Final Report

COFORD
Strategic Study

Maximising the Potential of Wood Use for Energy Generation in Ireland

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Preface

COFORD is responsible for promoting forest research and development in Ireland and wishes to carry out research aimed at increasing the competitiveness of the forest industry to allow it to become a major economic and environmental resource.

COFORD has convened and is facilitating a strategic group formed from the saw milling and forestry sectors which has appointed Electrowatt-Ekono, an international consultancy specialising in biomass and energy, to carry out a strategic study in the area of wood use for energy in Ireland. The assignment has been performed in partnership with the Tipperary Institute, an integrated education and development institute established by the Irish Government who focused on the Irish specific issues including the national energy balance and the wood potential.

The Tipperary Institute component of the project was managed by Mr. Kevin Healion, with assistance from Mr. Seamus Hoyne. The assistance of Ms. Kate Dwyer, Mr. Clifford Guest, Mr. John Kennedy, Mr. Ciarán Lynch and Mr. John Thompson is gratefully acknowledged. Tipperary Institute extends its sincere thanks to its subcontractors for their valuable inputs:

- Mr. Joc Sanders, Consultant, Dromineer, Co. Tipperary
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- Mr. Ben Hudson, Forestry Contracting Association, UK
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Executive Summary

Ireland has a significant energy potential in the country's wood resource. Exploitation of this resource as an energy source could yield a number of benefits including:

- Stimulation of rural development and employment as wood fuel supply chains evolve to meet market demands;
- Development of an environmentally beneficial fuel resource to replace the use of fossil fuels and consequently reduce the emissions of greenhouse gases.
- Contribute to national fuel diversity and enhance the security of national fuel supplies;
- The displacement of imported fossil fuels and the redirection of €1.7 million back into the Irish economy.
- The realisation of Government investment in forestry.
- Contribute to Ireland's European Union target for green house gas reductions and electricity generation from renewable sources.
- Generating base-load renewable electricity in contrast to the detrimental effects of unpredictable wind power electricity generation.

Ireland's annual Total Primary Energy Requirement (TPER) is presently 603 PJ, and this is forecast to rise 737 PJ by 2015. In contrast, the total annual energy potential of all pulpwood, sawmill residues and harvestable forest residues produced in Ireland is estimated to be currently 17.3 PJ (2.3 million green tonnes[1]), which would rise to 26 PJ (3.5 million green tonnes) by 2015. The price afforded by the energy market will determine how much of this potential is realised, however the minimum annual quantities that are currently available for energy production are 3.6 PJ (424,000 tonnes) and this is predicted to rise to 9.4 PJ (1,106,000 green tonnes) by 2015.

As part of the European Union, Ireland has committed to meeting environmental targets in respect to greenhouse gas reductions and electricity generation from renewable sources. Ireland has agreed to limit the growth in greenhouse gas emissions to 13% above the 1990 level by the target period 2008-2012. Without any limitations, the net annual emission levels are projected to increase by 37.3%. Reductions of 13.1 Mt CO_2 are required to meet the target.

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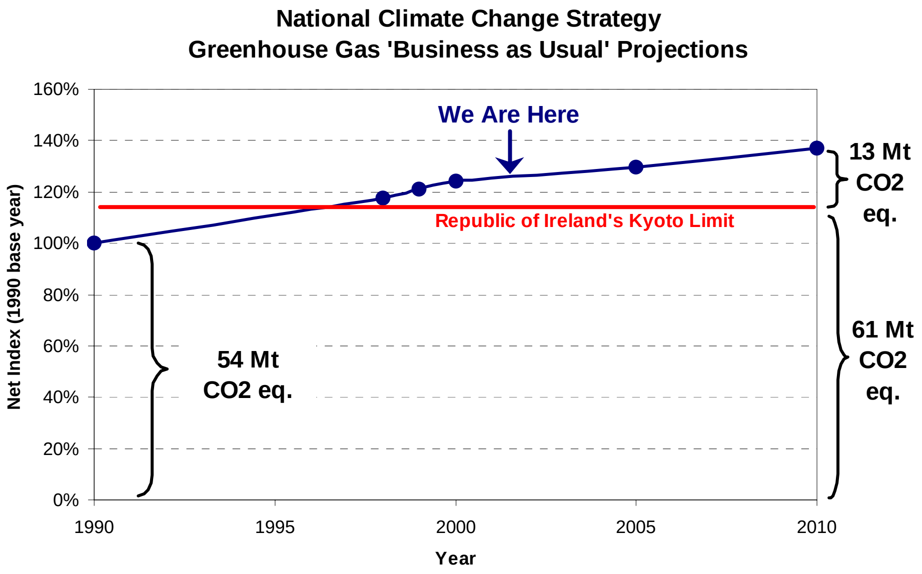
[1] Green wood, 50% moisture content, based on lower heating value

By 2010, Ireland is required to generate 13.2% (11.7% without large hydro) of its annual electricity requirement from renewable energy sources (RES). This is equivalent to 4.5 TWh per year. The Government Green Paper on Sustainable Energy sets out a working target of 500 MWe of additional renewable electricity generating capacity by 2005 in order to meet this target.



This strategic study focused on the contribution which wood can make to Ireland meeting its EU environmental targets. The minimum available wood-energy:

- If used for heat supply, has the potential to save about a third of a million tonnes of CO_2 emissions per year increasing to almost one million tonnes per year by 2015. This is equivalent to 3%, increasing to 8%, of Ireland’s GHG reduction commitment to the EU
- Could be used to create 50MWe of renewable electricity (RES-E) capacity, increasing to 132MWe by 2015. This could meet 10%, increasing to 26% of the Green Paper on Sustainable Energy working target of 500MWe
- In terms of annual RES-E consumption, could meet 9% (0.4 TWh), increasing to 23% (1 TWh) in 2015, of Ireland’s annual EU RES target of 4.5 TWh.

To realise the environmental benefits, financial support will be required to overcome the commercial barriers of wood-energy against mature fuels and technologies. The support mechanisms recommended, are:

1. The AER (Alternative Energy Requirement) to be extended to include:
    a. A *wood-energy* technology band with a band size of 20 MWe and a price cap of 6.412 EURcent per kWh. The band should make provision to include co-firing.
    b. A *wood-energy with CHP* technology band with a band size of 20 MWe and a price cap of 7.5 EURcent per kWh.
2. Investment support from the Sustainable Energy Authority of Ireland to encourage the development of heat supply from *wood-energy*:
    a. Directly subsidising the installation of domestic wood-fuel boilers to a level comparable with that of domestic oil and possibly coal boilers. A

        €5 million capital grant programme could stimulate the installation of 1000 domestic wood pellet boilers which would displace the use of fossil fuel boilers. This could save up to 6 ktCO_2 per annum in emissions and would cost the Government in the order of €78/tCO_2 saved. This compares with €89/tCO_2 saved by supporting new wood-fuelled power plant and €43/tCO_2 saved by supporting wood-fuelled CHP at 6.412 eurocent/kWh under AER VI.

    b. Providing support for a demonstration scheme programme for wood-fired boilers aimed at the public, commercial and industrial sectors.

3. Tax incentives, such as:
    a. An Enhanced Capital Allowance Scheme to enable businesses to claim 100% first year capital allowances on investments in wood-energy technologies and products. Businesses would be allowed to write off the whole cost of their investment against their taxable profits of the period during which they make the investment.
    b. Exempting wood-energy from any CO_2 tax by virtue of its CO_2 neutral position.

Other recommendations include:

4. Work with the Department of Communications, Marine and Natural Resources and other relevant Government Departments to ensure that the barriers to wood energy identified in this report are removed as quickly as possible, and that suitable support mechanisms are put in place.
5. Link the work of the COFORD Wood for Energy Strategy Group to ongoing work on transport and logistics in the wood industry (e.g. the COFORD sponsored OPTILOG project and any Supply Chain Management initiative established as a result of the Timber Industry Development Group report). Geographic Information System technology would be of value in optimising the supply of wood for energy.
6. Ensure as far as possible, through co-operation with ESB and Bord na Móna, that the new peat fired power plants to be developed at Lanesboro and Shannonbridge are compatible with the use of wood fuel for co-firing.
7. Continue the trials work on whole tree chipping commenced by COFORD this year. Whole tree chipping offers good potential for the production of low cost wood fuel from thinnings.
8. Commence trials work on the use of integrated harvesting on sites harvested using skylines. These trials should include the use of the Timberjack Fibrepac bundling machine.
9. Roadside residuals have the potential to provide low cost wood fuel. Their availability and cost for wood fuel production should be assessed in a pilot area.
10. There is considerable variation in published estimates of the breakdown on sawmill residues into chips, sawdust, bark and other. A comprehensive and reliable database on sawmill residues should be established and maintained (including information on quantity and moisture content).
11. A database on the moisture content of potential sources of wood fuel (including sawmill residues, pulpwood and forest residues) should be established and

maintained, as the delivered cost of energy from wood is quite sensitive to moisture content. Strategies to reduce the moisture content of wood fuel should be developed and implemented

12. Establish and maintain co-operation between COFORD, Sustainable Energy Ireland and its Renewable Energy Information Office, the Irish Bioenergy Association and the Local Energy Agencies on the promotion of wood for energy. A focus of this co-operation should be on the sustainable production and use of high quality wood fuel, including in the form of wood pellets.
13. A Strategic Environmental Assessment on the use of wood for energy should be undertaken to evaluate the environmental impacts of this Strategic Plan. Such a process would be a valuable component of integrating wood for energy into Sustainable Forest Management and forest certification.
14. A comprehensive inventory of the private forest resource has not been undertaken since 1973. The development of an adequately detailed National Forest Inventory for private forests is urgently required to provide reliable information on the future volumes of wood that are likely to become available for wood energy from the private sector. It is important that such an inventory can detail roundwood volume forecasts on a meaningful regional basis and also outline species, roundwood sizes, accessibility and other qualitative and quantitative information. Infrastructural constraints on the exploitation of these resources should also be identified in any inventory.
15. The quantity of harvestable forest residues has been calculated as an additional 9% of the roundwood production from spruce plantations in Ireland (based on expert opinion from the UK). This assumption should be tested by undertaking trials on spruce harvesting sites in Ireland

1 INTRODUCTION

COFORD - The National Council for Forest Research & Development is responsible for the co-ordination of forest research in Ireland and the development of a research programme for the forest industry. COFORD has identified the research areas needed to increase the competitiveness of the forest industry to allow it to become a major economic and environmental resource for future generations.

COFORD is heading a strategic group formed from the wood products industry which has appointed Electrowatt-Ekono, a world-leading energy consultancy in biomass and energy, to carry out a strategic study in the area of wood use for energy in Ireland. Electrowatt-Ekono is performing the study in partnership with the Tipperary Institute, an integrated education and development institute established by the Irish Government. The Tipperary Institute is addressing the Irish specific issues.

2 STUDY SCOPE

The scope of the study addresses:

1. Information and data review on Irish energy and biomass issues, specifically:
    - Energy demand and supply
    - Biomass demand and supply
2. A comparison of wind power with solid wood based power production technologies
3. Kyoto and renewable energy targets
4. The value of carbon credits for wood fuel producers in Ireland
5. Value of reductions in SOx emissions
6. Energy production technology and costs
7. Renewables in Europe and Ireland, in particular:
    - The use of renewables in Europe
    - Subsidy options for wood fuels and wind in Europe

    - Support mechanisms for Ireland

8. The basis of trading wood fuels.

3 INFORMATION AND DATA REVIEW ON IRISH ENERGY AND BIOMASS ISSUES

The following sections present information and data on energy use in Ireland. The scope encompasses:

- Primary energy demand and supply
- Electricity demand and supply, including electricity supply regulation
- Heat supply
- Biomass demand and supply

Summaries are presented at the start of key sections (on existing and potential biomass demand and supply; and on the energy potential and costs of pulpwood, sawmill residues and forest residues).

3.1 Primary Energy demand and supply

Total Primary Energy Requirement (TPER) is a measure of all energy used in Ireland, before losses. Total Final Consumption (TFC) is a measure of energy consumed directly by final consumers, excluding losses before it reaches them. The main losses are incurred in electricity generation, where thermal power stations use more energy in fuel than they deliver in electricity, and electricity transmission, though there are other smaller losses in gas transmission and peat briquette manufacture.

The Economic and Social Research Institute (ESRI) prepare Irish energy supply forecasts using their economic forecasting tool, based on historic data and assumptions[2] about the future. Figure 3-1…Figure 3-4 break down the latest (December 2001) (Duffy *et al*., 2001) forecasts for TPER and TFC by fuel and sector.

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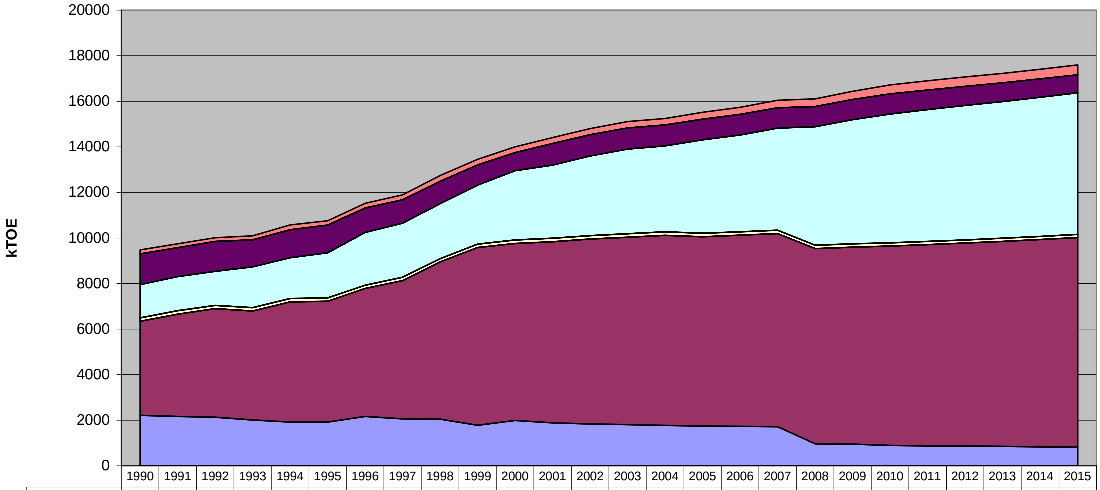
[2] See ESRI Working Paper 136 *Energy Demand to 2015*

Figure 3-1 TPER by Fuel

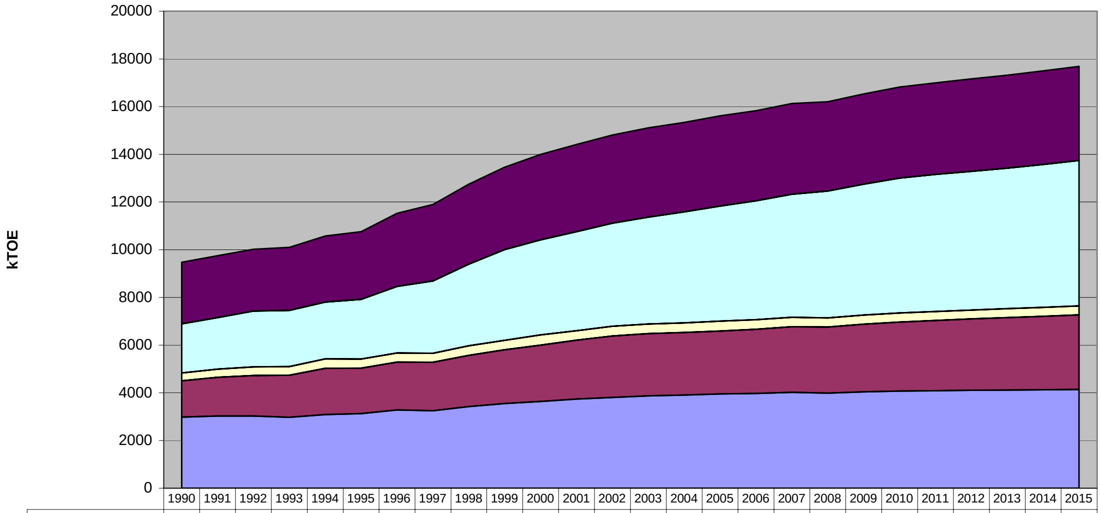


	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
■ Ren. & Hydro	169	175	166	167	207	191	209	223	255	247	249	257	267	278	289	302	316	331	348	366	402	407	412	417	422	427
■ Peat	1358	1271	1313	1197	1233	1214	1069	1026	981	887	789	944	935	927	918	909	900	892	883	874	881	863	845	827	809	791
□ Gas	1457	1495	1496	1790	1790	1977	2316	2373	2413	2594	3040	3218	3494	3719	3771	4104	4250	4482	5207	5457	5656	5784	5895	6000	6109	6218
□ LPG	148	153	146	147	153	148	140	143	144	148	155	154	152	151	150	148	147	146	145	144	143	141	140	139	138	137
■ Oil	4136	4492	4769	4789	5275	5307	5626	6079	6905	7805	7773	7948	8117	8231	8349	8309	8397	8484	8571	8655	8754	8834	8918	9000	9099	9203
■ Coal	2208	2160	2125	2002	1914	1917	2162	2053	2046	1774	1990	1884	1836	1800	1772	1748	1727	1709	961	945	889	875	860	846	832	817

Year

The data is presented as kTOE (thousands of tonnes of oil equivalent). The conversion factor to PetaJoules (PJ) is: 1 kTOE equals 0.0419 PJ. The Total Primary Energy Demand for 2002 is 14,801 kTOE, equivalent to 620 PJ.

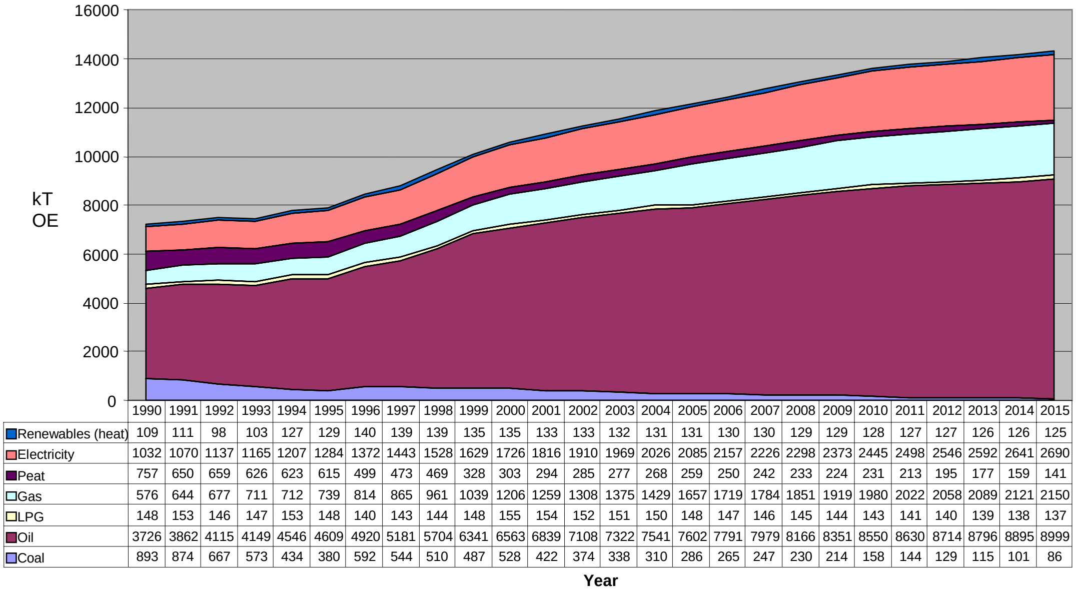
Figure 3-2 TPER by Sector



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
■ Industry	2585	2599	2594	2639	2770	2845	3062	3211	3350	3453	3590	3658	3695	3736	3757	3785	3781	3811	3743	3781	3813	3843	3872	3899	3924	3946
□ Transport	2062	2157	2341	2359	2388	2501	2794	3032	3420	3802	3980	4149	4318	4485	4652	4821	4989	5157	5326	5494	5662	5743	5820	5900	5995	6099
□ Agricultural	332	345	355	360	397	382	383	380	406	403	430	390	414	408	402	417	405	397	383	379	377	376	375	374	374	373
■ Commercial & Public	1517	1622	1705	1764	1930	1904	2002	2035	2144	2249	2365	2478	2571	2609	2620	2637	2687	2756	2767	2840	2898	2948	2995	3035	3083	3127
■ Residential	2980	3025	3023	2972	3089	3124	3284	3242	3426	3550	3633	3733	3807	3869	3909	3951	3968	4015	3987	4038	4067	4087	4100	4112	4125	4139

Year

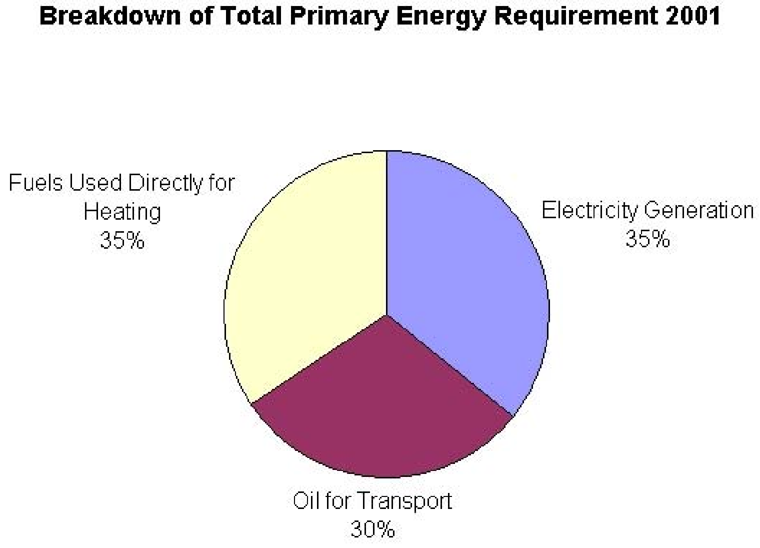
Figure 3-3 Total Final Consumption by Fuel



