Koch (10), 1979) Forwarding is more costly than skidding, for conventional harvesting This is because of the high volume density ratio of its load, (Hakkila (11), 1990), which may be whole trees or tree sections To overcome this forwarders are modified to enable them to carry greater loads The bunk can be enlarged by two or three metres and the pins extended to increase its capacity, (Mitchell et al (1) 1987, Bjorheden (2), 1990) The OSA 250 is a medium sized forwarder (weight 10 tonnes) with a grapple saw mounted on a 8 8m crane It is specially designed to fell, section and extract whole trees, (Bjorheden (2), 1990)

The products of whole tree chipping cannot be used as high quality pulp chips because of the high bark and needle content ie >1% The Jingson/Bruks pulp chip harvester can delimb debark and chip all in the one operation, up to a maximum tree diameter of 30cm High quality chips are produced after the delimbing and debarking operation, these chips can be used in paper making or fibreboard manufacture The debarking and delimbing devices can then be removed to allow the slash to be processed into chips, (Bjorheden (2), 1990)

2 3 INTEGRATED HARVESTING

Whole tree chipping systems maximise the utilisation of forest resources but are limited by the production of a single low specification product Integrated harvesting on the other hand yields two distinct product types, wood chips and timber assortments (eg pulpwood palletwood and sawlog), (Mitchell et al (12) 1989) Product separation can take place at either of the following three locations

1) At a Central Processing Facility (*CPF*)
2) At the Landing
3) At the Stump

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[2] This is a system of extraction where the tree is dragged along the forest floor using a tractor usually a four wheel drive tractor

[3] Rather than stems being dragged along the forest floor they are lifted of the ground and carried in a bunk or trailer

As the dıstance at whıch product separatıon takes place ıncreases from the stump so does the capıtal ınvestment requıred to set up the partıcular svstem For example the cost to set up a CPF would be around $2 mıllıon whereas a system to separate products at the stump would be $100 000 (Mıtchell et al (13) 1988)

2 3 1 Product Separatıon at a Central Processıng Facılıty

Integrated harvestıng ıs not practısed on a large scale eıther ın Ireland or ın the Unıted Kıngdom In Sweden where such harvestıng ıs an ıntegral part of theır tımber ındustry onlv 1% of tımber ıs harvested ın CPF's, (Bjorheden (2) 1990)

One of the most modern CPF's ın Europe ıs sıtuated ın Hufingen, Germanv It ıs run bv the Prınce of Furstenburg's Forest Dırectorate, (Zundel (14), 1986) The plant produces 100,000 m^3 of tımber per annum but also produces 20,000 to 30,000 m^3 of bıomass per annum, (Zundel (15), 1989) Trees are felled motor manually and then skıdded to the roadsıde They are then loaded onto a traıler whıch has sıde panels on ıt to reduce the wıdth of ıts load The transportatıon of these whole trees ıs very ınefficıent due to the hıgh volume densıty ratıo of the load In the case of the plant at Hufingen ıt ıs acknowledged that the extra cost ıs offset to some extent by the reduced handlıng and processıng of the stems at the forest sıte (Mıtchell et al (13), 1988)

At Hufingen a Lımbak unıt delımbs and debarks the stems The trees are run through a profile scanner where ınformatıon on stem sıze and form ıs passed ınto a computer The computer then makes the decısıon on convertıng the stem ınto planks Thıs system maxımıses the volume of materıal produced

The bıomass retrıeved ıs used on sıte to fuel kılns or ıt ıs sold The cost of establıshıng a sımılar system ın Canada whıch produces 283,200 m^3 of round wood and 95,500 tonnes of bıomass was $3 7 mıllıon, (Canadıan Dollars), (Hamılton (16), 1983) The cost of establıshıng such a system ıs therefore very great Thıs cost however, has been justıfied ın the case of the plant at Hufingen where the percentage of roundwood converted ınto sawlog has jumped from 37% to 52%, (Kwasnıtchka (17), 1978)

The maın advantages of a CPF are as follows (Mıtchell et al (12) 1988)

1) The hıgh degree of mechanısatıon ın the system enables several stems to be handed at the same tıme

2) Handlıng ın the forest ıs mınımısed and processıng ıs undertaken ın a controlled envıronment

3) High levels of mechanisation can be obtained in all stages of harvesting and processing, with product separation having the advantage of economies of scale

4) Biomass can be efficiently recovered and the volume of sawlog recovered can be maximised

This system of harvesting and processing would benefit sawmills which have high mill energy costs, high logging costs and slash disposal costs It is important that there is a large supply of material close to the mill for mechanised harvesters to work on (Zundel (15) 1986)

2 3 2 Product Separation at the Landing

Stems are brought to the landing in the same way as for processing in CPF's The stems can be delimbed and crosscut by chainsaw or by processor Alternatively the stems can be delimbed and debarked in a single operation This can be done using a flail delimber debarker, (Twaddle and Watson (18), 1990), or by a portable drum delimber (Cabro) or a trough delimber (AC-Invest), (Mitchell et al (19), 1988) In Sweden the new Bruks portable bunch delimber/debarker is showing great potential, with productivity of 25 m^3/pmh at a cost of $4 50/$m^3$ (American Dollars) In the USA a portable chain flail delimber/debarker can recover 67% debarked roundwood and 33% biomass for energy (Mitchell et al (20), 1988)

Improved efficiency in this system can be achieved by increased mechanisation in the area of felling and bunching This is particularly true where the stems are too large to be bunched manually (< 0 1m^3) However the efficiency and practicality of using these machines depends on the slope, bearing capacity and roughness of the ground

The advantages of this system are that the handling of individual stems is minimised Also the transportation of chips to a briquetting factory or an industry for burning would be cheaper than for the transportation of unprocessed stems as in the case of the CPF As biomass becomes concentrated at the landing it is important to have enough space to accommodate this build up

2 3 3 Product Separation at the Stump

The use of mechanised harvesters is increasing in Europe 25% of the timber cut in Sweden is done by harvester (Bjorheden (2) 1990) An important feature of harvesters is the concentration of slash in piles This feature makes the process of harvesting slash more economical

Commercial assortments can be forwarded along with the slash in order to improve the overall density of the forwarders load (Puttock (21) 1990) Alternatively a mobile chipper forwarder can be employed to harvest chip and forward the slash immediately after commercial assortments have been removed from the forest floor This is known as hot logging (Schneider (22) 1987) The efficiency of such a system is significantly reduced in the case of thinnings in particular first thinning This is due to the scattered nature of the slash (Mitchell et al (23), 1990)

2 4 POST HARVEST RECOVERY OF RESIDUE

This procedure of recovering slash for fuel can be considered to be a two stage or two pass, non integrated system It is considered to be uneconomical to employ this system in early thinnings or with low volume tree sizes, (Stokes and Sirois (24), 1983) A variety of technologies have been considered for collecting and processing tops and limbs These include topwood processors (Arola and Miyata (25), 1981, Christopherson and Barnet (26), 1983) and grapple skidders, skylines (Adams (27), 1981), and modified forwarders The slash can be chipped at the stump and forwarded to the roadside in the one operation, as mentioned previously

The Ferrics Recufor harvesting system has been developed in Canada The unit consists of a single rotor mounted on a Hydro-Ax tractor equipped with 15 curved teeth, placed in three rows of five The teeth scoop up the residue without prior bunching and without gouging the ground The residue is sheared against fixed knifes at the back of the rotor which reduces the residue to a form suitable for bulk handling

2 5 FACTORS AFFECTING CHIPPER PRODUCTIVITY

The productivity of harvesting slash regardless of the system employed will depend on several factors which will be discussed in this section

2 5 1 Operator skill

This can have a substantial effect on productivity The most difficult skill to acquire is operation of the grapple loader for feeding the chipper In the case of a Bruks 800CT mobile chipper the productivity of an experienced operator was double that of trainee (3 30 vs 1 71 o d t /pmh) (Richardson (4) 1986)

2 5 2 Biomass density

The amount of biomass within an area influences the productivity of chipping machines In the case of chipping at the roadside a buffer stock can be generated to facilitate the demand of high output roadside chippers In the case of mobile chippers the biomass density of an area influences the frequency of chipper moves necessary to collect a load As the density decreases, the percent of time spent moving between chipping increases and thus chipping productivity decreases The main factors affecting biomass density are

i) Original stand density ie stems per hectare

ii) Type of felling, feller - bunchers and mechanical harvesters can provide localised increases in biomass density whereas motor manual felling has no effect Thinning types also affect the density of biomas, eg bench felling

iii) Type of harvesting, the biomass density in full tree harvesting is always higher than for logging slash only

iv) Chipping system, systems where forwarders or other means are used to gather biomass and place it closer to the chipper increase the density within the chipping area

2 5 3 Extraction distances

Production decreases as the percentage of time spent in transporting the biomass to the landing increases An extraction distance of 300m is considered to be the maximum distance a forwarder should travel As described earlier a shuttle forwarder could be employed for greater extraction distances

2 5 4 Terrain Conditions

Flat firm terrain provides the best working conditions for terrain chippers Because of the high centre of gravity with the chipper and the bin chip harvesters are less stable on slopes than forwarders Soft ground particularly during periods of heavy rainfall can affect the manoeuvreability and productivity of terrain chippers not to mention the damage these machines can do to sites of this kind It is these factors which make terrain chipping most unsuitable in Irish conditions (Raftery (28) 1991)

2 5 5 Species Type

Some species naturally have more foliage than others For example foliage on spruce (*Picea spp*) would make up 6% of a tree's total biomass and the foliage on pine (*Pinus spp*), would make up only 2 5% of the total biomass The cost of harvesting a cubic metre of spruce slash would therefore be less than that in the case of a cubic metre of pine

2 5 6 Maintenance

All machines should be in prime working condition at all times Chipper knives should be sharpened regularly, usually once a day Failure to do so would reduce chipper performance and productivity

2 6 THE COST OF HARVESTING CHIPS

2 6 1 The Wood Fuel Supply Strategy report

This report investigated the feasibility of various harvesting systems designed specifically to recover biomass for fuel purposes It was carried out by the Forestry Department in the University of Aberdeen It was first published in 1990 A total of 24 different harvesting systems were studied a brief description of each system is given in Appendix A The 24 systems were grouped into the following familiar categories, these were

1) Residue Harvesting
2) Whole Tree Comminution
3) Integrated Harvesting

Category 2 included systems involving hardwood comminution which have been ignored in this analysis The twenty four less four hardwood systems were divided into four groups on the basis of the capital investment required to establish the system These groups the amount of capital required and the systems falling into the group are shown in Table 2

The cost of harvesting comminuting and extracting the wood to the landing was assessed in this report along with storage and the cost of supplying different sized combustion plants at varying transport distances This section will focus on the costs involved in getting the wood chips to the roadside Before investigating the results of the report it may be interesting for the sake of making comparisons that sawdust can be purchase from sawmills for approximately £6 per green tonne, (sawdust is currently being used for making "Heatlog" briquettes at Irish Carbon Products Ltd Callan, Co Kikenny) Table 3, shown below gives a breakdown of the total costs involved in getting the wood chips to the landing

Investment Category	Investment Required (£)	Models in Category[4]
Small	100 000	10, 12 14, 16
Medium	250 000	11, 15 18
Large	>250 000	30-38
Utility[5]	250 000	1, 2 13, 17

Table 2 Investment categories for each of the harvesting systems

The two systems of harvesting residue examined in Group 1 of the report, show that little difference exists between them with regard to production costs Each system involves heavy terrain equipment which could damage the soil Apart from this however, the cost of harvesting the slash is high

Model number	Species	Tree Size (m^3)	Thinning Clearfell	Felling (£/gt)	Extraction (£/gt)	Comm (£/gt)	Total (£/gt)
GROUP 1 - RESIDUE HARVESTING							
1	SS		CF		5 73	8 09	13 82
2	SP		CF			13 87	13 87
GROUP 2 - WHOLE TREE COMMINUTION							
10	SS	0 06	T	1 89	7 95	7 41	17 25
11	SS	0 06	T	3 90	4 65	6 65	15 20
12	SS	0 06	T	1 89		10 93	12 82
13	SS	0 06	T	3 90	4 65	3 98	12 53
14	SP	0 06	T	2 41	10 12	9 43	21 95
15	SP	0 06	T	4 97	5 91	8 47	19 35
16	SP	0 06	T	2 41		13 92	16 32
17	SP	0 06	T	4 97	5 91	5 06	15 94
18	LP	0 04	CF	1 67	3 30	5 78	10 76
GROUP 3 - INTEGRATED HARVESTING							
30	SS	0 06	T	2 86	3 41	5 12	11 39

[4] These models represent whole tree harvesting models which have been included in the Wood Fuel Supply Strategy Report

[5] The sole objective of this category is to supply wood fuel in a complete supply chain from the forest floor to the industrial user As a result investment is required for not only harvesting equipment but storage facilities and haulage to these facilities and to the end user

31	SS	0 18	CF	0 60	2 19	5 12	7 91
32	SS	0 27	CF	0 46	1 90	5 12	7 48
33	SS	0 46	CF	0 32	1 57	5 12	7 01
34	SS	0 46	CF	0 32	1 69	5 12	7 13
35	SS	0 69	CF	0 23	1 36	5 12	6 71
36	SS	1 23	CF	0 15	1 21	5 12	6 48
37	SP	0 06	T	3 70	4 40	5 39	13 49
38	SP	0 27	CF	0 45	1 85	5 39	7 69

Table 3 A summarv of the production costs for each of the 20 harvesting systems analysed in the Wood Fuel Supplv Strategv Report 1990

It is verv clear from this table that whole tree communution of first thinnings is quite an expensive exercise This can be attributed to the small average tree volume and the scattered nature of the biomass Also in this group the impact of greater capital investment can be seen from the difference in production costs of using a feller buncher and superior chipper ie between Model 11 and Model 10 Although the production costs are higher for the smaller investment categories these categories do have their advantages The main advantage being the smaller capital outlay involved, making the investment accessible to a greater number of people The primary source of power for these types of svstems, the tractor is a widely available machine with no maintenance and spare parts difficulties

In group 3 the influence of tree size on production costs is clearly evident The higher cost for the smaller trees is also due to the fact that the biomass density is lower for thinnings than for clearfellings

The costs shown above would all be dependent on ground conditions and other previouslv mentioned parameters Irish forest sites are not particularlv renowned for their bearing capacity or favourable topographv, so costs could, in a good deal of Irish sites be higher than those represented here in this table When sawdust can be purchased for £6 a green tonne the cost of harvesting chips for use in making briquettes is not justified in view of these figures

2 7 SITE DAMAGE AS A RESULT OF FUEL WOOD HARVESTING

The increase in mechanisation at all levels of harvesting has long been recognised as a source of significant damage both to the soil and remaining stems (Batardv and Abeels (29) 1985) With conventional harvesting a slash carpet is formed from the branches and needles of felled trees This provides a protective covering on which forest machines work After WTH however this covering doesn't exist and the soil is exposed to the damaging effects of heavy machinery (see plate 1 3 Appendix B)

Frequent passes of machines churn and dig up the soil This leads to erosion of the top-most fertile layer rutting and compaction It has been proven that soil compaction resulting from heavy machinery reduces the productivity of replanted trees growing on the compacted area

In wood fuel harvesting systems where the slash is harvested separately from the commercial stem, two passes over the site are necessary to complete the operation This would occur when the products are separated at the stump and the slash is harvested separately The post harvest recovery of residue also involves two passes over the site, whereas in conventional harvesting it is only one

Harvesting whole trees involves handling bulky and awkward stems, with branches intact There is a greater chance of nearby trees being damaged by these stems as they are being extracted, than by stems which have been fully processed in the forest This is the case for both terrain and landing chipping A study conducted by the Finnish Forestry Research Institute showed that with landing chipping 2 6% of trees were damaged and with terrain chipping 2% of trees were damaged Fifty seven percent of the damage was in the stems, 2% was in the root collar and 41% in the roots, (Siren (30), 1986) Exposed woody tissue arising from this damage has a 30% - 50% chance of becoming infected by *Fomes annosus*, (Wasterlund (31), 1986)

The majority of stem damage can be attributed to the grapple loader, where either it or the stem it is carrying, hits off an adjacent tree With regard to root damage, heavy machinery forces down soil surrounding the roots The roots become exposed, if they are not already exposed, and are ripped and sometimes torn apart by the wheels of forwarders, harvesters and other machines, (Nieuwenhuis (32), 1989) It is easy to imagine how a site of low bearing capacity, without a protective layer of slash, can be severely damaged by heavy equipment particularly during wet conditions

CHAPTER THREE

METHODS OF MANUFACTURING WOOD BASED BRIQUETTES

3 1 THE PREPARATION OF WOOD CHIPS FOR PROCESSING

3 1 1 Chip Size

In order to produce high quality briquettes, individual particles must be as small and uniform as possible, (Raftery (28) 1991) It is fair to say that neither of these characteristics exist in typical wood chips Sawdust on the other hand is ideal for producing briquettes and is currently being used for this purpose at Irish Carbon Products Ltd

The standard chipping machine can produce a range of different chip sizes between 5mm and 25mm long Chip size can be changed by adjusting several sieve plates which only allow certain sizes of chip to pass through Chips which fail to pass through the sieve are processed further, (Raftery (28), 1991) However standard chippers cannot produce chips of sufficient size and uniformity necessary for making briquettes Therefore after conventional chipping, the chips must be hammermilled This machine reduces large particles such as wood chips into finer more uniform particles

3 1 2 Moisture Content

Wood chips must be dry before being processed into briquettes This is to ensure that individual particles bind well together during processing, (Donohoe (33), 1991) Spruce and Pine trees which have just been cut would have a moisture content (MC) somewhere between 50% - 60% Wood that has been left out to dry typically has a MC in the range 20% - 30% Depending on the method of briquette production, the ideal MC of wood chips used for briquettes varies For example, a maximum MC of 10% is permitted for briquettes produced using the extrusion screw, and 12% for briquettes produced using the reciprocating ram (Gnaggs (34) 1991) The following are the reasons why it is necessary to reduce moisture content

1 Energy is consumed converting moisture into vapour therefore the less moisture there is in the briquette the more energy can be converted into heat

2 As solid fuel is normally sold by weight it is important from a marketing perspective that as little moisture as possible makes up the total weight of the fuel package The fuel must burn efficiently and value for money must be guaranteed if customer satisfaction is going to be achieved

3 If the moisture content is high then the machines involved in making the briquettes will physically not be able to make the briquette

It is easier and much cheaper to dry sawdust than it is to dry wood chips Therefore hammermilling precedes the process of drying Most dryers are powered by natural gas, however some, like the one at Irish Carbon Products Ltd , have been equipped to generate heat by burning sawdust The amount of sawdust required to dry a tonne of sawdust depends on the MC ICP would expect to use about 20% of every tonne of sawdust purchased to dry the remainder of sawdust, (Donohoe (33) 1991) The most efficient system of drying material is to use a rotating drum dryer As the drum rotates the sawdust is knocked from side to side mixing with the hot air

3 2 METHODS OF DENSIFICATION

Densification is the process of compacting the crushed wood chips into a solid log There are three methods of achieving this, these are,

1) The Rotating Wheel
2) The Extrusion Screw
3) The Reciprocation Ram

3 2 1 The Rotating Wheel

This system of densification produces pellets or nuggets, typically 10mm in diameter and 20mm to 50mm in length The system is basically made up of two rotating wheels One of the wheels contains many cylinders or dies arranged in rows Material is forced into these dies by the other rotating wheel to produce the pellets, (Gnaggs (34), 1991)

3 2 2 The Extrusion Screw

This involves a large screw extruder which forces material through a tapering die at a pressure of 1 378 x 106 Kp (20,000 psi) In addition to this a temperature of 300°C is created Under these extreme conditions individual particles bind together This is a result of the plasticising or softening of lignin and the intertwining of the individual particles As such the densified fuelwood is 100% wood and free of additives and binders (Hassler (35) 1990)

As the briquette leaves the densifyer it is turned through a right angle which shears it into 250mm lengths The briquette produced is relatively dense with each log (80mm in diameter and 250 mm in length) weighing approximately 1Kg (Hoag (36), 1990) The energy value of these logs is 19 5 MJ/Kg which is about two thirds that of coal (Gnaggs (34) 1991)

3 2 3 The Reciprocating Ram

This process of producing briquettes involves a large piston that compacts the wood chips into a die at around 5 86 x 106 Kp (8 500 Psi), (Hassler (35), 1990) The momentum of the piston is maintained by a large fly wheel The log formed by this process consists of a series of discs that are bound together primarily by the mechanical interaction of individual particles rather than lignin bonding The briquettes exit the processor as a continuous log and travel along a conveyor belt This allows the briquettes to cool but also to provide back pressure which helps increase the density of the log

As mentioned previously the logs produced from this method of densification are made up of dense sections separated by areas of weakness, (Hoag (36), 1990) These type of briquettes are therefore not as dense as the extruded type and hence do not give off as much heat, (Carre (37), 1983) In addition they are more inclined to break up and disintegrate, (Tierney (38), 1991) These briquettes, when being burned also tend to expand rather like an accordion This feature could prove to be dangerous, as portions of the briquette may fall from the fire

CHAPTER FOUR

THE ENVIRONMENTAL IMPACT OF WHOLE TREE HARVESTING

4 1 THE EFFECT OF WHOLE TREE HARVESTING ON SITE FERTILITY

4 1 1 The Nutritional Cost of Removing Slash

Harvesting the branches and foliage of felled trees has long been a subject of investigation and criticism Slash is a very important source of nutrients for future rotations and contains a higher proportion of easily decomposed material than soil organic matter (Dyck and Beets (39), 1987) The removal of slash may therefore place demands on the soil that may exceed the natural supplying capacity of the system (Wells and Jorgensen (40), 1979)

The nutrient content of slash was examined for a 50 year old crop of managed Sitka spruce (*Picea sitchensis*), (Carey (41), 1980) The study concentrated on the three major nutrients N, P and K, (nitrogen, phosphorous and potassium) These elements occur frequently in Irish soils in limiting quantities Figure 1 below represents a summary of Carey's findings It shows that the removal of slash along with the stem would result in a disproportional removal of nutrients, in relation to biomass This is due to the fact that there is a greater concentration of nutrients in the crown part of the tree than in the commercial stem, (Freedman et al (42), 1985, Phillips and Van Lear (43), 1984, Miller et al (44), 1980, Carey (41), 1980, Carey and O'Brien (45), 1979)

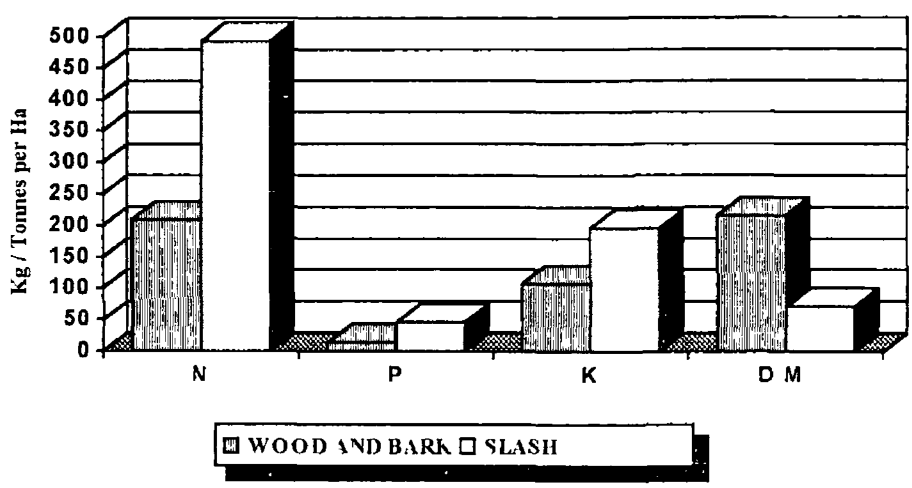

Figure 1 Dry Matter (tonnes per ha) Nitrogen Phosphorous and Potassium (Kg per ha) estimates for above ground tree components

The chart on the following page illustrates Figure 1 on a percentage basis It shows us quite clearly that by removing the slash as well as the stem the dry matter harvested would increase by 25% The cost of removing an extra 25% of biomass is to remove 70% 77% and 65% more N P and K Figure 2 The nutritional cost of harvesting this extra 25% is high and in many cases

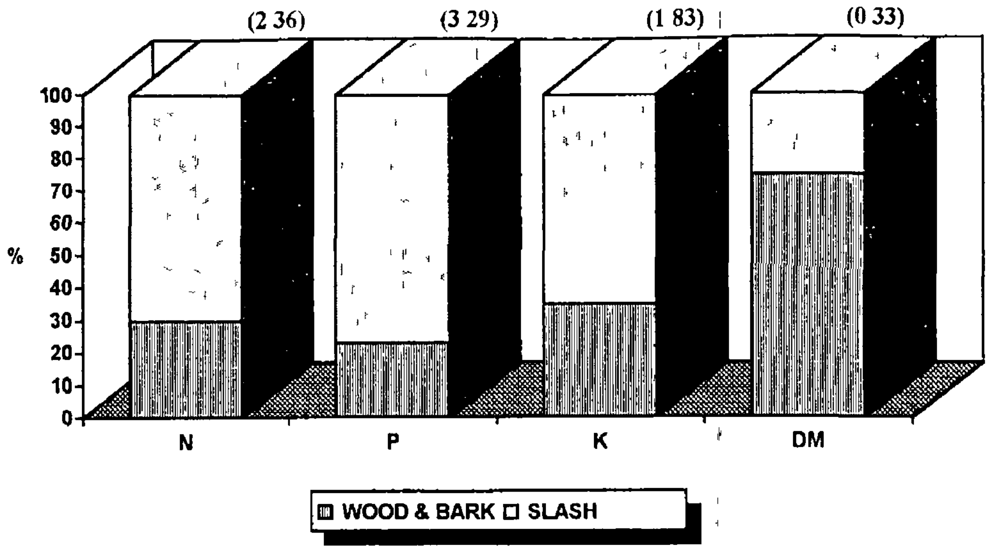

Figure 2 Graph showing percentage contribution of tree components to N, P, K and Dry Matter The figures in parentheses represent the ratio of quantities removed in conventional harvesting to those removed in WTH For example, in WTH the amount of nitrogen removed would be 2 36 times greater than for conventional harvesting (CH)

would be an important issue in deciding whether or not a site should be whole tree harvested or not, (McCarthy (46), 1991)