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Renewables (heat)	109	111	98	103	127	129	140	139	139	135	135	133	133
Electricity	1032	1070	1137	1165	1207	1284	1372	1443	1528	1629	1726	1816	1910
Peat	757	650	659	626	623	615	499	473	469	328	303	294	285
Gas	576	644	677	711	712	739	814	865	961	1039	1206	1259	1308
LPG	148	153	146	147	153	148	140	143	144	148	155	154	152
Oil	3726	3862	4115	4149	4546	4609	4920	5181	5704	6341	6563	6839	7108
Coal	893	874	667	573	434	380	592	544	510	487	528	422	374

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Renewables (heat)	132	131	131	130	130	129	129	128	127	127	126	126	125
Electricity	1969	2026	2085	2157	2226	2298	2373	2445	2498	2546	2592	2641	2690
Peat	277	268	259	250	242	233	224	231	213	195	177	159	141
Gas	1375	1429	1657	1719	1784	1851	1919	1980	2022	2058	2089	2121	2150
LPG	151	150	148	147	146	145	144	143	141	140	139	138	137
Oil	7322	7541	7602	7791	7979	8166	8351	8550	8630	8714	8796	8895	8999
Coal	338	310	286	265	247	230	214	158	144	129	115	101	86

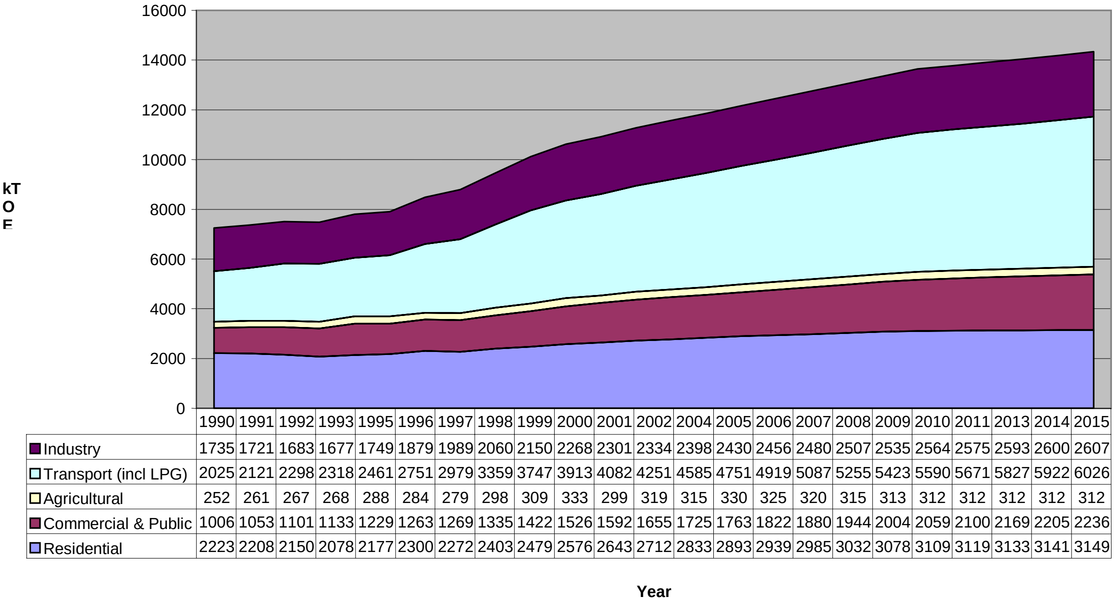
Figure 3-4 below shows the breakdown of TPER into the heat, electricity and transport sectors. As can be seen the three sectors consume about one third of TPER each. The "Electricity Generation" sector in the chart represents the primary energy input into power production – only about one third of this energy input is delivered to consumers in the form of electricity. Energy is lost as waste heat in power generation and from electricity transmission and distribution lines.



Source: Based on data from Department of Public Enterprise (no date). Representing 14,582 kTOE of TPER. Not including 170kTOE of "Own use/losses" of Oil and Natural Gas.

Figure 3-4 TPER 2001 Breakdown

Figure 3-5 Total Final Consumption by Sector



	1990	1991	1992	1993	1995	1996	1997	1998	1999	2000	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011	2013	2014	2015
■ Industry	1735	1721	1683	1677	1749	1879	1989	2060	2150	2268	2301	2334	2398	2430	2456	2480	2507	2535	2564	2575	2593	2600	2607
□ Transport (incl LPG)	2025	2121	2298	2318	2461	2751	2979	3359	3747	3913	4082	4251	4585	4751	4919	5087	5255	5423	5590	5671	5827	5922	6026
□ Agricultural	252	261	267	268	288	284	279	298	309	333	299	319	315	330	325	320	315	313	312	312	312	312	312
■ Commercial & Public	1006	1053	1101	1133	1229	1263	1269	1335	1422	1526	1592	1655	1725	1763	1822	1880	1944	2004	2059	2100	2169	2205	2236
■ Residential	2223	2208	2150	2078	2177	2300	2272	2403	2479	2576	2643	2712	2833	2893	2939	2985	3032	3078	3109	3119	3133	3141	3149

An analysis of the ESRI demand model, and the assumptions underlying it, reveal the following:

- The large increase in TPER in recent years (averaging 5.4% per annum for 1995-2000), driven by the high rate of economic growth, is expected to continue, but at a reduced rate averaging 2.1% per annum for 2000-2005 and 1.5% per annum for 2005-2010.
- The exceptionally large increase in consumption by the transport sector (93% for 1990-2000, projected 42% for 2000-2010) is almost entirely petrol and diesel for vehicles.
- The major component of the increases 1990-2000 in the residential and commercial sectors (22% and 56% respectively) are due to increased use of electricity in homes and offices.
- The consumption of coal reduced by 10% 1990-2000, due to reduced use in the residential and industrial sectors. A further 55% reduction is expected 2000-2010, as residential and industrial use continues to decline, and use for electricity in the Moneypoint power station is reduced for environmental reasons.
- The consumption of oil increased by 88% from 1990 to 2000, due to increased use primarily in transport, and secondarily in the residential and commercial sectors for heating, counter-balancing reduced use for electricity generation. A further 13% increase is expected 2000-2010, largely due to increasing use for transport, despite phasing out of oil for electricity generation.
- The consumption of gas leaped 109% from 1990 to 2000, due to increasing use for electricity generation and residential and commercial heating. This is expected to continue, causing a further increase of 86% 2000-2010.
- The consumption of peat reduced by 42% from 1990-2000, largely due to greatly reduced use for residential heating, but also a fall in use for electricity generation. The total use of peat decreased from 1,358 kTOE in 1990 to 789 kTOE in the year 2000. Consumption is expected to increase again by 12%

over the period 2000-2010, due to increased consumption in the new, more efficient peat fired electricity generating stations, despite use for residential heating continuing to reduce.

- The consumption of renewable energy sources increased by 47% 1990-2000, largely due to increased use of wind for electricity, and increasing use of wood by industry for heat. A further increase of 61% is expected 2000-2010, all for electricity generation, largely wind.
- The difference between TPER and TFC are due to losses in the 'transformation sector'. For 2001 these losses amount to 24.2% of TPER, of which losses in generation due to inefficient use of heat in power stations contribute 21.0 percentage points, and losses in electricity transmission contribute 2.2 percentage points. The former could potentially be reduced if more efficient electricity generating plant were installed, and the latter if generating plant were installed in smaller units closer to the point of use, i.e. 'embedded generation'.

Note that these figures are a 'central forecast' based on the economic assumptions of the 'Benchmark Scenario' in the ESRI's *Medium-Term Review: 2001-2007*. Because of uncertainties ESRI have also considered alternative high and low growth scenarios. Under these scenarios the differences in forecast growth of TPER are as follows:

Table 3-1Forecast Growth in Demand for Primary Energy, annual average, per cent

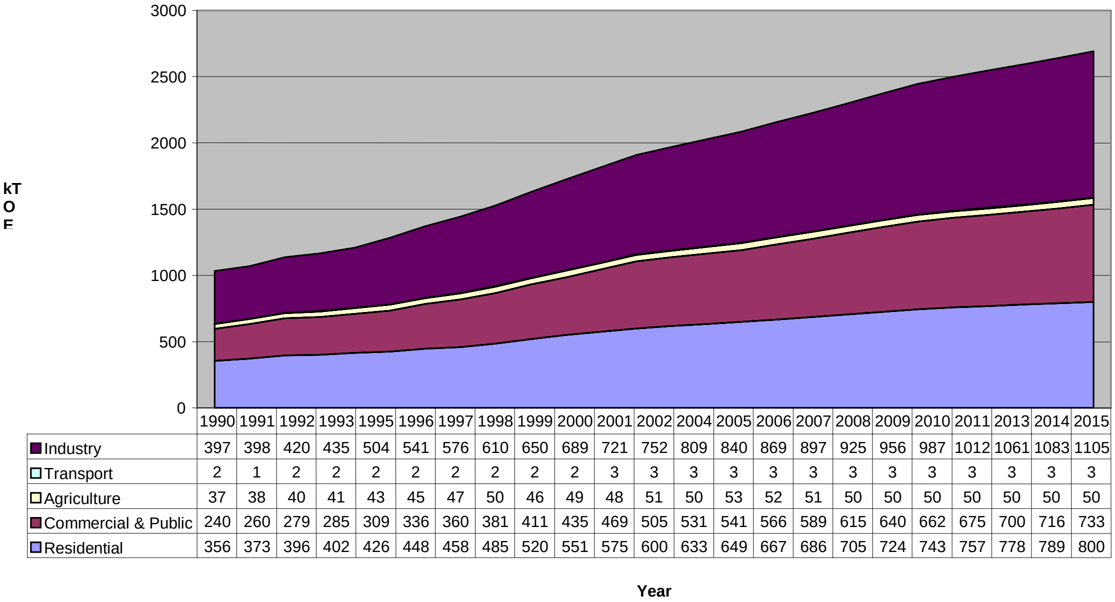
	2000-2005	2005-2010	2010-2015
Central Forecast	2.5	1.6	1.4
High Growth	2.6	2.2	2.1
Low Growth	2.1	1.3	1.3

3.2 Electricity Demand and Supply

Fig 5 gives actual and forecast demand for electricity by sector. The following points are evident:

- Total demand grew by 67% 1990-2000. This growth is expected to continue, but to moderate somewhat to 42% 2000-2010.
- The fastest growing sector is Commercial and Public, growing by 81% 1990-2000, and forecast to grow by 52% 2000-2010.
- The Industry sector grew 74% 1990-2000, and is forecast to grow 43% 2000-2010
- The Residential sector grew 55% 1990-2000, and is forecast to grow 43% 2000-2010

Table 3-2 Electricity Demand by Sector



	1990	1991	1992	1993	1995	1996	1997	1998	1999	2000	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011	2013	2014	2015
Industry	397	398	420	435	504	541	576	610	650	689	721	752	809	840	869	897	925	956	987	1012	1061	1083	1105
Transport	2	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3
Agriculture	37	38	40	41	43	45	47	50	46	49	48	51	50	53	52	51	50	50	50	50	50	50	50
Commercial & Public	240	260	279	285	309	336	360	381	411	435	469	505	531	541	566	589	615	640	662	675	700	716	733
Residential	356	373	396	402	426	448	458	485	520	551	575	600	633	649	667	686	705	724	743	757	778	789	800

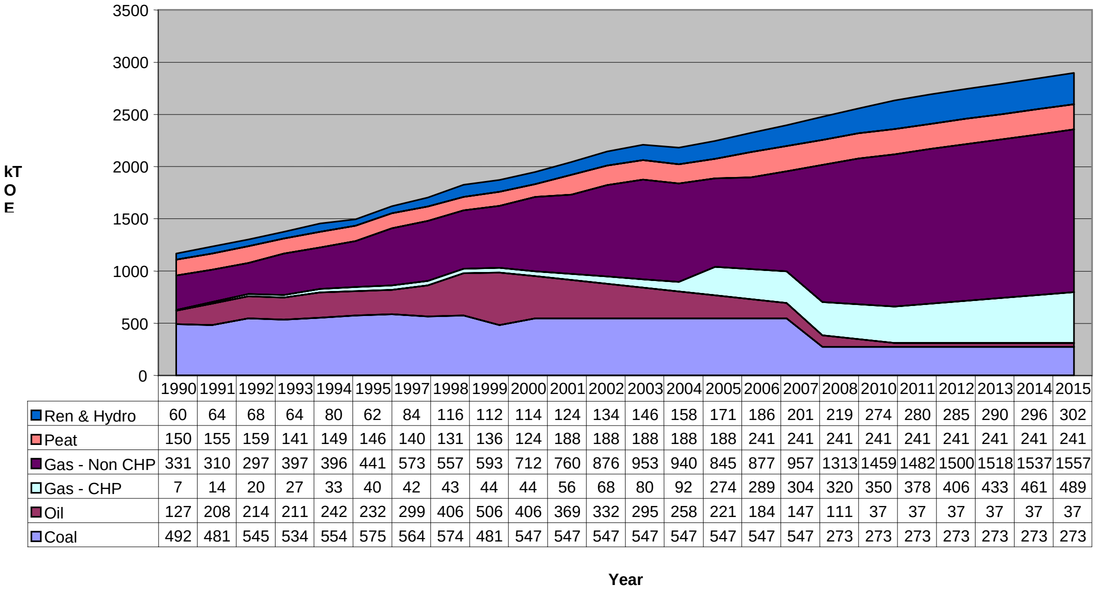
Table 3-3 shows the differences between the central forecast for electricity generation and the high and low growth scenarios.

Table 3-3 Forecast growth in Electricity Demand, annual average, per cent

	2000-2005	2005-2010	2010-2015
Central Forecast	3.9	3.3	2.5
High Growth	4.5	4.2	3.5
Low Growth	2.9	2.1	1.5

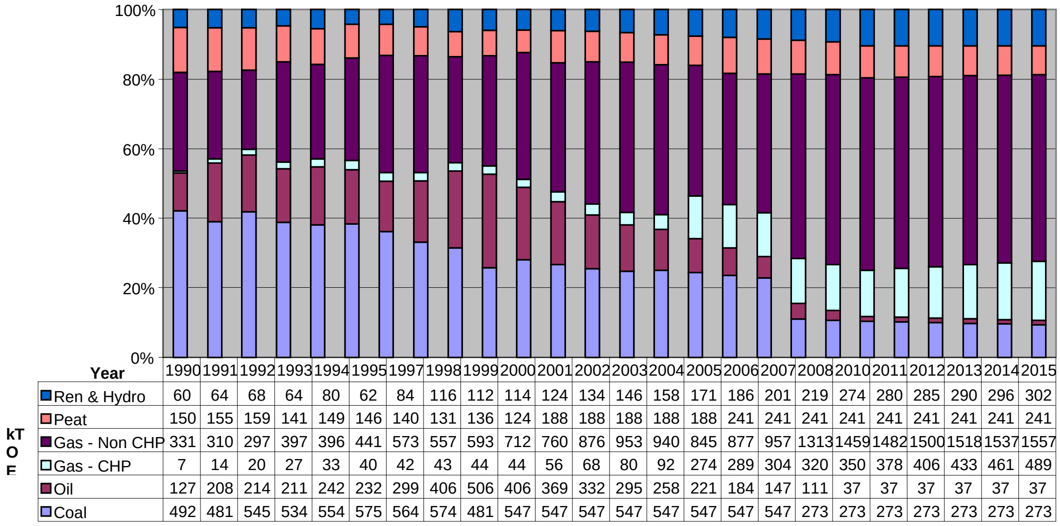
Figure 3-6 and Figure 3-7 show the absolute amount and share of electricity generated from different fuels (not the amount of the different fuels used to generate electricity).

Figure 3-6 Electricity Generation by Fuel



	1990	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2010	2011	2012	2013	2014	2015
Ren & Hydro	60	64	68	64	80	62	84	116	112	114	124	134	146	158	171	186	201	219	274	280	285	290	296	302
Peat	150	155	159	141	149	146	140	131	136	124	188	188	188	188	188	241	241	241	241	241	241	241	241	241
Gas - Non CHP	331	310	297	397	396	441	573	557	593	712	760	876	953	940	845	877	957	1313	1459	1482	1500	1518	1537	1557
Gas - CHP	7	14	20	27	33	40	42	43	44	44	56	68	80	92	274	289	304	320	350	378	406	433	461	489
Oil	127	208	214	211	242	232	299	406	506	406	369	332	295	258	221	184	147	111	37	37	37	37	37	37
Coal	492	481	545	534	554	575	564	574	481	547	547	547	547	547	547	547	547	273	273	273	273	273	273	273

Figure 3-7 Share of Electricity Generation by Fuel



	1990	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2010	2011	2012	2013	2014	2015
Ren & Hydro	60	64	68	64	80	62	84	116	112	114	124	134	146	158	171	186	201	219	274	280	285	290	296	302
Peat	150	155	159	141	149	146	140	131	136	124	188	188	188	188	188	241	241	241	241	241	241	241	241	241
Gas - Non CHP	331	310	297	397	396	441	573	557	593	712	760	876	953	940	845	877	957	1313	1459	1482	1500	1518	1537	1557
Gas - CHP	7	14	20	27	33	40	42	43	44	44	56	68	80	92	274	289	304	320	350	378	406	433	461	489
Oil	127	208	214	211	242	232	299	406	506	406	369	332	295	258	221	184	147	111	37	37	37	37	37	37
Coal	492	481	545	534	554	575	564	574	481	547	547	547	547	547	547	547	547	273	273	273	273	273	273	273

As Figure 3-7 shows, the share of natural gas in electricity generation has been steadily increasing since 1990, and is expected to continue to do so (nearly 70% of electricity generation could be fuelled by natural gas by 2010). In 2001, 93% of the natural gas used in the Republic of Ireland was imported (Department of Public Enterprise, no date). There will continue to be a high dependence on imported natural gas, even with additional indigenous production. The country is vulnerable to interruptions in supply and increases in gas prices. Over 70% of the world's gas reserves are located in the Middle East and Former Soviet Union (Bord Gáis Éireann, 2001). The issue of security of supply is addressed in the Green Paper on Sustainable Energy (Department of Public Enterprise, 1999): "The Department will examine the security of supply consequences of a substantial switch to gas in power generation. Among the security of supply issues to be examined are the following:- (i) risk analyses of potential disruption of gas supply arising from political developments or a subsea rupture of the gas pipeline; (ii) offsetting measures to compensate for increased gas dependency such as dual firing of power plants, liquid natural gas storage, additional pipelines and extension of interruptible tariffs; and (iii) controls by Government of the fuel mix.” The Republic of Ireland is now connected to the UK gas network via two interconnectors to Scotland.

The assumptions underlying these forecasts are as follows:

- Electricity from coal at Moneypoint is halved for environmental reasons in 2008
- Oil is largely phased out in the decade to 2010
- All the older peat plant is phased out by 2006 and replaced with new plant consuming the same amount of peat at a conversion rate of 37% (as at Edenderry Power) rather than 25% (historic performance of older plant)
- Renewables increase to 10% of electricity demand by 2010 from the 2000 level of 6.6%. It is ESRI’s responsibility to make its own independent, informed assessment of what will actually happen, not to reflect aspirations. This was ESRI’s best assessment as of mid 2001 (when the work was done), before the EU’s Renewable Electricity Directive was adopted in Oct 2001, which set an indicative target of 13.2% for 2010. Updated energy demand projections will be produced during 2003, and it is possible that this assumption may then be changed, perhaps to approach the Directive’s target more closely.
- CHP using gas as fuel, including a 250MW plant at Aughinish Alumina, is assumed to grow to 650MW by 2010
- The rest of electricity demand will be met by gas-fired CCGT

The electricity supply market is subject to regulation. The following description includes information on the current generating assets and the transmission and distribution network.

3.3 Electricity Regulation

Market changes

From 1927, when it was established, until 2000, the Irish electricity industry was completely in the hands of the Electricity Supply Board (ESB), a vertically integrated, semi-state monopoly, supplying all consumers large and small within the state, from its own generating stations, over its own transmission and distribution networks. Since then, the electricity market has been subject to massive change towards a liberalised, regulated market, with competing suppliers and generators. These changes are continuing, and the market is now in a transitional state before full opening, expected in 2005.

Statutory basis

The European Union initiated the drive toward liberalisation of the electricity market. The European Council and European Parliament adopted Directive 96/92/EC on 19/12/1996. This established a legal framework to commence liberalisation across all member states, with common rules for the generation, transmission, distribution and supply of electricity. In Ireland the Directive has been implemented through the Electricity Regulation Act 1999, which came into force on 19/7/99, and Statutory Instrument SI/445/2000, signed on 20/12/2000.

Regulation

Under these arrangements the Commission for Energy Regulation (CER) was set up to facilitate competition in the generating and supply of electricity by authorising construction of new plant, and by licensing new companies to generate and supply electricity to customers. The CER also has a regulatory role in relation to networks for transmission (110kV and upward) and distribution (less than 110kV), including approval of tariffs for access to them, and for regulating prices charged to customers of the ESB Public Electricity Supply. The legislation requires the CER, in carrying out its functions, to: Protect the interests of final customers; Not discriminate unfairly between players in the market; Promote continuity, security and quality of supply; Promote the use of renewable, sustainable or alternative forms of energy, and take account of the protection of the environment.

Market Opening

Electricity supply is being liberalised on a phased basis, with full opening expected by 2005. The top 28% by usage of the market was opened to competition in February 2000, consisting of about 400 of the largest customers using more than 4GWh annually at one address. This was extended to the top 40% by usage, a further 1200 high use customers using more than 1 GWh annually, in February 2002. These customers are known as ‘eligible customers’, and may choose to contract for their electricity from an independent supplier (i.e. not ESB) licensed by CER. In addition to the eligible market, since February 2000 the ‘green’ market has been fully open, so that a licensed supplier of renewable energy may supply any customer, and since April 2001, the CHP market has been fully open, allowing any licensed CHP supplier to sell electricity to any final customer.

Supply

There are now several independent companies licensed to supply eligible customers. Most are small, but the largest include Airtricity (specialising in ‘Green’ electricity), Viridian (trading as Energia), Bord Gáis, Duke Independent Energy, and ESB Independent Energy, a ring-fenced ESB subsidiary. Supply companies contract bilaterally with specific generators. Since very few independent power producers (IPPs) have yet commissioned their own generators, the CER has arranged for periodic ‘virtual IPP’ auctions of a proportion of the output of ESB generation capacity sufficient to supply the eligible market. The second such auction in October 2001 provided a total of 600MW capacity. The successful bidders were: Bord Gáis Éireann, Duke Energy International, ESB Independent Energy and Viridian Energy Supply Ltd (trading as Energia). As new IPP generation capacity becomes available, the capacity available by VIPP auction will be correspondingly reduced.

Since electricity cannot be economically stored, supply at any moment must be matched with demand. Hence suppliers requiring additional electricity beyond their own generating capacity must ‘top-up’ from other suppliers or generators, or ‘spill’ if they have a surplus. There is an active trading market in top-up/spill electricity, which is settled over 30 minute periods.

Generation

The following table summarises the generating plant in service in the state at the start of 2002. The capacity available is very close to the amount required to meet the peak winter demand, so that to ensure quality of supply during winter 2001-2 the ESB was obliged to install four small scale portable generators, which are extremely costly to run.

Table 3-4 Electricity Generation Capacity in 2002

Owner	**Area**	**Plant**	**Export Capacity (MW)**	**Fuel**
ESB	Dublin	Poolbeg	486	Oil
		Shellybanks	460	Gas
		North Wall	163	Gas
		North Wall	109	Oil
		Liffey	34	Hydro
		Turlough Hill	292	Hydro/pumped storage
	Cork	Aghada	528	Gas
		Marina	112.3	Gas
		Lee	27	Hydro
	Shannon Estuary	Tarbert	595.4	Oil
		Moneypoint	855	Coal
		Ardnacrusha	89	Hydro
	South East	Great Island	226	Oil
	North West	Erne	65	Hydro
		Bellacorick	36.8	Peat
	Midlands	Shannonbridge	114.5	Peat
		Lanesboro	77.5	Peat
		Rhode	37	Peat
		Total ESB	*4307.5*	
Edenderry Power Ltd	Midlands	Cushaling	115	Peat
Huntstown Power (Viridian)	Dublin	Huntstown	343	Gas
Synergen	Dublin	Ringsend (Irishtown)	400	Gas
Miscellaneous small scale renewable and embedded plant, some owned by ESB and the rest by a number of small IPPs		Renewables	120	Wind
			21	Hydro
			15	LFG/Waste
		CHP	122	
		Small scale generation (Thermal)	13	
		Total Miscellaneous	*289*	
		Total	5339.5	

Several new large scale plants are authorised or under construction:

Table 3-5 Large Scale Power Plants under Construction

Owner	Area	Plant	Export Capacity (MW)	Fuel	Commissioning Year
ESB	Midlands	Shannonbridge	150	Peat	2005
		Lanesboro	100	Peat	2004

In addition:

- A number of IPPs are also developing plans to build further large-scale plant.
- A number of small IPPs made successful applications in the AER5 competition for renewable energy power purchase agreements (PPAs) totalling 363MW (wind 354MW, Biomass 8MW, Hydro 1MW), though on past performance only a proportion of this capacity is likely to be built.
- Airtricity has been awarded a foreshore lease by the Department of the Communications, Marine and Natural Resources (DCMNR) for the construction of a 520MW offshore wind farm on the Arklow bank.
- Bord na Móna and ESB have applied for planning permission for a 320MW onshore wind farm at Bellacorick, Co. Mayo

As can be seen, the generating business of ESB still today generates almost all electricity within the Irish market, and under current authorised plans they will continue to do so for some time to come. Key obstacles to the involvement of more IPPs in the Irish market have been identified in a report by NCB Corporate Finance, commissioned by the CER:

- Securing planning permission has been a fraught process for a number of project proposers.
- Difficulties obtaining non-recourse project finance, since no supplier in the market is willing to offer long-term off-take contracts,
- Promoters and financial institutions will not fund projects on a recourse basis because under present market conditions the return is not commensurate with the risk, predominantly uncertainty about future trading arrangements.

The CER has brought forward its planned review of the overall trading arrangements from 2004 to 2002, to assist in reducing the uncertainties for new market entrants.

Network

The electricity network consists of two parts: the transmission network (or national grid), consisting of high-voltage lines 110kV and over; and the distribution network, consisting of the lower voltage lines to customer premises. Both networks up to now have been an integral part of the ESB.

An independent transmission system operator, to be known as Eirgrid, has been licensed by CER, with responsibilities to develop and maintain the transmission network, and to dispatch generation capacity when it is needed. It will also be responsible for administering the trading and settlement system. It will be financed by transmission network ‘use of system’ charges levied on generators and suppliers. Although ownership of the transmission network remains with ESB, which has been licensed as transmission system owner, Eirgrid will be ring-fenced in relation to accounting, information technology and resources.

ESB has also been licensed to operate the distribution system, again with provision for ring-fencing from the other ESB businesses. It will be responsible for developing and maintaining the distribution network, and will be financed through distribution system 'use of system' charges.

Interconnection with Other Systems

The Republic's national grid is linked to the Northern Ireland national grid through the North-South interconnectors. Although capacity constraints on other circuits will reduce their practical capacities for the time being, their nominal capacities after being upgraded in 2001 are as follows:

- Tandragee-Louth circuit – 2 by 600 MW
- Strabane-Letterkenny – 120MW
- Enniskillen-Corraclassy – 120MW

The Northern Ireland national grid is connected in turn to the national grid in Scotland through the Moyle interconnector, which has been upgraded to 500MW.

Capacity on the interconnectors is open to the market through auction.

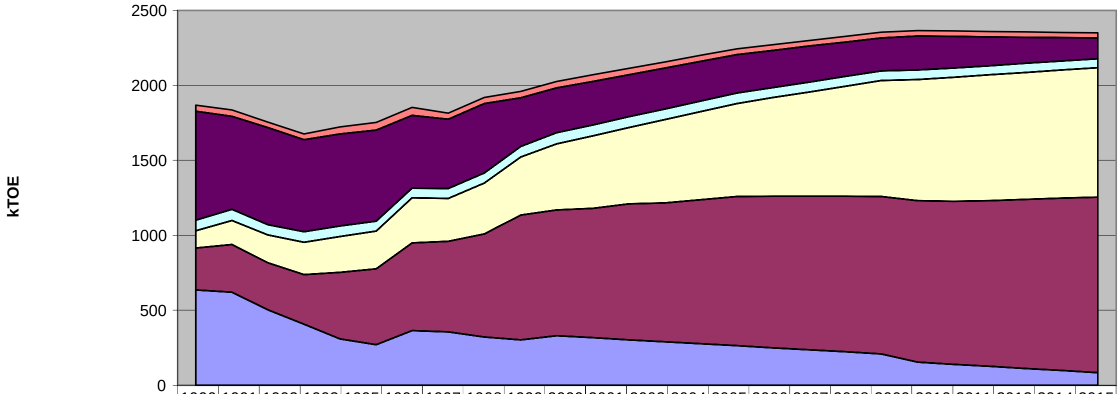
Public Service Obligations (PSOs)

National policy favours generation of electricity from renewable energy sources on environmental grounds, and from peat on grounds of social benefit and security of supply. However these technologies produce more expensive electricity than that available from 'best new entrant' technology, currently gas-fired combined cycle gas turbines (CCGT), so that their development requires financial support. In order that such support does not distort the market, it will be provided from a 'PSO levy', to be collected from final customers of all suppliers in amounts calculated by the CER to recover the additional costs of all parties. These arrangements have been approved by the European Commission, and the Minister exercised her powers under the Electricity Regulation Act 1999 in May 2002 to direct that they be implemented from January 2003.

3.4 Fuels used for Heat Supply

The following diagrams show fuel used for heat supply in the Residential, Commercial & Public, and Industry sectors respectively, excluding electricity used for heat supply. They are derived from the sectoral TFC breakdowns in the ESRI model, since in those sectors all fuels except electricity are used exclusively for heat supply, for instance oil used for driving equipment is included in the Transport sector. This is not true of the relatively small Agriculture sector however, where data collection does not distinguish oil used for heat from oil used for driving equipment (eg tractors).

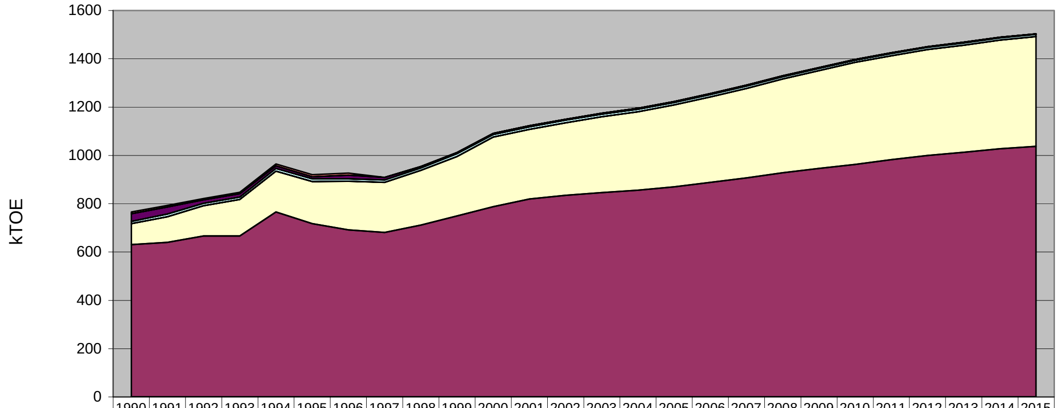
Figure 3-8 Fuel Used for Heat in the Residential Sector (Excluding Electricity)



	1990	1991	1992	1993	1995	1996	1997	1998	1999	2000	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011	2013	2014	2015
Other Ren	42	43	38	40	50	54	41	41	43	43	42	42	40	40	39	39	38	38	37	36	35	35	34
Peat	725	621	645	612	606	484	462	463	324	299	290	282	264	255	247	238	229	220	228	210	174	156	138
LPG	70	73	69	70	68	64	66	66	71	75	74	73	71	70	68	67	66	65	64	64	62	61	60
Gas	117	161	187	217	252	303	286	339	387	439	482	509	587	621	658	695	734	774	808	825	845	854	863
Oil excluding LPG	279	317	313	330	506	583	605	689	832	840	864	905	962	996	1011	1025	1037	1049	1075	1087	1127	1148	1169
Coal	634	620	502	407	269	364	354	320	302	329	316	302	275	262	248	235	221	208	154	140	113	99	85

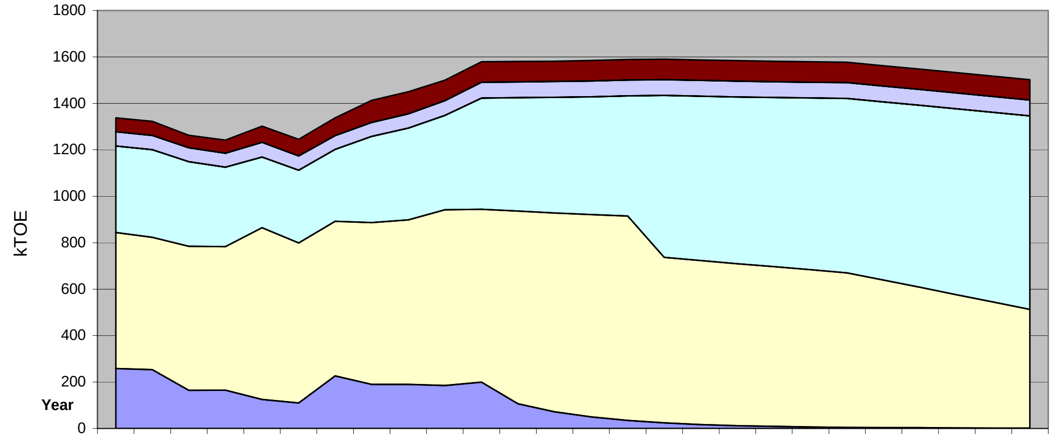
Data from Energy Action (1999) showed that only 7% of homes had electric heating as their primary heating system.

Figure 3-9 Fuel Used for Heat in the Commercial and Public Sector - Excluding Electricity



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Other Ren	7	7	6	6	8	8	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peat	32	29	14	14	11	9	15	11	6	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3
LPG	9	11	10	10	11	11	10	10	10	12	11	11	11	11	10	10	10	10	10	10	9	9	9	9	9	9
Gas	87	106	126	152	169	174	201	207	226	246	288	288	301	313	325	339	354	370	388	405	422	430	438	443	450	454
Oil excluding LPG	630	639	665	665	765	717	691	681	712	749	788	819	834	846	856	870	888	907	928	946	963	982	1000	1013	1028	1038
Coal	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 3-10 Fuel Used for Heating in the Industry Sector (Excluding Electricity)



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
■ Other Ren	60	61	54	57	70	71	77	95	95	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88
□ LPG	62	62	60	60	63	62	59	60	61	64	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
□ Gas	372	377	364	342	304	313	310	372	396	406	479	488	498	507	517	697	708	718	729	740	750	767	784	800	817	833
□ Oil excluding LPG	586	570	621	618	740	689	665	696	708	757	745	829	856	872	880	713	706	697	688	677	666	635	605	574	543	511
□ Coal	258	253	164	165	125	110	227	190	190	185	199	107	72	50	35	24	17	12	9	6	4	4	3	2	2	1

The following points can be noted:

- Peat is consumed as either sods or processed briquettes. The proportion consumed as briquettes has increased from 23% in 1990 to 41% in 2000 (source: DPE Energy Balances)
- In the residential sector, the absolute amounts and proportions of coal and peat have fallen in the last 10 years, and the absolute amounts and proportions of oil and gas have increased, within a modestly growing total consumption of energy for heat. These trends are expected to continue. Among the reasons for them are no doubt the inconvenience of solid fuels and the comfort and convenience of central heating based on oil and gas. The small consumption of renewables has remained constant over the last 10 years, but is assumed to fall slowly in future. The 'Renewables' in the ESRI projections appears to be firewood, but the use of geothermal energy is also now important in the domestic sector according to a return made to the European Commission in March 2002 (see Task 2, section A.2).
- In the Commercial & Public sector, there has been strong growth in use of oil and gas. Solid fuels are hardly used at all. The Office of Public Works (OPW) have responsibility for maintenance and utility supplies for all public buildings in Ireland. COFORD has approached OPW seeking to have some buildings fuelled with wood pellets. A response is awaited.
- In the Industry sector, there was strong growth in heat usage during the boom years of the late 90s, but a slight decline is expected in the next 10 years. Use of oil and gas for heat has expanded at the expense of coal, and this trend is expected to continue. Wood used for process heat in the wood processing industry accounts for the usage of renewables. Though small, this has grown overall by 47% since 1990, although the ESRI projection assumes it will remain constant in future.

3.5 Biomass Demand and Supply

3.5.1 General

The present existing and potential demand for wood biomass, and the existing and potentially “available” supply are summarised in the table below. As section 3.5.2 (Biomass Supply) shows, the energy potential of the total amount of pulpwood, sawmill residues and forest residues produced in Ireland is much greater that the potentially “available” supply shown in the table below. Section 3.5.2 gives details on how the “available” supply was calculated.

Table 3-6 Present Existing and Potential Demand and “Available” Supply for Wood Biomass

EXISTING AND POTENTIAL DEMAND	**% Co-firing**	**Capacity MWe**	**Efficiency**	**Fuel input MW**	**Load factor**	**GJ**	**TJ**	**PJ**
Existing use of wood (1% of total energy demand)								6.0
Coal Co-firing in Moneypoint at:	10%	86	32%	268	87%	7,353,622	7,354	7.4
Peat Co-firing in Edenderry Power at:	30%	35	37%	93	87%	2,558,251	2,558	2.6
Peat Co-firing in new plants at:	30%	75	37%	203	87%	5,561,416	5,561	5.6
New Wood CHP Plants (74 MWe)		74	30%	247	87%	6,767,626	6,768	6.8
Total								**28.2**
EXISTING AND POTENTIAL “AVAILABLE” SUPPLY		**Wet Tonnes**	**GJ NCV / wet tonne**			**GJ**	**TJ**	**PJ**
Existing supply of wood fuel (1% of energy demand)								6.0
Pulpwood		168,000	6.3			1,058,400	1,058	1.1
Additional sawmill residues		89,000	8.5			756,500	757	0.8
Available forest residues		198,000	8.5			1,686,000	1,686	1.8
Construction and demolition wood waste		118,000	15.1			1,781,800	1,782	1.8
Wood packing waste		85,000	15.1			1,283,500	1,284	1.3
Total								**11.4**

3.5.2 Biomass Demand

This section seeks to outline the potential sectors where wood fuel could be used to substitute existing fuels in solid fuel power plants and heat only plants in the domestic, commercial, public and industrial sectors.

Figure 3-11 Options for Wood Fuel

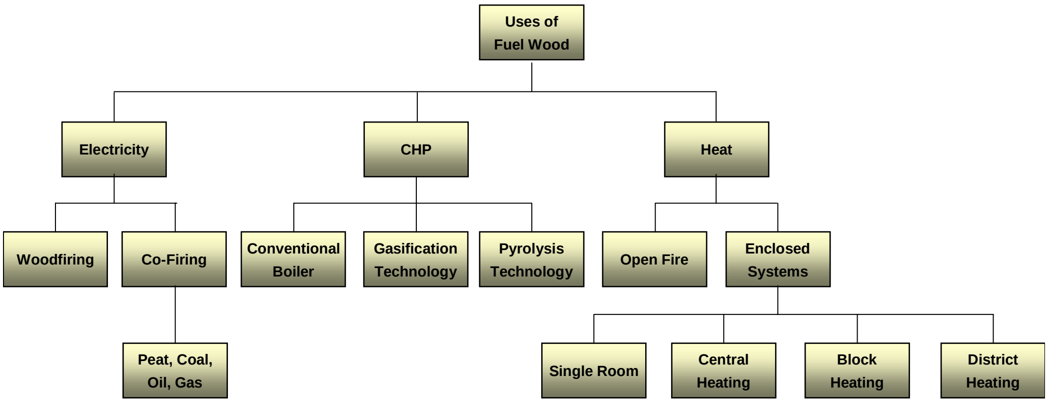


Figure 3-11 above illustrates the principal alternative uses of wood as a fuel:

- As an energy source, it may be used to generate electricity alone, to supply heat, or to do both together as combined and power (CHP)
- When used for electricity, it may be used alone in a wood-fired plant, or it may be co-fired with other fuels (coal, peat, oil or gas).
- When used to supply heat, it may be burned in a domestic open fire, or it may be burned in an enclosed system as logs, chips or pellets, to provide room or central heating for a house, block heating for a large building complex, or district heating for a neighbourhood.
- When used for CHP, it may be burned in a conventional solid fuel boiler, or gasification or pyrolysis technologies can be used to convert the fuel before burning.

Sectors in which biomass could provide an alternative fuel

The potential for the use of wood in the following sectors is discussed in the following sections:

- Electricity generation
- Industry sector
- Domestic sector
- Commercial sector
- Public sector

Potential for Wood in Electricity Generation

Based on previous assessment of the potential for electricity production from wood in Ireland (van den Broek *et al.*, 2001), sectors in which biomass can realistically provide an alternative fuel for electricity generation in the next decade are:

a) Co-firing in existing fossil fuel power plants, including peat plants, coal plants, oil plants and natural gas fired plants (Combined Cycle).
b) Stand alone power generation plants, possibly with CHP mode

In general, option (a) will be more cost effective, however there may be significant non-technical barriers associated with including co-firing in existing power stations. These could include:

- Commercial issues with existing long-term fuel supply contracts;
- Reluctance to alter the power station's operating regime where it is of national importance i.e., security of supply.

The question whether to include CHP or not, is not really a biomass energy related question, but a general heat supply question. With some combinations of heat demand and local circumstances (e.g. high alternative heating fuel prices) it can be interesting to go for CHP.

With option (b) interesting possibilities from an economic point of view in the next decade are:

- Large scale biomass combustion plants (> 10 MWe) with a rankine steam cycle. Proven technology.
- Medium scale (> 2 MWe) biomass combustion CHP plants (close to process heat demand). Proven technology.
- Small scale biomass gasification plants (100 kWe and generally smaller than 2 MWe) with a gas engine (or when larger with a gas turbine and/or combined cycle). In the case of very small scale plants (< 1 MWe) one could use fixed bed gasification. Above this, fluidised bed gasification is more attractive. Biomass gasification is still not proven commercially.

Examples for biomass projects are:

- Arbre: a 8 MWe biomass integrated gasification combine cycle gas turbine (BIGCCGT) power station project in the UK. Using a commercially unproven process, this project has reached the commissioning stage. It is supported by EU grants, UK Government Grants and has a NFFO contract for premium price electricity output. The project main contractor went into liquidation during the course of construction and the project owner continued the construction of the project to the commissioning stage. The commissioning period revealed many design issues that required further investment to resolve. The commissioning process effectively became a development programme which required additional funding.

  The project was sold to a renewables developer subject to the original owner funding the development of the plant to a point where it could be brought into commercial operation. The original owner decided this was not a viable approach and the new owner then placed the project in to liquidation. The plant is for sale, but it demonstrated the difficulties new technologies face in entering commercial operation.

- Powergen are developing a 40 MWe biomass power station project in Scotland in response to the requirement for licensed electricity suppliers to supply 10% of the electricity from renewable sources by 2010. The technology is expected to be based on conventional, proven, condensing steam turbine power generation. The biomass will be supplied from the local forest industry sector. The company is also undertaking trials in their existing coal fired power stations co-firing biomass.

Required modifications for co-firing in solid fuel fired power plants

The most important reasons why co-firing is rather attractive are:

- Economies of scale
- Small biomass supply risk
- Small investment risk for additional investment
- Range of proven technologies available.

In general with co-firing there is a range of possibilities, from almost no adaptations to extensive adaptations to the existing power plants. A short overview of these options is given below (from low to high level of adaptation).

Fuel mixing

When the available boiler and transport system are able to handle wood chips, hardly any adaptation is needed. This is for instance the case in the Edenderry peat plant, where truck based wood supply could be automatically mixed with peat. This mixture is then transported to a joint storage and jointly burned in the fluidised bed boiler. Since peat and wood are rather similar regarding fuel characteristics, this option seems quite realistic.

Adapted fuel logistics

If a fluidised bed boiler is available it may still be necessary to adjust the fuel supply for wood delivery and storage. Cost estimates of this have been presented in *Potentials for Electricity Production from Wood in Ireland* (van den Broek *et al.*, 2001), which concluded that:

- Co-firing wood and peat in the Edenderry Power plant is the most attractive option, with electricity production costs in the range € 0.033 to € 0.053 per kWh (compared to a cost of € 0.041 per kWh of electricity produced from peat).
- Co-firing wood and coal in Moneypoint, and small scale CHP generation using fixed bed gasifiers were also considered promising options.
- With regard to sawmill residues, there are uncertainties with respect to the cost and the net amount of CO_2 avoided. Because sawmill residues have existing non-energy markets, using them as fuel could impact on existing prices.