The different concentrations of N P and K in the stem and the slash is given in Table 4 below, (Freedman et al (42), 1985) These figures represent the average results from four conifer stands The table supports the findings of Carey illustrated in Figures 1 and 2 As a percentage of dry matter the concentration of major nutrients in the slash is far greater than that found in the stem

	N	P	K
Stem Only	0 1	0 014	0 053
Slash	0 43	0 058	0 190

Table 4 Nutrient concentration as a % of dry matter

4 1 2 The Nutritional Value of Slash Components

The two major constituents of forest slash are the branches and the needles Studies have shown that the concentration of nutrients in the foliage is greater than that in the branches (Carey and O'Brien (45) 1979 Dyck and Beets (39) 1987) Although the needles of Loblolly pine (*Pinus taeda*) make up only 2 5% of the total above ground biomass they contain 23% 25% and 11% of the trees total N P and K This is in contrast to the branches which make up 13% of the trees biomass but only 22% 25% and 22% of the trees N P and K (Phillips and Lear (43) 1984)

Under Irish conditions research on Sitka Spruce (*Picea sitchensis*) shows a similar trend, Table 5 (Carey (41), 1980) From the data presented here it can be seen that the proportion of foliage to branches is greater for spruces than it is for pines Apart from this the data underlines the fact that if you were to remove the branches and leave the needles behind a significant proportion of the trees nutrients would be returned to the soil At the relatively small cost of losing 6% of the biomass you would be returning about a third of the major tree nutrients to the soil Table 5

	D M	N	P	K
Needles	16936 *(6%)*	235 *(33%)*	19 *(32%)*	96 *(32%)*
Branches	55000 *(19%)*	258 *(37%)*	27 *(45%)*	102 *(34%)*
Total	**71936** ***(25%)***	**493** ***(70%)***	46 *(77%)*	**198** ***(66%)***

Table 5 Levels of Dry Matter and N P and K in Slash (Kg ha-1) Figures in parenthesis represents the percentage contribution that the needles or branches make to the total nutrient content of the tree

Any mechanical procedure attempting to separate the needles from the branches would involve extra costs You could wait for a period of time, (approx 6 months, Raftery (28), 1991), until the needles fall from the branches of their own accord, but this introduces more expense

4 1 3 The Effects of Age and Productivity on Nutrient Concentrations

For younger trees due for a first or second thinning the nutritional benefits of stem only harvesting are far greater than for a more mature stand of timber This is because the ratio of crown to stem biomass is high early in the life of the crop (Wells and Jorgensen (40), 1979, Anderson (47) 1983)

At 25 years around the age of first thinning for a Sitka spruce stand with a yield class[6] of 12 the crown would make up 54% of the trees above ground dry weight This is in contrast to 20% for a tree with the same yield class at a clearfelling age of 55 years Figure 3, (Anderson (47) 1983)

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[6]Yield Class is an estimation of forest productivity and is measured as the potential maximum mean annual volume increment in cubic metres per hectare per annum

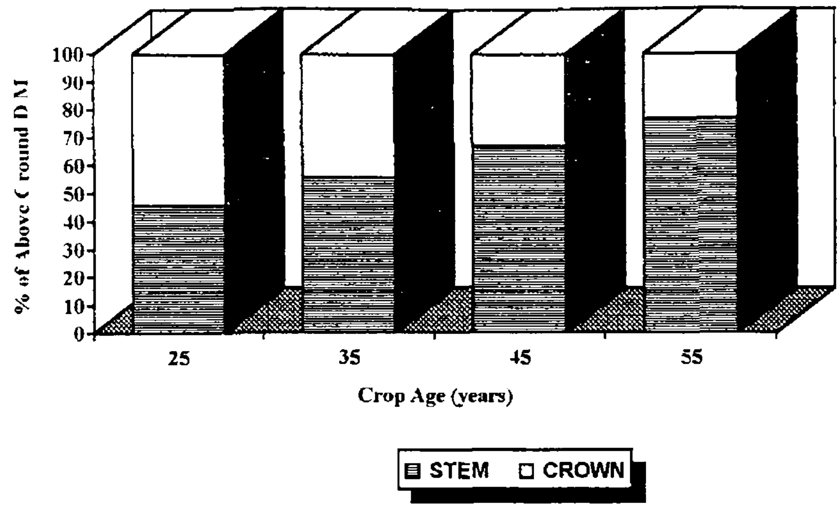

Figure 3 Distribution of Sitka spruce dry weight, Y C 12

It has been found that with increasing growth rates, the overall removal of nitrogen, phosphorus and potassium, increases out of proportion to the change in biomass production This imbalance is illustrated in Figure 4, (Miller et al (44), 1980)

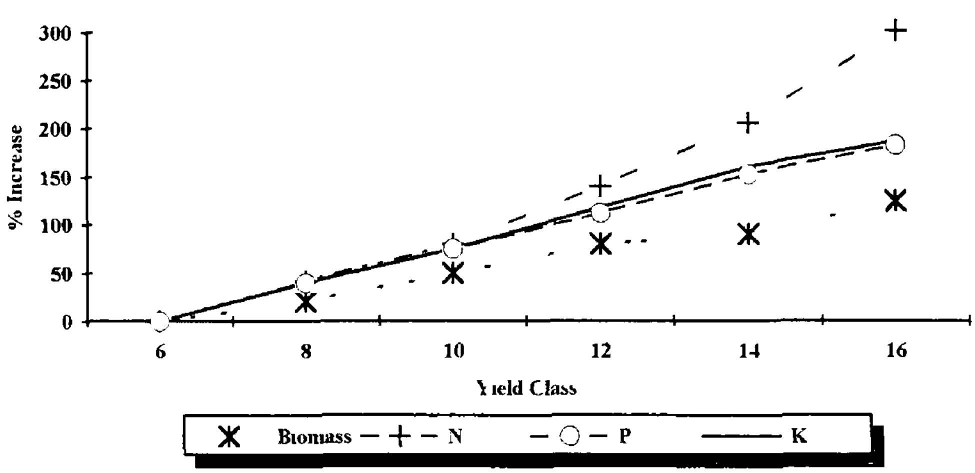

Figure 4 [7] Increases in the build up of N P K on a Kg per hectare basis and Biomass on a tonnes per hectare basis with increases in productivity

A site of yield class 16 for example would have 26% more biomass than a site with a yield class of 6, at the age of mean maximum annual increment (AMMAI)[8] The site of yield class 16 would however have 201% more N 95% more P and 100% more K than the site of yield class 6 Figure

[7] The data used for Figure 4 were taken from sites which were whole tree harvested when the top height (height of 100 largest diameter trees per ha) reaches 12 5 m (at ages 45 35 30 and 25 respectively)
[8] The AMMAI is the age at which a stand of trees should be felled

4 (Miller et al (44) 1980) This means that the nutrient resources of more fertile sites are depleted at a faster rate than on the less fertile sites

4 1 4 Calcium Depletion as a Result of WTH

The depletion of other nutrients particularly calcium is a cause for concern in the short term due to intensive harvesting practices (Weetman and Webber (48) 1972) Studies here in Ireland have shown that on Old Red Sandstone sites calcium deficiencies would occur, even after conventional harvesting, (Farrell (49), 1991)

Calcium is poorly conserved in forestry ecosystems (Mann et al (50), 1988) Averaged over four coniferous forests in Nova Scotia, it was discovered that the whole tree component is the equivalent to 30% of the calcium found in the forest floor and mineral soil This is in contrast to N, P and K, where the equivalent is 8 4%, 6 1% and 0 9%, (Freedman et al (42), 1985) WTH rather than CH could double calcium losses (Anderson (47), 1983, Freedman et al (42) 1985) With this in mind it is easy to see how WTH can seriously deplete the calcium reserves on poor sites

The sites on which calcium deficiencies are a threat after harvesting are typically derived from parent material lacking in calcium, such as granite and sandstone with the peatlands also becoming seriously deficient The weathering of such parent material would not release significant quantities of calcium to replace the calcium which is lost in WTH Limestone soils may replace some of the lost calcium through chemical weathering

4 1 5 Natural forms of Nutrient Replenishment

A substantial quantity of nutrients are returned to the soil through weathering of parent material and atmospheric deposition, (Farrell (49), 1991 Freedman et al (42) 1986 Rasmussen (51) 1990) The quantity of nutrients returned to the soil in this way is dependent on the parent material and location of the particular site, eg its proximity to industrial centres

Tests carried out on a ferric stagnopodzol soil in Wales have shown that through the weathering of mica shist the soil could supply enough potassium to support thirty more forest rotations (Goulding and Stevens (52) 1988) Freedman et al in their studies have shown the significant contribution weathering of minerals can make to nutrient replenishment The results from their studies show that you can expect 0 6 kg P ha^{-1} yr^{-1} 5 kg K ha^{-1} yr^{-1} 18 kg Ca ha^{-1} yr^{-1} and 5 kg Mg ha^{-1} yr^{-1} to be weathered from a soil derived from Devonian granite Nitrogen fixation is responsible for contributing about 10 Kg ha^{-1} yr^{-1} of N to the soil

Detailed studies carried out on a site in Ballyhooly Co Cork as part of the Exman project[9] illustrate the significant contribution atmospheric deposition makes on nutrient replenishment Table 6

	NH^{4+}	NO^{3-}	Ca^{2+}	Mg^{2+}	K^+	Na^+
Bulk Precipitation	4 0	1 5	3 7	4 6	2 7	62
Throughfall[10]	7 9	3 0	8 6	9 4	25	81

Table 6 Total loads in ecosystem water samples, Kg ha^{-1} yr^{-1}

Estimates are that 10-20 Kg N ha^{-1} yr^{-1}, 1-3 Kg P ha^{-1} yr^{-1}, and 6-10 Kg K ha^{-1} yr^{-1} are necessary to sustain tree growth[11], (Rodin and Bazilevech (53), 1965) If these figures are applicable then weathering and atmospheric deposition play a significant role in returning nutrients to the soil

4 2 CHANGES IN SOIL AND WATER PROPERTIES AS A RESULT OF WHOLE TREE HARVESTING

4 2 1 Changes in Soil Acidity

Plants take up their nutrients in the form of positively or negatively charged ions, for example Ca^{2+}, Mg^{2+}, K^+, Na^+ NH_4^+, SO^{2-} or NO^{3-} When a plant takes up a cation, for example Ca^{2+}, the soil becomes temporarily negatively charged In order to restore electrical neutrality the root system exudes two H^+ cations and as a result the soil becomes acidic

When anions are taken up by the plant, let's say SO_4^{2-},the anions that are substituted into the soil are $2OH^-$ or $2HCO_3^-$ If the amount of cations taken up by the plant equals the amount of anions then the contribution to soil acidity is zero (Nilsson (54), 1982) However this is not the case In its lifetime a tree takes up more nitrogen, in the form of NH_4^+ and other cations than it does nutrient anions The result of this is to increase the soil acidity

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[9] The objective of the Exman project was to monitor the impact of atmospheric deposition on forest ecosystems (Farrell 1991) The site at Ballyhooly was one of six sites throughout Europe in which such studies took place
[10] The forest canopy acts as a filter collecting particles contained in the atmosphere for example aerosols As precipitation passes through the canopy it carries these particles through to the forest floor this is known as throughfall
[11] No figure for calcium was available

If the forest crop was left to follow it's natural course the crop would eventually die and decompose As the trees decompose the cations would be returned to the soil and electrical neutrality would be restored However in most commercial forests the trees never get a chance to decompose instead they are removed and converted into sawlog and other products The cations therefore aren't returned to the soil The effects of this can be seen by comparing the CH figure after 10 years with the same figure for WTH ie the WTH site is more acidic than the CH site Popovic (1975) showed that the increase in acidity can be as much as 0 4 units, as a result of clearfelling

As there is more material removed during WTH the impact on soil acidity is greater than for CH, Table 7, (unpublished data from N Nykvist, Department of Forest Site Research, Swedish University of Agricultural Sciences) The ph of 3 7, in Table 7, is the result of cation uptake over the life of the stand After the crop is harvested, a proportion of the cations are returned to the soil in the form of slash This results in an increase in the ph, from 3 7 to 4 1 after one year and so on

	ph values *(All values refer to the humus layer)* **The original stand** *(Norway spruce)*	C H	W T H
1 Year after harvest	3 7	4 1	4 0
4 Years after harvest		4 4	4 3
10 Years after harvest		4 7	4 5

Table 7 Changes in pH value as a Result of CH and WTH

The figures for WTH show that the increase in pH is not as great as it is for CH This can be explained, again by saying that less biomass, and hence less cations are returned to the soil than in CH

The problem of soil acidity is compounded by the acceleration in decomposition, particularly nitrification (Lawrence et al, (55) 1987) Nitrification involves the release of H^+ ie

$$NH_4^+ + 2O^2 \;======>\; NO_3^- + H_2O + 2H^+$$

Because the insulating cover from the forest floor is removed in WTH soil temperature along with soil moisture increases to a greater extent than for CH Figure 5 (Anderson 1983) With increased soil temperature comes increased microbial activity and hence a greater rate of nitrification (Anderson (47) 1983)

Unfelled Area	CH	WTH
1 16	2 5	3 85

Figure 5 Litter Temperatures 24-hour range means of 10 instruments (^{o}C)

4 2 2 Changes in Stream and Soil Water Quality

In addition to nutrient losses through biomass removal, harvested sites lose nutrients through leaching, surface runoff, and erosion, (Mann et al (50), 1988) The extent of these losses is greater in the case of WTH than for CH because the slash which provides protective cover for the soil is removed The result of this is a decrease in stream pH and a significant increase in stream NO_3^- and basic cations, (Lawrence, Fuller and Driscoll (55), 1987) The release of H^+ from nitrification could increase mineral weathering and cation leaching through exchange reactions

Figures 6 to 9, (Lawrence, Fuller and Driscoll (55), 1987), illustrate the major changes over time, to stream water quality The data used for these graphs was taken from the Hubbard Brooks Experimental Forest (HBEF), in the White Mountains of New Hampshire, USA The site was whole tree harvested in October 1983 and harvesting continued into the spring of 1984

As a result of leaching, the concentration of NO_3^- in the streams increases dramatically as a result of WTH, Figure 6 Nitrate outflows have been shown to be highest a year or two after treatment and that concentrations decline after several years (Hart et al (56), 1981) This decline can be

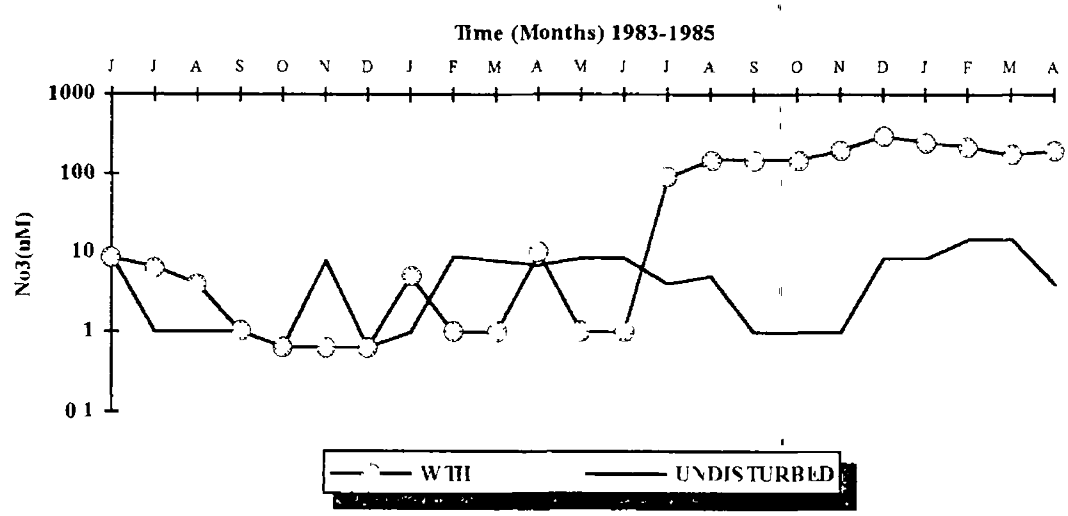

Figure 6 Changes in nitrate concentration in stream

attributed to the flush of vegetative growth following WTH which takes up NO_3^-, preventing it from being leached (Fahey et al (57) 1991)

The increase in decomposition results in the release of basic cations These cations are available for plant uptake Figure 7 shows that a significant proportion of these cations are leached however and never become available for plant use

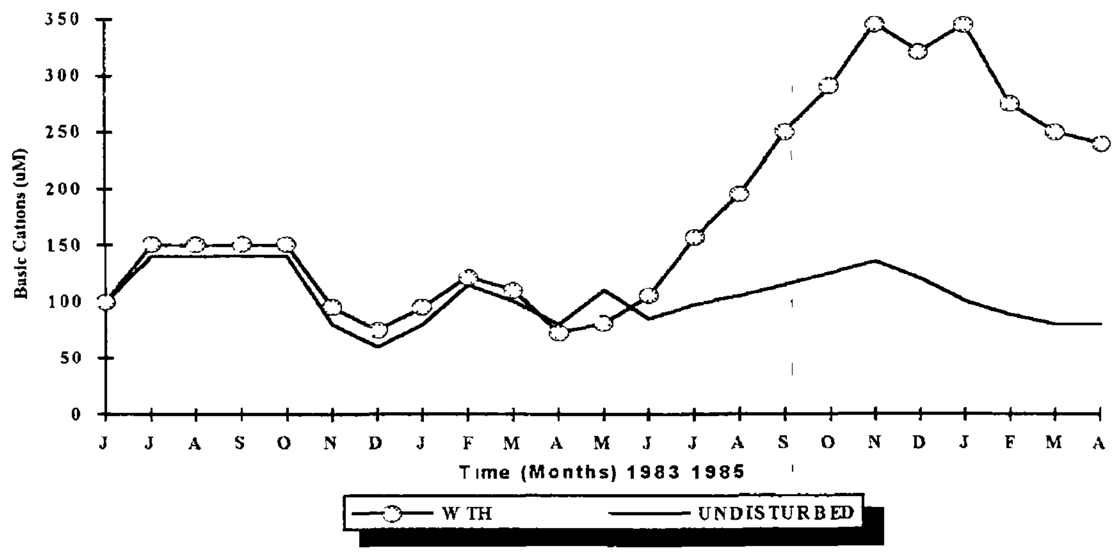

Figure 7 Changes in basic cation concentration in stream water, in an undisturbed watershed and in an area where whole tree harvesting has taken place

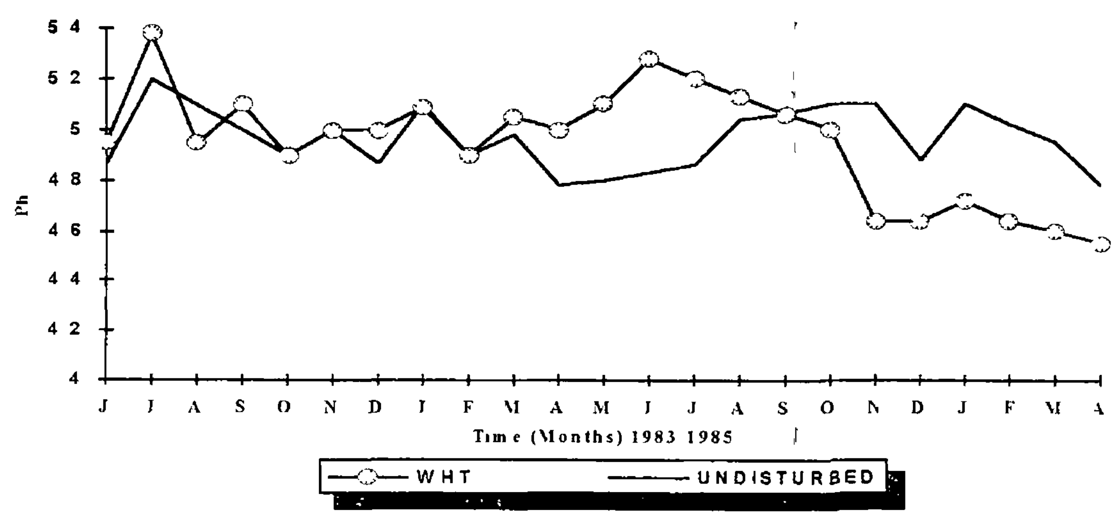

Figure 8 Changes in pH of stream water

Figure 8 shows the changes in pH in an undisturbed watershed and in an area which was WTH It illustrates the very real impact on stream water acidity as a result of WTH The decrease in pH lags about four months behind the increase in NO_3^-, figure 8 and again is brought about by the increase in decomposition and subsequent leaching

4 2 3 Changes in Aluminium and Sulphate Concentrations in Stream Water

Increased acidity is responsible for the dissolution of aluminium in the soil which eventually passes into nearby watercourses, (Lawrence et al (55), 1987) This relationship can be seen by comparing Figure 8 with Figure 9 It is evident from this comparison that as the pH decreases, after WTH the concentration of Al increases

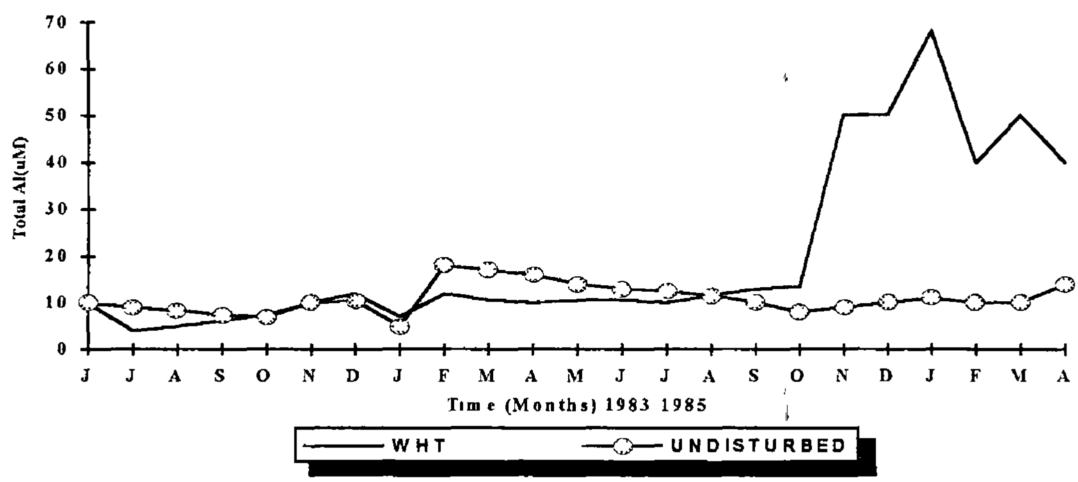

Figure 9 Changes in total Al concentration in stream water in an undisturbed watershed and in an area which has been WTH

Previous work has shown Al to be toxic to fish at lower levels than that illustrated in Figure 9

A further consequence of WTH, is the decrease in SO^{2-}_4 concentration in stream water, (Mitchell and Driscoll et al 1989, Fuller et al (58), 1987) Studies at the HBEF have shown that short term SO^{2-}_4 dynamics in soil solutions and streams is regulated by sulphate adsorbtion that is enhanced by acidification induced by nitrification following WTH, (Fuller et al (58) 1987

The impact on stream water quality as a result of WTH is not confined to the immediate area It has been shown (Lawrence and Driscoll (59) 1988), that downstream water chemistry is also effected but to a smaller extent It has been suggested that WTH on a large scale could have a severe impact on downstream chemistry as well as on the immediate water courses

4 3 THE IMPLICATION OF WTH IN IRISH FORESTRY

The data presented in the preceding sections is supported by other research done on the subject, (Phillips and Van Lear (43) 1984) In conclusion WTH represents a serious loss of nutrients for the majority of Irish forest sites (McCarthy (46), 1991) Marginal sites, on which Irish forestry has been established are more sensitive to WTH than sites which are more fertile and productive The accelerated depletion of nutrient reserves on these sites as a result of WTH, would reduce the productivity of subsequent rotations The more fertile sites, however would in most cases be capable of sustaining repeated removal, for several rotations of all above ground tree parts, (McCarthy (46), 1991, Carey (41), 1980)

PART TWO

DEMONSTRATION PROJECT: THE PRODUCTION, COST & MARKETING OF SLASH BRIQUETTES

CHAPTER FIVE

THE MANUFACTURING OF SLASH BRIQUETTES AND THEIR CALORIFIC VALUE

5 1 INTRODUCTION

One of the main objectives of the project was to manufacture a sample of bnquettes using slash By doing so, several key factors would be established

1 It would prove that solid well defined bnquettes can be manufactured from slash

2 The calonfic value of the bnquettes could be calculated This would allow compansons to be made with other competing forms of domestic fuel

3 Certain charactenstics of the bnquette could be established which may give it a comparative advantage over other fuels Questions such as, are they easy to light, or do they give a pleasant odour when burned could be answered

Three different types of bnquettes were manufactured The first was made from clean white chips This would enable a companson to be made between this bnquette and the "Heatlog" bnquette which is made from sawdust This would help establish the effect of particle size (density) on heat content for each bnquette

The second type of bnquette was made from the matenal left behind after delimbing and debarking This matenal is intended to represent slash However bnquettes manufactured from this matenal would contain a higher percentage of bark, than a bnquette produced from the waste left behind after conventional harvesting This matenal was however the closest matenal to slash that could be sourced and hence this fact was overlooked (the likelihood of any difference accruing from this fact would probably be very small)

The final bnquette was manufactured from a 3 1 mixture of clean white chips and mulch This mixture represented the chips produced from whole trees Producing a bnquette using this matenal would show that bnquettes can be manufactured from whole tree chippings Harvesting and comminuting whole trees for the purpose of making bnquettes could be a viable alternative to conventional harvesting of first thinnings The latter is a costly exercise which normally yields low value pulp and palletwood

The first step in producing these bnquettes is to source the matenal

5 2 SOURCING THE RAW MATERIAL

Processing machines designed for inwoods chipping arrived from Scotland on the 16th March 1992 They had been brought to Ireland on a trial basis where productivity and the logistics of whole tree harvesting would be studied The exercise was conducted at Oughterard 28 Km from Galway City on a site of Low Level Atlantic Peat

The machines were working on lodgepole pine planted in 1966, which was being clearfelled prematurely Average volumes varied between 0 077m^3 and 0 116m^3 depending on each sub-compartment and yield classes were either 12 or 14 The machines which were brought over from Scotland were the Manitowoc delimber debarker, the Morbark chipper and the Barkbuster

5 2 2 The Manitowoc

This machine delimbs and debarks trees with the purpose of producing clean stems which can be processed for pulp chips, (see plate 5, Appendix B) At Oughterard the chips were being sold to Medite to make MDF (Medium Density Fibreboard) The machine is fed by a forwarder feeding up to 12 trees at a time into the machine The chips produced from these stems had a percentage bark content of 1 5%, however if the percentage of bark in the chips went above 5% the chips could not be used for manufacturing MDF

Occasionally the bark content of the chips did go above 5% It was suggested that the poor form of the Lodgepole pine, particularly basal sweep could be responsible for this high bark content Whenever the bark content did reach unacceptable levels the flail speed was increased and less trees at a time were put into the Manitowoc

The machine itself was manufactured in Manitowoc Wisconsin U S A The delimbing mechanism is made up of six sets of six chains attached to each of two vertical drums The chains themselves are made up of eight links The drum rotates at 525 - 625 revolutions per minute and the Manitowoc can process 38 m/min There is some fibre loss due to the action of the chains which can be as high as 4%

5 2 2 The Morbark Chipper

The Morbark like the Manitowoc is an exceptionally powerful and productive machine (30 green tonnes per hour) which could chip stems as quickly as they were delimbed and debarked For this reason the two machines can be used successfully together Stems were fed by crane into the feeder drum which grips the stems and feeds them in against the chipping drum This drum which is horizontal literally slices away at the stems in a downward action to produce chips

The chips produced by the Morbark vary in size considerably and are eventually blown through a chute into the back of a lorry, (see plate 6) Because all foliage is removed before chipping there is a smaller chance of chipping blades becoming blunt from dirt carried in on trees during skidding Any foreign material that may find its way into the chipper is crushed instantaneously

5 2 3 The Barkbuster

Branches and bark removed by the Manitowoc ends up on a conveyor belt which feeds into the third machine on trial at Oughterard, the Barkbuster, (see plate 7) The Barkbuster is actually owned by a firm which has to prune an orchard comprising 300 acres Debris from the Manitowoc is processed into a mulch by the Barkbuster This is achieved by a horizontal rotating drum 1 25 m in length and 65cm in diameter It has a total of 88 rectangular metal plates or hammers fixed onto it The metal plates can be turned around to expose a new cutting surface There are five different screens available, they are 2 5cm, 3 75cm, 5cm, 7 5cm and 10cm The bin itself is 3 3m in diameter and 1 45m deep Quantities of the mulch were purchased by local garden centres that realised the nutritional value of the branch needle and bark mixture

5 2 4 A Overview of the Harvesting Operation at Oughterard

The purpose of including this section in the chapter is to outline the difficulties that can be encountered on forest sites in Ireland when it comes to whole tree harvesting The removal of the slash carpet which protects the soil and helps support the heavy machinery is a serious obstacle to successful harvesting, in a great number of Irish forests

Conditions at the site in Oughterard can be described as very difficult, The depth of peat varied on the site from being very shallow to being about 2m deep A Nooka forwarder was working on the site but it could only manage half loads on some occasions for fear of getting bogged down Two clambunk skidders (Bruunettes) were in operation and they had been delegated to work in the worst ground on the site (see plate 2) A fourth forwarder was positioned at the delimber debarker which fed trees into the machine (see plate 4)

To overcome the problem of the slash carpet 25% of stems were left behind These stems were positioned along the racks where machine traffic would be concentrated 25% of stems does however represent a significant quantity of biomass and such a situation does seem to contradict itself, as the operation in the first place was designed to harvest biomass

Forwarders and skidders unloaded at the delimbing machine The delimber processed trees much quicker than it could be supplied and a buffer stock only accumulated when the delimber shut down As the chipper could work at the same rate as the delimber both machines were frequently idle As a result rather than 30m^3 per hour being chipped only 8m^3 per hour was being achieved This situation is to a large extent due to the low productivity of the forwarder and skidders brought about by the poor conditions

It was estimated that in order to maintain a constant level of production under these conditions, at least 300m^3 should be accumulated at the landing This would mean that the landing site would have to be increased from its existing area of 60m x 25m to around 80m x 25m to allow for the build up of inventory at the delimbing machine A build up of inventory could be achieved by forwarders starting an hour or two earlier in the day or indeed working later in the day than the processing machines It is certain however that one or two more forwarders would have to be introduced to make the system run smoothly

A landing area was cleared and gravelled prior to the arrival of the machines Particular attention was given to creating a strong durable surface at Oughterard because of the wet climate, the underlying peat soil and the expected level of heavy traffic At least sixteen lorry loads of gravel was used to surface the landing area at this site However, as the level of traffic increased at the landing the gravel began to sink into the peaty soil As a result more lorry loads of gravel had to be commissioned to surface the landing area

As the forwarders had to travel further to collect a load extraction costs increased If forwarders spent more time travelling rather than loading and unloading, less trees would be brought to the landing and the delimber and chippers would have less material to work with Ideally a new landing should be constructed closer to the source of raw material once the extraction distance reaches 300m In the situation at Oughterard the cost of constructing a new landing was far greater than the extra costs incurred as a result of the extraction distance exceeding 300m

5 2 5 Gathering the Raw Material

Six industrial sized bags of clean white chips were filled this made up a total of 1m^3 In addition to this four bags of broken down branches needles and bark (which will be referred to as mulch) were also filled (see plate 8)

5 3 PREPARING THE RAW MATERIAL FOR PRODUCING BRIQUETTES

Before the briquettes can be manufactured they must be first dried to a moisture content of 10% This took place in two stages the first at Bolton Street, College of Technology and the second at Eolas in Glasnevin Once this was achieved the chips themselves had to be broken down to a smaller particle size

5 3 1 Reducing the Moisture Content

The material arrived in Dublin from Oughterard on 30th March 1992 It was brought to Bolton Street and laid out in the boiler room there The boiler room created a warm environment where the chips could be dried to a moisture content of 25% After approximately 3 months of constant turning, the desired moisture content was achieved[12]

The next stage of drying took place at Eolas, where a fan kiln was made available to reduce the moisture content to 10% The kiln was made up of three large fans each approximately one metre in diameter A large wooden framed container surrounded by two layers of chicken wire was constructed to contain the chips in the kiln while the fans were in operation, (see plate 9)

This arrangement worked well for the white chips, but the mulch was too fine and simply fell through the mesh of chicken wire A new strategy had to be devised for the latter As it was now summer and the weather was particularly good, it was decided that a special outdoor kiln would

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[12]The moisture content of the material was monitored on a weekly basis Four samples (weighing approximately 20grms each) were taken from both the white chips and the mulch The samples were taken completely at random, from the surface of the piles and from the centre The eight samples were then brought to the chemistry laboratory in Bolton Street for testing The procedure for measuring the moisture content was as follows

1) Eight beakers were cleaned and weighed and labelled from A to H
2) Each sample was placed into a designated beaker and weighed By subtracting the weight of the beaker from the weight of the beaker plus sample the weight of the sample could be calculated
3) The eight beakers were put into an oven and removed and weighed after one hour Before the beakers are weighed however, they are allowed to cool for approximately half an hour in a desicator The desicator contains a quantity of silica gel which removes any moisture that may be present in the glass container The reason for this is that the sample must be weighed in an equilibrium temperature to avoid incorrect readings from the weighing scales A heated sample weighed in a cold environment will give a reading slightly less than the true weight of the sample This processes is repeated every half hour until the weight of the sample becomes constant, this signifies that all the moisture has been driven from the sample
4) The weight of the sample after drying is then subtracted from the original weight of the sample before drying The difference is then divided by the weight of the latter The resultant figure is then multiplied by 100 to give the percentage moisture content The average moisture content was then calculated from the four samples

The same procedure was followed whenever moisture contents had to be determined and the importance of choosing samples at random was never underestimated be constructed to dry the mulch Two wooden panels each 1 5 wide and 3m long were placed alongside each other and supported off the ground by a number of bricks A double layer of polythene was put over the panels on which the mulch was laid Another layer of polythene was then supported above the material and the whole structure resembled a very primitive kiln using the energy of the suns rays to drive out the moisture in the chips The effect of the suns rays were maximised by facing the wooden panels in a southerly direction at a slight angle This system worked very well and after only 3 weeks the desired moisture content of 10% was achieved It was considered for a while that the white chips could be dried in a similar fashion but since the weather could not be relied upon this option was overlooked

The white chips had still to be dried, and access to the kiln at Eolas was eventually granted for the month of August A drying schedule was drawn up for the kiln which outlined that unheated air would be circulated in the first three weeks and heated air circulated for the final week The direction in which the fans of the kiln rotated changed after a period of approximately one hour, this meant that air was being alternatively blown into and sucked out through the chips The chips inside the cage were also agitated by turning the cage upside down and around each day This meant that the cage was now upside down with the opposite side of the cage facing into the fans

The chips were successfully dried to 15% moisture content using unheated air On the final week however the gas burner brokedown after four days, the moisture content of the chips at the time was 12 2% This level was judged to be sufficient

5 3 2 Hammermilling the Mulch and White Chips

The raw material was transported to Irish Carbon Products Ltd in the beginning of September The material was broken down usmg a chain flail type hammermill with had a 3mm screen attached The screen acted as a sieve preventing particles greater than 3mm into the collection area The process began by first emptying the bags filled with mulch onto a conveyor belt which fed the material into the hammermill[13], (see plate 10,11) The broken down mulch was blown through a series of pipes and eventually ends up in a small holding silo The material is then collected at this point in plastic bags (see plate 12) This process is repeated for the white chips

[13]Under normal conditions at ICP Ltd where the raw material is sawdust all the stages of manufacturing the briquettes are done mechanically A continuous feed mechanism is in place which avoids any manual handling of the material until the packaging stage Briefly the material is passed through a sieve at its arrival at the factory Any material which fails to pass through the screening process is too large to be used for making briquettes and it is fed automatically into the hammermill The rest of the material is transported into a large holding silo from which sawdust is continually fed into the briquetting machines The larger particles on the other hand leave the hammermill and are fed into a much smaller holding silo where the material is fed into the extrusion screws

and a total of five bags of broken down material was produced (two bags of mulch and 3 bags of white chips) In order to create the 1 3 ratio of mulch to white chips, representative of the material produced from whole trees, half of one bag of mulch was thoroughly mixed by hand with one and a half bags of white chips

5 3 3 Manufacturing the Briquettes

Briquettes were manufactured using an extrusion screw, (see 3 2 2) The three different samples of material, the mulch, the white chips and the 1 3 mixture were then fed separately by hand into the extrusion screw, (see plate 13) The resulting briquettes were immediately bagged and marked according to the briquette type

The process of densification proceeded smoothly except in the case of the white chips Just as the white chip briquette emerged from the die of the extrusion screw, there was a loud bang and the briquette flew out of the machine This can be attributed to the higher moisture content of the white chips As the high temperature and pressure was applied to the chips a certain proportion of moisture in the chips was converted into water vapour This water vapour can be seen escaping through the hollow in the centre of the briquette (see plate 14) If the moisture content is around 12% or greater, as in the case of the white chips not all of the steam can escape through the hollow This resulted in the build up of pressure, culminating in a loud bang and the briquette was thrown out of the die like a bullet

5 4 DETERMINING THE CALORIFIC VALUE OF SLASH BRIQUETTES

Samples from each of the three briquettes produced along with a commercially available "Heatlog" (ie the briquette type manufactured at ICP Ltd using sawdust), were labelled as follows,

1 = Clean White Chip Briquette
2 = Mulch Briquette
3 = Mulch and White Chip Mixture
4 = Heatlog

The briquettes were taken to the Industrial Chemistry Department at Eolas Glasnevin where the gross calorific value of each of the four samples was determined This was conducted under the specifications outlined in British Standards BS 1016 "Analysis and Testing of Coal and Coke"

The following sections outline the basic procedures taken by Eolas when calculating these calorific values

5 4 1 The Mahler Bomb Calorimeter

Each sample is ground down to a size not greater than 0 2mm (ground to pass a 212μm sieve test as specified in BS 1017) The samples were exposed in a thin layer long enough for the moisture content to reach approximate equilibrium with the laboratory atmosphere The sample was mixed by mechanical means before being subdivided and subdivided again before a sample of approximately 1 gramme was taken for testing

A tablet making device was used to compress the samples, (Figure 10) Before this was done a thin piece of pre weighed platinum wire, about 10cm in length was put into the grooves of the tablet machine

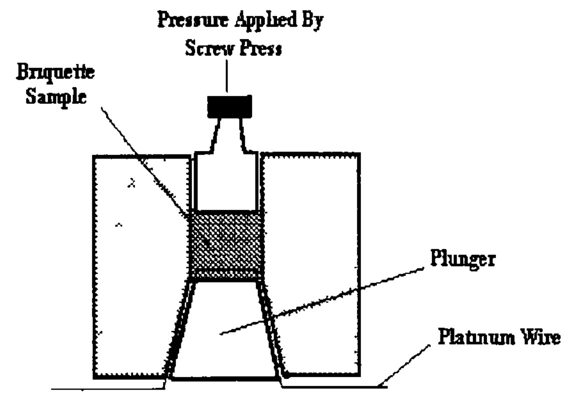
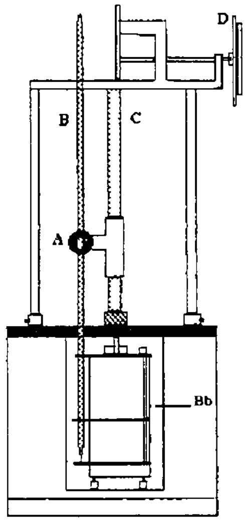


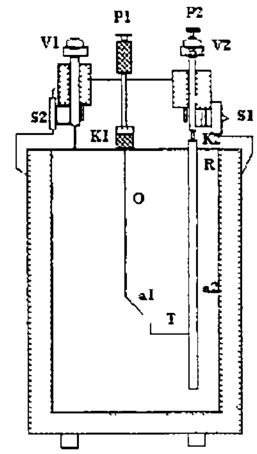
Figure 10 Details of the Tablet Machine

The ground samples were then put into the chamber of the tabletting device at which point the plunger was inserted and pressure applied with a screw After 150 - 200 seconds the plunger was removed and the tablet with the wire passing through, was carefully weighed The tablet was then put into the bomb (figure 11) and placed on the crucible The platinum wire was then attached to the terminal rods

The head of the bomb was then screwed on and tightened with a bar spanner A few drops of water ensured a good gas seal, and care was taken that the head washer was not damaged by excessive force After closing the outlet valve, the oxygen delivery pipe was connected to the bomb and the inlet valve opened half a turn By means of the needle valve on the cylinder head oxygen was allowed to pass slowly into the bomb until the pressure reached 2,000 - 5,000 kN/m^2 The valves on the cylinder and bomb were closed simultaneously the oxygen delivery pipe was removed and the screw stoppers were replaced 1800 cm^3 water at room temperature was poured into the calorimeter the firing leads to the bomb were connected and the bomb was placed in the calorimeter within the constant temperature enclosure The electrically driven stirrer and a 10 - $25^{o} \pm 0\ 001^{o}C$ thermometer were lowered into the calorimeter taking care to ensure that they did not come into contact



The Calorimeter with Bomb in Place



The Bomb Enlarged

Key

A	= Thermometer Telescope	K1, K2	= Oxygen Outlet and Inlet
B	= 10 -25° Thermometer	O, R	= Electrical Terminals
C	= Stirrer Shaft	S	= Screw Plugs
D	= Drive Pulley	V	= Oxygen Needle Valves
Bb	= The Bomb	T	= Crucible
		a	= Crucible Supports & Connections for Platinum Wire
		P	= Electrical Connections

Figure 11 The Berthelot - Mahler Bomb Calorimeter

The cover was fitted to the calorimeter and the apparatus was left running for 600 - 750s Temperature readings were then taken every 60 s for 300 s at which point the ignition switch was closed and the briquette sample fired Temperature readings were taken every 60 s during the period of temperature rise and continued into the third and final period At the end of the experiment the bomb was removed from the calorimeter and the outlet valve opened half a turn to release the pressure The head was then removed to check that the combustion was complete and only ash remained

The Calorific Value was calculated as follows

([14]Total Water Equivalent × [15]Specific Heat × [16]Corrected Temperature Rise) - (Weight of Wire × Calorific Value of Platinum)/Weight of Sample

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[14] The total water equivalent of the calorimeter plus the total volume of water used in the calorimeter

[15] The cooling correction plus the temperature rise during firing (Cooling correction = (length of firing period) * (mean of initial and final cooling rates)

[16] The rise in temperature recorded is the increase in temperature of the surrounding water in the calorimeter This increase must be converted to the actual increase in temperature of the surrounding air

The results of the test from the four samples are presented in the following tables

	Samples 1	2	3	4
Cal/g	4315	4380	4330	4430
Btu/lb	7770	7890	7800	7970
KJ/Kg	18070	18350	18140	18550
Moisture content of briquette (%)	8.6	7.4	8.5	7
Moisture content of chips before briquette manufacture (%)	12.2	10.0	11.6	9.0

Table 8 Gross Calorific value as received

	Samples 1	2	3	4
Cal/g	4720	4790	4680	4805
Btu/lb	8500	8620	8420	8650
KJ/Kg	19770	20050	19580	20120

Table 9 Gross Calorific Value on a Dry Basis

The figures in these tables show that there is little difference in calorific value between the four briquette samples. The slightly higher calorific value for the slash briquette can be attributed to its lower moisture content, see section 3.1.2. The reason for this is that energy is required to convert the moisture to vapour during combustion. Another interesting fact emerging from the results from Eolas is the extent to which the chips loose moisture as they pass through the extrusion screw. This moisture manifests itself as steam rushing out through the central hollow as the briquette emerges from the extrusion screw. The reduction in moisture content of 3.6% for sample 1 as apposed to 3.1% or 2.0% for sample 3 and 4 resulted in a build-up of steam which was responsible for the rifle effect described in section 5.3.3. Although the reduction of moisture was 2.6% for sample 2 the vapour was able to escape before a build-up of steam developed. Figure 12 compares the slash briquette to two other forms of domestic fuel.

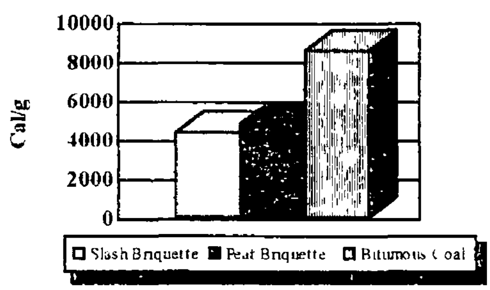

Figure 12 GCV Comparison between 3 Fuels

Since the density of the briquettes is important from a marketing perspective these densities are shown in table 10. For example a 25Kg bag of briquettes manufactured from whole trees would be 14.5% larger than a bag of "Heatlogs" as a result of the difference in densities. The density of the bnquette depends to a large extent on the particle size of the raw matenal In the case of sawdust, the surface contact between the particles is much greater than for the other samples hence the greater density

	Samples			
Samples	1	2	3	4
Density (grams/cm^3)	1 06	1 04	1 1	1 19
Vol per 25Kg bag of Bnq (cm^3)	23585	24038	22727	21008
Cal/ cm^3	5003 2	4981 6	5148	5718
Cal/bag	1 18x10^8	1 197x10^8	1 17x10^8	1 2x10^8

Table 10 A Companson of bnquette densities

The lower density of the mulch bnquette can be attnbuted to the higher proportion of bark This means that a 25kg bag of mulch bnquettes would have to be 8% larger than a bag of "Heatlogs" As might be expected the number of calories per 25kg bag of bnquettes isn't significantly different for each of the four different bnquettes The only significant difference occurs in the actual volume of the bag the bnquettes would be held in

5 4 2 Conclusion

By successfully manufacturing slash bnquettes the following points have been proved,

1 A bnquette can be manufactured using slash, in addition to this, a bnquette can also be made from whole tree chippings This can be achieved by reducing the moisture content of the chips to 10%, and hammermilling them to a size not greater than 3mm

2 Slash bnquettes produce a pleasant aroma when burnt not unlike the smell given off from burning peat

3 Slash bnquettes have the same qualities at "Heatlogs' insofar as they light easily and they do not disintegrate easily

CHAPTER SIX

THE SUPPLY OF RAW MATERIAL

6 1 INTRODUCTION

This chapter is in two sections the first section deals with determining the volume of residue a stand generates when it is harvested Having a reasonably accurate estimation of the volume of slash on the ground is a crucial step in determining the cost effectiveness of harvesting this material Equally as important is achieving an accurate estimate of this volume at the lowest cost possible This chapter illustrates a cost effective and accurate method of carrying out such an inventory The technique outlined may precede any operation that involves the harvesting of slash

The ideal location for a briquetting plant would be in Co Wicklow, where a large supply of raw material can be guaranteed Its proximity to the large Dublin market also makes it an ideal choice for establishing such a factory This chapter deals with determining the volume of slash which is generated in this region This data is then used to determine where in Wicklow a briquetting plant could be most cost effectively located, with regard to haulage costs

6 2 THE LINE INTERSECT METHOD OF ASSESSING FOREST RESIDUE

6 2 1 Background and Theory

The necessity of obtaining reasonably accurate estimates of logging residue first arose during the initial phases of harvesting in 1957 at Kaingora Forest New Zealand The pulpmill purchasing the residue, reduced its residue size limit for extraction from ten cubic feet to a minimum billet size of four feet in length and two inches in diameter at the small end It became necessary therefore for the Forest Service in New Zealand to obtain accurate estimates of this volume at a low cost for revenue purposes

The task of developing an accurate and cost efficient system of estimating the volume of forest residue was undertaken by W G Warren and P F Olsen, (60) of the New Zealand Forest Service Their exhaustive studies using conventional plot methods, showed that no worthwhile advantage was achieved by altering the size or shape of the plots except that long rectangular plots sampled the pattern of distribution more adequately This length and breadth relationship was taken to the extreme when Warren and Olsen suggested using a straight line with no width for sampling

Their research using this method of sampling led them to establishing a regression line which illustrated the close relationship between the number of pieces[1] intersecting the line and the total volume of these pieces This meant that instead of the volume of individual pieces having to be recorded once the basic data was available a mere count of the intersected qualifying pieces would suffice In the case at Kaingora the only measurements required would be to check whether certain pieces complied with the minimum size requirements

The accuracy of estimating the volume of residue in this way is however affected by the counting technique A true representation may not be achieved mainly due to the variation in the volume of the pieces, length, distribution and orientation of the pieces, and also the length and orientation of the sampling line With these factors taken into consideration Warren and Olsen devised the following formula

Volume per acre = 660 xn/IcB Where

B = The length of sampling line
n = The number of pieces intersected by the line
x = A factor dependant on the dimension characteristics of the piece population
Ic = A factor dependant on the orientation of the pieces in relation to the direction of the sampling line
660 = The scale factor required to convert to volume in cubic feet per hectare

It was found that x remained reasonably constant However values of Ic varied considerably depending on the type of harvesting operation Preliminary tests therefore, had to be undertaken in order to attain an accurate value for Ic Regardless of this, the method of sampling gave volume estimates of good precision

Warren and Olsen's research laid down the foundations for a more practicable method of sampling which did not require preliminary tests for bias in the orientation of pieces This method, devised by C E Van Wagner (61) of the Department of Forestry of Canada is the method on which the field studies were based

The basic formula is as follows

$V = \pi^2 \Sigma d^2/8L$ Where

V = The volume of wood per unit area
d = Piece diameter
L = length of sample line
π = 3 14

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[1] Pieces refer to the residue left behind after harvesting including branches and portions of the main stem

The basic formula depends on three assumptions

1 The pieces are cylindrical However the presence of taper probably introduces no error
2 All pieces are horizontal The vertical angle can be quite large before the error is serious
3 The pieces are randomly orientated Bias in orientation can be corrected by special factors determined in field trials (the approach of Warren and Olsen), or by running sample lines in two or more directions and applying the basic formula

Van Wagner approached his counterparts line intersect method of sampling by saying that if the line that intersects the pieces has infinitesimal width then the volume per unit area can be stated in terms of cross sectional area per unit length of line In order to overcome the orientation bias Van Wagner illustrated that two transects should be employed at right angles to one another If three lines at different angles to one another were used the error would be reduced even further The following section involves a field trial using this method of estimation