Adapted fuel pre-treatment

When solid fuel is fired in a pulverised fuel boiler (as is the case in Moneypoint and in the existing Lanesboro peat station) pulverisation of the wood may enable firing of the wood in a boiler that is not adapted. This has been done in the Electrabel pulverised coal fired plant in Nijmegen in the Netherlands. It may be necessary to adapt the fuel burner as well. Another interesting option that is recently being considered is torrefaction. This is a similar type of treatment (“roasting”) to that normally done with coffee beans. The wood is heated up to about 200-300°C, enabling crushing and pulverising with a normal coal mill.

Biomass pre-gasification as pre-treatment step

When a gasifier is put in front of the solid fuel plant, the syngas can be cofired. Advantages of this are that gas burning is relatively easy in most boilers, that the gas can be cleaned before burning (low volumes) and that the gasifier can be rather flexible in terms of biomass fuels (when a fluidised bed is used).

Reconstructing the present boiler

As has been demonstrated in Finland, a pulverised solid fuel boiler can be retrofitted into a fluidised bed boiler by modifying the lower part of it. This will enable multi fuel use.

Pre-combustion as pre-treatment step and flue gas integration

Instead of pre-gasification, pre combustion can be considered as well. The biomass is combusted in a separate furnace and the hot flue gas is added to the flue gas of the existing solid fuel boiler.

Pre-combustion as pre-treatment step and steam integration

Comparable with option (f), but the biomass boiler generates steam as well and has a separate stack. The efficient steam cycle of the larger scale fossil fuel fired boiler is used.

100% retrofit into biomass boiler.

As is being considered in a few coal fired boilers in the Netherlands one could fully retrofit a coal fired boiler into a biomass fired boiler. A large part of the infrastructure could still be used, making this option cheaper (and perhaps also more efficient) than building a stand alone biomass power plant.

Co-firing with natural gas

Natural gas fired combined cycles are currently also considered (e.g. by Electrabel in the Netherlands) for cofiring of biomass. The idea here is that the biomass is gasified, the syngas is cleaned and the clean syngas is mixed with the natural gas and will enter the existing combined cycle. A big advantage of this option is its high efficiency (combined cycles have efficiencies higher than 55%). A disadvantage is the fact that the syngas has to be cleaned considerably (e.g. tars) and that this has to be monitored and operated very well in order not to damage the existing gas turbines.

Firing ground wood pellets in an oil burner

This option has been implemented by at the ENA Kraft CHP plant in Sweden.

Potential Biomass Demand in Electricity Generation

A trial at the Edenderry Power Ltd. peat-fired power station in August 2002 showed that it can deal with a fuel mix of at least 30% wood (Fortum, 2002). If co-firing were to be implemented at 30% in Edenderry Power and the new stations at Lanesboro and Shannonbridge it would provide the equivalent of 110 MWe of wood-fuelled electricity generation capacity (35 MWe in Edenderry Power and 75 MWe in the new plants). There may however be non-technical barriers to the implementation of co-firing at significant levels (i.e., unacceptable impact on existing peat fuel supply contracts).

The Irish Energy Centre (2001) gives the economic potential for CHP using Wood Industry Residues as 48 MWe and that for Forestry Residues as 26 MWe (based on data in ESB International and ETSU, 1997). This gives a total of 74 MWe of potential new wood CHP capacity. The potential for installation of some of this capacity in the panel board sector is discussed in further detail below.

A techno-economic analysis of the potential for electricity generation from wood has been previously undertaken by van den Broek *et al.* (2001). This included examination of the potential for co-firing wood with coal in the Moneypoint power station (three options were investigated – no pre-treatment of the wood fuel, pre-treatment via pulverisation and pre-treatment via gasification). A 10% co-firing level has been suggested in this study. Again however there are possibly non-technical barriers – the need to keep Moneypoint in base load operation, and restricted lorry access to the site. The possibility of co-firing sawdust should not however be ruled out (suitable sawdust would not require pre-treatment before co-firing in Moneypoint).

EXISTING AND POTENTIAL DEMAND	**% Co-firing**	**Capacity MWe**	**Efficiency**	**Fuel input MW**	**Load factor**	**GJ**	**TJ**	**PJ**
Existing use of wood (1% of total energy demand)								6.0
Coal Co-firing in Moneypoint at:	10%	86	32%	268	87%	7,353,622	7,354	7.4
Peat Co-firing in Edenderry Power at:	30%	35	37%	93	87%	2,558,251	2,558	2.6
Peat Co-firing in new plants at:	30%	75	37%	203	87%	5,561,416	5,561	5.6
New Wood CHP Plants (74 MWe)		74	30%	247	87%	6,767,626	6,768	6.8
Total								**28.2**
EXISTING AND POTENTIAL "AVAILABLE" SUPPLY		**Wet Tonnes**	**GJ NCV / wet tonne**			**GJ**	**TJ**	**PJ**
Existing supply of wood fuel (1% of energy demand)								6.0
Pulpwood		168,000	6.3			1,058,400	1,058	1.1
Additional sawmill residues		89,000	8.5			756,500	757	0.8
Available forest residues		198,000	8.5			1,686,000	1,686	1.8
Construction and demolition wood waste		118,000	15.1			1,781,800	1,782	1.8
Wood packing waste		85,000	15.1			1,283,500	1,284	1.3
Total								**11.4**

Table 3-6 shows the potential biomass demand for electricity generation, based on: 30% co-firing with peat in Edenderry Power and the new planned peat plants; 10% co-firing with coal in Moneypoint; and 74 MWe of new wood-fired CHP plant (based on the economic potential for 'Wood Industry Residues' and 'Forestry Residues' in Irish Energy Centre, 2001).

Power Plants

A list of current power plants, detailing their capacities and fuel types is provided in Table 3-4 Electricity Generation Capacity in 200. The location of the power plants is shown in Appendix 1.

Industry Sector

There is no comprehensive dataset available on the types of heating systems in the industrial sector. Indications from the data in Task 1.1 indicate a reduction in the use of coal and stabilisation of the use of 'Other Renewables' which is comprised mainly of wood fuel in the wood processing sector (panel board mills and sawmills). Discussions with Sustainable Energy Ireland (Bolger, 2002) confirmed the trend that there had been a switch from solid fuel. There was no knowledge of wood fuelled heating systems, outside of the wood processing sector.

The Renewable Energy Information Office (1999) investigated the potential for wood-fired CHP in the panel board sector. The report states: *"There are currently four large industrial wood processing plants in [the Republic of] Ireland. They have a combined heat capacity of over 110 MW and a combined electricity requirement of over 40 MW. All of these plants use wood waste to provide their process heat and then buy in their electricity separately. None of these plants currently uses CHP…. All of these Irish plants could generate electricity from wood fired CHP."* The potential is also identified in the draft Timber Industry Development Group report (2001, page 38): *"The European [panel board] mills have the advantage of being supported to build biomass-based power plants using cheap recycled feedstock. The power generated is then exported to the national grid and bought back in at a reduced rate. The net effect is almost a nil power cost to the mill itself. There is potential for the Irish panel board mills to play a leading role in the utilisation of biomass and waste for energy. This possibility should be further explored."*

There has also been interest in the potential for wood as a fuel from a number of companies in other industrial sectors, particularly from the agrifood sector.

In the analysis of potential biomass demand and supply it has been assumed that the existing level of demand for wood fuel for heating in the industrial sector is maintained (additional capacity is assumed to be added in the form of CHP).

Domestic Sector

The data from the assessment of current and future fuel uses for heating in Task 1.1 indicates that the predominant use of solid fuels in 2001 in the domestic sector is in the form of coal (316 kTOE), followed closely by peat (290 kTOE) and finally wood fuel (42 kTOE). The trends indicate that the absolute use of coal and peat as heating fuels in the domestic sector in Ireland will reduce up to 2015 to be replaced by oil and gas. The quantity of wood fuel used in 2001 is the same as that for 1990, with some fluctuation in the intervening years. The ESRI projections are for the use of wood fuel in the domestic sector to decline, but other scenarios are of course possible.

Work by Blackstock and Binggeli (2000) indicated that the wood fuel market in Ireland is predominantly a 'black market' based economy. In addition, wood fuel is typically burned in inefficient open fires in log form. There is little or no use of densified fuels such as briquettes or pellets.

A recent assessment of the status of Fuel Poverty in Ireland (Homes for the 21st Century, Energy Action) included an assessment of the type of heating systems used in the domestic sector in Ireland. This provided a breakdown as follows:

- Gas fired Central Heating: 20% of Total Housing Stock
- Oil Fired Central Heating: 30% of Total Housing Stock
- Solid Fuel Central Heating: 23% of Total Housing Stock
- Solid Fuel Non Central Heating: 20% of Total Housing Stock
- Electric Storage Heating: 7% of Total Housing Stock

Unfortunately there is little or no up to date data, at a national level, on the technical condition of the solid fuel based heating systems in Ireland. The experience of Tipperary Institute and the Tipperary Energy Agency in dealing with queries from the public over a number of years demonstrates that there is an interest in efficient and convenient wood-fuelled systems for domestic heating, including wood pellet systems. Wood pellet systems allow wood fuel to compete on a convenience basis with oil and gas. In the analysis of potential biomass demand and supply it has been assumed that the existing level of demand for wood fuel in the domestic sector will be maintained. To achieve this will require promotion of the efficient production and use of domestic firewood to ensure that market share is not lost to oil and natural gas.

Commercial and Public Sectors

The energy demand data from Task 1.1 for the commercial and public sectors shows that oil and gas supply most of the heating requirements of the sector (there is also some use of electricity for heating, but that can not be calculated from the available data). There is a very low usage of solid fuels (only 4 kTOE of peat).

Work was completed by Buckley and Barry (1997) to identify markets for small scale CHP plants fuelled by short rotation coppice in Ireland. Their report includes an energy survey, which identified one site which was fuelled by coal, 13 which were fuelled by peat briquettes, one fuelled by sod peat and 11 which were fuelled by sawdust. The ones fuelled by sawdust are all sawmills. The sites fuelled by peat briquettes are predominantly hospitals i.e. the public sector. It has not been possible to ascertain if these systems are still in operation as there is no comprehensive dataset available on heating systems in the commercial or public sectors. Discussions with Sustainable Energy Ireland (Bolger, 2002; Sproule, 2002) revealed that there was a major public sector refurbishment programme in the 1990s with change over from solid fuel (coal and peat) to oil and natural gas (where available).

With no significant use of solid fuels in the commercial or public sectors, it seems difficult for wood fuel to penetrate this market segment unless wood fuel can compete aggressively with oil and gas on the basis of cost and convenience. There have however been a number of feasibility studies into the potential for wood energy systems in the public and commercial sectors. The authors are not aware of any of these possibilities having progressed beyond feasibility study stage.

Location of Power and Heat-only plants

The map in Appendix 1 shows:

- the current power stations in Ireland,
- the location of the large wood-fuelled heat-only plants in the panel board mills
- the Irish Timber Council sawmills

New Power plants and CHP

There are three new power plants under construction or being planned (indicated on the map in Appendix 1 and listed in Table 3-5). One of these is natural gas fired and two peat fired. The Commission for Energy Regulation launched a competition for new power production capacity in December 2002. The aim of the competition is to secure 300 to 400 MW of additional capacity for 2005.

A number of potential project developers are examining the feasibility of biomass-fired CHP projects at locations around the Republic of Ireland. The fuels under consideration include sawmill residues, forest residues and short rotation coppice.

3.5.3 Biomass Supply

This section examines three principal potential sources of wood fuel:

- Sawmill residues
- Small diameter roundwood
- Forest residues (or ‘logging residues’)

Each of these sources is examined in terms of total quantities produced at present, projected total quantities into the future and quantities potentially available for energy production. The delivered cost of wood fuel for each of these three sources is then estimated (in Euro per GigaJoule of energy content on a Net Calorific Value basis).

Three other potential sources of wood fuel are also discussed briefly: firewood from deciduous woodlands; arboricultural residues; and construction and demolition wood waste.

The base scenario moisture contents used in the report (pulpwood, pokers and whole tree thinnings at 60% moisture content on a wet weight basis; sawmill residues and forest residues at 50% MCwb) do not seem to be unduly pessimistic. Data received from A. W. Jenkinson’s gives a range of monthly average moisture contents of sawdust from 50% to 58% on a wet weight basis.

SUMMARY

Table 3-7 shows the energy potential of the total estimated production of pulpwood, sawmill residues and forest residues for 2000/2001, 2005 and 2015.

Table 3-7 Wood Fuel Resource Summary

Wood Fuel Source		2000/01	2005	2015
		Million wet tonnes		

Wood Fuel Source		**2000/01**	**2005**	**2015**
Pulpwood		1.141	1.277	1.914
Sawmill residues		0.978	1.197	1.347
Available forest residues		0.198	0.224	0.284
Construction and demolition wood waste		0.118		
Wood packing waste		0.085		
PetaJoules	**PetaJoules / million wet tones**	**2000/01 PJ**	**2005 PJ**	**2015 PJ**
Pulpwood	6.3	7.2	8.0	12.1
Sawmill residues	8.5	8.3	10.2	11.4
Available forest residues	8.5	1.7	1.9	2.4
Construction and demolition wood waste		1.8		
Wood packing waste		1.3		
Total		**20.3**	**20.1**	**25.9**

The quantity of pulpwood and sawmill residues that would actually be available for energy production depends on the price that the energy market can afford to pay. An assessment of the quantity of pulpwood and sawmill residues that may be available for energy production has been made, based on the assumption that the energy market would not draw pulpwood or sawmill residues away from existing non-energy markets. Further detail on assessing the “available” resource is given in the section “Potential Availability of Sawmill Residues and Pulpwood for Energy Production”.

Table 3-8 shows the estimated energy potential from available pulpwood, sawmill residues and forest residues for the years 2000 or 2001, 2005 and 2015. Table 3-9 gives the delivered cost of various types of wood fuel per GigaJoule (GJ) Net Calorific Value (NCV – also termed Lower Heating Value or LHV). The quantities of pulpwood produced in Ireland will increase significantly from 2007 onwards. The increase will be mainly as a result of thinning operations in private forests. Whole tree thinning offers a low cost method of producing wood fuel from thinning operations. However, it may not be possible to apply this harvesting method on a large scale in Irish conditions due to the need for a brash mat of forest residues to support harvesting machinery, and due to environmental constraints. For these reasons most thinning operations for the foreseeable future are likely to be undertaken using conventional techniques. It is possible however to recover an additional wood fuel assortment from thinning and clearfell operations without major changes to harvesting methods. Wood fuel could be recovered as cleaned tops (‘pokers’ – the cleaned top of the tree, less than 7cm in diameter) and dead stems. Costs for ‘Pulpwood Low’, ‘Pulpwood High’ and ‘Pokers’ are presented in the following section. A small quantity of forest residues will be available at the ‘Residues – Integrated’ cost, arising from skyline harvesting. In recognition of its potential as a low cost method for wood fuel production on suitable sites, the trials work commenced by COFORD on whole tree thinning / chipping should be continued. The type of sawmill residue most likely to be available for energy production is sawdust.

Table 3-8 Energy Potential of Additional Wood Fuels, 2001-2005-2015

Wood Fuel Source		**2000/01**	**2005**	**2015**
		Million wet tonnes		
Pulpwood		0.168	0.095	0.732
Sawmill residues		0.089	0.129	0.280
Available forest residues		0.198	0.224	0.284
Construction and demolition wood waste		0.118		
Wood packing waste		0.085		
PetaJoules	**PetaJoules / million wet tones**	**2000/01 PJ**	**2005 PJ**	**2015 PJ**
Pulpwood	6.3	1.1	0.6	4.6
Sawmill residues	8.5	0.8	1.1	2.4
Available forest residues	8.5	1.7	1.9	2.4
Construction and demolition wood waste		1.8		
Wood packing waste		1.3		
Total		**6.7**	**3.6**	**9.4**

Table 3-9 Example costs for chipped and delivered wood fuel for 0 to 40 km Distance Band

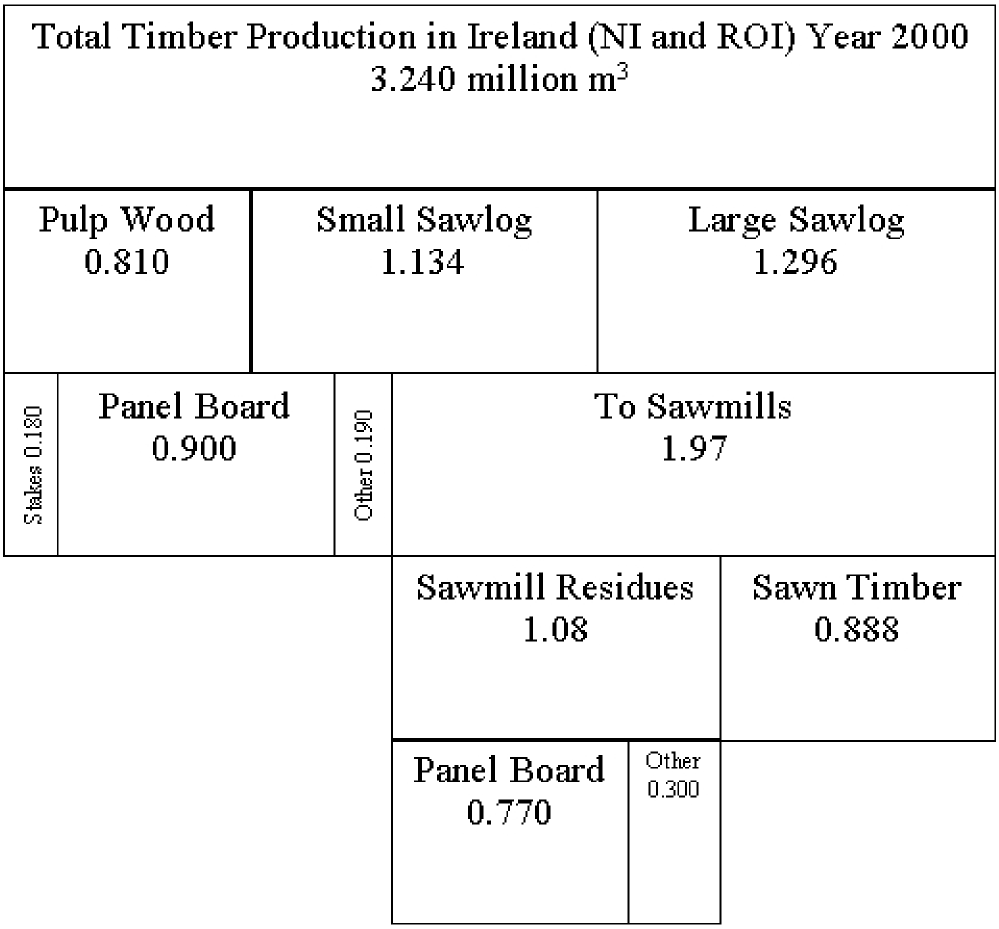
Form of Wood Fuel	**Delivered Cost per Green Tonne**	**Delivered Cost per GJ NCV**
Pulpwood Low	€25.9	€4.1
Pulpwood High	€34.8	€5.5
White Chip	€26.6	€3.1
Sawdust	€13.6	€1.6
Bark	€14.8	€1.7
Roadside residuals	€16.6	€2.0
Residues - Long tops	€50.8	€6.0
Residues - Alternate method	€56.2	€6.6
Residues - Conventional	€50.4	€5.9
Residues - Integrated	€24.8	€2.9
Pokers	€24.2	€3.8
Whole tree thinnings	€15.9	€2.5

- Moisture content of pulpwood, pokers and whole tree thinnings assumed as 60% (wet weight basis). Net Calorific Value 6.3 GJ per green tonne. Pokers are the cleaned (delimbed) tops of trees below pulpwood top diameter (normally 7 centimetres).
- Moisture content of other forms of wood fuel assumed as 50% (wet weight basis). Net Calorific Value 8.5 GJ per green tonne.
- Conversion factor for wood from volume to mass (weight) was taken as one cubic metre = 0.9 wet tonnes (Coillte / PTR, 2002).

Overview of Timber Production and Use in Ireland

The diagram below shows the total timber production in the Republic of Ireland and Northern Ireland for the year 2000, the breakdown of that production into top diameter categories, and the processing destinations for each category.

Figure 3-12 Balance for timber produced in Ireland in 2000



Notes:

i. Based on data contained in the draft Timber Industry Development Group report, 2001. The width of each component of the balance diagram is proportional to the volume of timber represented.
ii. Pulpwood is timber with a top diameter of 7 to <14 cm, small sawlog (‘palletwood’ or ‘boxwood’) 14 to <20 cm and large sawlog >20 cm. However, small sawlog may be ‘downgraded’ to pulp on the basis of poor quality. Thus the total volume of pulpwood quality timber in the above balance is 1.27 million m^3 (made up of components ‘Stakes’, ‘Panel Board’ and ‘Other 0.190’).
iii. The component ‘Other 0.190’ consists of: pulpwood export; and unprocessed roundwood (minor species, some pulpwood and some shorter length small sawlog).
iv. Further detail on the types and uses of sawmill residues is provided in the following sections (including detail on the component ‘Other 0.300’).

In summary, pulpwood (small diameter roundwood) is used as a raw material in the panel board sector. Small sawlog and large sawlog are processed in sawmills, with the majority of the sawmill residues produced going to the panel board sector.

The panel board sector consists of five mills, four in the Republic of Ireland and one in Northern Ireland. Table 3-10 lists the five mills, their locations, products and type of raw material processed (based on TIDG, 2001).

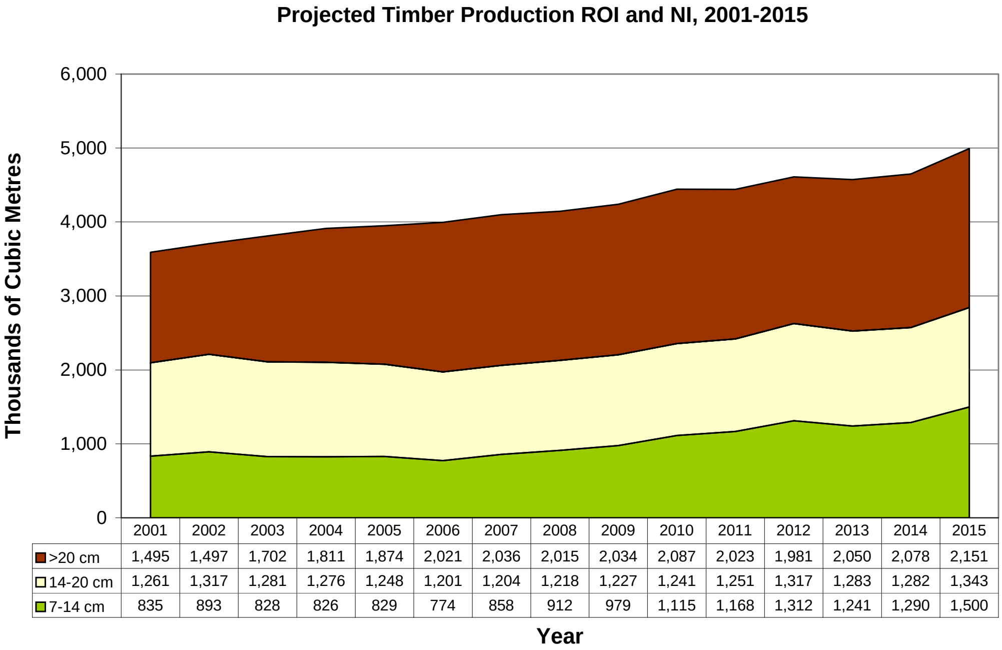
Table 3-10 Panel Board Mills in the ROI and NI

Name	Location	Product	Raw Material
Finsa Forest Products Ltd.	Scariff, Co. Clare	Chipboard	Pulpwood and sawmill residues
Smart*Ply* Europe Ltd.	Belview, Co. Waterford	OSB (Oriented Strand Board)	Pulpwood
Masonite Ireland	Carrick-on-Shannon, Co. Leitrim	Door facings	Sawmill residues (wood chip)
Spanboard Products Ltd.	Coleraine, Co. Derry	Chipboard	Pulpwood and sawmill residues
Weyerhaeuser Europe Ltd.	Clonmel, Co. Tipperary	MDF (Medium Density Fibreboard)	Pulpwood and sawmill residues

The location of the panel board mills is shown on the map in Appendix 1.

The volume of timber produced in Ireland will increase significantly in the coming years. The projected increase is shown in the graph below (Figure 3-13). The total volume of timber produced is projected to increase from about 3 million m^3 in 2000 to 5 million m^3 in 2015. Most of the increase is in the large sawlog and pulpwood top diameter classifications.

Figure 3-13 Projected Timber Production in Ireland to 2015



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
🟥 >20 cm	1,495	1,497	1,702	1,811	1,874	2,021	2,036	2,015	2,034	2,087	2,023	1,981	2,050	2,078	2,151
☐ 14-20 cm	1,261	1,317	1,281	1,276	1,248	1,201	1,204	1,218	1,227	1,241	1,251	1,317	1,283	1,282	1,343
🟩 7-14 cm	835	893	828	826	829	774	858	912	979	1,115	1,168	1,312	1,241	1,290	1,500

Produced from data in Gallagher and O'Carroll (2001) and Timber Industry Development Group (2001).

Three possible sources of wood fuel will result from the increased volume of timber production: sawmill residues produced from the processing of the increased volume of sawlog; pulpwood in excess of the demand from the panel board industry and other pulpwood uses; and forest residues.

Sawmill Residues

The Irish Timber Council (ITC) is the representative body for sawmills on the island of Ireland. The ITC have kindly supplied data on the sawmilling sector in Ireland. Table 3-11 below lists the main sawmills on the island of Ireland (both members and non-members of the ITC). Those sawmills that are members of the ITC are shown on the map in Appendix 1.

It is projected by the ITC that over 2.4 million m^3 of roundwood will be processed by the sawmilling sector in the year 2002 (compared to just under 2.0 million m^3 in 2000). Most of that throughput (2.3 million m^3) is processed by ITC members. From 1997 to 2001 the sawmills significantly increased their processing capacity. The Timber Industry Development Group (2001) consider that there is now sufficient sawmilling capacity in place to process the additional sawlog output projected to the year 2015.

Table 3-11 Sawmills in Ireland

Name	ITC Member	Address	County
Balcas Timber Ltd.	Yes	Magherafelt	Co. Derry
Balcas Timber Ltd.	Yes	Enniskillen	Co. Fermanagh
Balcas Timber Ltd.	Yes	Newtowngore	Co. Leitrim
Coolrain Sawmills Ltd.	Yes	Coolrain	Co. Laois
Drenagh Sawmills Ltd.	Yes	Limavady	Co. Derry
Drenagh Sawmills Ltd.	Yes	Glenties	Co. Donegal
ECC Teo	Yes	Corr na Móna	Co. Galway
Glennon Bros Ltd.	Yes	Fermoy	Co. Cork
Glennon Bros Ltd.	Yes	Longford	Co. Longford
Laois Sawmills Ltd.	Yes	Portlaoise	Co. Laois
Murray Timber Products Ltd.	Yes	Ballon	Co. Carlow
Murray Timber Products Ltd.	Yes	Ballygar	Co. Galway
Nordale (Banagher Sawmills)	Yes	Banagher	Co. Offaly
Palfab Ltd.	Yes	Macroom	Co. Cork
SFE (Grainger Sawmills Ltd.)	Yes	Enniskeane	Co. Cork
Woodfab Timber Ltd.	Yes	Aughrim	Co. Wicklow
Crowe's	No	Mohill	Co. Leitrim
Diamond's	No	Coleraine	Co. Derry
Irish Forest Products (ceased)	No	Mountrath	Co. Laois
O'Grady's	No	Hollyford	Co. Tipperary
Wood Industries	No	Rathdrum	Co. Wicklow

Size and Origin of Roundwood Processed

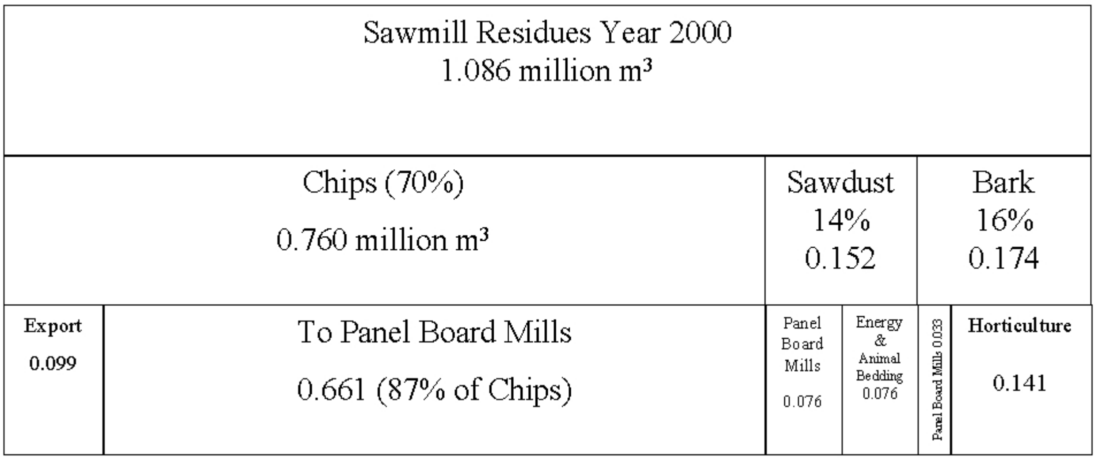
46% of the timber processed by ITC members is in the small sawlog category, and 54% in the large sawlog category. For non-ITC members the percentages are 27% and 73% respectively. The overall percentages for the sector are 45% small sawlog and 55% large sawlog.

The data received from the ITC gives the origin of timber based on whether it is from the forests of Coillte, Private owners or the Department of Agriculture and Rural Development Northern Ireland (DARD NI). For ITC members 83% of material is sourced from Coillte with private forestry providing 4% and DARD NI providing the remainder (13%). The figures for Non-ITC members are 56% (Coillte), 19% (Private) and 25% (DARD NI) respectively.

Types and Quantities of Sawmill Residues Produced in 2000

Sawmills produce three principal types of residue – wood chips, sawdust and bark. A small amount of low quality residue known as boiler fuel is also produced, and there are minor losses. The Timber Industry Development Group draft report (2001) gives details on the types and uses of sawmill residues produced in Ireland in the year 2000. The data is presented graphically in Figure 3-14. The panel board mills took in 0.900 million m^3 of pulpwood in addition to the 0.770 million m^3 of sawmill residues shown in the sawmill residue balance diagram.

Figure 3-14 Sawmill Residue Balance for Year 2000



Sawmill Residues Year 2000
1.086 million m³

Chips (70%)
0.760 million m³

Sawdust
14%
0.152

Bark
16%
0.174

Export
0.099

To Panel Board Mills
0.661 (87% of Chips)

Panel Board Mills
0.076

Energy & Animal Bedding
0.076

Panel Board Mills 0.033

Horticulture
0.141

Note: Based on data contained in the draft Timber Industry Development Group report, 2001, using the percentage composition of sawmill residues given on page 28 of the report (chips 70%, sawdust 14% and bark 16%). An alternative breakdown is given on page 56 of the report (chips 56%, sawdust 17%, bark 17% and other 10%).

Types and Quantities of Sawmill Residues Produced in 2002

As part of this study, sawmill residue production for the year 2002 was calculated from data supplied by the Irish Timber Council on sawmill throughputs and conversion percentages (see Table 3-12).

Table 3-12 Conversion percentages for sawmill residues

Product	% of Roundwood Volume
Sawn Timber Production	
Sawn timber (weighted average taking account of yields from large and small sawlog).	49%
Chips	35%
Sawdust	10%
Bark	5%
Boiler fuel and losses	1%
Stake Production	
Stakes	80%
Chips	12%
Bark	8%

The conversion percentages above equate to a breakdown for sawmill residues from sawn timber of: chips 69%, sawdust 20%, bark 10% and other 2%.

Quantities of sawmill residues in cubic metres were converted to wet tonnes using the standard Coillte factor of 1.11 cubic metres to one wet tonne (Coillte / PTR, 2002). Data on sawmill residue production in 2002 is presented by county in Table 3-13). The table shows a total sawmill residue production of almost 1.1 million wet tonnes in 2002 (over 1.2 million m^3).

Table 3-13 Sawmill residue production in 2002

County	Chips / wet tonnes	Sawdust / wet tonnes	Bark / wet tonnes	Other / wet tonnes	Total / wet tonnes
Co. Galway	166,993	47,712	23,856	4,164	242,726
Co. Cork	166,684	47,624	23,812	4,156	242,275
Co. Fermanagh	107,555	28,570	19,325	2,493	157,943
Co. Derry	57,891	16,540	8,270	1,443	84,145
Co. Longford	57,278	16,365	8,183	1,428	83,254
Co. Laois	53,736	15,353	7,677	1,340	78,106
Co. Wicklow	40,033	11,438	5,719	998	58,188
Co. Carlow	37,727	10,779	5,390	941	54,836
Co. Leitrim	19,530	5,580	2,790	487	28,387
Co. Donegal	8,840	2,526	1,263	220	12,848
Co. Offaly	6,441	1,840	920	161	9,362
Co. Tipperary	3,150	900	450	79	4,579
Other ROI	12,600	3,600	1,800	314	18,314
Other NI	3,150	900	450	79	4,579
TOTAL	**741,608**	**209,728**	**109,904**	**18,302**	**1,079,541**

Existing Markets for Sawmill Residues

Data on current markets and prices for sawmill residues was provided by the Irish Timber Council (2002) and is presented in Table 3-14.

Table 3-14 Markets and Prices for Sawmill Residues

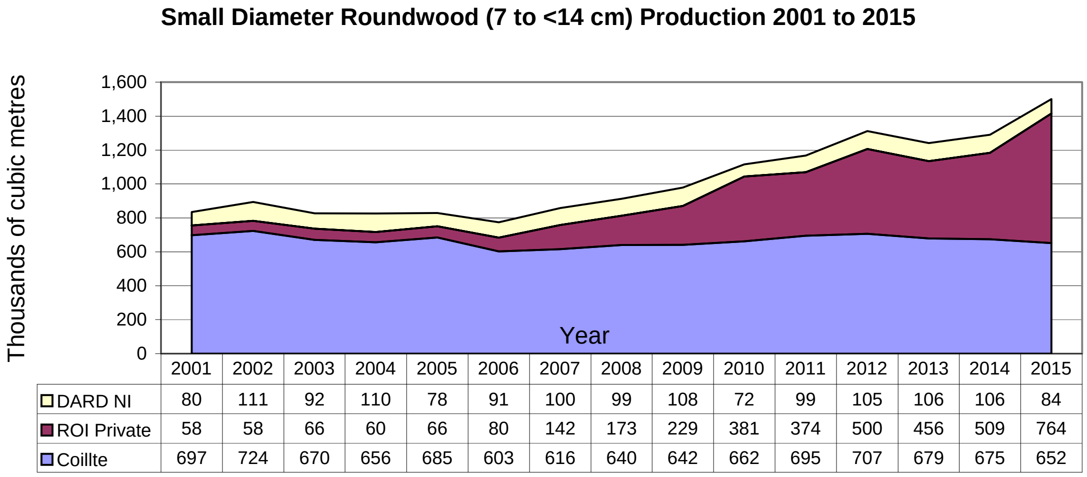
Product	Principal Markets	Price per Wet tonne Ex-Yard
Chips	Panel board mills	€ 23
Sawdust	Panel board mills; use in sawmills for heating; animal bedding.	€ 10
Bark	Horticulture; panel board mills (including as boiler fuel)	€ 10.50 - €12

Pulpwood (Small Diameter Roundwood)

The production forecast for the pulpwood size category is presented in Figure 3-15 for the years 2001 to 2015. The graph shows that the production of pulpwood is set to increase significantly during the period. The increase is almost completely as a result of production from private woodlands in the Republic of Ireland. In these plantations pulpwood production will be mainly as a result of thinning operations. In the future pulpwood may compete with sawmill residues as a source of fibre for some of the panel board mills, thus exerting pressure to find alternative markets for the sawmill residues displaced (Timber Industry Development Group, 2001, p23).

Markets for pulpwood are important to ensure overall timber availability: *"The absence of markets for one product such as pulpwood can reduce the availability of other products such as sawlog"* (Coillte, 2001). One of the challenges faced in ensuring viable markets for pulpwood is the distance of a significant proportion of the pulpwood resource (in the west and north-west of Ireland) from the major users (panel board mills).

Figure 3-15 Pulpwood Volume Forecast 2001 to 2015



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
☐ DARD NI	80	111	92	110	78	91	100	99	108	72	99	105	106	106	84
■ ROI Private	58	58	66	60	66	80	142	173	229	381	374	500	456	509	764
■ Coillte	697	724	670	656	685	603	616	640	642	662	695	707	679	675	652

Produced from data in Gallagher and O'Carroll (2001) and Timber Industry Development Group (2001)

The cost of harvesting and extracting pulpwood to the forest roadside using the conventional shortwood harvesting system varies considerably depending on whether the pulpwood arises from thinning operations or from clearfelling. Site conditions also influence the cost of extraction. A range of €12 to €20 per cubic metre at forest roadside was used in the calculation of the cost of energy from pulpwood (Coillte, 2002a).

There is potential to use whole tree chippers for thinning operations. 20% of the total volume of timber harvested from Coillte forests over the period 2001 to 2010 will be from thinning operations (calculated from Coillte, 2002). Thinnings will make up a much greater proportion of the production from private forestry in the Republic of Ireland: from 47% of total harvest volume in 2001, to 90% in 2015 (Gallagher and O'Carroll, 2001, quoted in Timber Industry Development Group report, 2001). The projected cost of whole tree thinning is presented in a later section, taking a stumpage value of € 4 per cubic metre. It may not be possible to apply whole tree chipping / thinning on a large scale in Irish conditions due to the need for a brash mat of forest residues to support harvesting machinery, and due to environmental constraints.

Potential Availability of Sawmill Residues and Pulpwood for Energy Production

The Timber Industry Development Group report (2001, page 36) describes the challenge faced by the Irish timber industry in securing markets for sawmill residues and pulpwood: *".. demand [for pulpwood and residues] is projected to increase to 2.1 million* m^3 *by 2005. As the output by the industry of pulpwood and residues for 2005 is estimated at 2.7 million* m^3*, the industry must find additional markets and uses for up to 600,000* m^3 *of these by-products. A particular problem will be the increased level of sawdust generated, as this is not a favoured raw material by the panel board mills. This situation may be further exacerbated in the future by the use of re-cycled timber as a source of fibre and by the fact that the majority of the projected additional timber available after 2011 will be from the private sector and most suitable for use as pulpwood by fibre processing operations." "In particular, the additional volumes of sawdust, that are forecast to come on stream, will require the formulation of an urgent action plan for the commercial utilisation of this material. Failure to do so will fundamentally weaken the development potential of the industry."* (page 4).

The report presents two scenarios (A and B) for pulpwood and sawmill residue supply in 2005. These two scenarios are shown in Table 3-15 and also extended to the year 2015. The table shows that between 600,000 and 700,000 m^3 of pulpwood and sawmill residues will be in excess of the requirements of the panel board mills in 2005 (the intake of the panel board mills is expected to be 2.1 million m^3). The excess could rise to over 1.5 million m^3 by 2015 if panel board mill capacity does not expand, or if other significant markets for pulpwood and sawmill residue are not secured.

There are other uses of pulpwood and sawmill residues - the production of stakes, sawdust for animal bedding and heating in sawmills and bark for horticulture. The volumes of these markets in 2000 has been subtracted from the quantities of pulpwood and sawmill residues in excess of the requirements of the panel board mills. Finally, the estimates of the overall excess of pulpwood and sawmill residues in 2005 and 2015 is presented. Table 3-15 averages the estimated excess quantities for 2005 and 2015, and converts the figures in cubic metres to wet tonnes. This is the basis for the calculation of the energy potential of pulpwood and sawmill residues.

Table 3-15 Estimate of Volumes of Excess Pulpwood and Sawmill Residues, 2005 and 2015

Volumes in millions of cubic metres	**2000**	**2005 A**	**2005 B**	**2015 A**	**2015 B**
Total pulpwood (quality classification)	1.266	1.324	1.510	2.024	2.225
Total sawmill residues	1.086	1.459	1.199	1.604	1.387
Total pulpwood and sawmill residues	**2.352**	**2.783**	**2.709**	**3.628**	**3.612**
Panel board mill intake as pulp (54% - 2000 figure)	0.900	1.132	1.132	1.132	1.132
Panel board mill intake as residue (46% - 2000 figure)	0.770	0.968	0.968	0.968	0.968
Total panel board mill intake	**1.670**	**2.100**	**2.100**	**2.100**	**2.100**
Pulpwood in excess of panel board requirements	0.366	0.192	0.378	0.892	1.093
Residues in excess of panel board requirements	0.316	0.491	0.231	0.635	0.419
Total in excess of panel board requirements	**0.682**	**0.683**	**0.609**	**1.528**	**1.512**
Pulpwood for stakes in 2000	0.180	0.180	0.180	0.180	0.180
Residues for heat, animal bedding, horticulture, 2000	0.217	0.217	0.217	0.217	0.217
Overall excess of pulpwood	0.186	0.012	0.198	0.712	0.913
Overall excess of sawmill residues	0.099	0.274	0.014	0.418	0.202

Based on these two scenarios A and B, estimates were made of the average overall excess of pulpwood and sawmill residues for 2005 and 2015. A sample calculation for excess pulpwood in 2015 is as follows:

	Million Green Tonnes
Pulpwood in excess of panel board requirements (2015 A)	0.892
Less pulpwood for stakes	0.180
= Overall excess of pulpwood	0.712
Pulpwood in excess of panel board requirements (2015 B)	1.093
Less pulpwood for stakes	0.180
= Overall excess of pulpwood	0.913
Average of Scenarios A and B for overall excess of pulpwood	0.813

Table 3-16 Estimate of Excess Pulpwood and Sawmill Residues, 2005 and 2015

	2000	**2005**	**2015**

Pulpwood (million cubic metres)	0.186	0.105	0.813
Sawmill residues (million cubic metres)	0.099	0.144	0.310
Pulpwood (million wet tonnes)	0.168	0.095	0.732
Sawmill residues (million wet tonnes)	0.089	0.129	0.280

The ITC estimate that 100,000 wet tonnes of sawdust could be available for other markets, including energy, in 2002 (this estimate fits well between the estimates of 89,000 wet tonnes in 2000 and 129,000 in 2005). Counties Galway, Cork and Fermanagh produce the largest amounts of sawdust.

Theoretically all of the pulpwood and sawmill residues produced could be available for energy if the energy market could pay a sufficiently high price. Table 3-17 below shows the total estimated production of pulpwood and sawmill residues in the years 2000, 2005 and 2015. The figures for 2005 and 2015 are the averages of the A and B scenarios described above.

Table 3-17 Estimate of Total Pulpwood and Sawmill Residue Production, 2000, 2005 and 2015

	2000	**2005**	**2015**
Pulpwood (million cubic metres)	1.266	1.417	2.124
Sawmill residues (million cubic metres)	1.086	1.329	1.496
Pulpwood (million wet tonnes)	1.141	1.277	1.914
Sawmill residues (million green tonnes)	0.978	1.197	1.347

Forest Residues

Forest residues are defined as ‘all above ground material removed from marketable trees and including tops, branches, foliage and un-marketable stem pieces from in-forest conifer harvesting operations’ (Forestry Contracting Association, 1997). Forest residues act as ‘brash mats’ to support harvesting machinery and also have an important role in the recycling of nutrients back to forest soils. A realistic model for early exploitation of clean forest residues for energy should assume that only the top portion of the tree and dead stems would be made available to the energy market. These tops and dead stems can be handled efficiently using existing forestry equipment, particularly if they have been passed through a harvesting head and are partially cleaned of twigs and needles. The resulting chip will also be more uniform, with less small material and a more rounded form. Another advantage of using this material is that it can be harvested from all spruce plantations, almost regardless of the soil types or terrain conditions. The brash mats from pine and minor conifer species are considered to be structurally weaker and, consequently, all residues in these plantations are considered necessary to protect the soil during harvesting operations.