6 2 2 Methods and Materials

A forest site at Avonmore, Co Wicklow was chosen for the field trial' It was chosen because the residue from the stand would most probably be harvested if a briquetting plant did exist in the Wicklow region The stand was poorly managed and consisted of a mixture of lodgepole pine and sitka spruce 1,000 stems per hectare were clearfelled prematurely and the average stem volume was 0 1 m^3 The Yield class was a very poor 6

Two people are required to conduct the field evaluation and the following are the materials required,

i) 2 X 30m Nylon cord
ii) 4 X Wooden Stakes
iii) Vernier Calipers
iv) Mallet

A point was chosen randomly by walking 100m into the site At that point a stake was driven into the ground One length of the nylon cord was then fixed to the stake and extended to its full length in a randomly chosen direction The end of the cord was tied to a second stake which was driven into the ground A second line was then set up like the first but running at right angles to it extending from its middle point (see figure 13)

Using the Vernier Calipers, the diameter of any branch intersecting the cord was measured and recorded using the gate system (*branches under 8mm in diameter not recorded*)

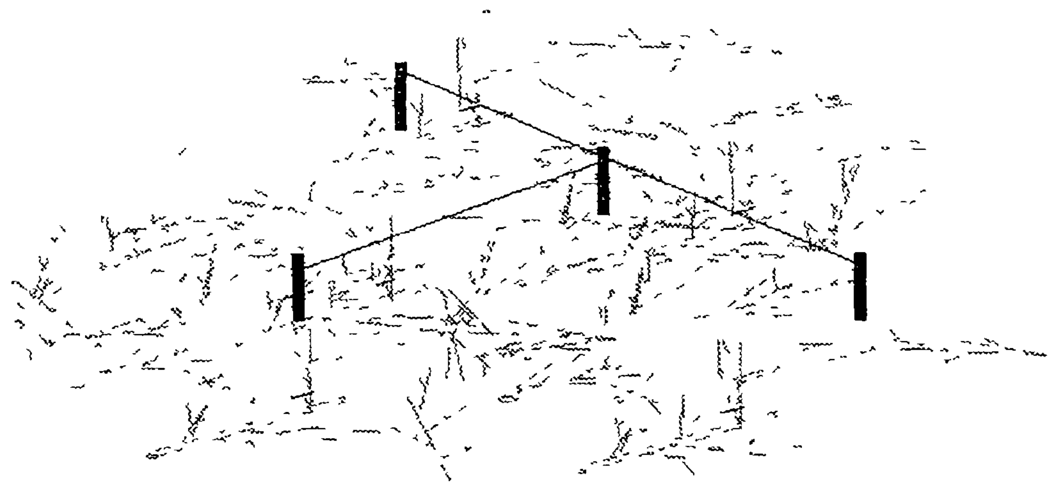

Figure 13 Illustration of field trial layout showing the brash carpet, the stakes and the two lengths of cord

An example of a record sheet is shown in figure 14 The numbers shown are the diameter classes in millimetres of the branches which make up the residue Each vertical stroke represents a branch which has been counted as belonging to a particular diameter class When four strokes are marked a diagonal line is drawn across them to indicate a group of five This system of marking makes it easier to record and count the number of branches

Line Intersect Number One	
8 卌卌	17 卌卌卌|
9 ||	18 卌卌||
10 卌|	19 卌||
11 |	20 ||||
12 |||	21 |
13 卌卌||	22 ||
14 卌卌卌|	23
15 卌卌|||	24 |
16 卌|||	25

Figure 14 Example of record sheet

Three sets of intersect lines like that shown in figure 13 were set up and a summary of the data recorded is shown in Appendix C Van Wagners formula is then used to calculate the volume of residue per hectare This is achieved as follows

Line Intersect No 1 $V = \pi^2 \Sigma d^2/8L$

$= \pi^2(1476996mm^2)/8*30m*2$
$= 1476996mm^2/480m$
$= 14\ 76996m^2/480m$
$= 0\ 03077m^2/m$ (*This is the area of slash along a single metric line which has no width*)
$= 0\ 03077m^3/m^2$ (*This is the volume of slash in a single square metre*)
$=$ **30 77 m^3/ha** (*ie 0 03077 m^3/m^2 *10000 to give the volume per ha*)

Line Intersect No 2 V $= \pi^2(2228675mm^2)/8*30m*2$

$= 2228675mm^2/480m$
$= 22\ 28675m^2/480m$
$= 0\ 04643m^2/m$
$= \mathbf{46\ 43m^3/ha}$

Line Intersect No 3 V $= \pi^2(1457454mm^2)/8*30m*2$

$= 1457454mm^2/480m$
$= 14\ 57454m^2/480m$
$= 0\ 03036m^2/m$
$= \mathbf{29\ 93m^3/ha}$

The Mean Volume $= (30\ 77m^3/m^2 + 46\ 43m^3/m^2 + 30\ 36m^3/m^2)/3$
$= \mathbf{35\ 85m^3/ha}$

6 2 3 Discussion

Warren and Olsen carried out a field trial similar to that carried out at Avonmore Forest After spending four hours in the field, they decided to test the accuracy of their results They did this by area sampling, ie weighing and measuring the volume of the residue within selected area plots They showed that 4 hours using the line intersect method of volume estimation yielded results just as accurate as twenty hours of conventional area sampling

In the case of C E Van Wagner the diameter of branches were measured over a length of 71m per hectare (*the site consisted of 20 ha and the test lasted 5 hours*) Van Wagner was confident that his results were accurate and he didn't feel the need to verify them using the time consuming methods of conventional volume estimation In the trial carried out at Avonmore a total of 180m/ha of intersect line was measured (as the total area of the plot was 1 ha) As this was more than twice the length used in Van Wagners field trial it can be assumed that the results achieved are reasonably accurate The trial itself took a total of three hours to complete and within this time period an acceptable level of accuracy was achieved thus showing that a quick efficient method of volume estimation can be successfully carried out in the field

6 3 DETERMINING THE LOCATION OF THE SLASH BRIQUETTING PLANT

This section deals with determining where in the Wicklow region a briquetting factory should be located The location of the plant will be restricted to one of the fifteen forests in the 11 and 12 districts listed in table 11 The assessment is planned to take place over a four year period 1993-1996

Forest	Forest Code
Delgany	1102
Glencree	1104
Glendalough	1105
Killakee	1106
Roundwood	1108
Blessington	1109
Hollywood	1110
Ballinglen	1201
Aughrim	1202
Avoca	1203
Gleneally	1204
Glenmalure	1205
Greenane	1206
Ballinglen	1208
Avonmore	1210
Glen of Imaal	1211
Rathdangan	1212

Table 11 List of forests in the Wicklow and Dublin region

During the course of this exercise the total volume of residue will be calculated for each forest in the Wicklow Region over the four year period The volume of residue generated from thinnings and clearfellings for all species will be included These results should then allow a reasonably accurate appraisal of where the plant should be located, as well as providing some indication as to whether a sustained supply of residue can be expected in the future

A database (using Microsoft Works) will be set up initially to tabulate and organise the large volume of data which needs to be processed Information from the database will then be used to calculate the cost per m^3 of transporting the chips from the forests The cost of transporting the finished briquettes from the briquetting plant to the marketplace Dublin, will also be calculated and hence the total transport cost per m^3 for each forest will be determined Whichever forest has the lowest transport costs will therefore be the ideal location for the briquetting plant Although there are other factors which come into play when determining where a factory should be located the only parameter used in this exercise will be haulage costs

6 3 1 Assumptions

To calculate where exactly the briquetting plant should be located is quite a large undertaking Realistically it would involve the writing of a computer model to simulate the haulage of material to and from a huge number of possible sites Such a model would have to take into consideration factors such as route suitability ie would the proposed route, which would include small bridges support the loads being transported on them In addition to this the model would have to calculate the exact amount of residue which would be recovered from the forest and which is available for transportation to the briquetting plant In this case it is fair to say that not all of the raw material generated by the forests will be recovered, some will be left behind on the roadside as waste The exact level of raw material consumed by the briquetting plant, including waste would also have to be accurately assessed, taking into account seasonal changes and the level of market demand

The following are the assumptions that are made in this section, regarding the briquetting plant,

a) An environmental impact assessment has been conducted for each of the forests listed in table 11 The results of the assessment showed that a briquetting plant located in any one of the fifteen forests would result in minimal disturbance to wildlife as a result of increased traffic and emissions The assessment also stated that pollution control and monitoring proposed by the factory was also satisfactory The report concluded by recommending that the briquetting plant should be located in one of the forests, stating that the aesthetic quality of the region could be maintained once the factory is surrounded by trees Therefore it is assumed that the factory can be built in any one of the forests listed in table 11

b) Raw material will only be supplied from the 11 and 12 forest districts

c) Dublin is the main market for the briquettes where the business can successfully sell all its output

c) All roads are passable

6 3 2 The Residue Inventory Database

The data necessary for calculating the volume of residue generated over the period 1993-1996 was supplied by *Coillte Teoranta* This information consisted of a harvesting forecast by forest and species group for districts 11 and 12 The printouts were also subdivided into thinnings and clearfellings Coillte were also able to supply the average stem volume for thinnings and clearfellings for both districts over the four year period This information was processed and tabulated by means of a database From the information supplied by Coillte the volume of residue

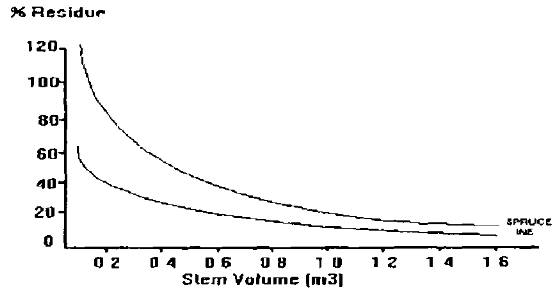

Figure 15 Estimation of Residue per Stem Graph

generated by each forest over the four year period could be determined This was achieved by using a graph generated by the *Wood Supply Research Group* based in the University of Aberdeen This graph enabled the estimation of residue volume perstem by linking stem volume with a percentage value This percentage value could be multiplied by the stem volume to get the volume of residue for that stem This graph is shown in figure 15

The total volume of residue generated in the 11 and 12 districts over the period 1993 - 1996, as calculated by the database was 292 273 m^3 A list of reports generated from the database is presented in Appendix D and the bar chart below represents a summary of these reports

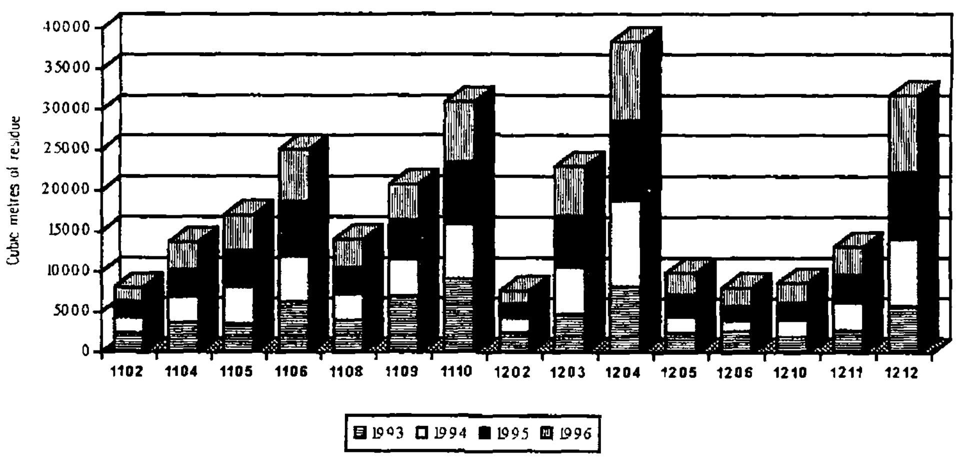

Figure 16 Graph showing the volume of residue generated in each forest and the breakdown of this residue over the four year period

The bar chart above clearly shows the uniform distribution of residue in each forest over the four year period This suggests that there will be a sustained yield of residue from each forest which is important for the future survival of the proposed briquetting plant The pie chart in figure 17 supports this claim This figure shows that there is no significant difference between the volume of residue supplied in each year From figure 16 it is clear that there is great variation in volumes produced by each forest this will influence the final location of the briquetting plant as it would be more practical for it to be situated in the middle of a large supply of raw material This is particularly true if

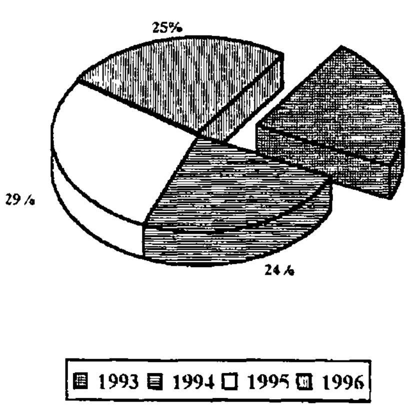

Figure 17 Percentage of total volume generated in each year

the levels of production decline as it would then be able to minimise haulage costs by giving priority to the surrounding forest when it comes to being supplied However a full analysis must be undertaken in order to find the best location for the briquetting plant under the assumptions outlined in this section

6 3 3 Haulage Costs

The main criteria which will determine the location of the briquetting plant are minimal haulage costs and a large quantity of residue generated in close proximity to the forest Calculating the cost of haulage begins with determining the distance that raw material would be hauled over if the briquetting plant was located in any one of the 15 forests in districts 11 and 12, eg if the briquetting plant was located in forest 1102 the distance from all the other forests to 1102 must be calculated Appendix E shows the distances from one forest to another and the total for each forest if that forest is chosen as the site of the briquetting plant Appendix E also gives the distances from each forest to the marketplace, Dublin

Coillte Teorantas haulage rates, (Appendix F) were assigned to each distance outlined in Appendix E, as shown in Appendix G[2] The rates are based on tonnes rather than m^3 so the volumes presented in Appendix D must be converted to tonnes The density of freshly felled lodgepole pine is 0 95 tonnes/m^3, when this is chipped the volume increases 2 5 times, therefore the density decreases to 0 95 tonnes/2 5m^3 or 0 38 tonnes/m^3 Therefore "cubic metres" of lodgepole pine chips can be converted to "tonnes" by multiplying the volume by 0 38

Appendix H shows the haulage costs between forests these values being calculated by multiplying the haulage rates, Appendix G, by the number of tonnes transported The following table gives the total costs for haulage for each forest when the particular forest is chosen as the site for the briquetting plant The table also shows the cost of haulage to the marketplace, Dublin This must be treated separately because both the total volume generated over four years and the reduction weight of the material (as a result of drying the chips before and during briquette manufacture) must be considered The moisture content of freshly felled and chipped lodgepole pine is approximately 56% and this is reduced to around 8% after the briquette has been made table 8 This means that the weight of the briquette is only 52% of its original weight when it was in the form of chips

[2]The lowest haulage rate of £3 25/tonne is used when the raw material is generated in the forest in which the factory is located This value takes into account the cost of hauling material from different locations within the forest

Forest	Total Vol Residue (m^3) 1993-1996	Total Haulage Distance (Km)	Haulage Costs to Briq Plant (£)	Haulage Costs to Dublin (£)	Total Cost of Haulage (£)
1102	8,108	621	477 540	228 915	706 455
1104	13,756	582	457,887	228 915	686 802
1105	17,022	399	398 873	280 805	679 678
1106	25,053	625	485 895	198 395	684 290
1108	14,072	429	431 802	262 492	694 294
1109	20,784	613	469,646	228 915	698,561
1110	30,951	550	449 860	262 492	712 352
[3]**1202**	44 717	576	447 900	262,492	710,392
1203	7 736	562	440,393	250 283	690,676
1204	38,358	514	441 319	228 915	670,234
1205	9,943	468	425,147	280 805	705,952
1206	8,123	423	407,065	262 492	669,557
1210	8 712	401	403,425	250,283	653,708
1211	13,177	662	457,619	280 805	738,424
1212	31 762	578	434,732	323 536	758 268

Table 12 Total haulage costs over fours years 1993-1996[4]

This table shows that the forest with the lowest haulage costs over four years is 1210, Avonmore The briquetting factory should therefore be located at this forest The relatively low costs for this forest is largely due to the plentiful supply of raw material which is situated close by The proximity of this forest to the market place, 36Km, is also responsible for the relatively low cost

[3]Residue figures for Aughrim and Ballinglen were added togther and put under Aughrim forest as these two forest were amalgamated

[4]The following is an eample of how the figure for haulage costs to Dublin was caculated for forest 1102
308 930 m^3(volume of residue before chipping) * 0 38 (this figure converts the slash to tonnes in chip form) = 117 393 tonnes
117 393 * 0 52 (this figure takes into account the moisture lost during kiln drying and briquette manufacture) = 61 044 tonnes (this is the weight of briquettes which must be transported to Dublin)
61 044 * £3 75 (this is the haulage rate to Dublin) = £228 915

CHAPTER SEVEN

THE COST OF HARVESTING AND COMMINUTING SLASH

7 1 INTRODUCTION

Assessing the cost of harvesting slash and converting it into a densified form of domestic fuel is undertaken in two stages The first stage is concerned with the process of harvesting and chipping slash at the forest Costs have been calculated with the aid of a harvesting simulation programme known as the Harvesting Decision Support System (HDSS) which will be discussed in the following section The second stage will involve studying the fixed and variable costs associated with producing briquettes

7 2 CALCULATING THE COST OF HARVESTING AND COMMINUTING BIOMASS

7 2 1 The Harvesting Decision Support System (HDSS)

HDSS is a computer software programme which is specially designed to simulate the operation of harvesting and chipping forest biomass The programme itself was developed by the University of Aberdeen and can be used to calculate the cost of harvesting commercial sawlog and comminuted slash for any site type specified

The programme begins by allowing the operator to choose the system of harvesting biomass, whether its terrain, whole tree harvesting or integrated harvesting For each harvesting site crop data (including yield class, species age, stem volume and terrain classification[5]) is entered into the programme The cost of harvesting and processing the biomass is therefore based on these site parameters with higher costs associated with poor quality sites

Once site characteristics have been established, the programme gives various options at the different stages of harvesting For example, at the felling stage chainsaws, feller bunchers or harvesters can be selected This process is repeated for all the stages of harvesting and processing right through to chipping

7 2 1 The Range of Forest Sites Examined Using the HDSS

The main advantage of the HDSS is the ability to compare the results of many different sites In order to achieve a sufficiently diverse range of site conditions for examination, forests were chosen from three major site classification groups These were wet mineral lowlands (WML)

[5] Terrain Classification This is a system where a site is graded from 1 to 5 (from good to bad) on the basis of bearing capacity, ground roughness and slope in that order

mountain and hillands (M&H) and finally peatlands (P) Information on the majority of these sites was supplied by the local forester However in the case of Ballinglen Forest due to its proximity to Dublin data was collected personally at the site using conventional forest mensuration techniques[6] Details on these sites are given in table 13

Forest	Compart No	Site Type	Spp	YC	Age	Mean DBH	Av Stem Vol (m^3)	Stems/ha Harv	Terr Class	Extract Dist (m)
Manorhamilton (a)	62159I 01	WML	SS	24	18	14	0 09	700	3 3 3	120
Manorhamilton (b)	61668D 02		LP	14	23	16	0 09	550	3 3 3	100
Ballybofey (a)	65151B 07		SS	12	51	25	0 4	400	3 3 5	110
Ballybofey (b)	65151B 10		LP	10	51	24	0 36	640	3 3 5	110
Ballinglen (a)	82351J 01	M&H	SS	20	42	35	1 2	263	3 2 4	90
Ballinglen (b)	82352E 02		SP	14	42	23	0 32	225	3 2 4	70
Ballinglen (c)			SS	12	42	22	0 14	600	3 2 4	50
Glenhest	53902S 01	P	SS	16	20	12	0 05	800	4 4 1	150
Cloosh Valley (a)	51567B 03		LP	12	21	12	0 05	1000	4 3 1	80
Maum (a)	52265B 01		SS	16	39	20	0 27	1500	4 3 1	60
Cloosh Valley (b)	51553E 01		LP	12	28	15	0 11	2300	4 3 1	110
Maum (b)	52262Q 02		SS	18	40	21	0 28	2150	5 3 4	30
Maum (c)	52255H 03		LP	12	41	23	0 24	1040	2 3 3	70

Table 13 Site Parameters for each of the Forests involved in the simulation

The harvesting types in which comparisons were made are the following,

a) 1st Thinnings [7]
b) Clearfell
c) Premature Clearfell[8]

Conventional methods of harvesting cannot be employed where the end product required is biomass in the form of chips Therefore, different systems of harvesting biomass must be employed. (these systems were examined in Chapter Two) and the most suitable systems under Irish conditions are examined in this exercise The following table lists these systems and the

[6] 0 04ha plots were measured out Stem volume was calculated by measuring the dbh of each tree within the 0 04 Ha plot The number of trees per ha was also calculated by finding out the number of trees in the 0 04ha plot and then using this to calculate the number in a ha

[7] The inclusion of 1st Thinnings in the *simulation* will allow a basic economic assessment to be made on the possibility of substituting conventional harvesting for whole tree harvesting and chipping of 1st Thinnings for biomass This alternative method of harvesting may prove to be more cost effective

[8] The existence of a large volume of poor quality Lodgepole pine in the West of Ireland prompted an examination of the costs involved in whole tree harvesting the crop for biomass Greater profits may be made by harvesting the crop prematurely for white chips (for pulping) and mulch (for the garden trade or briquettes) rather than for billets of pulpwood and a small volume of palletwood this was the case at Oughterard In the HDSS exercise the premature clearfell crop was harvested for sawlog as well as residue

different machines involved in each while the map on the following page shows the location of these sites

Site No	Forest	Harvest Type	Harvesting System	Machinery used in Simulation			
				Felling	Extraction	Processing	Chipping
T1	Manorhamilton (a)	1 st Thinning	WTC-Landing	Chainsaw	Fwd art s		Chip Hdt
T2	Manorhamilton (b)						
T3	Glenhest						
T4	Cloosh Valley (a)						
C1	Ballybofey (a)	Clearfell	Res-Landing		Fwd art s		Chip Hdt
C2			[9]Res-Terrain			-Fm -	
C3	Ballybofey (b)		Res-Landing		Fwd art s		Chip Hdt
C4			Res-Terrain			-Fm -	
C5			Integ-Landing	Chainsaw	Fwd art s	Pro art m	Chip Hdt
C6	Ballinglen (a)		Res-Landing		Fwd art s		Chip Hdt
C7			Integ-Landing	Chainsaw	Fwd art s	Pro art l	Chip Hdt
C8	Ballinglen (b)		Res-Landing		Fwd art s		Fm
C9			Integ-Landing	Chainsaw	Fwd art s	Pro art l	Chip Hdt
C10	Ballinglen (c)		Res-Landing		Fwd art s		Fm
C11			Integ-Landing	Chainsaw	Fwd art s	Pro chain f	Chip Hdt
PC1	Maum (a)	Premature Clearfell	[10]Integrated	Chainsaw	WSkid art	Pro art l	Chip Hdt
PC2	Cloosh Valley (b)			Chainsaw	WSkid art	Pro art l	Fm
PC3	Maum (b)			Chainsaw	WSkid art	Pro art l	Chip Hdt
PC4	Maum (c)			Chainsaw	WSkid art	Pro art l	Chip Hdt
PC5				Fb l	WSkid art	Pro art l	Chip Hdt

Table 14 Forest Sites and Harvesting Systems Examined in the Simulation Exercise

[9]Terrain chipping would not be possible for this site which has a terrain classification of 3 3 5 However for the sake of comparing the cost of terrain chipping to the cost of landing chipping for residues the classification of this site was changed to 2 2 2 This has enabled the simulation of terrain chipping to take place on this site The same situation applies to the second site at Ballybofey

[10]Integrated because there are two distinct products being harvested, white chips for pulp and mulch for briquettes or garden fertiliser

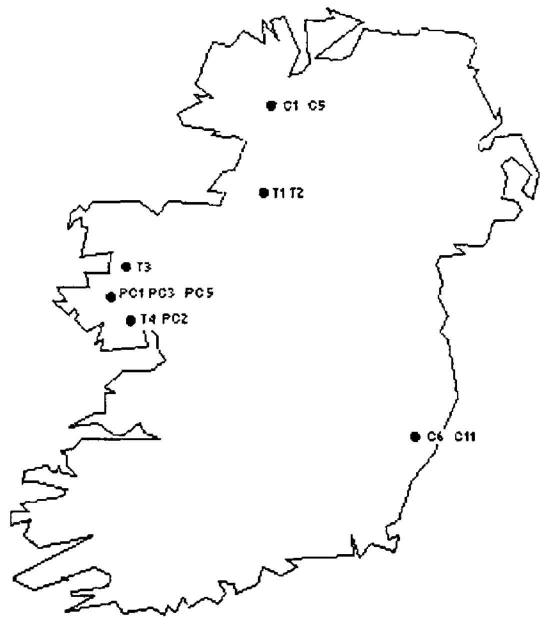

Figure 18 Map showing the location of forest sites where the harvest simulation exercise took place

7 2 2 The Objectives of the HDSS Exercise

The main objectives are,

1 To determine the cost of harvesting slash on different site types

2 To illustrate the main factors which influence the cost of harvesting slash

3 To illustrate how site conditions effect the type of machinery that can be utilised Some machines are unsuitable for use under conditions common on Irish sites, this results in higher costs due to less efficient machines being used

7 3 RESULTS

The data listed in Table 13 and the different harvesting scenarios outlined in Table 14 were sent to the University of Aberdeen where the data was processed using the HDSS The following sections present a summary of the printouts received from Aberdeen

7 3 1 1st Thinning

Site No	Felling £/gt	Extraction £/gt	Chipping £/gt	gt/ha	Total Cost/ha	Cost/gt
T1	0 91	2 16	3 06	105 92	648 92	6 13
T2	1 01	2 31	3 38	75 24	504 08	6 70
T3	1 27	2 47	3 18	77 84	539 26	6 93
T4	1 53	2 57	4 01	77 24	626 01	8 10

Table 15 Harvest Type 1st Thinning - Landing

The difference in costs per green tonne between T1 and T2 is largely due to the greater volume of biomass to be found per hectare in T1 This is due to the greater number of stems per hectare plus the fact that the species harvested was Sitka Spruce and not Lodgepole Pine the latter having less biomass per stem than Sitka, (*see section 4 1 2*) Having a larger volume of biomass per hectare has the following effects,

1 The cost of felling is reduced because less time is taken to find and fell a cubic metre of biomass The fact that there is 700 stems per hectare in T1 rather than 550 in T2 means that the feller can find and move from one stem to the next much quicker

2 Extraction costs are reduced because the forwarder spends less time searching for stems and it also has less ground to cover in order to complete a load

3 The cost of chipping is less mainly due to the fact that the chipper is more likely to be working at 100% capacity when there is a large volume of material in supply

The significance of the species harvested is evident in the two peatland sites T3 and T4 Although 200 more stems per hectare were harvested in T4 than in T3 the volume of biomass recovered per hectare is almost equal for both sites this is due to the fact that more slash is generated from sitka spruce than for lodgepole pine, (see section 2 5 5) This situation means that more stems have to be felled, extracted and chipped in T3 in order to make up the same volume

The difference in harvesting costs between the wet mineral lowland sites and the peatland sites can be attributed to the smaller average stem volume found in T3 and T4 plus the poorer conditions found in these sites The very poor bearing capacity means that extraction is difficult and suited only to tracked or modified forwarders These conditions and the use of less productive machines are responsible for the increase in harvesting costs

7 3 2 Clearfell Harvestıng

Sıte No	Extractıon £/gt	Chıppıng £/gt	gt/ha	Total Cost/ha	Cost/gt
C1	6 53	4 83	80 56	915 16	11 36
C3	6 43	4 83	93 66	1054 61	11 26
C6	6 24	4 83	143 22	1585 81	11 07
C8	5 08	9 08	29 43	416 89	14 16
C10	4 46	7 03	53 92	619 28	11 48

Table 16 Harvestıng Type Resıdue - Landıng

The lower overall costs experıenced on the mountaın and hıll land sıtes, C6, C8 and C10 are due to the hıgher densıty of bıomass per hectare, (the exceptıon ıs C6, where the value of 143 22 ıs subject to debate, thıs estımate seems exceptıonally hıgh) The relatıvely small volumes of bıomass recovered ın the two wet mıneral lowland sıtes has resulted ın hıgh chıppıng costs Thıs ıs due to the fact that the chıpper does not have enough materıal to keep ıtself busy and as a result ıt ıs ıdle for a percentage of ıts tıme Rather than usıng the powerful traıler mounted chıpper ın thıs sıtuatıon, ıt would probably be more economıcal to use a less productıve machıne such as one powered by tractor The proxımıty of C8 and C10 to a forest road has meant that extractıon costs have been kept down

Sıte No	Harvestıng Cost £/gt	gt/ha	Total Cost/ha	Cost/gt
C2	10 64	80 56	857 49	10 64
C4	10 87	93 66	1018 20	10 87

Table 17 Harvestıng Type Resıdue - Terraın Chıppıng

It has already been stated that such a harvestıng system would not be suıtable under Irısh condıtıons Indeed the mınımum recommended terraın classıficatıon of 2 2 2 for such a system ıs not met by any of the sıtes ın thıs study However for the sake of makıng comparısons the terraın classıficatıon of C2 and C4 was changed to 2 2 2 so that a terraın chıppıng sımulatıon could take place on these sıtes The figures however compare well to those for chıppıng at the landıng ıe C1 C3 C6 C8 and C10

Site No	Felling £/gt	Extraction £/gt	Chipping £/gt	gt/ha	Total Cost/ha	Cost/gt
C5	0 36	1 32	4 67	93 66	594 74	6 35
C7	0 13	1 21	4 83	143 22	883 97	6 17
C9	0 38	3 30	6 75	29 43	306 95	10 43
C11	0 68	3 01	4 83	53 92	459 47	8 52

Table 18 Harvest Type Integrated - Landing

It is quite evident from the figures shown in the table above that whole tree extraction and product separation at the landing is the most efficient way to harvest the non commercial parts of a forest crop, (as opposed to the collection of slash after harvesting has taken place) Of course, if the increase in the cost of harvesting the sawlog portion of the crop is greater than the return on selling the slash then the operation is not a viable one

The low costs experienced in C7 is again due to the high volume of biomass found on this site The same can be said of site C5 The low volume of slash on site C9 and C11 has resulted in significantly higher extraction costs and chipping costs in the case of C9 The higher chipping costs in this case can again be attributed to the low utilisation rate of the chipping machine In the case of C11 almost the same number of trees were handled per hectare as in C5 but 43% less slash was recovered

7 3 3 Premature Clearfell

Site No	Felling £/gt	Extraction £/gt	Chipping £/gt	gt/ha	Total Cost/ha	Cost/gt
PC1	0 41	1 39	4 57	218 44	1390 74	6 37
PC2	0 82	2 28	9 08	126 82	1545 33	12 18
PC3	0 42	1 36	4 57	322 32	2047 98	6 35
PC4	0 45	1 49	4 67	113 77	725 08	6 61
PC5	1 68	1 49	4 67	113 77	892 53	7 84

Table 19 Harvest Type Integrated - Landing

All the above sites are located on the blanket peatlands of the west Looking at the first four sites the cost of harvesting on site PC2 seems very high The reason for this can again be attributed to the relatively low volume of biomass found on this site In addition to this fact the high cost is precipitated by the large number of small volume stems that must be harvested per hectare to achieve this relatively small volume

The significance of stem volume and stems per hectare is again highlighted when comparing sites PC2 and PC4 Although the volume per hectare of the latter is less than that for PC2 the cost of harvesting is significantly lower An examination of the site parameters for both sites shows why this is so The average stem volume in PC4 is twice that of PC2 while the number of stems harvested per hectare is less than half

Attempts to make this system of harvesting biomass more productive by introducing a harvester (PC5), has only resulted in increasing the costs The harvester, which is acting as a feller buncher is not suited to this task especially when the average stem volume is so small and ground conditions are so poor

Winch skidding should certainly not have been used for the above sites Winch skidding on soft ground is not the best option as this can result in severe rutting A tracked forwarder or clam bunk skidder should have been used instead

7 3 4 The Accuracy of the HDSS

Although the printouts received from Aberdeen did provide the vast bulk of information required there were some discrepancies in the data

1 There were several missing figures in the printouts These had to be filled by studying the trial reports of similar harvesting operations and by comparing other results in the data sheets

2 A small fraction of the figures given in the results seemed to be incorrect Where this occurred a very close examination of the data was undertaken and comparisons made with other sites For example, in the case of C3, where the volume of biomass per hectare was 93 66 m^3, the cost of chipping per green tonne was £6 75 On the nearby Sitka Spruce site, C1, the cost of chipping was only £4 83/gt even though there was less biomass per hectare on the site, 80 56m^3 It was clear therefore that the figure of £6 75 was not accurate In order to improve the accuracy of the analysis a value of £4 83 was assigned as the chipping figure for C3 as this seemed to best reflect the true cost of chipping, presuming that the chipper was operating at full capacity Aberdeen confirmed that inaccuracies were possible and that they resulted from the model itself not being 100% compatible with Irish conditions

3 After the results of the field trials described in section 6 2 2 in which the line intersect method was used to assess the volume of biomass per hectare the biomass figures for residue harvesting generated by the HDSS seemed very high The figure of 143 22m^3 for example on site C6 and C7 seems unusually high considering that the residue of only 263 trees make up this amount (that's approximately 0 54m^3 of residue per tree)

4 The cost of extraction seems to be quite low in most cases For example the cost of extracting whole trees, (T1-T4 and PC1-PC5) appears to be far less expensive than it should be The cost of extracting the products of conventional thinning is around £6/m^3 while for whole tree harvesting it's on average around £3/m^3

Irrespective of the doubts cast upon the accuracy of the HDS system it still remains the only tool to assess the efficiency of harvesting biomass on a wide range of site types From this point of view the system does fulfil its main objective of allowing comparisons to be made between different sites

7 4 DISCUSSION

The volume of biomass per hectare has been emphasised as an important factor in determining harvesting costs Another important factor in minimising costs is choosing the most appropriate machinery for the job of harvesting and comminution This factor is quite evident throughout the study particularly with regard to chipping machines Choosing the right sized chipper means selecting one whose productivity matches the rate at which it can be supplied plus the rate which it can comminute In the case of C8, C9 and C10 the low utilisation rate of the chipper is due to the low volume of biomass harvested per hectare In these situations a smaller chipper, perhaps one powered by tractor, would be more suitable for the job of comminution In the other extreme where the trailer mounted chipper is overwhelmed with material as in the case of some premature clearfelled sites (PC1 and PC3) larger chippers could be used, for example one powered by a lorry

The effect of site conditions on harvesting costs did not manifest itself to any great extent during the simulation However when comparing the peatland and the wet mineral lowland thinning sites terrain did seem to have an impact on costs What is evident from the study though, is the extent of the limitations imposed by Irish site conditions on machines which can be used on harvesting operations For example winch skidders could not operate on any of the sites listed in table 14, except maybe for site PC4 Sites having poor bearing capacity eg T3 T4 PC1, PC2 and PC 4 would have no option but to use tracked or modified forwarders to extract material Conventional wheeled forwarders would get bogged down if they had to operate on these sites particularly when the brash carpet is absent Indeed all sites mentioned in this study would suffer greatly in terms of soil compaction and disturbance as a result of the absence of the brash layer

It is worth mentioning that clambunk skidders could be used successfully on any of the sites where whole trees are extracted It would have been interesting to examine the cost of using different machines on the sites involved in the study such as the clambunk skidder but unfortunately this was not possible in the time available

7 5 CONCLUSIONS

The most efficient systems for harvesting biomass are those which offer a mode of harvesting and extraction which is able to supply enough material for processing to keep the machines operating This would include having good systems configuration ie enough forwarders would be in operation to keep delimbers and chippers supplied with material These machines would not be under utilised or bogged down because they are ideally suited to processing the volume of material being supplied to them by the forwarders

From the analysis conducted in this chapter, two systems exist which could be cost effective under Irish conditions, these are 1st thinning and premature clearfelling 1st thinning systems have the following advantages,

1 The cost of extracting whole trees for the purpose of comminution is less than for extracting slash only The volume weight ratio is much less for transporting whole trees than for slash and this is responsible for the lower cost

2 The cost of chipping is also less because of the efficient utilisation of large productive machinery This is not only due to the greater volume of biomass harvested but also because processing dense material, such as whole trees utilises to a greater extent, the high feed and processing rate of large chippers

Integrated harvesting of premature clearfellings means that the slash and sawlog portions of the crop is harvested together This means that the costly process of post harvest accumulation of slash is avoided The main factor which is responsible for making this system of integrated harvesting more cost effective than other systems is the fact that it's a premature clearfelling operation, hence there is a much larger number of stems harvested per hectare than for normal clearfelling In addition to this the large volume of material generated from this clearfell operation is accessible to the chipper, as it is concentrated in a small area at the landing This fact may indeed cause problems due to the limited space found at most landings Unless the material can be quickly gathered and chipped a space may have to be created at the landing to facilitate the accumulation of slash

From the basic study conducted in this chapter the following assumptions can be made

1 The sites chosen for harvesting must be either

a) 1st thinning sites where there entire stem is extracted to the roadside and chipped or

b) Premature clearfell sites where again the entire tree is extracted and product separation whether its sawlog and mulch or white chips and mulch takes place at the roadside These two systems of harvesting guarantee a large supply of material while the extraction of whole trees minimises harvesting costs

2 Choosing the right chipping machine is essential in keeping down costs

3 Good ground conditions must prevail in order to minimise ground damage which results in the absence of slash and to allow the extraction operation to proceed efficiently

CHAPTER EIGHT

FACTORY COSTS

8 1 INTRODUCTION

The production target at Avonmore shall be set at 8,000[11] tonnes per annum, this means that 40,485m^3 of chips would have to be supplied in order to reach the specified level of production However this volume of raw material will have to be increased if the method of drying the chips involves using a proportion of these chips to fuel the kiln During normal production at ICP Ltd 1 7 tonnes of chips produced 1 35 tonnes of briquettes with the balance (20% of the raw material) being used to fuel the kiln In order to manufacture 8,000 tonnes of briquettes the factory at Avonmore would have to be supplied with 50,606 m^3 of slash chips per annum

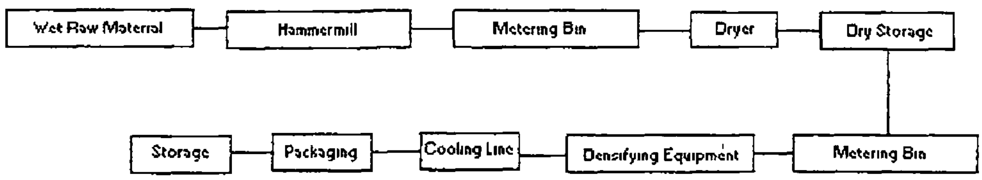

Figure 19 Flow diagram for proposed briquetting factory

The simple flow chart shown above summarises the different stages of production which must be taken into account when designing the layout of the factory

8 2 PLANT REQUIREMENTS

The factory would require an area of approximately 1 25 hectares, it would be in operation for 40 hours per week 50 weeks in the year The necessary equipment for the factory would include the following,

i) a metal detection device (to prevent broken sections of the flail or chipping devices to pass into the extrusion screw)

ii) a hammermill (for breaking down chips)

iii) a wet storage bin

iv) a metering bin

v) a rotating kiln

vi) a dry storage bin

vii) a screw conveyor from the dry storage bin to the to the densification equipment

viii) extrusion screws

ix) a cooling line

x) packaging equipment

xi) inventory storage for the palletised product

[11]This figure represents approximately 2 5% of the Dublin market Factory costs and configuration were also taken into consideration when determining this figure

Because the factory would be a stand alone operation, receiving and storage facilities would also need to be constructed. Such a building is estimated at 20m X 15m, and designed to allow a 40 foot truck to back into it for unloading. The storage area would have a maximum capacity of approximately 2,400 m^3, (the total volume of material used each week would be approximately 1 012m^3). The building would have a concrete floor and an augering system through the centre that feeds a blower which transfers raw material into the storage silo.

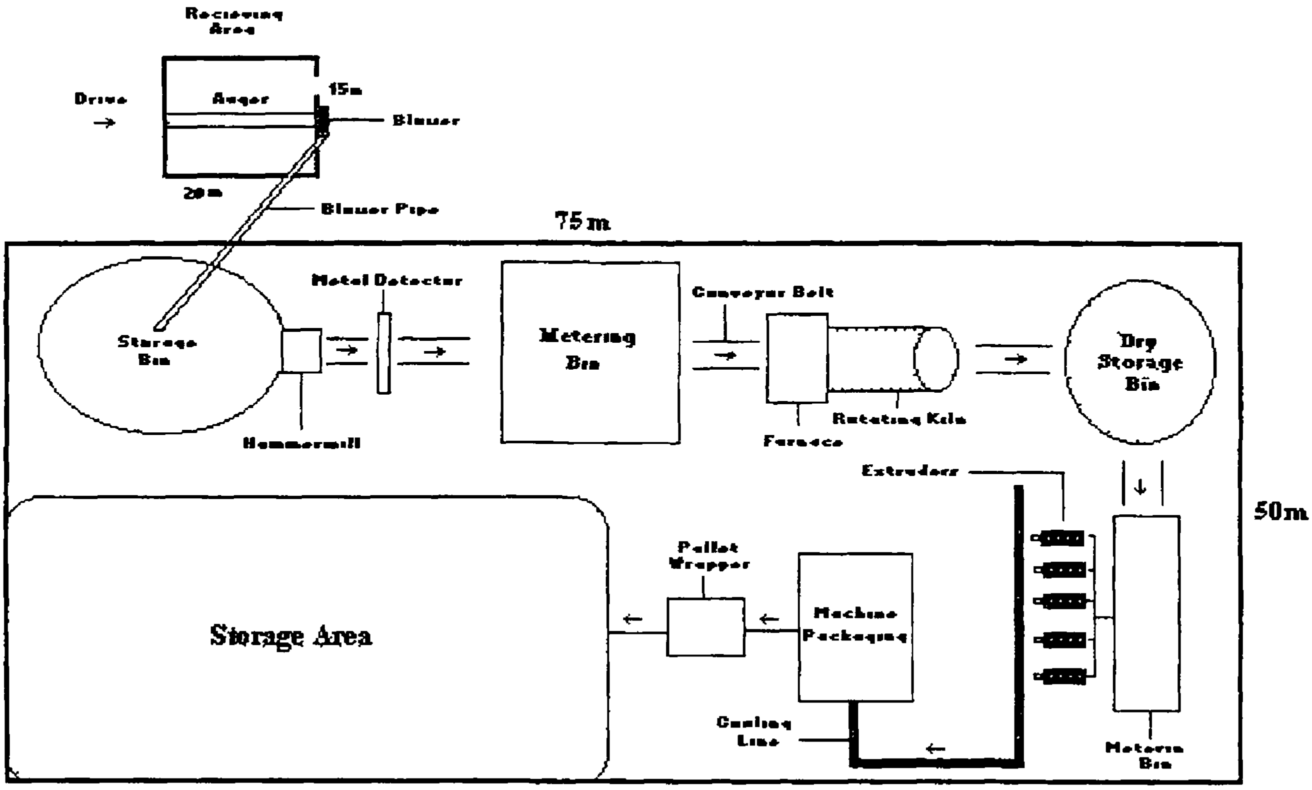

Figure 20 Potential plant layout for a briquetting factory

Once the chips are blown via the auger into the storage bin the chips are fed into the hammermill. The hammermill breaks the chips down into particles small enough to pass through a 3mm sieve. This material is then passed along a conveyor belt through a metal detector and then into a metering bin. This transfers measured quantities of material into the rotating kiln which then dries the chips down to a moisture content of 10%[12]. From the dry storage silo the material is then fed into a second metering bin which controls the volume of material which is fed into the extruders. There are five extrusion screws in all which would operate at around 80% efficiency. Each extrusion screw would be capable of producing 0 907 tonnes of briquettes every hour (a total of 36 tonnes being produced each day manufacturers rating). The briquettes are then fed onto a cooling line and then into the packing area where they are bagged and loaded onto pallets. Figure 20 shows a possible layout for such a briquetting factory (Hassler et al (35) 1990)

[12] Drying of chips takes place at this stage because it is more efficient to dry small pieces than large ones

8 3 FIXED COSTS

Fixed costs are related to the passage of time and within certain output or turnover limits tend to be unaffected by fluctuations in volume of output or turnover for example rent rates and executive salaries

8 3 1 Building Costs

The cost of industrial zoned land can be as much a £25,000 per hectare In the region surrounding Avonmore the land is mostly agriculture, as you would expect and there is very little land zoned for industrial development, (Brennan (62), 1993) The price of agricultural land in the region varies greatly depending on its use and how much the owner himself values it For the purpose of this project 4 acres of agricultural land is purchased at a cost of £2,500 per acre

Construction costs are measured on a square metre basis depending on the type of building being built The following figures have been checked and approved by the Department of Surveying, Bolton Street, College of Technology

Main Building

8 - 14m bay height, factory shell with 10% office space @ £450/m^2

Storage Building

6 - 8m bay height, basic warehouse @ £300/m^2

The following table lists the various costs involved in installing different services In addition to the costs shown here there are also the cost of external works which be put at 15% of the total cost of construction, (Woods (63 1993) There are also the costs for professional fees 12% and VAT which is 12½%

Service	Cost £
ESB[13]	25 000
Telecom Eirinn (8 phone lines)	1 000
Sewage & Water	10 000

Table 20 Service Installation Costs

[13] The cost of hooking up to the ESB network is site specific with numerous factors playing a role in determining the overall costs It is impossible even to give an average figure until the site and surrounding area can be examined for existing power services The figure given in this table is at best a notional figure (Richard King ESB Regional office Enniscorthy 1993)

8 3 2 Plant & Equipment Costs

The following table lists the cost of equipment and machinery required for the factory

Item	Investment (£)
Receiving/Storage equipment	£3 400
Silo (two 20 tonne capacity)	£3,000
Hammermill	£13 600
Metal Detector	£1,800
Conveyors	£13,600
Metering Bin for Dryer	£20,400
Rotating Kiln	£108 800
Metering Bin for Extruders	£5 000
Extruders (5 X £47,600)	£238 000
Cooling Line	£6 800
Automatic Packaging Machine	£34,000
Pallet Wrapping Machine	£6,120
Fork Lift (4 000 lb capacity)	£13,600
Total Capital Costs	£468,120

Table 21 Machinery & equipment costs for a briquetting plant

The receiving and storage equipment listed above includes an auguring system and a blower system with sufficient tubing The packaging equipment is expensive but because it is automated the savings on labour would make it worth the investment The bags of briquettes would be placed on pallets where they would be shrink wrapped for security during transport to the retail market

8 3 3 Depreciation and Interest on Commercial mortgage

The straight line method of depreciation will be used for factory buildings, where the life of the factory buildings is 33 years (Ford (64), 1993) and the salvage value of the plant is assumed to be the value of the land The same method of depreciation will be employed for machinery and equipment with the life of the machinery being 10 years the scrap value being 10%

Interest Rates for a commercial loan is approximately 12% (April 1993) This figure is based on quotes from Smurfit Finance and Leasing and the Irish Permanent Building Society

8 3 4 Insurance

The total annual cost of insurance for the factory and employees is £10 000 This is a quote given by Boland Ryan Ltd

8 4 VARIABLE COSTS

Variable costs tend to vary in direct proportion to changes in the volume of production or sales Variable costs are made up of direct and indirect costs Direct costs are incurred as a direct result of manufacturing additional units of production, for example raw materials, packaging wages etc Indirect costs can be described as variable overheads which cannot be directly attributed to the production of additional units of production, for example, electricity, telephone costs and marketing

8 4 1 Direct Costs

The following are the direct costs which would be incurred at the briquetting plant,

- *a)* Transport Costs
- *b)* Material costs
- *c)* Packaging Costs
- *d)* Parts & Repairs
- *e)* Labour

a) **Transport Costs**

These costs can be broken into two, firstly the cost of transporting raw material to the factory and secondly the cost of transporting the finished product to retail outlets in Dublin City In order to calculate the cost of transporting raw material to the briquetting plant it must be first established which forests would supply the factory The table below,derived from appendix G, shows the total cost of hauling this material for each year as well as listing the forests which should supply this material This table shows that the same forests, the ones which are closest to Avonmore are the forests which would supply material to the briquetting plant each year

Year	Forests Supplying Material	Total Volume Supplied(m^3)	Cost of Haulage (£)
1993	1105 1108 1202,1203,1204, 1206 1210,1205 1212 1110	54,277	71,236
1994	1105 1108 1202,1203,1204 1206 1210 1205 1212 1104	52 784	68 012
1995	1105 1108 1202 1203 1204 1206 1210 1205 1212,1104	53 801	69 359
1996	1105 1108 1202 1203 1204 1206 1210 1205,1212	54 048	69 868

Table 22 Forests which would supply Avonmore with raw material and the total cost of haulage from these forests for each year

A few thousand tonnes over the target figure (50,606 m^3) is supplied each year to take into account wastage. The differences found in the last forest chosen for each year, arises from the fact that haulage costs are being kept to a minimum. This is achieved by choosing a forest which allows the minimum volume of material to be transported while still allowing the target volume to be reached and in addition allowing for wastage.

As well as calculating the cost of hauling raw material, the cost of transporting the finished goods to the marketplace or more correctly, the cost of distribution must be calculated. Rather than attempting to determine the cost of transporting the briquettes to every outlet in the target market region, the cost of transporting the goods to Dublin's City Centre was calculated instead. Coillte Teoranta's haulage rates are again used to calculate this cost. From Appendix G the haulage rate from Avonmore to Dublin is £4.10 per tonne. Therefore the cost of haulage to the marketplace each year would be approximately £32,800.

b) **Material costs**

It is assumed that the actual suppliers of the slash do not charge for the raw material. It is realistic to assume that the suppliers would have a stake in the business or alternatively they could be satisfied by having the forest floor cleared of debris, which would reduce the cost of replanting. The cost of the raw material is therefore the cost of getting the slash chips to the forest roadside.

The target volume of raw material, 50,606 m^3, is achieved by harvesting clearfell, premature clearfell and thinning sites within the Wicklow region. This represents a huge range of diverse site types, with different harvesting costs for each site, (see chapter seven). It is beyond the scope of this project to attempt to calculate the exact cost of harvesting this volume, so a reasonably realistic cost per green tonne at the roadside has been used. However, it is necessary to identify the most appropriate value from tables 15, 16, 17, 18 and 19 which can be used for this purpose.