The estimate of the annual potential resource of forest residues in Ireland is based on three sources of timber harvesting projections as follows:

- State forests in the Republic of Ireland (Coillte, 2001)

- Private forests in the Republic of Ireland (Gallagher and O'Carroll, 2001)
- State forests in Northern Ireland (Binggeli et al., 2001)

Timber harvesting projections for private forests in Northern Ireland are not available. The volume of private timber production in Northern Ireland is small when compared to the three principal sources listed above - previous estimates are between 4,500 and 20,000 m3 per year (Fintrac, 1985; Blackstock, 1997). There is no evidence that production from private forests in Northern Ireland will increase significantly in the next decade. The potential residue production from private forests in Northern Ireland is therefore not included here. Residues produced in non-softwood private forests in the Republic of Ireland are also not included.

No accurate estimates are available on the amount of cleaned tops and dead stems produced in spruce plantations in Ireland. Data from the UK (Edwards and Christie, 1981; Forestry Contracting Association, 1997) are not entirely applicable as the thinning regimes and stem taper differ between Scotland, England and Ireland. In the absence of detailed Irish data on the amount of timber left in the un-harvested stem tops and in dead stems, estimates were sought from two experts researching forest residues in the UK (Hudson, 2003; Matthews, 2003). These estimates suggested that it was likely that the equivalent of at least 9% of the total harvested timber would remain as stem tops or un-harvested stems in Irish spruce plantations. This estimate has been adopted here. It is clear however that there is an urgent need to verify this assumption by undertaking trials on spruce harvesting sites in Ireland.

In order to calculate the quantity of harvestable (or 'available') forest residues, data on the projected roundwood production from spruce forests by county was required. Coillte (2001) provides this data for the state forests in the Republic of Ireland. Spruce production from private forests in the Republic of Ireland and state forests in Northern Ireland was estimated by applying a factor of 0.7 to the production forecasts in Gallagher and O'Carroll (2001) and Binggeli et al. (2001) respectively. This was to account for pine and minor conifer plantations, as the residues from such plantations are not considered to be available.

Data from Timber Industry Development Group (2001) was used to produce estimates of the forest residue production in the period 2011 to 2015. Specific data on production from spruce forests was not available for this time period. Therefore production forecasts for state and private forests in the Republic of Ireland and for state forests in Northern Ireland were multiplied by a factor of 0.7 as described above to estimate spruce timber production. Available residues were then calculated based on the 9% figure used above.

In addition to the recovery of cleaned tops and dead stems from spruce plantations (as described above) there is a niche opportunity to utilise forest residues produced in skyline harvesting operations. Areas where skyline harvesting is used include the Antrim Glens, the Mournes, the Carlingford Mountains, Wicklow and in the Slieve Bloom Mountains. It is estimated that about 9,000 m3 of forest residues are produced per year from skyline harvesting in Ireland. The removal of forest residues from the whole tree processing point could enhance the economic attractiveness of skyline harvesting.

Results

Table 3-18 shows the harvestable (or 'available') forest residue resource by county from 2001 to 2010, based on application of the methodology described above.

Table 3-18 Available Forest Residues in Ireland, 2001 to 2010 (thousands of cubic metres)

County	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Cork	21	26	27	32	29	39	38	35	34	29	311
Wicklow	19	16	18	24	23	24	25	25	24	23	221
Galway	15	15	19	21	16	21	16	19	15	24	182
Donegal	16	15	18	18	15	16	18	12	20	18	166
Tipperary	12	11	12	12	12	11	15	12	15	19	132
Clare	8	8	8	11	12	11	15	20	15	17	125
Waterford	10	9	12	12	13	16	12	12	15	12	124
Laois	10	10	12	9	10	12	17	16	14	11	121
Fermanagh	9	9	11	12	12	13	12	12	12	13	116
Kerry	8	9	10	7	12	15	14	13	13	12	114
Leitrim	12	8	8	11	12	9	9	11	11	12	102
Mayo	13	15	11	10	5	7	6	5	13	14	99
Tyrone	5	5	6	6	7	8	10	10	10	11	79
Sligo	6	5	5	6	10	6	6	7	9	11	72
Limerick	4	6	6	8	6	7	7	8	7	8	67
Cavan	3	9	5	5	8	6	6	6	6	13	66
Offaly	4	5	6	6	6	8	7	7	9	6	63
Kilkenny	7	8	6	5	6	5	5	4	6	7	59
Wexford	7	6	6	4	5	6	8	6	5	3	56
Roscommon	4	4	5	6	3	5	5	3	5	6	45
Antrim	2	2	2	3	3	3	6	6	6	7	41
L'Derry	4	4	4	4	4	4	3	3	3	4	36
Westmeath	2	2	1	2	4	6	5	6	1	3	32
Kildare	4	3	3	2	3	3	2	3	4	4	31
Carlow	3	3	3	2	4	2	3	3	4	3	30
Monaghan	4	4	4	2	2	2	1	3	1	3	26
Longford	2	2	1	1	2	1	2	4	4	4	23
Dublin	1	1	1	3	2	2	3	2	2	2	19
Meath	2	1	2	1	2	1	2	2	1	2	15
Down	1	1	1	1	1	1	2	2	2	2	14
Armagh	1	1	1	1	1	1	1	1	1	3	12
Louth	1	1	2	1	1	1	1	1	3	1	11
Total	**220**	**224**	**235**	**246**	**249**	**273**	**283**	**281**	**293**	**308**	**2,612**

The table shows that the quantity of harvestable forest residues will increase gradually over the decade, from 235,000 m3 in 2003 to over 300,000 m3 in 2010. The quantity of harvestable residues in year 2015 has been estimated at 315,000 m3, based on data in Timber Industry Development Group (2001) and the application of the methodology described above. The estimates for 2001, 2005 and 2015 are summarised in millions of cubic metres and millions of wet tonnes in Table 3-19.

Table 3-19 Estimate of Available Forest Residues in Wet Tonnes, 2001, 2005 and 2015

	2001	**2005**	**2015**
Available forest residues (million cubic metres)	0.220	0.249	0.315
Available forest residues (million cubic tonnes)	0.198	0.224	0.284

Delivered Wood Fuel Costs

The delivered cost for wood fuel from sawmill residues, pulpwood and forest residues was calculated using the previously presented information on costs at sawmill or forest roadside, a comminution cost if applicable, and the addition of a transport cost based on information kindly provided by Coillte (2002b). The basis for calculation of the delivered wood fuel costs is presented in Table 3-20. The delivered costs (in Euro per GigaJoule of Net Calorific Value) are presented in Table 3-21. Sensitivity analyses are given in Table 3-22 (Alternative Moisture Content Scenarios) and Table 3-23 (Alternative Transport Cost Scenario). The base scenario data is presented in Figure 3-16.

It is important that practical trials of forest residue harvesting, in particular whole tree thinning, be carried out in Ireland in order to provide reliable information on the costs involved in Irish conditions.

Table 3-20 Basis for Calculation of Delivered Wood Fuel Costs

Cost Component per Wet Tonne	**Sawmill Residues**	**Pulpwood**	**Forest Residues**
Cost at sawmill or at roadside	White chip €23 Sawdust €10 Bark €10.50 to €12 Irish Timber Council, 2002.	€12 to €20 per cubic metre. Coillte, 2002a. Conversion factor 1 m^3 = 0.9 wet tonnes. Coillte / PTR, 2002.	Data supplied on subcontract by the Forestry Contracting Association, UK, 2002, with modified stumpage values.
Transport cost	Coillte roundwood transport costs multiplied by a factor of 0.72. Factor based on example transport cost for sawmill residues from McNamara, 2002.	Coillte roundwood transport costs.	Coillte roundwood transport costs applied for all forest residue fuels (including pokers, roadside residuals, Fiberlogs (bundles) and whole tree chips).
Comminution cost	Not applicable.	€7.65 per wet tonne (Forestry Contracting Association, UK, 2002). Assumes comminution in large scale facility.	€7.65 per wet tonne where applicable (Forestry Contracting Association, UK, 2002). Assumes comminution in large scale facility.

Notes:

- No storage or secondary transport costs are included in the delivered energy prices.
- Lower costs for forest residue harvesting and extraction have been reported from other countries. The costs in the UK and Ireland may fall as economies of scale develop

Table 3-21 Delivered Cost of Chipped Wood Fuel (Euro per GJ Net Calorific Value): Base Scenario

Transport distance band (km)	Midpoint distance (km)	Pulpwood Low	Pulpwood High	White Chip	Sawdust	Bark	Roadside residuals	Residues - Long tops	Residues - Alternate method	Residues - Conventional	Residues - Integrated	Pokers	Whole tree thinnings
0 to 40	20	€4.1	€5.5	€3.1	€1.6	€1.7	€2.0	€6.0	€6.6	€5.9	€2.9	€3.8	€2.5
40 to 80	60	€4.4	€5.8	€3.3	€1.7	€1.9	€2.2	€6.2	€6.8	€6.1	€3.1	€4.1	€2.8
80 to 120	100	€4.7	€6.1	€3.5	€1.9	€2.1	€2.4	€6.4	€7.1	€6.4	€3.4	€4.5	€3.1
120 to 160	140	€5.0	€6.4	€3.6	€2.1	€2.2	€2.6	€6.7	€7.3	€6.6	€3.6	€4.8	€3.4
160 to 200	180	€5.4	€6.8	€3.8	€2.3	€2.4	€2.9	€6.9	€7.5	€6.9	€3.8	€5.1	€3.8
200 to 240	220	€5.6	€7.0	€3.9	€2.4	€2.5	€3.0	€7.1	€7.7	€7.0	€4.0	€5.3	€4.0
240 to 320	280	€5.9	€7.3	€4.1	€2.6	€2.7	€3.3	€7.3	€8.0	€7.3	€4.3	€5.7	€4.3

- Pulpwood, pokers and whole tree thinnings at 60% MCwb, 6.3 GJ per wet tonne, other fuel types at 50% MCwb, 8.5 GJ per wet tonne
- Transport costs for sawmill residues (white chip, sawdust and bark) set at 72% of Coillte roundwood transport costs

Table 3-22 Alternative Moisture Content Scenarios

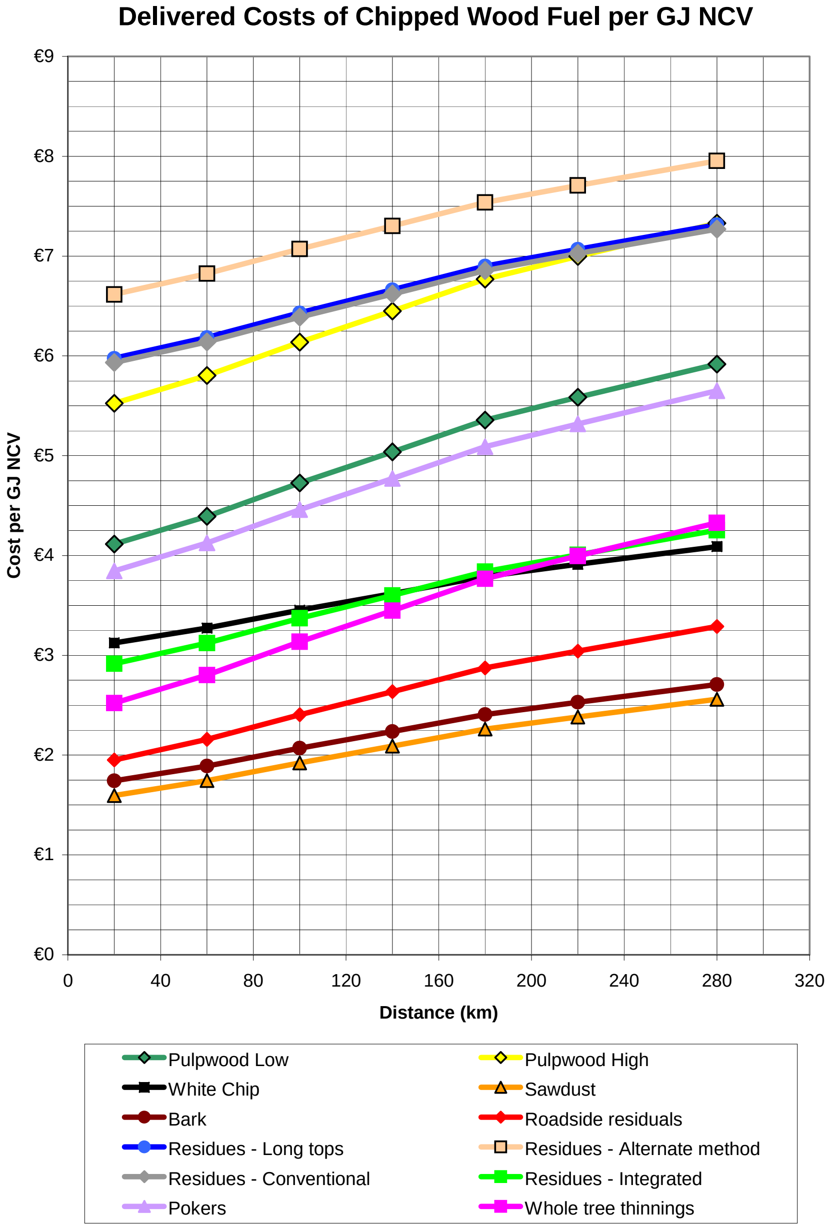
Transport distance band (km)	Midpoint distance (km)	Pulpwood Low	Pulpwood High		Pulpwood Low	Pulpwood High		Pokers	Whole tree thinnings
		50% MCwb, 8.5 GJ per wet tonne			40% MCwb, 10.7 GJ per wet tonne			50% MCwb, 8.5 GJ per wet tonne	
0 to 40	20	€3.0	€4.1		€2.4	€3.3		€2.9	€1.9
40 to 80	60	€3.3	€4.3		€2.6	€3.4		€3.1	€2.1
80 to 120	100	€3.5	€4.5		€2.8	€3.6		€3.3	€2.3
120 to 160	140	€3.7	€4.8		€3.0	€3.8		€3.5	€2.6
160 to 200	180	€4.0	€5.0		€3.2	€4.0		€3.8	€2.8
200 to 240	220	€4.1	€5.2		€3.3	€4.1		€3.9	€3.0
240 to 320	280	€4.4	€5.4		€3.5	€4.3		€4.2	€3.2

Table 3-23 Alternative Transport Cost Scenario

Transport distance band (km)	Midpoint distance (km)	White Chip	Sawdust	Bark
0 to 40	20	€3.1	€1.5	€1.7
40 to 80	60	€3.2	€1.6	€1.8
80 to 120	100	€3.3	€1.8	€1.9
120 to 160	140	€3.5	€1.9	€2.1
160 to 200	180	€3.6	€2.1	€2.2
200 to 240	220	€3.7	€2.2	€2.3
240 to 320	280	€3.9	€2.3	€2.5

- Transport costs for sawmill residues set at 60% of Coillte roundwood transport costs (72% in Base Scenario)

Figure 3-16 Delivered Costs of Wood Fuel per GJ NCV



The graph shows that the cheapest form of wood fuel is sawdust, followed by bark, roadside residuals, whole tree thinnings, forest residues from integrated harvesting (skylines) and white wood chip. Pokers, pulpwood harvesting using the shortwood harvesting system, and second pass forest residue harvesting systems are more expensive forms of wood fuel. The sensitivity analysis shows that the delivered costs per GJ for pulpwood, pokers and whole tree thinnings are quite sensitive to the moisture content of the trees being harvested. The delivered costs of these three fuels falls significantly if the trees harvested are at less than the 60% moisture content (wet weight basis) assumed in the base scenario presented in Figure 3-16

Other Sources of Wood Fuel

Three other possible sources of wood fuel are discussed briefly below:

- Firewood from deciduous woodlands
- Arboricultural residues
- Construction and demolition wood waste

Firewood from Deciduous Woodlands

In Northern Ireland and the Republic of Ireland the domestic woodfuel market is dominated by farm woodland and hedgerow exploitation, or with waste from the arboricultural industry. Because this market has not been linked to the established forestry sector and has not been, normally, scrutinised by the tax authorities, woodfuel sales have not been accurately catalogued or understood. Sales of at least 22,000m^3 per annum of woodfuel were identified in Northern Ireland and at least 58,500m^3 per annum were identified in the Republic of Ireland (Blackstock & Binggelli 2000). The small scale and fragmented nature of the domestic wood fuel market makes accurate estimation of the volume of domestic wood fuel used difficult Although some of the largest players in this market may be able to supply wood chip into the CHP market, it is just as likely that the domestic woodfuel market will compete for better quality forest residues, particularly if the cost of fossil fuels remains high.

Arboricultural Residues

Only sources of arboricultural waste that are greater than 1,000 m^3 per year have been included. Given the structure of the arboricultural industry in Ireland (with a few well-established firms servicing geographically large hinterlands, most of who process their arboricultural waste at a central location), this resource will be treated as originating from ‘point sources’. There are significant sources of un-utilised arboricultural waste in South Antrim (3,000m^3), North Derry (2,000m^3), Tyrone (1,000m^3), Down (2000m^3), Louth (1000m^3), Dublin (2,500m^3), Wicklow (2,000m^3) and Cork (1,000m^3).

Wood Waste

The COFORD-sponsored project WoodWaste aims to quantify the amount of wood waste generated by the construction and demolition sectors in Ireland. Preliminary results indicate that between 104,000 and 131,000 tonnes of construction and demolition wood waste is generated in 2002, of which 48% arises in the greater Dublin area. If 50% of the midpoint of that range is suitable and available as wood fuel (118,000 tonnes), it represents 1.8 PetaJoules of energy potential (assuming a moisture content of 20% on a wet weight basis, giving a net calorific value of 15.1 GigaJoules per wet tonne).

In addition to construction and demolition wood waste, there are significant arisings of packaging wood waste. The quantity of packaging wood waste produced in 1998 is estimated at 85,336 tonnes (Clean Technology Centre, 2002). Assuming a similar moisture content and net calorific value as for construction and demolition wood waste, this represents a potential fuel resource of 1.3 PJ.

In order to estimate the cost of wood waste as a fuel, data on three cost components was assembled. These costs are: the avoided cost of landfilling the wood waste; transport cost from source to energy user; and comminution cost. An example landfill cost for

2003 is €125 per tonne (as advertised by Laois County Council). The WoodWaste project report gives a transport cost of €4.30 per tonne of timber for a 40 kilometre distance. A comminition cost of €7.65 per tonne is assumed (as per the other sources of wood fuel discussed in this report). The total 'cost' for wood waste transported 40 kilometres and then chipped at the user in a large scale comminution facility is therefore -€112, equivalent to -€7.4 / GJ NCV. Clearly the use of waste wood has major cost advantages over other types of wood fuel. It must be borne in mind however that the use of contaminated waste wood is subject to environmental constraints which increase the cost of the energy conversion equipment required

Investment in Forestry

- From 2002 onwards, increased volumes of timber will be available from private forest plantations. Much of this timber will be in the pulpwood category. It is imperative that markets for this private pulpwood be secured to ensure a livelihood for the private growers and a return on the substantial amounts of money invested by the state and the EU. Over the last six years, 1997 - 2002, expenditure on forestry amounted to over €540 million or an average annual spend of €90 million (Browne, 2002).

4 A COMPARISON OF WIND POWER WITH SOLID WOOD BASED POWER PRODUCTION TECHNOLOGIES

4.1 Wind Power

The use of wind as a renewable energy source involves the conversion of power contained in moving air into rotating shaft power. The conversion process utilizes aerodynamic forces (a combination of lift and drag) to produce a net turning moment on a shaft, resulting in the production of mechanical power, which can then be converted to electrical power.

Wind is a very complex resource. It is intermittent and strongly influenced by geography and topography (terrain effects). There is a non-linear (cubic) relationship between instantaneous wind speed and available power. However, energy yield from wind turbines does not increase with the cube of the annual mean wind speed (AMWS) for two reasons:

- The power conversion efficiency varies with wind speed, peaking at around 7-10 meters per second (m/s);
- As mean wind speed increases, a greater proportion of the energy in the wind is spilled as the control system limits the power output to its rated level.

Typically a site with an AMWS of 8m/s could be expected to produce 80% more electricity than the same turbines on a site with an AMWS of 6m/s. If capital costs are similar then the increased output will be reflected in a correspondingly cheaper cost of energy.

Wind turbines are being developed over a range of power outputs from a few hundred watts to several megawatts and are available commercially as individual turbines up to approximately 3 MWe. The size currently being chosen for wind farms in Europe is generally in the range 500-2,000kWe.

Large-scale generation of electricity requires a number of machines (typically around 20) to be grouped together for economy and ease of operation. The machines are usually spaced 5 to 10 rotor diameters apart to reduce interaction effects, which impair their performance. A wind farm of about 20 machines usually extends over some 3-4km^2 of land, although the actual machines and access tracks occupy only about 1-2% of this area, leaving the remaining land to be farmed.

The net energy output of a typical 600kWe machine operating in a wind farm would be around 1,600MWh/year on a site with an AMWS of 7.0m/s at a height 45m above ground level.

The technology is well established. Making allowances for the lower rating of the older machines, the total number of grid-connected turbines is probably approximately 40,000. Now that the fatigue life and reliability can be adequately demonstrated, wind power can be regarded as technically mature.

The turbine design lifetimes are around 25 years; experience of operating modern wind turbines is limited to around 15 years. The technical reliability of wind turbines has increased steadily during the past decade as better designs have evolved; modern turbines are now operating with a machine availability of 97%-99%.

Decommissioning wind turbines at the end of their design life presents few difficulties as it entails only the removal of scrap material and cabling. The concrete bases are a few cubic meters in size and can be removed, though they are usually buried. There is no residual waste or land contamination.

Wind farms can also be build in offshore locations. The technology for offshore deployment is similar to that for onshore, but the harsher climate and relative inaccessibility place more stringent requirements on the initial design and subsequent reliability. Additionally, because the foundations of a machine and their installation would comprise a much greater proportion of the total project cost, machines of at least one megawatt rating need to be deployed to minimise the cost of energy. Such machines are now becoming commercially available and are already being deployed on land.