The below shows the most efficient harvesting system for first thinning, clearfelling and premature clearfelling which were employed in the HDSS exercise. The most

Site No.	Harvest Type	Harvesting System	Felling	E xtraction	Process-ing	Chipping	Cost/gt (£)
T1	First Thinning	WTC-Landing	Chainsaw	Fwd art s		Chip Hdt	6.13
C7	Clearfell	Integrated-Landing	Chainsaw	Fwd art s	Pro art l	Chip Hdt	6.17
PC3	Premature Clearfell	Integrated-Landing	Chainsaw	WSkid art	Pro art l	Chip Hdt	6.35

Table 23: The most efficient harvesting systems of the HDSS exercise

efficient systems are chosen because conditions in the Wicklow Region are generally good for harvesting, unlike the boglands of the West or the Hilly Old Red Sandstone soils of the Tipperary and Limerick region This means that the most efficient types of harvesting systems can be employed in a large number of cases

In the residue inventory database their is no distinction made between first thinnings and second or third thinnings The figure generated for the volume of residue for thinnings is therefore the volume if the harvesting of all thinnings including first thinnings, was integrated[14] The figure in table 23 for first thinnings is the cost of whole tree chipping, which would be significantly less than for subsequent thinnings which are harvested using an integrated systems This figure can therefore not be used to calculate the cost of harvesting thinnings let alone clearfell operations

A much more realistic figure which could be used for the value of slash chips at the roadside is £6 35/gt, the figure for the premature clearfell operation at Maum Co Galway The reason for this is that its higher value will to some extent compensate for the higher values for thinning that one would expect and for the range of different site types that would be encountered in the Wicklow region Apart from the obvious weaknesses of using this figure it does represent a scientific assessment of the cost of harvesting residue under Irish conditions On this assumption, the following table shows the total cost of raw material for each year at the road side

Year	**Volume Harvested (m^3)**	**Volume Harvested ([15]green tonnes)**	**Cost of Chips at the Roadside (£)**
1993	54,277	49 935	317,087
1994	52,784	48,561	308 362
1995	53,801	49,497	314,306
1996	54,048	49,724	315,747

Table 24 Raw material costs 1993-1996

c) **Packaging Costs**

The cost of packaging can be put at approximately £0 375 per package (Donohoe, 1992) If the number of packages produced is 800,000 then the total cost of packaging is £300,000 (this includes the cost of pallets and the cost of securing the packages on these pallets)

[14]For first thinning operations as for all the harvesting operations in the database only the volume of the foliage was included in the total residue volume figures

[15]The density of freshly felled Sitka Spruce is 0 92 tonnes/m^3 Sitka spruce is chosen because the majority of timber felled in the Wicklow region would be Sitka spruce

d) <u>Parts & Repairs</u>

The major equipment repair/maintenance items will be the extruder and the hammermill All the equipment in the plant will need a routine maintenance programme of grease and oil The extruder will need the tapered sleeve, forming head front screw and cylinder sleeve removed machined and resurfaced periodically These rebuilt parts will keep the logs uniform, while keeping the machine operating efficiently The hammermill will need the chains replaced periodically to insure that the machine operates efficiently The total cost of parts and maintenance for a year would be approximately £20,000

e) <u>Labour</u>

It is assumed that the factory does not require a full time manager The manager who may be the local forester or manager of a local sawmill has a supervisory role He would appoint a foreman who would look after maintenance duties as well as the day to day running of the factory A full time secretary is included in the overall cost to take charge of raw material receipts, orders and general office duties The overall labour requirements for the briquetting plant is as follows,

Employee	**Wage Rate (£/hour)**
Extruder Operator/Foreman	7
Kiln operator	3 5
Raw material Handler	3 5
Three Packaging Operators	10 5
Secretary	4 5
Total	**29**

Table 25 Labour costs (including social welfare contribution)

The total wage bill for all employees for a year is £60,320 (assuming that they receive wages while on annual leave)

8 4 2 Indirect Costs

The following indirect costs would be incurred at the briquetting plant

a) Operating Costs
b) Marketing Costs

a) **Operating Costs**

An extruder operates on approximately 60KWh equipped with a 100-hp motor The cost of electricity for industry per KWh is 4 71 pence, (Eolas, 1991), therefore annual electricity costs for one extruder would be £5,652/annum Electricity usage for all the supporting equipment, assumed to be 65 KWh per extruder, would cost £6,123 per machine per annum The total annual electricity cost for all six extruders and supporting equipment would therefore be £70,650

There is no expenditure on gas because a) the kiln is fuelled entirely on chippings and b) no gas is used in the extrusion process as the enormous pressure applied by the extruders themselves (generating a temperature of 400°C) is sufficient to plasticise the lignin and thus create the briquette This extruder is of a different nature to the one used at ICP Ltd, it is more expensive to purchase but because it doesn't require gas, it is more economical to use and hence the investment is worthwhile in the long run

b) **Marketing Costs**

The cost of marketing includes the cost of employing a single sales representative plus the cost of advertising the product through local newspapers and leafleting A single sales representative would be in charge of all marketing affairs including the distribution of the product The budget for advertising should be set at £10,000[16] while the cost of employing the sales representative including car and expenses would be £40,000

8 5 DETERMINING UNIT PRICE

As the annual sales figure is assumed to be 8,000 tonnes or 800,000 units the breakeven price of the product rather than the breakeven sales will be calculated The following is the formula for calculating total profit,

[17]TOTAL PROFIT = TR - TC , or
TOTAL PROFIT = QP - (VC + FC)

Total profit will be equal to 0, as the breakeven point is being determined The formula now looks like the following,

---

[16] The cost of advertising in a local newspaper, for example South News (which is published fortnightly and has a circulation of 50 000) is £1 950 for a full page advertisement and £18 80 for square column inch Advertising by door to door leafleting would cost £42 per 1000 deliveries

[17] TC=Total Costs TR=Total Revenue Q=Quantity Sold P=Price per Unit VC=Variable Costs FC=Fixed Costs

$$0 = QP - (VC + FC),$$

The only unknown is the price per unit,

$$P = (VC + FC)/Q$$

The table on the following page lists the costs involved in constructing and equipping the factory This table calculates the cost of depreciation and the mortgage on the buildings and the machinery It assumes that the entire cost of establishing the enterprise is financed by means of a

BUILDINGS	**Floor Area (m^2)**	**Cost/m^2 £**	**Total Cost £**			
Main Building 75m X 50m	3,750	450	1,687,500			
Warehouse Building 15m X 20m	300	300	90,000			
External Works @ 15%			266,625			
			2,044,125			
Professional fees @ 12 5%			255,516			
			2,299,641			
VAT @ 12 5%			287,455			
Total Building Costs			2,587,096			
UTILITIES						
ESB			25,000			
Telecom Eirinn			1,000			
Sewerage & Water[18]			10,000	Salvage Value £	Life (years)	Depreciation p a (£)
Total			2,623,096	10,000	33	79,185
Annual payment to clear 33 year mortgage @ 12%[19]			322 432			
MACHINERY						
Total Cost			468 120	46,812	10	42,131
Annual payment to clear 10 year mortgage @ 12%			76,184			

[18] This figure was supplied by Mr Michael Mangan Assistant Engineer Wicklow County Council

[19] The formula used to calculate the annual mortgage was $P/[1-(1+r)^{-n})/r]$ where P is sum borrowed n is the payment period and r is the interest rate

commercial loan There is, however grant aid from the IDA of £4 000 per job created (Ford (68), 1993), but this funding is not guarantied and is therefore not taken into account in this analysis The following table lists fixed and variable costs, with variable costs broken into indirect and direct costs From this table it is then possible to calculate the breakeven price of the product

FIXED COSTS		**£**	**Total**
Building Mortgage		322,432	
Equipment Mortgage		76,184	
Depreciation	Buildings	79,185	
	Equipment	42,131	
Insurance		10,000	529,932
VARIABLE COSTS			
Direct			
Materials		317,087	
Packaging		300,000	
Haulage (raw material)		71,236	
Haulage (market place)		32,800	
Labour		60,320	
Parts & Repairs		20,000	801,443
Indirect Costs			
Operating Costs		70,650	
Marketing		50,000	120,650
Total Costs			1,452 025
Unit Output			800 000
Breakeven Price			1 81

A breakeven price of £1 81 for a 10Kg bag of fuel is very high Assuming a retail profit margin of 25% the final product would be offered to the public at around £2 26 per unit The implications of this figure on the products performance in the marketplace will be discussed in the marketing section of this project

CHAPTER NINE

FORMULATING MARKET OBJECTIVES AND STRATEGIES

9 1 INTRODUCTION

This section of the project is presented in the form of a marketing plan which is mainly based on the research done in the marketing audit and domestic fuel survey, Appendix J and K

9 2 THE CORPORATE MISSION

To supply a convenient to carry, easy to light, environmentally friendly supplementary[20] domestic fuel at a competitive price The company is profit orientated with a view to expanding its product range

9 3 CONSUMER PROFILE

Due to the significantly higher price of wood briquettes, households belonging to the socio-economic groups A, B, C1 and C2[21] are the target market

The people most likely to purchase wood briquettes within this target market, place convenience very high on their list of priorities They would more than likely purchase bales of peat briquettes, because they are, to a certain extent convenient to carry Having said this, the bales of briquettes do not offer the most comfortable method of carrying the fuel for some people The bale itself is quite heavy and the coarse, narrow plastic band which the carrier is supposed to grip, makes the bale most uncomfortable to carry for prolonged periods of time

A description of the sort of consumer likely to purchase wood briquettes is someone who is living in rented accommodation, either on their own or sharing with others They would be young graduates or recently qualified people from the country, who have come to Dublin to work Other likely consumers would be married couples with either no family or a very young family, (see section on the Demographic Environment, Appendix J) The following scenario would be typical of the situation most of these people would find themselves in at some stage or other The potential consumer, rushing home from work suddenly realises that he/she has nothing to throw on the fire that night That person goes into the local shop and is confronted with a range of different fuels from which to chose The person will chose wood briquettes because he/she sees that the briquettes are available in handy sized carrier bags and that they will light very easily

[20] The briquettes can be burnt as a primary fuel or in a mixture with coalite or other solid fuels The briquettes may also be used occasionally for example at weekends by those people who have gas or oil and who still want to use an open fire

[21] A represents upper middle class B the middle class C1 the lower middle class and C2 the skilled working class

Another possible segment of the market that may purchase wood briquettes are people who have converted from solid fuel to either gas oil or electricity These households may still have facilities to burn solid fuel and may be tempted to use an open fire on special occasions or at the weekends An open fire creates a relaxing ambience which may be desirable when entertaining friends

When fuel is purchased on such a once off basis the actual cost of the fuel is not important Wood briquettes would be an attractive fuel for these people to purchase because of their environmental qualities etc The high cost of the briquettes would be overlooked by people who don't normally buy solid fuel The higher cost of the briquettes may in fact work in their favour, with customers attaching a snob value to the product Keeping in mind that the briquettes may only be purchased irregularly, purchasers may prefer to pay more for the briquettes because of their environmental image The more they pay for the product, the more they feel they are contributing to the conservation of our environment This theory would certainly attach a higher snob value to the briquettes

9 4 STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS (THE SWOT ANALYSIS)

9 4 1 Strengths

1) Wood Briquettes are made from a renewable resource of raw material which is 100% Irish

2) They are clean, burn efficiently and light easily

3) Households can still enjoy the warm glow of an open fire knowing that they are burning a smokeless, environmentally friendly fuel

4) Wood briquettes can be sold in convenient carrier bags, (see Figure 19)

9 4 2 Weaknesses

1) Wood briquettes would be more expensive than all other forms of smokeless fuels

2) They have only about 2/3 the heat content of Coalite

3) Wood briquettes don't offer the same convenience as other home heating systems For example, being able to switch on to an immediate supply of fuel or being able to use the same system for heating, cooking or lighting, as in the case of electricity Gas and electricity are also much cleaner to use, as there are no ashes to clear away

9 4 3 Opportunities

1) Briquettes may become a more acceptable source of fuel in the years to come This may come about as the price of fossil fuels increases For example, the cost of natural gas may rise in the future as a result of more expensive foreign gas being pumped into Ireland This will begin once the Kinsale gas field runs out at the end of this decade and if no more gas is discovered in the meantime There is also the threat of an increase in oil prices although the present trend is downwards

2) People are more environmentally conscious now than they ever were in the past and they are willing to pay more for goods which are kinder to the environment People therefore may purchase the wood briquettes regardless of the fact that they are more expensive than other forms of domestic fuel

3) The increase in two income families and people living either on their own or with children, (see table 27, Appendix J), represents an increase in the potential market for Wood Briquettes Two income families would have more money to spend on fuel and would therefore be more inclined to purchase a more expensive fuel because of its environmental advantages People living on their own or with one other person, would be more inclined to purchase their fuel in smaller quantities They would purchase a fuel supplied in conveniently sized bags

9 4 4 Threats

1) The impact of whole tree harvesting on the environment should not be overlooked (see chapter 4)

2) The search for more gas fields in the Celtic Sea continues with the full backing of the Government A new gas find could mean cheap gas for some time to come for consumers connected to the national grid

3) The price of wood briquettes will increase if the new European carbon tax is introduced This tax will be imposed on all fuels emitting carbon and not just oil This tax may have more

damagıng effects on the demand for wood bnquettes than the other fuels because of its existing high pnce

4) The size of the solid fuel market is steadily dimimishing, (see figure 20, Appendix J and the domestic fuel survev question 8, Appendix K)

9 4 5 Cntical Success Factor Analysis

Table 26 below, compares wood bnquettes with its competitors It attempts to identify how competitive these bnquettes would be with other sources of home heating energy Listed in the table are the key Cntical Success Factors (CSF) These are the main reasons why a consumer may chose one source of home heating fuel over another Each CSF is weighted out of 100, the weighting is based on the findings of the Domestic Fuel Survey, Appendix K Each competing fuel is scored out of 10 and then multiplied by each CSF The total weighted score is then calculated

Cntical Success Factor	**Weighting Factor**	**Slash Bnq**	**Peat Bnq**	**Coalite**	**Oil**	**Gas**	**Electricity**
Pnce	35	4	8	6	7	6	5
Heating properties	15	6	4	7	7	7	7
Convenience	20	8	8	7	9	10	8
Cleanliness	15	8	8	5	10	10	9
Aesthetic Appeal	10	8	7	8	5	6	6
Environmental Friendliness	5	9	7	7	7	7	10
Total Weighted Score	100	635	725	645	665	760	680

Table 26 Cntical success factor analysis

The analysis above suggests that wood bnquettes would perform poorly in the marketplace Although slash bnquettes score well in all CSFs' except for pnce it doesn't have a clear competitive advantage over its competitors The pnce of the bnquettes is the greatest obstacle to the product's success Competing fuels are cheaper to buy while having most of the benefits wood bnquettes have to offer

In order for wood bnquettes to succeed it would be necessary to avoid competing head on with the above forms of fuel The business should create a separate niche for itself in the market place This can be achieved bv further development of the product and a marketing campaign which can successfully identify the bnquettes as a unique product servicing a need other solid fuels can't fulfil The marketing mix in the following chapter suggests ways of accomplishing this

9 5 OBJECTIVES OF THE COMPANY

Both objectıves and strategıes are based on the findıngs of the SWOT analysıs The followıng poınts are the maın objectıves of the proposed company

1) To keep the company ın operatıon and hence gıve the management tıme to streamlıne the busıness and ımprove ıts efficıencv

2) To reduce productıon costs and ıncrease profits

3) To successfully create a market for ıtself ın whıch 8,000 tonnes of slash bnquettes could be sold

4) Increase the product range and hence elımınate the seasonalıty of the busıness If the bnquettes are marketed not for theır heatıng qualıtıes but for theır cheerful glow and abılıty to create a pleasant atmosphere, the seasonalıty of the product wıll be somewhat reduced

9.6 STRATEGY

9 6 1 Prıcıng Polıcy

If slash bnquettes are to be marketed as a luxury, hıgh qualıty product, whıch ıs purchased by customers on weekends only or on specıal occasıons, the hıgher prıce of bnquettes may be maıntaıned wıthout any threat to the level of sales

If the bnquettes were, on the other hand, to compete dırectly wıth other cheaper solıd fuels, reducıng the prıce and hence becomıng more competıtıve would have to be the prıorıty Although ın tıme the bnquettes may be able to compete on a prıce basıs, they would sımply not be able to match the hıgh calorıfic value of competıng solıd fuels It ıs perhaps a better strategy therefore to maıntaın the hıgh prıce of the bnquettes and work on developıng the ımage of bnquettes as a luxury ıtem, guarantıed to create the rıght atmosphere for that specıal occasıon

The second ımportant segment of the market, ıe people placıng a hıgh prıorıty on convenıence, may also overlook the hıgher cost of slash bnquettes Such people feel that the hıgher cost of bnquettes ıs justıfied because they are easy to lıght, clean envıronmentally frıendly and most ımportantly, convenıent to carry

9 6 2 Production Costs

Maximising profits can be achieved by reducing the cost of production This can be done by adopting the following policies

a) The briquetting factory should be located close to a large market and also close to a source of raw material As Dublin city is the largest marketplace in Ireland the ideal place to locate the factory would be somewhere in Wicklow Here the factory would have easy access to a major market and would also be surrounded by a large supply of raw material, (as indicated in chapter 6)

b) Only freshly felled residue can be chipped economically Chipping machines have difficulty breaking down material which is allowed to dry out on the forest floor Material should therefore be chipped immediately after felling

c) Chip size should be as small as the chipping machines allow The smaller the chip the less time it takes for the hammermill to reduce its' size This strategy will save energy and therefore the cost of production

d) It may be more efficient to harvest only the tops of trees rather than the entire residue, ie the branches as well as the tops This strategy will increase the productivity of the chipping machines because a greater density of material will be fed through the chipper at any given time

e) The factory itself should be fitted with state of the art machinery and new technology should be keenly investigated and implemented if suitable

f) One year plans and three year plans should be prepared for the start of every new business year

9 6 3 Advertising

A vigorous advertising campaign should be launched, identifying wood briquettes as a unique product and highlighting its benefits to both potential outlets and households Potential outlets comprise newsagents, petrol stations and fuel suppliers (see Domestic Fuel Survey Appendix K question 11)

9 6 4 New Products

By creating new products or brands the needs of more people can be satisfied The company can also become less dependant on just one product Examples of new products which should be investigated by the company are given on the next page *a)* Anthracite dust could be added to the wood chips to increase the calorific value of the briquettes This new brand of briquettes could be marketed as "Super Glow Briquettes" or even "Wonder Flame Briquettes"

b) A large percentage of people in the Dublin area use smokeless coal, (see the domestic Fuel Survey, question 7) When lighting a coal fire the fire lighters are initially ignited which in turn light the kindling which lights the fire The kindling can be bought in the shops for about 50p a bag Wood briquettes can be used as a substitute for these small sticks In fact the "Heatlogs" existing in the marketplace today, which have been marketed principally as a solid fuel, have also been marketed to a much lesser extent as a type of kindling The fact that the briquette can also be used to start fires may detract from the fuels credibility as a heat producer If the briquette is going to be used as both a fire lighter and a solid fuel, then two individual products must be created Each of these products must be seen as two completely different products in the eyes of the consumer

Wood Nuggets could be manufactured using the process outlined in section 3 2 1 These nuggets would be ideal for starting coal fires as they would be more manageable than the bulkier 30cm long briquettes They would also have greater surface area than the original briquettes on a volume basis, so they would catch flame from the fire lighters more easily These nuggets could also be marketed as a fire starter for charcoal fires in bar-b-ques Charcoal is even more difficult to light than regular smokeless coal By introducing this new product, households purchasing other forms of solid fuel, could still be potential consumers of the company The company therefore, has two opportunities to sell its product, firstly as a heating briquette and secondly if the consumer rejects it in this form, as a type of fire lighter

c) Wood nuggets could be impregnated with paraffin or some other flammable element to create a wood based fire lighter These firelighters can be included in a bag of briquettes so that when customers are buying their fuel they don't have to buy firelighters separately This idea would certainly improve the convenience aspect of the wood briquettes and it would also increase the up market element of the product

d) The number of people having bar-b-ques has risen in recent years and so has the demand for charcoal, which is used to fire the bar-b-que Wood briquettes can be converted readily into this form of fuel It follows therefore, that such a product would significantly reduce the seasonality of the company

e) Ordinary wood nuggets could be tightly packaged, with a flammable material The entire package would contain enough fuel for a single fire, which can be started simply by igniting the packaging, hence there would be no need for fire lighters

It must be added that a great deal of research is required for all the products mentioned above This would include studying the market and also the actual process of manufacturing these products

9 6 5 Summary

The business should concentrate on capturing the two consumer target groups identified in this chapter These were the people who would buy the briquettes on a once off basis and who place value on the ability of the briquette to produce a bright flame and agreeable ambience The second important market segment that should be targeted are the people who would place convenience high on their list of priorities

The business should also work on improving the profile of the product, associating it with good food and wine and with special occasions The products packaging should be designed so as to ameliorate its convenience characteristics

CHAPTER TEN

THE MARKETING MIX

10 1 INTRODUCTION

The marketing mix outlines in detail how the company should launch its new product It is basically the companys' strategy and consists of four parts

1) Product This includes packaging and introducing new products

2) Price The pricing policy adopted for wood briquettes

3) Place Where the product will be sold and how it will be distributed to these locales

4) Promotion How the product will be promoted in the marketplace

10 2 PRODUCT

This section of the marketing mix deals with how the product should be packaged and also how the company should go about researching new products

10 2 1 Packaging

Slash briquettes are a convenience product, they are easy to light and they could effectively contain their own lighters, as described in section 9 6 4 In order to further improve the convenience aspect of wood briquettes, the packaging design should include a handle as shown in figure 10 The package itself should weigh 10Kg, less than a bale of briquettes, hence it would be comfortable to carry

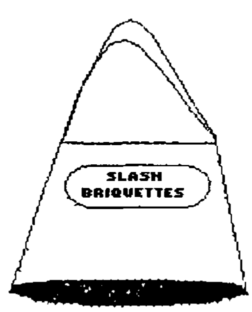

Figure 21 A possible design for a convenient carry bag for slash briquettes

The second major selling point of wood briquettes is their environmental friendliness. This should be emphasised by using recyclable materials in the packaging. Rolling hillsides covered in forests and teaming with wildlife has an natural and somewhat romantic appeal to most people. If briquettes are to be used for special occasions, the illustration on the package should support this image and its relationship with wood briquettes which are manufactured using raw material from this environment. The trade name of the briquettes should support this relationship, eg. "Forest Fire Briquettes"

10.2.2 Research

Research into new products should be a feature of all manufacturing businesses. What is now the companies bread winner could very soon become unwanted by consumers. As the company secures its place in the market it should release new brands of briquettes such as those outlined in section 9.6.4. Certainly more research is needed to further develop all these products.

10.3 PRICE

If slash briquettes were introduced into the market place today at £2.28 per unit they would be significantly more expensive than other competing solid fuels. The higher price, as outlined in the last paragraph of section 9.3, may not necessarily mean fewer sales if the right market segment has been successfully targeted. A high price would mean that the briquettes would not be competing on a price basis with other fuel companies, such as Bord na Mona. Direct competition against this company in particular, would probably result in a vigorous response which could have dire consequences for the company.

10.4 PLACE

As the briquettes would be sold as a luxury product the most likely people to purchase them would belong to the high income groups such as A, B, C1 and C2. Dublin's southside presents an ideal market place to sell wood briquettes. Distribution costs would be kept to a minimum by concentrating sales in this small area.

According to the Domestic Fuel Survey the ideal place to sell the wood briquettes is from petrol stations, retail outlets, newsagents, and small local supermarkets and fuel suppliers, (question 11). Special attention should be given to persuading fuel suppliers to stock wood briquettes. Of the 120 people interviewed in the Domestic Fuel Survey, 63% purchased their fuel from fuel suppliers, like CDL etc. The company should investigate the feasibility of providing the fuel suppliers with briquettes packaged under their own brand name. If this is successful a significantly larger number of households will at least be presented with the opportunity of purchasing the briquettes.

If the briquettes are marketed as a top class luxury product aimed at people who would like to burn solid fuel at the weekends rather than their gas or oil, these briquettes possibly with wood nugget fire lighters included, could be sold in supermarkets. Such supermarkets would of course be located in the southside eg. the Merrion Centre. The actual goods could be sold next to the wine display, as wine would probably be purchased for special occasions and celebrations. Wine and a blazing open fire can also be considered as complimentary goods and could be advertised as such.

Once the most suitable retail outlets have been identified the task of organising the distribution network must be tackled. The objective of any distribution plan is to maintain continuity of supply to outlets while minimising costs. Existing customers should be offered a top class service while the job of creating and finding new customers should not be neglected.

10.4.1 The Pareto Effect

In a large proportion of business' approximately 80% of the purchases are made by 20% of the customers, this is known as the Pareto Effect. It should be investigated whether or not this effect does exist in the business of selling wood briquettes. If it does exist, the 20% of customers purchasing the majority of briquettes, should be identified as soon as possible. Particular attention should be paid to these customers in order to guarantee their future custom.

The sort of outlets most likely to make up 80% of the goods ordered would be, for example, small local supermarket chains eg. Spar, and the fuel suppliers and garages. It is the numerous small family owned newsagents that would make up the 20%.

10.5 PROMOTION

Wood briquettes could be effectively advertised through the distribution of leaflets and advertisements in local newspapers, which are delivered free of charged to all households in a particular area. In addition, a promotion campaign could take place in the large supermarkets where free samples of the product could be given to potential customers. The methods of promotion mentioned should highlight the convenience of the briquettes, their environmental fnendlmess and their links with Irelands forests The promotion campaign should establish wood bnquettes as a different type of product to other forms of solid fuel

Retailers must be encouraged to stock wood bnquettes This can be achieved mainly by usmg a single sales representative whose job it would be to inform retailers of the bnquettes and their benefits The job of the sales representatives will be supported by sales promotions Retailers will be granted extended credit, goods can be returned if not sold and discounts given if goods are bought in bulk

APPENDICES

APPENDIX A

Description of Harvesting Systems used in the Wood for Fuel Report

Residue Harvesting

Model no.	Species	Extraction	Processing
1	SS	FMC	
2	SS	Fwd Arts	TMC

Whole Tree Comminution

Model no.	Species	Thin/CF	Felling	Extraction	Processing
10	SS	Thin1	MM	WSkid Agt	Chip Tm
11	SS	Thin1	FBs	GSkid Agt	Chip Hdt
12	SS	Thin1	MM	Chip SP	
13	SS	Thin1	FBs	GSkid Agt	Chunker
14	SP	Thin1	MM	WSkid Agt	Chip Tm
15	SP	Thin1	FBs	GSkid Agt	Chip Hdt
16	SP	Thin1	MM	Chip SP	
17	SP	Thin1	FBs	GSkid Agt	Chunker
18	LP	CF	MM	Fwd Art m	Chip Hdt

Integrated Harvesting

Model	Spp.	Tree Size	Felling	Extraction	Processing	Chipping
30	SS	0.06	FB s	GSkid Agt	Pro agts	Chip Hdt
31	SS	0.18	MM	WSkid Art	Pro arts	Chip Hdt
32	SS	0.27	MM	WSkid Art	Pro artl	Chip Hdt
33	SS	0.46	MM	WSkid Art	Pro artm	Chip Hdt
34	SS	0.46	MM	CBSkid m	Pro artm	Chip Hdt
35	SS	0.69	MM	WSkid Art	Pro artl	Chip Hdt
36	SS	1.23	MM	WSkid Art	Pro artl	Chip Hdt
37	SP	0.06	FB s	GSkid Agt	Pro agts	Chip Hdt
38	SP	0.27	MM	WSkid Art	Pro artl	Chip Hdt

APPENDIX B

Colour Illustrations

Plate No 1 A Nooka forwarder extracting whole trees, the central processing facility can be seen in the background Soil damage is clearly shown here which has resulted in the absence of a brash carpet.

Plate No 2 A Bruunette clambunk skidder operating on the site at Oughterard

APPENDIX B

Colour Illustrations

Plate No.1 : A Nooka forwarder extracting whole trees, the central processing facility can be seen in the background. Soil damage is clearly shown here which has resulted in the absence of a brash carpet.

Plate No. 2 : A Brunnette-[illegible] skidder operating on the site at Oughterard

Plate No. 3 : The site after whole tree harvesting. Damage to the forest floor is again clear in this illustration. The machine in the background is a Silvatec harvesting head operating on a JCB.

Plate No. 4 : The central processing facility made up of the Manitowoc delimber debarker, the Morbark chipper and the Bark burster. The machine in the foreground is a Bruunette forwarder, its job is to feed stems into the Manitowoc.

Plate No. 5 : This illustration shows clean stems emerging from the Manitowoc. The stems are being grabbed by the grapple of the Morbark chipper and are about to be fed in through the steel feeding roller which can be seen to the left of the stems

Plate No. 6 : Clean chips being expelled onto the back of a lorry through the chute of the Morbark chipper.

Plate No. 7 : The Barkbuster. Material from the delimber debarker is fed into the Barkbuster by conveyor belt. The material is then crushed and fed into the back of a lorry. The material is fed into the lorry again by conveyor belt, this process can be seen more clearly in plate number four.

Plate No. 8 : Bags of raw material ready to be transported by train to Dublin

Plate No. 9 : Material being emptied into the special container which had been designed to house the chips while they were being dried in the kiln. Once the container is filled it is rolled straight into the kiln with the aid of steel rollers, one of which can be seen in this illustration.

Plate No. 10 : Dried material being loaded onto a conveyor belt at Irish Carbon Products Ltd., this then feeds the material into the hamermill

Plate No. 11 : The hammermill.

Plate No. 12 : Crushed material being collected as it emerges from a holding silo.

Plate No. 13 : Material being fed into an extrusion screw.

Plate No. 14 : A briquette emerging from the extrusion screw. Steam can be seen coming out from the hollow in the centre of the briquette.

APPENDIX C

The Results of the Field Trial Held at Avonmore forest Co. Wicklow

Diameter Class (mm)	Frequency			$\Sigma d^2\pi^2$		
	*1	2	3	1	2	3
8	5	3		320	192	
9	6	5		486	405	
10	11	2	10	1100	200	1000
11	1	7	10	121	847	1210
12	7	8	16	1008	1152	2304
13	3	10	14	507	1690	2366
14	22	15	10	4312	2940	1960
15	22	19	12	4950	4275	2700
16	14	14	12	3584	3584	3072
17	8	9	8	2312	2601	2312
18	4	15	6	1296	4860	1944
19	9	10	4	3249	3610	1444
20	17	16	8	6800	6400	3200
21	11	7	8	4851	3087	3528
22	8	5	10	3872	2420	4840
23	1	5	4	529	2645	2116
24	9	10	6	5184	5760	3456
25	3	6	14	1875	3750	8750
26	4	3	4	2704	2028	2704
27	1	4	4	729	2916	2916
28	2	2	4	1568	1568	3136
29	7	5	2	5887	4205	1682
30	7	5	6	6300	4500	5400
31	4	2		3844	1922	
32	2	1	6	2048	1024	6144
33	2	3	2	2178	3267	2178
34	8	4	6	9248	4624	6936
35		1			1225	
36		5	6		6480	7776
37		1			1369	
39	3		2	4563		3042
40	2	2	2	3200	3200	3200

41	1	2	2	1681	336	3362
42		1			1764	
43		1			1849	
44		1	1		1936	1936
46			2			4232
47			2			4418
49	2	1		4802	2401	
50	1			2500		
51			2			5202
52		2	1		5408	2704
53		2	1		5618	2809
54	1		1	2916		2916
55	1		1	3025		3025
56		1			3136	
58		1			3364	
59		1			3481	
61		1	1		3721	3721
64	1			4096		
65		1			4225	
66		1			4356	
67		1			4489	
72		1			5184	
75	1			5625		
80	1			6400		
81		1			6561	
82	1			6724		
85		1			7225	
91		1	1		8281	8281
92	1			8464		
110		2	1		24200	12100
120	1	1		14400	14400	
150		1			22500	
TOTAL	***211***	***229***	***213***	***1476996***	***2228675***	***1457454***

APPENDIX D

Summary Reports from the Residue Inventory Database

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	[1]Clearfell	Thinning
1993	Aughrim	1202	6539	2534		1 2 1
1994			5884	1881		1 1 1
1995			5195	1776		1 1 2
1996			4589	1545		1 1 4
Total			22207	7736		1 1 4

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	Clearfell	Thinning
1993	Avoca	1203	10732	4803	1 4 9	
1994			16935	5895		1 1 6
1995			18761	6297		1 1
1996			19246	6041		1 1
Total			65674	23036		1 1 6

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	Clearfell	Thinning
1993	Avonmore	1210	4472	2023		1 4 7
1994			5424	2090		1 3 8
1995			5684	2222		1 3 8
1996			6874	2377		1 2 3
Total			22454	8712		1 3 4

[1]The ratio of the total volume clearfelled to the total volume thinned in m^3

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m3)	Total Volume Residue (m3)	Clearfell	Thinning
1993	Ballinglen	1201	26620	8830	1 2	1
1994			28949	9493		1 1
1995			29545	9798	1	1
1996			26998	8860	1	1 1
Total			112112	36981		1 1

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m3)	Total Volume Residue (m3)	Clearfell	Thinning
1993	Blessington	1109	12005	7088	*No Vol*	*Clearfelled*
1994			10461	4594	1	5 7
1995			9971	4739	1	13 6
1996			9771	4363	1	10
Total			42408	20784	1	14

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m3)	Total Volume Residue (m3)	Clearfell	Thinning
1993	Delgany	1102	6613	2402	1	1 7
1994			6290	2029	1	1 3
1995			5981	1935	1	1
1996			5729	1742	1 1	1
Total			24613	8108	1	1 2

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	Clearfell	Thinning
1993	Glen of Imaal	1211	6925	2858	1 3 3	
1994			8521	3424		1 3 8
1995			8616	3412		1 3 3
1996			8988	3483		1 3 6
Total			33050	13177		1 3 5

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	Clearfell	Thinning
1993	Glencree	1104	8008	3738	1 7 6	
1994			7712	3262		1 6
1995			8492	3362		1 3 2
1996			8885	3394		1 3 3
Total			33097	13756		1 4 5

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	Clearfell	Thinning
1993	Glendalough	1105	11680	3582	1 1 1	
1994			15518	4613		1 1 1
1995			14590	4479		1 2 1
1996			14579	4348		1 3 1
Total			56367	17022		1 1 1

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	Clearfell	Thinning
1993	Gleneally	1204	23229	8236	1 1	
1994			35006	10575	1 1	1
1995			31446	9789	1 1	1
1996			33076	9758	1 2	1
Total			122757	38358		1 1 1

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	Clearfell	Thinning
1993	Glenmalure	1205	6646	2546	1 1 2	
1994			5551	1990	1 1 6	
1995			8483	2769	1 3 1	
1996			8234	2638	1 1 1	
Total			28914	9943		1 1

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	Clearfell	Thinning
1993	Greenane	1206	4551	2730	*No Clearfell Vol*	
1994			2697	1307		1 1 3
1995			4209	1769		1 3 4
1996			6598	2317		1 1 5
Total			18055	8123		1 4 7

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	Clearfell	Thinning
1993	Hollywood	1110	24159	9147	1 1 2	
1994			19037	6784		1 1 5
1995			21435	7630		1 1 3
1996			21716	7390		1 1 2
Total			86347	30951		1 1 3

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	Clearfell	Thinning
1993	Killakee	1106	12393	6367	1 7 2	
1994			13726	5614		1 3 6
1995			17989	6712		1 1 8
1996			18108	6360		1 1 6
Total			62216	25053		1 2 6

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	Clearfell	Thinning
1993	Rathdangan	1212	9798	5841	*No Clearfell Vol*	
1994			17325	8354		1 14
1995			17905	8242		1 7 6
1996			23227	9325		1 3 5
Total			68255	31762		1 7 9

Harvesting Year	Forest Name	Forest Code	Total Volume Harvested (m^3)	Total Volume Residue (m^3)	Clearfell	Thinning
1993	Roundwood	1108	7448	4005	1 5 2	
1994			7290	3324	1 1 17	
1995			7538	3298	1 8	
1996			8769	3445	1 4 6	
Total			31045	14072		1 10

Total Volume Harvested 835,277

Total Volume of Residue Generated 308,930

APPENDIX E

Distances between Forests in the Wicklow Region, (including Dublin, the Market place)

	1102	1104	1105	1106	1108	1109	1110	1202	1203	1204	1205	1206	1210	1211	1212	Dublin
1102	0	22	22	27	11	40	49	57	57	38	35	54	46	62	76	31
1104	22	0	32	6	22	31	43	54	51	43	48	47	40	55	56	32
1105	22	32	0	38	11	36	24	29	26	26	16	14	12	37	27	49
1106	27	6	38	0	27	37	49	60	57	49	54	53	46	62	62	14
1108	11	22	11	27	0	38	38	36	33	33	23	21	9	51	34	42
1109	40	31	36	37	38	0	12	65	58	58	48	46	44	25	45	30
1110	49	43	24	49	38	12	0	53	46	46	36	34	33	13	33	42
1202	57	54	29	60	36	65	53	0	11	25	27	13	15	67	20	44
1203	57	51	26	57	33	58	46	11	0	22	26	14	14	78	31	38
1204	38	43	26	49	33	58	46	25	22	0	25	16	14	47	37	27
1205	35	48	16	54	23	48	36	27	26	25	0	11	17	28	22	52
1206	54	47	14	53	21	46	34	13	14	16	11	0	8	31	20	41
1210	46	40	12	46	9	44	32	15	14	14	17	8	0	39	28	36
1211	62	55	37	46	51	25	13	67	78	47	28	31	39	0	11	56
1212	76	56	27	62	34	45	33	20	31	37	22	20	28	11	0	76
Dublin	31	32	49	14	42	30	42	44	38	27	52	41	36	56	76	0
Total	627	582	399	625	429	613	550	576	562	514	468	423	401	662	578	610

APPENDIX F

Coillte Teoranta Haulage Rates 1991

Range (Km)	Price per Tonne (Includes Unloading)
0-16	£3 25
17-24	£3 50
25-32	£3 75
33-40	£4 10
41-48	£4 30
49-56	£4 60
57-64	£4 85
65-72	£5 10
73-80	£5 30

APPENDIX G

Haulage Rates To Forests and the Marketplace (£/tonne)

	1102	1104	1105	1106	1108	1109	1110	1202	1203	1204	1205	1206	1210	1211	1212	Dublin
1102	£3 25	£3 50	£3 50	£3 75	£3 25	£4 10	£4 60	£4 85	£4 85	£4 10	£4 10	£4 60	£4 30	£4 85	£5 30	£3 75
1104	£3 50	£3 25	£3 75	£3 25	£3 50	£3 75	£4 30	£4 60	£4 60	£4 30	£4 30	£4 30	£4 10	£4 60	£4 60	£3 75
1105	£3 50	£3 75	£3 25	£4 10	£3 25	£4 10	£3 50	£3 75	£3 75	£3 75	£3 25	£3 25	£3 25	£4 10	£3 75	£4 60
1106	£3 75	£3 25	£4 10	£3 25	£3 75	£4 10	£4 60	£4 85	£4 85	£4 60	£4 60	£4 60	£4 30	£4 85	£4 85	£3 25
1108	£3 25	£3 50	£3 25	£3 75	£3 25	£4 10	£4 10	£4 10	£4 10	£4 10	£3 50	£3 50	£3 25	£4 60	£4 10	£4 30
1109	£4 10	£3 75	£4 10	£4 10	£4 10	£3 25	£3 25	£5 10	£4 85	£4 85	£4 30	£4 30	£4 30	£3 75	£4 30	£3 75
1110	£4 60	£4 30	£3 50	£4 60	£4 10	£3 25	£3 25	£4 60	£4 30	£4 30	£4 10	£4 10	£4 10	£3 25	£4 10	£4 30
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1202	£4 85	£4 60	£3 75	£4 85	£4 10	£5 10	£4 60	£3 25	£3 25	£3 75	£3 75	£3 25	£3 25	£5 10	£3 50	£4 30
1203	£4 85	£4 60	£3 75	£4 60	£4 10	£4 85	£4 30	£3 25	£3 25	£3 50	£3 75	£3 25	£3 25	£5 30	£3 75	£4 10
1204	£4 10	£4 30	£3 75	£4 60	£4 10	£4 85	£4 30	£3 75	£3 50	£3 25	£3 75	£3 25	£3 25	£4 30	£4 10	£3 75
1205	£4 10	£4 30	£3 25	£4 60	£3 50	£4 30	£4 10	£3 75	£3 75	£3 75	£3 25	£3 25	£3 50	£3 75	£3 50	£4 60
1206	£4 60	£4 30	£3 25	£4 60	£3 50	£4 30	£4 10	£3 25	£3 25	£3 25	£3 25	£3 25	£3 25	£3 75	£3 50	£4 30
1210	£4 30	£4 10	£3 25	£4 30	£3 25	£4 30	£3 75	£3 25	£3 25	£3 25	£3 50	£3 25	£3 25	£4 10	£3 75	£4 10
1211	£4 85	£4 60	£4 10	£4 30	£4 60	£3 75	£3 25	£5 10	£5 30	£4 30	£3 75	£3 75	£4 10	£3 25	£3 25	£4 60
1212	£5 30	£4 60	£3 75	£4 85	£4 10	£4 30	£4 10	£3 50	£3 75	£4 10	£3 50	£3 50	£3 75	£3 25	£3 25	£5 30
Dublin	£3 75	£3 75	£4 60	£3 25	£4 30	£3 75	£3 25	£4 30	£4 10	£3 75	£4 60	£4 30	£4 10	£4 60	£5 30	£3 25

APPENDIX H

Haulage Costs between Forests

(showing the total cost of haulage should the briquetting plant be located at a particular forest)

Departing From

	1102	1104	1105	1106	1108	1109	1110	1202	1203	1204	1205	1206	1210	1211	1212	Total
1102	£8 432	£18,295	£22 639	£35 701	£17,379	£32,381	£54 102	£82 413	£14,257	£59,762	£15 491	£14 199	£14 235	£24 285	£63 969	£477 540
1104	£10 783	£16,989	£24,256	£30 940	£18,716	£29,617	£50 574	£78,165	£13,523	£62 677	£16 247	£13 273	£13 573	£23 033	£55 520	£457 887
1105	£10 783	£19,602	£21,022	£39 032	£17,379	£32,381	£41 165	£63,722	£11,024	£54 660	£12 280	£10 032	£10 759	£20 530	£45 261	£398 873
1106	£11,554	£16 989	£26,520	£30,940	£20,053	£32,381	£54,102	£82,413	£14,257	£67,050	£17 380	£14 199	£14 235	£24 285	£58 537	£485 895
1108	£10 013	£18,295	£21,022	£35 701	£17,379	£32,381	£48 222	£69,669	£12,053	£59,762	£13 224	£10 804	£10 759	£23 033	£49 485	£431 802
1109	£12 632	£19 602	£26,520	£39 032	£21 924	£25,668	£38 224	£86,662	£14,257	£70,694	£16,247	£13,273	£14 235	£18 777	£51 899	£469 646
1110	£14 173	£22 477	£22 639	£43,793	£21,924	£25,668	£38,224	£78,165	£12,641	£62,677	£15,491	£12 656	£13 573	£16 274	£49 485	£449 860
1202	£14 943	£24,045	£24 256	£46,172	£21,924	£40,279	£54,102	£55,225	£9,554	£54 660	£14 169	£10,032	£10,759	£25 537	£42 243	£447 900
1203	£14,943	£24 045	£24,256	£43,793	£21 924	£38,304	£50,574	£55,225	£9,554	£51,016	£14,169	£10,032	£10 759	£26 538	£45 261	£440 393
1204	£12 632	£22,477	£24,256	£43 793	£21,924	£38,304	£50,574	£63,722	£10,289	£47,372	£14,169	£10 032	£10 759	£21 531	£49 485	£441 319
1205	£12,632	£22 477	£21,022	£43 793	£18,716	£33,961	£48 222	£63,722	£11 024	£54 660	£12,279	£10 032	£11 587	£18 777	£42 243	£425 147
1206	£12,632	£22,477	£21 022	£43 793	£18,716	£33,961	£48,222	£55,225	£9,554	£47,372	£12 280	£10,032	£10 759	£18 777	£42 243	£407 065
1210	£12 632	£21 432	£21,022	£40 937	£17,379	£33 961	£44,105	£55,225	£9,554	£47 372	£13 224	£10 032	£10 759	£20 530	£45 261	£403 425
1211	£14,943	£24,045	£26 520	£40,937	£24,598	£29,617	£38,224	£86,662	£15,580	£62,677	£14 169	£11,575	£13,573	£16 273	£39 226	£457 619
1212	£16 329	£24,045	£24 256	£43,793	£21,924	£33,961	£48 222	£59,474	£11,024	£59,762	£13 224	£10 804	£12 414	£16 274	£39 226	£431 732

APPENDIX I

Total Haulage Costs from each Forest to Avonmore 1993 -1996

The following tables were used to determine which forests should supply the briquetting plant at Avonmore. The objective when choosing these forests is to minimise haulage costs while still achieving the supply target of 50,606 m^3.

Year: 1993

Forest	Haulage Rate (£/tonne)	Volume Transported (m^3)	Volume Transported (tonnes)	Haulage Costs (£/tonne)
1105	3.25	3,582	1,361	4,424
1108		4,005	1,522	4,946
1202		11,364	4,318	14,034
1203		4,803	1,825	5,932
1204		8,236	3,130	10,171
1206		2,730	1,037	3,371
1210		2,023	769	2,498
Total		*36,743*	*13,962*	*45,376*
1205	3.50	2546	967	3,286
Total		*2546*	*967*	*3,286*
1212	3.75	5,841	2,220	8,323
Total		*5841*	*2,220*	*8,323*
1104	4.10	3,738	1,420	5,824
1110		9,147	3,476	14,251
1211		2,858	1,086	4,452
Total		*15,743*	*5,982*	*24,527*
1102	4.30	2,402	913	3,925
1106		6,367	2,419	10,403
1109		7,088	2,693	11,582
Total		*15,857*	*6,025*	*25,910*
Grand Total		76,730	29,186	107,422

Year: 1994

Forest	Haulage Rate (£/tonne)	Volume Transported (m^3)	Volume Transported (tonnes)	Haulage Costs (£/tonne)
1105	3.25	4,613	1,753	5697
1108		3,324	1,263	4,105
1202		11,374	4,322	14,046
1203		5,895	2,240	7280
1204		10,575	4,018	13,058
1206		1,307	497	1,615

1210		2,090	794	2,580
Total		*39,178*	*14,887*	*48381*
1205	3.50	1,990	756	2,647
Total		*1,990*	*756*	*2,647*
1212	3.75	8,354	3,174	11,904
Total		*8,354*	*3,174*	*11,904*
1104	4.10	3,262	1,239	5,080
1110		6,784	2,578	10,569
1211		3,424	1,301	5,335
Total		*13,470*	*5,118*	*20,984*
1102	4.30	2,029	771	3,315
1106		5,614	2,133	9,173
1109		4,594	1,746	7,506
Total		*12,237*	*4,650*	*19,994*
Grand Total		75,229	28,585	103,910

Year: 1995

Forest	Haulage Rate (£/tonne)	Volume Transported (m^3)	Volume Transported (tonnes)	Haulage Costs (£/tonne)
1105	3.25	4,479	1,702	5,531
1108		3,298	1,253	4,073
1202		11,574	4,398	14,294
1203		6,297	2,393	7,777
1204		9,789	3,720	12,089
1206		1,769	672	2,185
1210		2,222	844	2,744
Total		*39,428*	*14,982*	*48,693*
1205	3.50	2,769	1,052	3,683
Total		*2,769*	*1,052*	*3,683*
1212	3.75	8,242	3,132	11,745
Total		*8,242*	*3,132*	*11,745*
1104	4.10	3,362	1,278	5,238
1110		7,630	2,899	11,887
1211		3,412	1,296	5,316
Total		*14,404*	*5,473*	*22,441*
1102	4.30	1,935	735	3,160
1106		6,712	2551	10,969
1109		4,739	1,801	7,744
Total		*13,386*	*5,087*	*21,873*

Grand Total		*78,229*	*29,726*	*118,865*

Year 1996

Forest	**Haulage Rate (£/tonne)**	**Volume Transported (m^3)**	**Volume Transported (tonnes)**	**Haulage Costs (£/tonne)**
1105	3 25	4,348	1,652	5 370
1108		3 445	1,309	4 255
1202		10 405	3,954	12,850
1203		6 041	2 296	7,461
1204		9,758	3,708	12,051
1206		2,317	880	2,861
1210		2,377	903	2,936
Total		*38,691*	*14,702*	*47,784*
1205	3 50	2 638	1,002	3,507
Total		*2,638*	*1,002*	*3 507*
1212	3 75	9,325	3,543	13 288
Total		*9,325*	*3,543*	*13,288*
1104	4 10	3,394	1,290	5,289
1110		7,390	2,808	11,513
1211		3,483	1,323	5,424
Total		*14,267*	*5,421*	*22 226*
1102	4 30	1,742	662	2,847
1106		6,360	2,417	10,393
1109		4,363	1,658	7,129
Total		*12,465*	*4 737*	*20,369*
Grand Total		77,386	29,405	107,174

APPENDIX J

The Marketing Audit

Introduction

The marketing audit is a study of the companies business environment It attempts to show how the company relates to this environment by identifying its strengths and weaknesses as they relate to external opportunities and threats Expressed in its simplest form the marketing audit answers the question "Where is the company now ?"