General technical description of a 1 MWe wind turbine

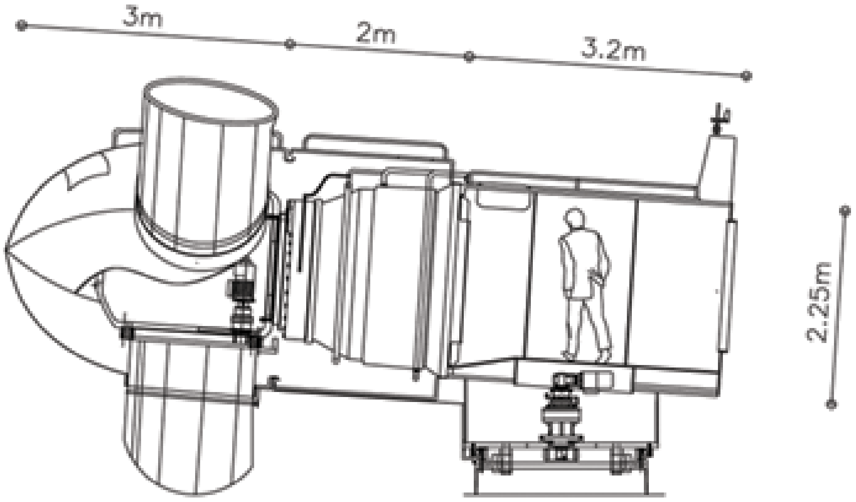


Figure 4-1 Dimensions of a 1 MWe wind turbine nacelle

The drive train of the wind turbine consists of a single-stage planetary gear and a low-speed synchronous generator. The technical details are summarised in Table 4-1. The relationship between wind speed and power output is illustrated in Figure 4-2.

Table 4-1Specification of a 1 MWe Wind Turbine

General	
Rated power	1000 kW
Power control	Pitch
Type	3 blades, 4 degree tilt, up-wind
Cut-in wind speed	3,0 m/s
Rated wind speed	12,5 m/s
Cut-out wind speed	25,0 m/s
Design maximum	59,5 m/s (at hub height)
Colour of tower and nacelle	RAL 7035 grey
Classification	IEC II, -8.5 m/s, 20 years
	S, -7.5 m/s, Ti= 14%, 30 years
	-30...+ 30 ºC
Operating temperature	-30...+ 30 ºC

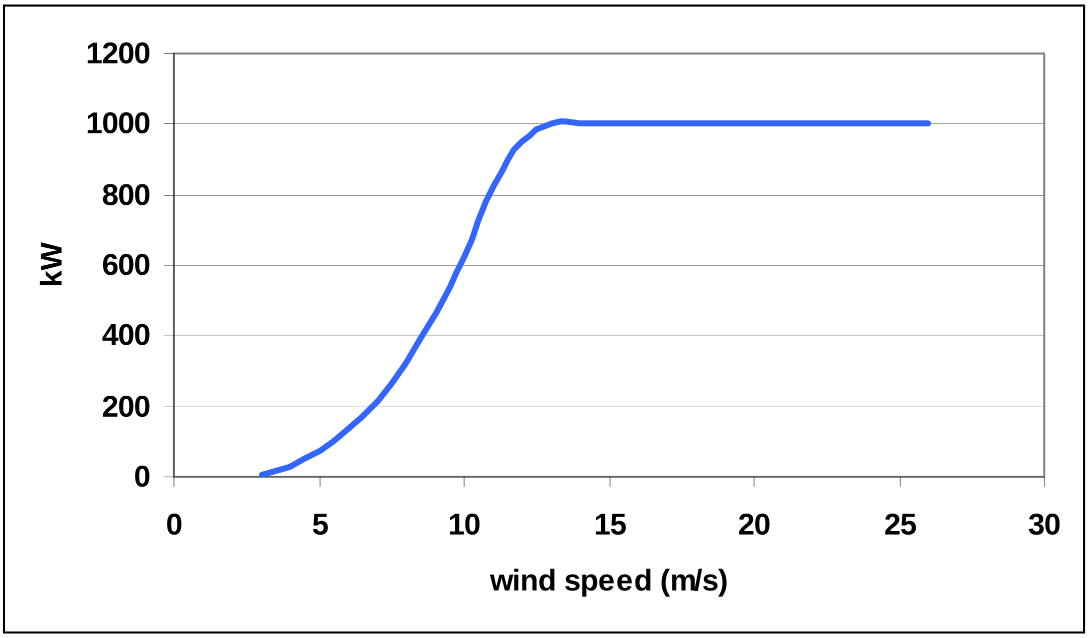


Figure 4-2 Power generation for a 1 MWe plant at different wind speeds

Wind Power Load Factor

Analysts are frequently interested in the load factor for wind power. The load factor for a generating technology is equal to the annual energy production divided by the theoretical maximum energy production if the generator were running at its rated power all the year.

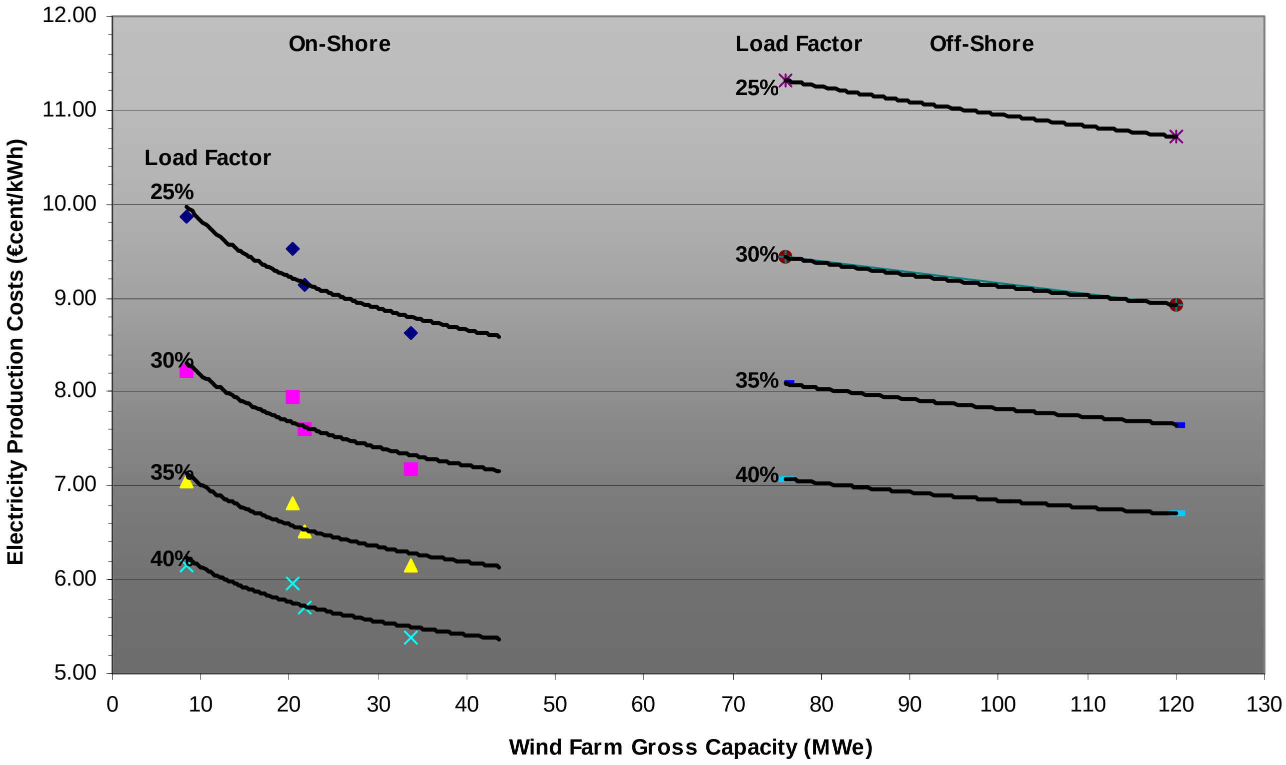
Depending on the wind statistics for a particular site, the typical load factor for a wind turbine is somewhere around 25-30% of the installed capacity which results in a minimised cost per kWh. It is definitely not desirable to increase the load factor for a wind turbine since this would overestimate the price of electricity generated. Capacity factors will be very different for different machines, but likewise the prices (or costs) of those machines will be very different. In the final analysis, it is the cost per kWh of energy produced, not the capacity factor.

Wind Power Project Electricity Production Costs

Figure 4-3 provides an illustration of typical electricity generation costs for both on-shore and off-shore wind farm projects. The figure has been based on the costs of realised and planned projects in the UK. The array curves assume different load factors (actual annual generation divided by maximum theoretical generation). The key points are:

- Discount rate: 10%
- Project period: 15 years
- Annual operating and maintenance costs, expressed in terms of % investment costs, are in the range:
  - On-shore: 1…2.0%;
  - Off-shore: 2.0…3.0%
- Off-shore wind farm sizes will be significantly larger than on-shore wind farms.

Figure 4-3 Wind Power Production Costs (10% discount rate, 15 years)



4.2 Biomass combustion technology

The are three technologies that can be considered for the energy conversion of biomass:

- Gasification, which is regarded as a demonstration technology for power generation using biomass;
- Grate boiler, which are a conventional, well proven combustion technology
- Fluidised bed, a modern combustion technology finding wide application for the combustion of biomass.

4.2.1 Gasification

The concept of gasification is to convert the chemical energy of solid fuels into gaseous form. Gaseous fuel is easier to burn than a solid and makes it possible to use gas burners and even gas turbines and gas engines. The use of engine technology offers the potential of higher efficiency electricity generation compared with a boiler/steam turbine arrangement.

Gasification is an evolving technology and not yet commercially fully mature which creates a significant barrier to its uptake.

There are three principle approaches to biomass gasification technology:

Conventional fixed bed gasification systems are used in small-scale energy production (<10 MWth).

- In updraft gasifier the fuel is fed to the top of gasifier, wherefrom it flows down slowly through drying, pyrolysis, gasification and combustion zones. Ash is removed from the bottom where the gasification air and steam are introduced. The gas leaves at the top. The major advantage of updraft gasifier is its simplicity and fuel flexibility. The major drawbacks are the high amounts of tar in product gas and pyrolysis products. High tar content causes problems in engine use and therefore extensive gas cleaning is required.
- In downdraft gasifier the fuel is fed at the top and the air intake is also at the top or from the sides. The gas leaves at the bottom of the gasifier, so the fuel and gas move in the same direction. The use of small downdraft gasifiers has long history in Finland, where hundreds of cars, busses and boats were operated by wood gas during the World War II. The major advantage is low tar content of product gas, which is nearly suitable for engine applications. Downdraft gasifiers have relatively strict requirements on fuel.

Atmospheric CFB/BFB (circulating fluidised bed/bubbling fluidised bed) gasification of dried biomass is commercial technology in Finland. The product gas can be burned under ambient conditions. However, gasification in stand-alone boilers without support fuel produces gas of very low heat value that is difficult to burn. A solution is to lead the product gas directly into a coal– or oil-fired large-scale boiler, enabling co-combustion of the lean gas in the gas burner. The BFB technology seems to be economically more suitable to medium size applications (15-40 MW) while the CFB technology is most economic on larger scale (40-100 MW).

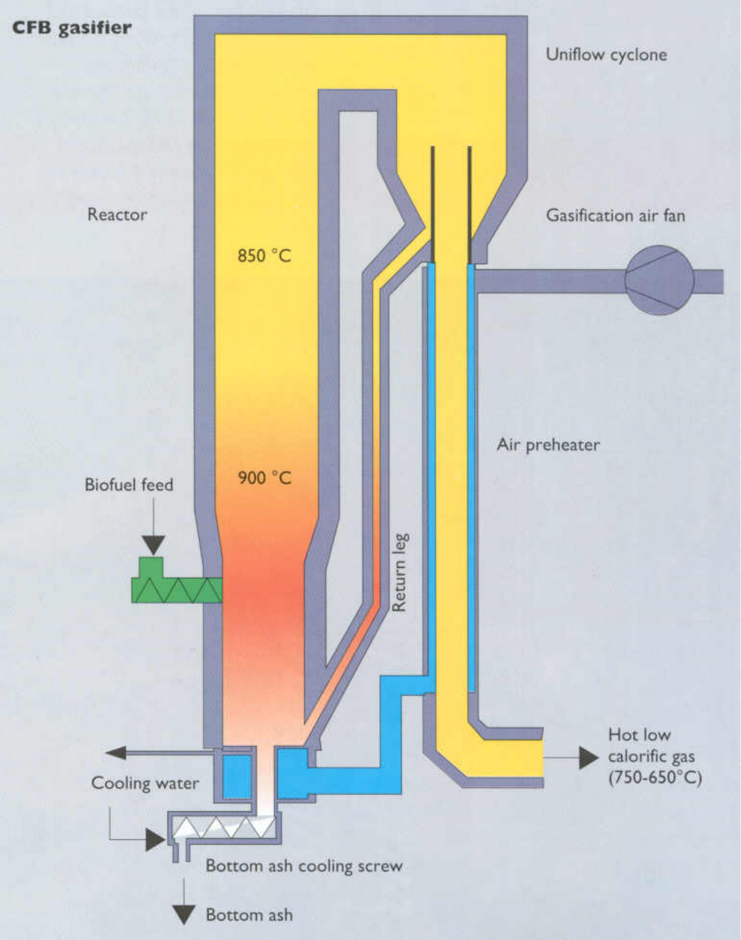


Figure 4-4 CFB Gasifier

In 1998 a new CFB gasifier supplied by Foster Wheeler Energia Oy was taken into operation in the Kymijärvi Power plant in Lahti, southern Finland. The gasifier utilises roughly 300 GWh/a of different solid biofuels and refuse-derived fuels from the Lahti area. The moisture content can be up to 60 %. The capacity of the gasifier is 40-70 MW depending on the moisture content and heating value of the input fuel. Produced gas replaces 15 per cent of the fossil fuel used in coal boiler and reduces significantly SO_2, NO_x and CO_2 emissions.

An **IGCC (Integrated Gasification Combined Cycle)** power plant consists of a pressurized or an atmospheric gasifier, gas cooling and cleaning, possible compressor and a gas turbine that can be either fully or partly integrated into a normal combined cycle process. After cooling and cleaning and possible pressurizing, gasification gas from the gasifier is burnt in the combustion chamber of a gas turbine to produce electricity. Hot gases are then led to a heat recovery steam generator (HRSG) to produce steam that is expanded in a steam turbine for further generation of electricity.

An IGCC process based on pressurized fluidised bed gasification with air, hot gas cleaning, often called a simplified IGCC process, is suitable for size range between 30 and 100 MW_e, when biomass are used as fuels. The operational experiences of the VÄRNAMO plant in Sweden were not promising/encouraging for the use of this technology. At present the plant is shut down and conserved for possible future R&D projects.

The Arbre is an 8 MWe IGCC project in the UK is a similar in configuration to VÄRNAMO plant. It has been frustrated with technical and consequently commercial problems and has yet to complete commissioning.

The high investment costs of IGCC technology prevent it from being considered as a commercially viable option for biomass fuelled, small-scale power generation.

4.2.2 Grate Boilers

Grate boiler is the oldest boiler type for solid fuels. In the past it has been widely used for boiler sizes up to 160 MW, but after the development of fluidised bed boilers in 1980's, their popularity has reduced to small power production in the size range of 1 MW_{th} to about 30 MW_{th}..

In grate boilers, solid fuel is fed on a grate where combustion takes place. The grate can be either stationary or moving. Stationary grate is best suitable for small boilers. Bigger grate boilers are usually constructed with moving grates, on which fuel moves continuously through the combustion zone from the fuel feed to ash discharge.

The main weaknesses of grate boilers are poor boiler efficiency, high emissions and a need for rather uniform fuel quality. Despite of these weaknesses, grate boilers are still in operation in many places, especially where environmental legislation is not so stringent, due to simple boiler structure leading to low investment costs.

4.2.3 Fluidised Bed Combustion

Fluidised bed combustion has been widely used from 1980's onwards in applications under 600 MW_{th}.

The operating principle of fluidised bed combustion is to feed crushed fuel into the boiler and burn it utilising a bed that consists of inert material such as sand or fuel ash. Because the bed has high heat capacity this method is very suitable for burning fuels with high moisture content. There is no need for separate fuel drying before the boiler. The high heat capacity of the bed material also means that the quality of the fuel can vary more than with other boiler types.

The combustion air is introduced to the boiler in several levels. The primary air flows upwards and fluidises the bed while the secondary air is injected above the bed. The combustion temperature in fluidised bed boilers is lower than in grate boilers, typically 800 - 900 °C, which enables low NO_x emissions.

When using sulphur rich fuels, such as coal, sulphur dioxide can be removed in the combustion process by adding limestone to the bed, eliminating the need for an external desulphurisation process. The calcium oxide formed from the calcination of limestone reacts with SO_2 to form calcium sulphate, which is removed from the flue gases together with fly ash. The low combustion temperature of fluidised bed combustion minimises limestone requirements, because the required calcium to sulphur ratio for a given SO_2 removal efficiency is minimised in this temperature range.

The fact that a fluidised bed can be operated at such low temperatures is mainly related to the effect of heat conduction with the bed particles, which gives more efficient heat transfer than just radiation used in grate boilers. The temperature of the bed must be kept low, so that the ash in fuel cannot melt and result in the collapsing of the bed.

Bubbling Fluidised Bed Boiler (BFB)

The first fluidised bed boiler developed was a Bubbling Fluidised Bed boiler (BFB). The word “bubbling” refers to the fact that the velocity of the primary air flowing through the bed is not high enough to make the bed particles fly away, the air just makes the bed “bubble”.

Bubbling bed boilers are especially suitable for burning different biomass mixtures such as wood, wood wastes, straw and sludges, which has high volatile content. On the other hand, coal burning in BFB boilers is not efficient. This is due to the fact that coal has only about 20 - 30 % of volatile matter, thus needing several seconds for full combustion in low temperatures. This cannot be achieved in bubbling bed boilers.

The combustion technology has no risks, quite contrary; it is very flexible with the particle size and moisture of the fuel.

Circulating Fluidised Bed Boiler (CFB)

If full coal firing is sought for then a suitable solution is Circulating Fluidised Bed boiler (CFB). In circulating bed boilers the primary air velocity is higher than in bubbling bed boilers, thus making the bed particles blow away from the bed. As a result, a large percentage of the solid particles is carried out of the combustion chamber in the flue gases. These are removed from the flue gases in a cyclone together with unburned fuel particles and returned to the bed. Because of this, the combustion time is now sufficient when burning coal or other low-volatile fuels and the combustion efficiency is good.

4.3 Investment cost of biomass-fired power plant

Typical investment costs of Finnish power plants are presented in the next picture. Investment cost includes main equipment (boiler, steam turbine, fuel handling system,..), automation, auxiliary equipment, electrification, civil construction work, design engineering, project management and interest during construction. Gasification technology is not mature nor fully commercial yet, which is why the investment costs of gasifiers are not presented. However, in future, the investment of gasification plant will be close to those of conventional boiler plants.

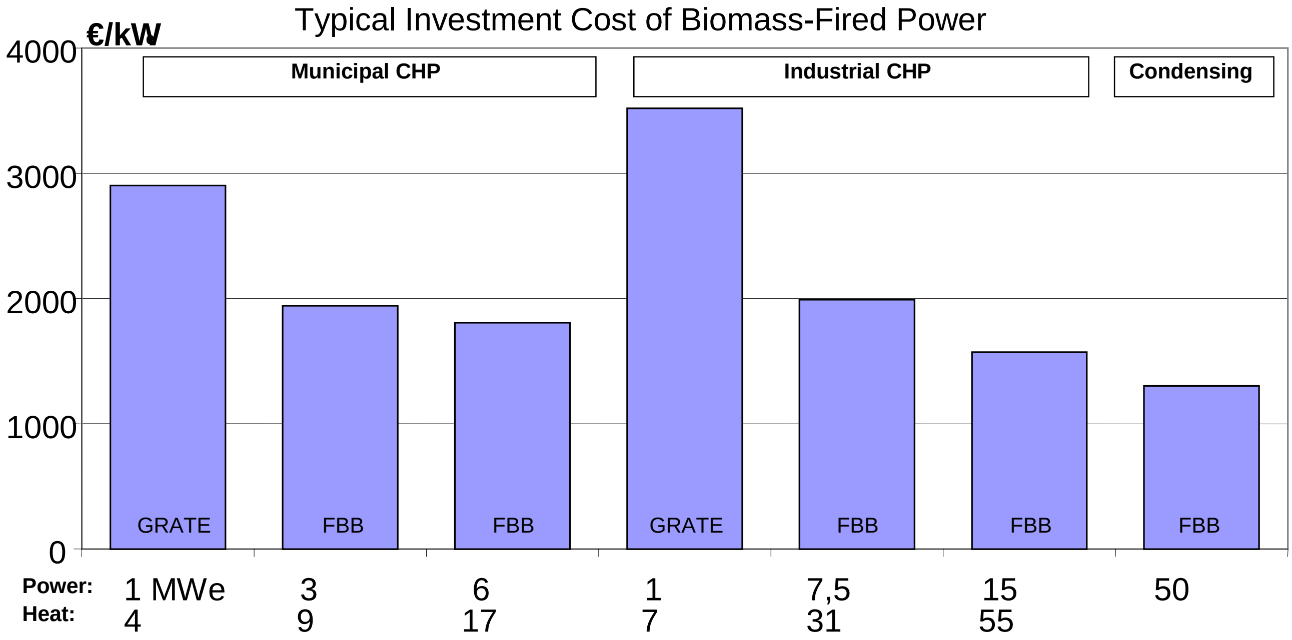


Figure 4-5 Typical investment cost of biomass-fired power plant, €/kWe

The breakdown of annual costs of biomass-based (CHP) power plant are typically allocated as follows:

- Fuel costs approximately 45%
- Operation and maintenance 25%
- Other/investment costs 35%

Smaller units the share of investment is usually higher. Annual maintenance cost (including periodic overhaul requirements) is typically 1-1,5% per cent of the initial investment cost.

5 KYOTO AND RENEWABLE ENERGY TARGETS

5.1 Kyoto protocol and Ireland’s commitments

The Conference of Kyoto (December 1997) was held as the third conference of the parties (COP 3) of the United Nations Framework Convention on Climate Change (UNFCCC) following Rio in 1992. The aim of the Kyoto Protocol is a 5,2% reduction of global emissions of six greenhouse gases – carbon dioxide, methane, nitrous oxide, sulphur hexafluoride as well as hydrofluorocarbons and perfluorocarbons – in the period of 2008-2012.