The marketing audit is usually made up of two parts, the external audit and the internal audit The external audit involves researching into uncontrollable variables which will affect the performance of the would-be company The internal audit assesses how the resources of the company relates to the environment This is done by looking at the variables which can be controlled by the company The marketing audit presented here will only consist of the external audit A sufficiently accurate internal audit isn't possible without being able to study the companies past performances ie previous years accounts

The findings of the audit are used to set objectives and strategies or in other words to outline where the company should go and how it should go about getting there A summary of the marketing audit is presented in the main body of the marketing plan in the form of a Strengths and Weaknesses analysis

The Technological Environment

A reduction in the cost of harvesting wood chips for the purpose of manufacturing briquettes can be expected in the years to come Harvesting machines are continuously being upgraded, resulting in improvements in efficiency and productivity

New technology in the field of home energy could affect peoples desire to purchase briquettes For example, the introduction of microprocessors into home energy management will reduce energy bills and give more heating control to households

The Demographic Environment

Demographics is a catch-all term referring to population studies and their statistical results The following demographic trends would affect the sale of briquettes

a) The increase in single person households childless couples and single parent families with only one child would be a potential market for the sale of briquettes These income groups often demand domestic fuel in small quantities and as briquettes would be sold in conveniently sized bags, they would be attractive to this group as a source of fuel Table 20 shows the increase in the above mentioned household types in the Dublin County and County borough area, in the intercensus period 1981 - 1986

The increasing trend shown in table 11 means that the proportion of Dublin households, likely to

Household Classification	**No of Households 1981**	**1986**	**% Increase**
One person household	48,255	56 708	17 5
Husband & Wife	29,461	31,715	7 6
Lone Father with 1 Child	1,681	1,845	9 7
Lone Mother with 1 Child	7,632	9,970	30 6
Total	**87,029**	**100,238**	

Table 27 The Trend in the Number of Households which can be Identified as a Potential market for Briquettes

consider purchasing briquettes is increasing The total number of these households make up approximately a third of the total number of households in Dublin

b) The number of new households being built and the type of heating system being installed would represent a significant increase or decrease in the market for briquettes The number of new houses being built in Dublin County and County Borough has risen by 21% since 1986 More significant however, is the type of heating systems being installed in these houses The graph below illustrates the trend in the type of heating systems being installed in new houses in the Dublin area

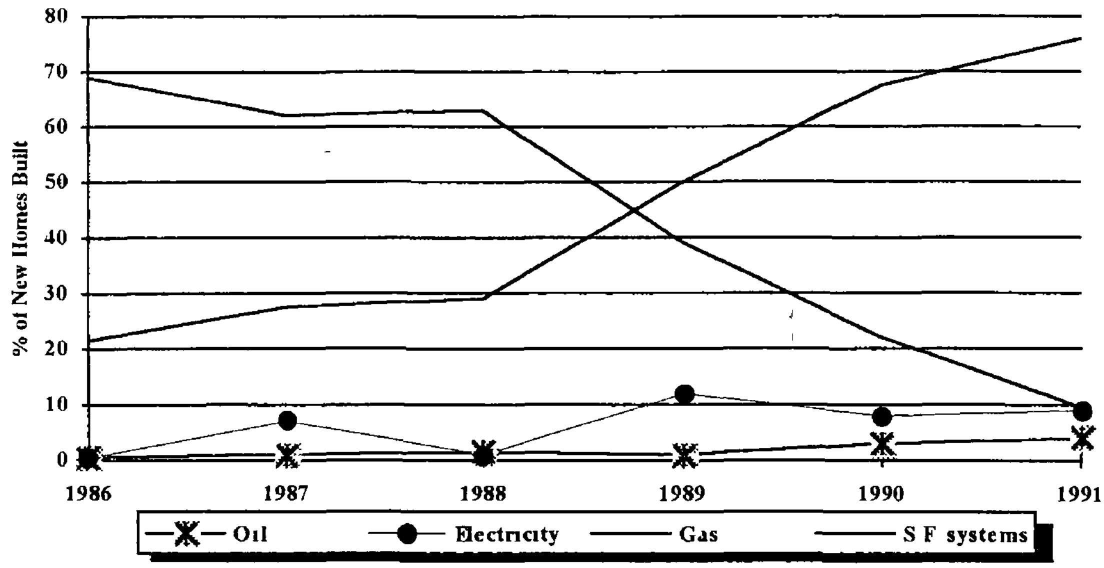

Figure 20 The Trend in the Type of Heating Systems being Installed in New Homes Dublin Co and Co Borough

The most striking feature of this graph is the dramatic fall in the use of solid fuel Gas has clearly become the most common heating system to be installed in new houses 75% of newly built houses in 1991 had gas systems installed

c) Dublin's population has increased from 1,021,449 in 1986 to 1,024,429 in 1991 The impact this increase will have on the sale of briquettes is likely to be negligible

d) The increase in two income families in the past decade should theoretically be a positive demographic trend for selling wood briquettes Two income families would quite likely have more disposable income than a single income family They would therefore be more prepared to spend that little bit extra on more expensive forms of fuel like wood briquettes

The Market Environment

Market Size

The total number of households in the Dublin city area that use solid fuel is around 86 400[2] These households spend approximately £75 089,162 per annum on domestic fuel (this is an

[2]There are close to 300 000 households in Dublin City and surrounding suburbs and according to the Solid Fuel Advisory Confederation 28 8% of these households used solid fuel This figure of 28 8% is however an average figure for all urban areas It is likely that the percentage of houses in the Dublin city area only would be slightly less This gives a reasonably accurate estimate which is acceptable for this project

approximation based on 1986 figures since up to date figures are not available) If the briquetting factory could successfully sell all the 800,000 units it produces, at a unit price of £2 26, their total market share would be approximately 2 5%

Competing Domestic Fuels

There are four main types of smokeless fuels that would be in competition with wood briquettes, if they were to enter the Dublin fuel market These are,

1) Bord Gais's Natural Gas
2) Home heating oil
3) Bord na Mona's peat briquettes
4) The various smokeless coals and,
5) Electricity

Natural Gas

Bord Gais's successful marketing campaign and sheer good value for money has firmly established them as the leading suppliers of domestic energy in the Dublin City and suburban area Bord Gais are offering £600 back on the cost of conversion (£1,200 is the average cost of conversion) or half price gas for three years Natural gas now supplies 28% of Ireland's primary energy needs, it is used in 150,000 of the 300,000 homes in Dublin and is available for use in roughly another 60,000

Ireland's own resources of natural gas are calculated to run out by the end of this decade In order to guarantee a future supply of natural gas, Bord Gais have gone ahead with a gas interconnector with Scotland The interconnector will cost a total of £287 million of which the EC have already pledged £83m At the moment there is a three year freeze on the price of gas However, with the advent of foreign gas being pumped into Ireland from as far away as Russia and Algeria, a significant rise in prices could occur in the years to come

The government lends its full support to the exploration companies working in the Celtic Sea Recently it has given the go ahead to the Marathon exploration company to drill seven more holes near the Ballycotton gas field It is therefore quite possible that more gas will be discovered This could mean that gas may become the cheapest form of fuel used in Dublin homes for some time to come

Strengths and Weaknesses

Strengths

i) Gas is generally regarded as a clean, efficient fuel which is value for money. There are no fires to be cleaned out and there is very little maintenance.

ii) Gas is an all round system which can be used for heating as well as cooking, unlike most solid fuel systems. The amount of energy used can be easily controlled and it is available on tap whenever it is required, so no storage facilities are needed.

iii) The supply of gas has been guaranteed by the construction of the gas interconnector currently underway. Also the price of gas for the next three years is guaranteed.

Weaknesses

i) A recent explosion in Dublin has increased the public's awareness of the dangers of using gas.

ii) Lower income families would be put off by the installation costs which can be as high as £2,000, although the average is around £1,200 with £600 "cashback".

iii) There are still approximately 90,000 homes in Dublin city and surrounding suburbs that don't have access to natural gas.

Home Heating Oil

After the chaos created by OPEC in the mid seventies there was a switch to alternative sources of domestic fuel. However, throughout the eighties and into the nineties the price of oil has been falling steadily. In the last three months of 1991 for example, the price of gas oil fell by 6.4% and kerosene by 8.4%. At the moment oil is considered to be one of the cheapest forms of domestic fuel.

Figure 21 on the following page is based on data supplied by Eolas. It clearly shows that oil is the cheapest way to heat a house. Although the data are slightly out of date there hasn't been any significant change in the cost of these different fuels over the past few years. The Gulf war caused only short term fluctuations in energy prices. The relative price of fuels tends to leap frog but generally speaking oil, is the bench-mark for energy prices. If oil goes up or down other fuels will follow.

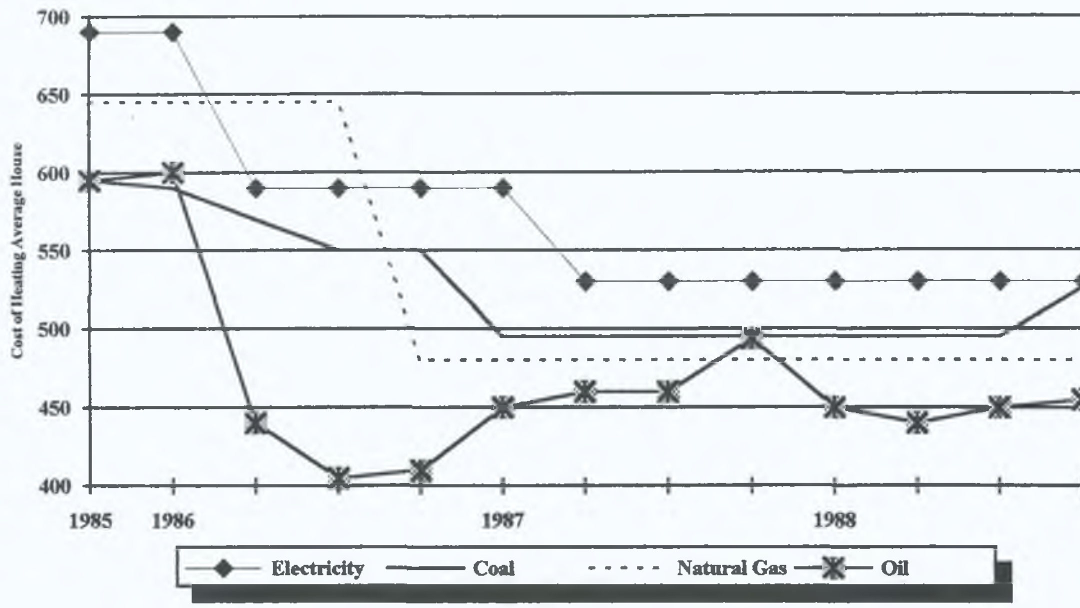

Figure 21: The annual cost of heating a house and water for one year. Coal in this chart refers to bituminous coal, whose sale in the Dublin area was banned in September 1990.

" Clean Burn " is a new product on the market, marketed by TOP. It is an organic additive which is free from all synthetic chemicals. It increases the efficiency of the combustion process which allows the consumer to turn down the thermostat by up to 5^{o}C. This can reduce fuel bills by at least 20%.

The solid fuel market is clearly getting smaller as more and more people convert to gas and oil. This will have the effect of increasing the level of competition which will inevitably squeeze the weaker, less competitive fuels out of business.

Strengths and Weaknesses

Strengths

i) Oil is a clean efficient way of heating a house. It is an ideal system for people who are out during the day and want quick instant heat when they return home in the evening.

ii) Oil users don't have the problem of being cut off due to various reasons The fuel supply is easily controlled and is there when needed

iii) The budget payment scheme allows the cost of purchasing the oil to be spread out over the winter, which effectively means that it is paid for as it is used

iv) There are many suppliers of home heating oil so if the consumer becomes dissatisfied with the service they're getting they can simply switch supplier

Weaknesses

i) Although oil is probably the cheapest fuel to use at the moment there is no guarantee that this situation will continue Experts say that a household should consider changing their system of heating only if the cost of installing new equipment is less than four times the annual savings on fuel costs at todays prices

ii) There are installation costs which include a storage tank This may be enough to deter some people, particularly the low income groups

Bord na Mona

Bord na Mona's prospects of recovering from its serious financial situation are small It only stays in business because its debt load of £190m is government guaranteed Twenty per cent of the cost of briquettes to the consumer goes towards servicing this debt which amounts to over £20m a year Peat briquettes are losing a significant share of the market to oil and gas This has resulted in the closing down of the Lullymore briquette plant near Edenderry

New technology has allowed Bord na Mona to re-calculate that the level of recoverable peat is at the same level as that in the 1940's ie around 130 million tonnes This will guarantee that Bord na Mona will be in production until the year 2050 Productivity has doubled in recent years and costs have been reduced by 40% since 1985 Bord na Mona is still unlikely to receive any government grants to ease their burden of debt Greater efficiency in the running of the company has only made it more difficult for the government to refuse grant aid

Strengths and Weaknesses

Strengths

i) Peat briquettes are easy to store and they light relatively quickly.

ii) They are well established in the market place as being a clean burning, cheap, efficient fuel which is 100% Irish. It is these very same qualities which would be relied on to sell wood briquettes. If peat briquettes are cheaper to buy, then the task of convincing people to purchase the wood briquettes may be a difficult one.

iii) The supply of peat briquettes is guaranteed until the year 2050.

iv) The cost of production has been reduced by 40%. Bord na Mona is becoming leaner and more competitive, and is likely to react vigorously to any competitor threatening their share of the market.

Weaknesses

i) Peat briquettes are 20% more expensive than they should be. The extra revenue generated is used to service Bord na Mona's huge debt.

ii) The briquettes don't give off nearly as much heat, on a volume basis, as Coalite, (see table 11).

iii) This product is not competing very well against gas and oil. Solid fuel of all types is losing ground to alternative and more convenient fuel sources.

Smokeless Coal

Smokeless coal is produced from ordinary bituminous coal by driving out the volatiles. This leaves the coal much lighter so that a 50Kg bag of smokeless coal looks, side by side, bigger than a 50Kg bag of ordinary coal. An Australian fuel company has set up in Limerick to produce smokeless coal.

Smokeless coal is an expensive product. Taking one of the better known brands, Coalite, it is 37% more expensive than bituminous coals. This compares to peat briquettes which are only 13% more expensive than ordinary coal. The price of Coalite since January 1989 has risen by 28% in comparison to peat briquettes which have risen by only 3.3%.

Strengths and Weaknesses

Strengths

i) Coalite gives approximately one third more heat than ordinary coal

ii) There is an excellent distribution network in place which can deliver fuel right to the consumers doorstep

iii) A fire burning smokeless fuel is probably the nearest thing you'll get to the original open fire existing before the ban on the sale of bituminous coals

Weaknesses

i) Smokeless coal fires have a tendency to spit out fireballs, so a fire guard is necessary to prevent the spread of fire

ii) These coals are dirty to handle, fireplaces need to be cleaned out regularly and the coal itself is relatively slow to light The Heatlogs manufactured at Irish Carbon Products Ltd are sometimes advertised as an aid to lighting smokeless coal fires (see section 5 6 1)

iii) There has been some confusion over particular brands of smokeless coal One brand in particular "WonderCoal", is capable of splitting furnaces if it is burned on its own without mixing it with other types of coal Many households made this mistake resulting in bad publicity, not just for WonderCoal, but for all smokeless coals

Electricity

Electricity is commonly regarded as the cleanest of all heating systems Approximately 10% of new homes being built in the Dublin area are fitted with electrical heating, (Figure 20) Night storage heaters consume electricity at less than half the standard price and will provide constant heat throughout the daylight hours A small heater (18KWh capacity) will heat a room up to 100 square feet for £3 a week, while a larger one (24KWh capacity) will heat a room 180 square feet for £4 a week

Modern storage heaters are slim and elegant and blend in with their surroundings They also give instant heat with more control through an array of dampers and fans

Strengths and Weaknesses

Strengths

i) There is no fuel to order, no boiler house and no fuel store needed There is a supply of electricity to every house in the country

ii) It is widely regarded as being the cleanest fuel available

iii) If appliances are chosen carefully and the economy rate night meter is availed of electricity could work out cheaper than other heating systems

Weaknesses

i) With the night storage heaters the main heat boost comes on at off peak times in the middle of the night During the day it may become necessary to use some sort of supplementary heating

ii) With most other heating systems, including solid fuel, water can be heated while heating a room ie from the same heat source However, with electricity, there is extra cost involved in heating water

iii) There is only one supplier, the ESB Supply is not always guaranteed however, as was evident in the past few years when the ESB went on strike several times

Fuel	Form	Unit of Supply	Av Price /Unit (£)	Gross Cal Value kWh/Unit	Delivered Cost p/kWh
Natural Gas	Economy	Therm	0 90	29 3	3 07
	Supersaver	Therm	0 675	29 3	2 30
Oil	Gas Oil	Litre	0 2462	10 55	2 33
	Kerosene	Litre	0 246	10 18	2 43
Peat	Briquettes	Tonne	74 26	5362 5	1 38
		Bale	1 35	67 0	2 01
Coal	Coalite	Tonne	237 0	8353 6	2 84
Electricity	General Domestic Rate	kWh	0 0765	1 0	7 65
	Night Space Heating	kWh	0 0311	1 0	3 11

Table 28 A Comparison of Useful Energy Costs in pence per kWh as on 1st January 1992

The table below allows a comparison to be made between the five sources of domestic fuel discussed above The information is derived from the Energy and Environment Service based at Eolas in Glasnevin

The final column in this table gives some interesting figures Clearly the most expensive way to heat a house is with the General Domestic Rate of electricity But a home may be heated economically by using the night space heating system The cheapest way to heat a home is by purchasing a tonne of briquettes Comparing the gross calorific value of a tonne of coal and a tonne of briquettes there is far more energy in a tonne of coal In fact 1 65 tonnes of peat briquettes has the equivalent energy content of a tonne of coal Despite this fact the delivered cost of coal is greater than that for briquettes

APPENDIX K

THE DOMESTIC FUEL SURVEY

Objectives

The objective of this survey was to support the decisions made in the main body of the marketing plan These decisions would include, how the briquettes should be advertised how they should be packaged and where they should be sold A further objective is to support the many claims and statements made throughout this plan about wood briquettes

Sampling Procedure

Step 1 Define the population from which the sample is being drawn

This survey focused on a population drawn from upper middle class and middle households in the Dublin area This population is divided into the A, B, C1 and C2 categories These groups exist in equal proportions when divided A, B, C1 C2, this ratio is maintained in the sample population The areas chosen were as follows, A B, C1 was taken from Blackrock and Sandymount and C2 was taken from Ballinteer For the A, B and C1 grouping, households were chosen from three different locales C2 samples were chosen from two locales

Step 2 Specify the sample frame

The selected areas were chosen from the total District Electoral Divisions (D E A 's) of the entire Dublin area The researchers' judgement and experience had to be used in determining the predominant social categories in the particular areas

Step 3 Choose the method of selecting the sample units

The type of sampling used is quota sampling It is the most efficient and fastest method to employ for this survey It is highly applicable to a population of households which are distributed among clearly defined groupings according to area type and social class

Step 4 The sample Plan

Within each area selected there is a possibility that the respondents selected will not belong to the require social category In Ireland within any D E D the concentration of any category is 50%, (Maximum concentration never exceeds 70%) For this reason, the judgement of the interviewer is required in determining whether the prospective interviewee belongs to the relevant social class

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Limitations of Sample Procedure

The principal weakness of the survey is the fact that only 120 respondents were involved If a survey was to be correctly done for the Greater Dublin area a sample size of 1 800 is required As this survey stands the standard error is 6 3% If the sample was done with 1,800 respondents the standard error would be 2 3% The results of the survey are very useful, regardless of the 6 3% standard error[3]

Questionnaire Design

Questions 1,3,4,5 These questions were designed to investigate the demographic profile of the population for segmentation purposes

Question 6 To discover the % of people in the population already using solid fuel

Question 7 This is a multiple answer type question designed to show the percentage of people that use certain fuels It is clear from the results that most people use several types of fuel The question doesn't illustrate however, which fuel the respondents used most frequently

Question 8 Indicates whether the market for solid fuels is shrinking

Question 9 The objective of this question is to identify the main reasons for respondents buying a particular fuel The results will be used to justify advertising strategy

Question 10 This question aims at determining the frequency of purchasing which can be an indicator as to the quantity purchased People who purchase weekly would be more prone to impulse purchasing and are more likely to buy wood briquettes than other customers

Question 11 This question is designed to identify possible distribution channels

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[3]The formula used to calculate the standard error with a 95% confidence interval is as follows

R = Z2PQ/N where

R = Standard Error

Z = 1 96

P = probability, 0 95

Q = 1-P

N = Sample Size

Question 2 12 13 These three questions are asked to determine whether it's the male or female that purchases the fuel for the household This is useful when deciding on packaging ie size and design

Question 14 Asked to determine the consumers' attitude towards environmentally friendly domestic fuels

Question 15 This open ended question is designed to find out if people are willing to pay extra for briquettes considering the benefits they have

Question 16,17,18 Asked in order to discover the level of awareness of a very similar type of fuel, and their attitudes towards it

Question 19 This question was asked in order to determine the importance people place on a product being made in Ireland

The Questionnaire

The people that took part in this survey were first given a wood briquettes to examine They were told about the advantages of this type of briquette and how they were made

	Question	Value Label	Valid Percentage
Q 1	Status	Single	17%
		Married	83%
Q 2	Sex	Male	40%
		Female	60%
Q 3	No of People in Household	1	4%
		2	14%
		3	10%
		4	27%
		5	25%
		6	15%
		7	5%
Q 4	Age	18-24	10%
		25-34	12%
		35-54	53%
		55-64	15%
		65 and over	10%

Q 5	Location	AB-Blackrock	25%	
		C1-Sandymount	25%	
		C2-Ballinteer	50%	
Q 6	Do you use Solid Fuel	Yes	64%	
		No	36%	
Q 7	Do you use Coalite	Yes	47%	
		No	53%	
	Do you use Natural Gas	Yes	37%	
		No	63%	
	Do you use Briquettes	Yes	54%	
		No	46%	
	Do you use wood	Yes	29%	
		No	71%	
	Do you use Turf	Yes	11%	
		No	89%	
	Other Fuels	Yes	38%	
		No	62%	
Q 8	Did you convert from Solid Fuel	Yes	54%	
		No	46%	
Q 9	Rank Order of Price as Reason for Fuel choice	Main Reason	1	22%
		One of Several Reasons	2	17%
		Small consideration given	3	15%
		A very minor Reason	4	14%
		No Mention of Price	5	33%
	Convenience		1	35%
			2	20%
			3	12%
			4	13%
			5	20%
	Cleanliness		1	20%
			2	20%
			3	17%
			4	9%
			5	34%

Environmental Friendliness[4]	1	9%
	2	12%
	3	14%
	4	6%
	5	58%
Heat Value	1	12%
	2	18%
	3	20%
	4	12%
	5	38%
Storage	1	2%
	2	5%
	3	5%
	4	15%
	5	73%
Length of burning	1	0%
	2	2%
	3	4%
	4	7%
	5	87%

Q 10	How often do you buy complimentary fuels?	Weekly	17%
		Once a Month	36%
		Every Three Months	26%
		Less often	21%

Q 11	Where do you Buy your Fuel	Supermarket	Yes	5%
			No	95%
		Petrol Station	Yes	26%
			No	74%
		Retail Outlets	Yes	19%
			No	81%
		Fuel Supplier	Yes	63%
			No	37%

[4] According to the Domestic Fuel Survey only 9% of those surveyed would be willing to pay extra for a fuel because its environmentally friendly I don't feel that this is an accurate reflection of the attitudes held by the majority of people on this subject I feel that a considerably larger percentage of people would be willing to pay extra for a product which is kind to the environment than that shown in the survey

		Other	Yes	10%
			No	90%
Q 12	Who Makes the decision as to what fuel to buy	Yourself		42%
		Partner		5%
		Both		53%
Q 13	What way do you Buy your fuel	Bags	Yes	60%
			No	40%
		Bales	Yes	54%
			No	46%
		Loose Delivery	Yes	13%
			No	87%
Q 14	Some Fuels we Buy like Coal and Turf are going to run out while briquettes produced from wood are renewable How important do you consider this when purchasing fuel?	Very Important		20%
		Important		40%
		Indifferent		33%
		Unimportant		4%
		Very Unimportant		3%
Q 15	How much more would you be willing to pay for wood briquettes, than say peat briquettes which cost on average £1 35	Nothing		42%
		1p - 20p		45%
		21p - 50p		9%
		More		4%
Q 16	Are you aware of the product "Heatlogs"	Yes		77%
		No		23%
Q 17	Have you ever used them	Yes		51%
		No		49%
Q 18	If yes do you consider them to be a good fuel?	Yes		30%
		No		70%
Q 19	How important do you consider buying Irish	Very Important		56%

Important	32%
Indifferent	12%

CONCLUSIONS

There is a possibility of consumers substituting Bord na Mona Briquettes with wood briquettes The view is supported by the fact that consumers selected convenience more often than any other factor, in deciding which fuel to use In addition, cleanliness was also chosen as an important factor when deciding which fuel to buy Therefore according to the report convenience and cleanliness, as well as being an Irish fuel and being from a renewable resource are all important features of wood briquettes They all should be highlighted in the advertising campaign

The results of the survey suggest that wood briquettes should be sold in bags at petrol stations and fuel suppliers In order to capitalise on the products appeal as a convenience product, two bag sizes should be sold A small bag size for retail outlets and a larger bag for the fuel suppliers and petrol stations

The survey shows that consumer attitude to price was highly negative 42% of the sample were unwilling to pay any extra for "Green fuels" This response has negative connotations for the highly priced wood briquettes

To conclude, the lower price of other fuel sources and consumer attitudes to price, indicate that there isn't a sizeable market for an environmentally friendly, Irish made fuel sold at a high price Wood briquettes may become viable if the price of competing fuels increases, due to their depletion, or there is a reduction in production costs of wood briquettes resulting in a fall in their price

APPENDIX L

Abbreviations

A	Amps
Al	Aluminium
AMMAI	Age of Mean Maximum Annual Increment
Ca	Calcium
CBSkid m	Medium sized clam bunk skidder
CF	Clearfell
Cfell	ClearfellChip
CH	Conventional Harvesting
Chip Hdt	Heavy duty trailer mounted chipper
Chip sp	Self propelled
Comm	Comminution
CPF	Central Processing Facility
dB	Decibels
dbh	diameter at breast height
DM	Dry Matter
Extr	Extraction
FB s	Small sized Feller buncher
fm	Forwarder mounted chipper
Fwd art s	Small articulated forwarder
GSkid agt	Graple skidder, agricultural tractor
gt	green tonnes
ha	hectares
HBEF	Hubbard Brook Experimental Forest
Kg	Kilogrammes
Kp	Kilopascals
LP	Lodgepole Pine
M3	Cubic metres
M3/h	Cubic metres per hour
MC	Mosture Content
Mg	Magnesium
MJ	Mega Joules
mm	millimetres
N	Nitrogen
No	Number
o d t	oven dried tonnes

P	Phosphorus
pmh	Productive Man Hours
Pro agt	Agri-tractor mounted processor
Pro art l	large aticulated processor
Pro art m	Medium articulated processor
Pro art s	Small articulated processor
Pro chain f	Chain Flail Processor
Psi	Pounds per Square Inch
SP	Scots Pine
Spp	Species
SS	Sitka Spruce
T	Thinning
vs	versus
WSkid agt	Agricultural tractor winch skidder
WSkid art	Articulated winch skidder
YC	Yield Class

APPENDIX M

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