For the first time in the history of international climate policy quantitative ceilings where set on greenhouse gas emissions. According to Annex-B of the Kyoto Protocol, the parties´ contributions to the average emission target were defined individually:

Table 5-1 Parties' Kyoto Emission Target Contribution by 2010 (Baseline = 1990)

Country	Target
EU-15, Bulgaria, Czech Republic, Estonia, Latvia, Liechtenstein, Lithuania, Monaco, Romania, Slovakia, Slovenia, Switzerland	-8%
US	-7%
Canada, Hungary, Japan, Poland	-6%
Croatia	-5%
New Zealand, Russian Federation, Ukraine	0
Norway	+1%
Australia	+8%
Iceland	+10%

The EU accepted the Kyoto targets and aimed to meet the targets by introducing a framework directive aimed at facilitating the medium-term increase in the use of electricity generated from renewable sources (RES-E). The directive proposes that Member States are required to ensure the level of RES-E develops in conformity with the energy and environmental objectives undertaken at national as well as Community level. Member state therefore have to set and meeting national targets for the domestic future consumption of RES-E.

On the basis of the potential for further development of RES in the Community, the Commission’s White Paper on Renewable Energy Sources suggested an indicative target of 12% of the gross inland energy consumption of the Community as a whole by 2010. This 12% was translated into a specific share of consumption of electricity produced from renewable energy sources of 22.1%. The 1997 and 2010 RES-E of Member States is given in Table 5-2.

Table 5-2 Member States 1997 official EUROSTAT RES-E compared with indicative targets in 2010

	RES-E % 1997	RES-E % 2010	RES-E % 1997 without large hydro	RES-E % 2010 without large hydro
Austria	72.7	78.1	10.7	21.1
Belgium	1.1	6.0	0.9	5.8

Denmark	8.7	29.0	8.7	29.0
Finland	24.7	35.0	10.4	21.7
France	15.0	21.0	2.2	8.9
Germany	4.5	12.5	2.4	10.3
Greece	8.6	20.1	0.4	14.5
Ireland	3.6	13.2	1.1	11.7
Italy	16.0	25.0	4.5	14.9
Luxembourg	2.1	5.7	2.1	5.7
Netherlands	3.5	12.0	3.5	12.0
Portugal	38.5	45.6	4.8	21.5
Spain	19.9	29.4	3.6	17.5
Sweden	49.1	60.0	5.1	15.7
United Kingdom	1.7	10.0	0.9	9.3
European Union	**13.9%**	**22.1%**	**3.2**	**12.5%**

The possibilities of using large hydro are to a large extent dependent upon geographical conditions. In order to adjust for this, the above comparisons are presented both including and excluding large hydro. The differences in the country figures with regard to the current penetration of RES-E without large hydro indicate to some extent whether promotional RES policies have been successfully implemented.

The targets for individual Member States is presented in Table 5-3.

Table 5-3 Indicative figures for Member State targets for contribution of RES-E to gross electricity consumption by 2010

	Percentage*	**TWh**
Austria	78.1	*55.3*
Belgium	6.0	*6.3*
Denmark	29.0	*12.9*
Finland	35.0	*33.7*
France	21.0	*112.9*
Germany	12.5	*76.4*
Greece	20.1	*14.5*
Ireland	**13.2**	***4.5***
Italy	25.0	*89.6*
Luxembourg	5.7	*0.5*
Netherlands	12.0	*15.9*

Portugal	45.6	*28.3*
Spain	29.4	*76.6*
Sweden	60.0	*97.5*
United Kingdom	10.0	*50.0*
European Union	**22.1%**	***674.9***

*RES-E consumption as % of total gross electricity consumption of 3.058 TWh as forecasted in the baseline scenario

5.2 Initiatives undertaken in Ireland

As a consequence of the 1997 Kyoto agreement, Ireland has made a commitment to limit the growth in greenhouse gas emissions (principally CO_2) to 13% above the 1990 level by the target period 2008-2012. This is to contribute to the EU as a whole reducing emissions by 8%. The National Climate Change Strategy (NCCS) published in November 2000 by the Department of Environment and Local Government sets out how Ireland will achieve this target. Without the action set out in the strategy, it is projected that net annual emissions would increase by 37.3%. Reductions of 13.1 Mt CO_2 equivalent are required to meet the target.

Under the EU directive, adopted in September 2001, for the promotion of electricity from renewable energy sources, Ireland has also been set an indicative target of 13.2% of its national electricity consumption to be from renewable sources by 2010, compared with 3.6% (0.84TWh) in 1997. Under the Directive, Ireland had to adopt and publish a report in October 2002, setting a 10 year national indicative targets as a percentage of electricity consumption, and outlining the measures taken or planned, at national level, to achieve this national indicative target. The report (Department of Communications, Marine and Natural Resources, 2002) sets a national indicative target of a minimum contribution of 13.2% of green electricity to total electricity consumption by 2010. The planned approach is to intervene in the electricity generating market (in contrast to focusing on the consumers of electricity). The Department will engage in public consultation during 2003 to determine how best to meet the target set.

The EU White Paper for a Community Strategy and Action Plan for Renewable Sources of Energy sets a target for renewables penetration of 12% of gross inland energy consumption (TPER) by 2010, for the EU as a whole. Within this individual member states are left to determine their own targets and strategies. The Green Paper on Sustainable Energy provides this for Ireland. It sets a working target of 500MWe of additional electricity generating capacity from renewable resources for the period 2000-2005, the bulk of which will come from wind. Table ** summarises the contribution the working target is expected to make:

Table ** Renewable Energy Contribution based on additional 500MW 2000-05

RE Contribution to	1998	2000	2005
Installed capacity			
MW	308	407	937
%	7.15	8.75	16.61
Electricity generated			
GWh	1177	1454	3487

	%	6.09	6.31	12.39
TPER				
	kTOE	241	264	586
	%	1.9	1.93	3.75

* including large hydro

5.2.1 Initiatives in Response to the Targets

The Department of the Environment and Local Government issued a progress report on implementation of the NCCS in May 2002. The key points relevant to the Irish energy sector (heat and electricity, excluding transport) are:

- AER Competition. In order to attain the 500MW, the 5th AER competition was launched in May 2001, inviting tenders for 255MW of capacity from wind, biomass and hydro. In the event, in February 2002 PPAs for 370MW of capacity were offered.
  On 15th November 2002, Mr Demot Ahern, Minster for Communications, Marine and Natural Resources announced his intentions for AER VI. The intended category bands are:
    - Wind energy up to 470 MWe, divided into three sub-categories; large scale wind (350 MWe, cap price €cent 5.215 per kWh), small scale wind (70 MWe, cap price €cent 5.742 per kWh) and off-shore wind (up to 50 MWe, market test price €cent 8.4 per kWh).
    - Biomass up to 25 MWe (cap price €cent 6.412 per kWh)
    - Hydro up to 5 MWe (cap price €cent 7.018 per kWh)

  All information is subject to final confirmation by Government.
- Off-Shore Wind. The construction and operation of a 200 turbine, 520MW offshore wind farm in the Irish Sea on the Arklow Bank has been approved. Construction of Phase 1 (60MW) is expected to get underway by 2003. The development of off-shore wind resources is in addition to the 500MW target.
- CHP. Full market access has been granted to electricity from CHP. A report by the Irish Energy Centre published in December 2001, *An examination of the future potential of CHP in Ireland*, examines the status of CHP in the current market, its potential for growth, the barriers to growth, and measures to assist CHP meet NCCS targets.
- More Efficient Electricity Generation. Two new gas fired plants were commissioned during 2000, generating electricity at 55% efficiency compared to 34% for coal plant. Construction has been authorised of two new peat plants by 2005, to operate at 37% efficiency, as against 27% for the old peat plant they will displace.
- Sustainable Energy Authority of Ireland. Legislation was enacted in February 2002 to establish the Sustainable Energy Authority of Ireland as an independent body, incorporating the Irish Energy Centre, with increased funding and staffing. The new Authority has been allocated €222.5M in the National Development Plan 2000-06. Its brief is to promote the development of a sustainable national energy economy, through a greater awareness and understanding of energy issues, more efficient energy use, and a greater exploitation of renewable energy sources. Among the initiatives it is leading are:

  i. The €21.1M *House of Tomorrow* programme offering support for R&D and demonstration projects leading to more sustainable energy performance in Irish housing
  ii. A major €12.7M work programme to improve energy efficiency in public-sector buildings
  iii. A *Best Practice Programme* to stimulate energy efficiency in industry and commerce, including seminars, workshops, conferences, exhibitions, site visits, publications, the National Boiler Awards, and a Self-Audit Scheme for large industry.
  iv. The Renewable Energy Information Office to promote and provide information about renewable energy sources.
  v. A €16.5 Research, Development and Demonstration Programme for renewables was launched on 19th July 2002.
  vi. A €5 million Combined Heat and Power (CHP) / District Heating (DH) Research, Development & Demonstration programme.

- Building Regulations. In September 2001 consultation documents were issued on the revision of national building regulations relating to energy conservation. The changes were expected to become operative from 1 July 2002 reducing the requirements for space and water heating by 23-33%. In June 2002 the revised regulations were made operative from 1 January 2003.
- National House Condition Survey. Questions on heating types, fuel consumption and methods of insulation have been added to the survey, which is carried out every 10 years.
- Carbon Energy Taxation. The Minister for Finance announced in December 2002 that "… the Government has asked the relevant Departments to advance the plans for a general carbon energy tax, with a view to introducing this from the end of 2004." (Department of Finance, 2002).
- Emissions Trading. The National Climate Change Strategy proposed Irish participation in the EU pilot emissions trading scheme (over the period 2005-2007) and in international emissions trading. This proposal is now being implemented. The scheme will involve about 35 of the largest energy users in the Republic of Ireland.
- Afforestation Rate. The national planting target is 20,000 hectares per year to 2030, with the overall aim of achieving 17% forest cover (Department of Agriculture, Food and Forestry, 1996). The total area afforested in 2001 was 15,464 hectares (Forest Service, Coillte and Magner, 2002). The area planted in 2003 is expected to be significantly reduced due to the national budgetary situation.
- Short Rotation Coppice development. Two pilot projects have been approved to establish short rotation willow coppice, one in the south-east and the other in the north-west, both of 50 hectares.
- District Heating. A study on the potential of district heating in Ireland, commissioned by Sustainable Energy Ireland, was published in September 2002 (WS Atkins Consultants Ltd., 2002).

5.2.2 Support Mechanisms

The ESB is obliged by Government to purchase electricity generated from peat and renewables. This costs the ESB more than electricity purchased from a "Best New Entrant" generator (currently gas-fired CCGT). Historically the additional costs of electricity generated from peat and renewables have been recovered by the ESB from customers through higher prices for electricity than would otherwise have been charged. Table 5-4 presents the financial support for different renewables under the most recent Alternative Energy Requirement competition (AER V). These are contrasted with the intended AER VI prices announced by the DCMNR on 15th November 2002.

Table 5-4 Financial Support for Renewables under AER V

Technology/Fuel		Price eurocent/kWh	Amount of Support eurocent/kWh	Intended AER VI cap price at 15th November 2002.
Best New Entrant 2002		4.41	0	
Renewables	Large Wind	4.55 to 4.81	0.14 to 0.40	5.216
	Small Wind	4.72 to 5.30	0.31 to 0.89	5.742
	Biomass	3.77 to 5.92	-0.64 to 1.51	6.412
	Small Hydro	6.41	2.00	7.018

Notes:

- The prices given are for export from the generating station, before transmission losses.
- The amount of support is the difference between the export price and the BNE price.
- The prices for the different renewables are taken from the AER V competition results announced in February 2002: for large and small wind and biomass these are the lower and upper limits of the prices accepted; for small hydro it is the weighted average.
- The Best New Entrant price for electricity is determined annually by the Commission for Energy Regulation. The 2002 price is taken from CER (2001).

Statutory Instrument 217 puts in place a new Public Service Obligation (PSO) system from 1st January 2003. The additional costs above Best New Entrant costs of specified peat and renewable generation, and associated administrative expenses, are recovered from customers of all suppliers through a PSO levy added to their bills. From 1st January 2003 the extra cost is separately identified on electricity bills as “Public Service Obligations Levy”. The Commission for Energy Regulation has published the allocation of the 2003 PSO as follows (CER, 2002):

Table 5-5 Allocation of 2003 PSO

Cost	Million euro	GWh
Peat-related costs	38.929	1910
AER-related costs	6.568	710
Administrative costs	1.076	
Total	**46.573**	**2620**

Based on the above data, the amount of PSO 2003 support per kWh for peat (including both ESB PowerGen and Edenderry Power) and renewables (through AER) can be calculated. The result is shown in Table 5-6.

Table 5-6 PSO 2003 Support for Peat and Renewables

Cost	PSO Support Cent per kWh
Peat	2.04
AER	0.93

ESB is also obliged under the PSO to construct and commission new peat power generating stations at Lanesboro and Shannonbridge, and to purchase the peat required "...on terms having equivalent economic effect (as determined by the Commission) as the terms of the fuel supply agreement made between Bord na Móna and Edenderry Power Limited.." The peat must be harvested within the State. The costs of building the new plants at Lanesboro and Shannonbridge will be included in future PSO Levies. It is the Consultants' understanding that these costs are not included in the 2003 PSO Levy. Bord na Móna sells peat at market prices to the electricity generators, who are compensated for the extra cost of generating power from peat through receipt of monies from the PSO levy. The Transmission System Operator is to give priority of dispatch to generating stations using peat or renewables.

Eligibility of Co-firing under AER and the Peat PSO

AER has not to date supported co-firing. The invitation for AER5 stated:

> *Proposals in the biomass category may include plants requiring the use of some fossil fuel source to prepare and/or ignite and/or sustain combustion of non-fossil fuel(s). Such biomass plants may be considered eligible for this competition provided that they are designed and operated to use the minimum of fossil-fuel necessary for that purpose and provided that in any event less than 10% of the fuel input is from fossil fuel sources.*

The Department of Communications, Marine and Natural Resources has been asked whether this might change in future AER rounds, and have replied that there should not be*"...insurmountable problems about reviewing the current threshold providing the proposal is within the spirit of the renewables programme generally."*

The Electricity Regulation Act 1999 (Public Service Obligations) Order 2002 (SI217/2002) expresses the PSO for peat in the following terms:

> *There shall be imposed by the Commission (CER) on the Board (ESB) a requirement to take such steps and make such arrangements as are necessary to secure that (…) the Board has available to it and purchases the amount of electricity generated by the generating station (…) being a generating station which uses peat as its primary energy fuel source (…)*

The term 'primary energy fuel source' is not defined, and needs clarification, but an informal indication suggests co-firing up to 13% might be compatible with peat being considered the primary fuel. Two points arise:

- If the amount of co-firing was low enough not to effect the status of peat as primary energy fuel source, the electricity generated by co-firing would appear to be eligible for the peat PSO levy
- If not, the terms of the order would need to be changed to allow co-firing without prejudicing the peat PSO levy

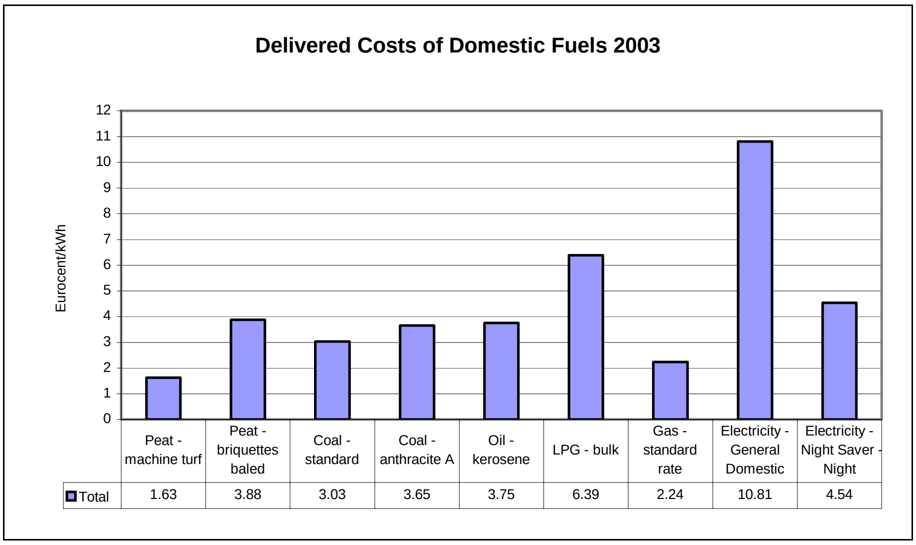
Taxation of Fuels Used For Heat

There is no direct subsidy for the use of any fuel for heat. However, differential rates of taxation act in effect as a negative subsidy. All fuels used for heat are subject to VAT at the reduced rate of 13.5%, but additionally oil and LPG are subject to excise duties, though these are substantially less than on the use of these same fuels for transport.

Residential (Domestic) Fuels

Figure 5-1 presents the delivered costs for residential (domestic) fuels in 2003 (Sustainable Energy Ireland, 2003; ESB, 2003). The figures exclude bimonthly standing charges which are as follows: bulk LPG €15.23; natural gas standard rate €27.92; electricity standard tariff "Private Dwellings - Urban Standard" €6.95 plus PSO levy €2.18; electricity standard tariff "Night Storage Heating" €1.08.

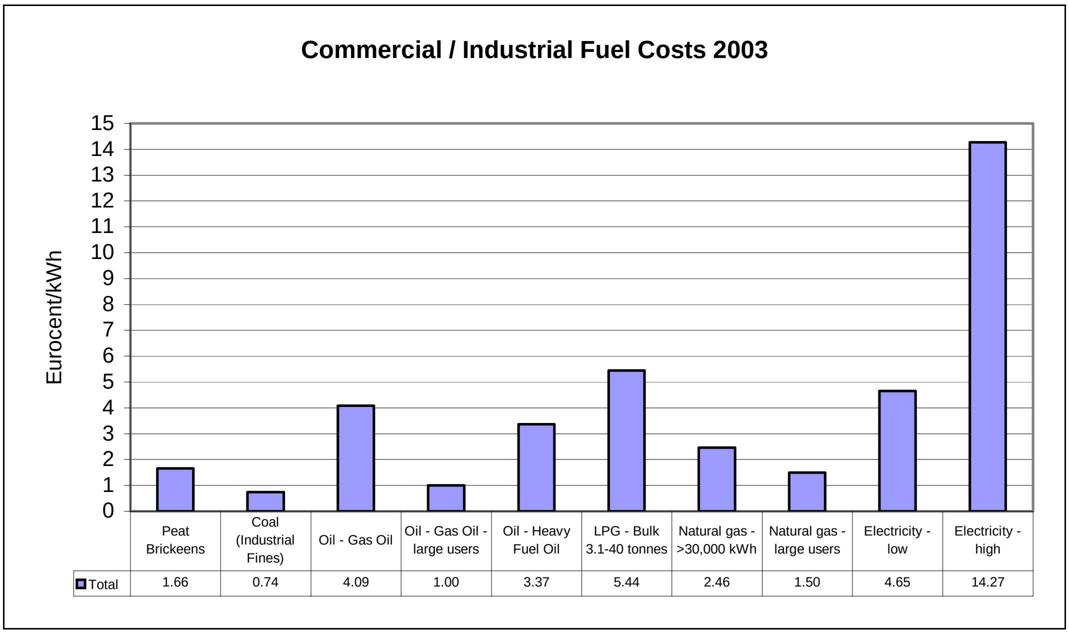
Figure 5-1 Delivered Costs for Domestic Fuels 2003



Commercial / Industrial Fuels

Figure 5-2 presents the costs for commercial and industrial fuels (Sustainable Energy Ireland, 2003; O'Rourke, 2002; ESB, 2003). The costs for peat and coal do not include delivery charges. The cost for natural gas excludes standing charges. The cost for electricity excludes standing charge, PSO levy, demand charge, service capacity charge and low power factor surcharge. The price per kWh of electricity for business consumers depends on a number of factors including supply voltage, consumption and time of year. Low and high electricity cost examples are given. The gas oil price of 4.09 cent per kWh is equivalent to 43 cent per litre.

Figure 5-2 Commercial and Industrial Fuel Costs 2003



5.3 Penalties of not meeting the targets set by Kyoto protocol, RES-E directive and proposal for GHG trading directive

5.3.1 RES-E directive

The directive on the promotion of electricity from renewable energy sources in the internal electricity market (2001/77/EC) sets indicative targets for Member States for proportion of renewable energy sources in gross electricity consumption. For Ireland this target is 13,2 %. The directive, however, suggests no penalties of not meeting this target.

5.3.2 Proposal for GHG trading directive

The proposal for a directive establishing a scheme for greenhouse gas emission allowance trading within the Community (COM(2001) 581 final, 23.10.2001) suggests strong penalties for non-compliance. According to the Explanatory Memorandum of the proposal *"essential is that the penalties for non-compliance are sufficiently high to ensure that it makes no sense for an operator not to go out and buy from the market a sufficient number of allowances to cover the installation's actual emissions."*

It was confirmed in December 2002 that with effect from 1 January 2005, all installations carrying out any of the activities listed in Annex I[3] and emitting greenhouse gases must be in possession of an appropriate permit issued by the competent authorities. In the first phase of the scheme (2005-2007) a financial penalty of EUR 40[4]

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[3] Annex 1, in respect to carbon dioxide emissions: Energy activities: combustion installations with a rated thermal input exceeding 20 MW (excepting hazardous or municipal waste installations)…also Other activities: Industrial plants for the production of pulp from timber or other fibrous materials and paper board with a production capacity exceeding 20 tonnes per day.

[4] Announced on 9th December 2002

per excess tonne or twice the average market price during a predetermined period, whichever is the higher, is proposed. Respectively, from the Kyoto commitment period onwards (from 2008 onwards) the proposal suggests imposition of a financial penalty either at a rate of EUR 100 per excess tonne or twice the average market price during a predetermined period, whichever is the higher. Furthermore, payment of the excess emissions penalty shall not release the operator from the obligation to surrender an amount of allowances equal to those excess emissions when surrendering allowances in relation to the following calendar year. Other than setting the level of penalty for each tonne over-emitted, Member States shall determine and apply sanctions for breaches of the Directive that are “effective, proportionate and dissuasive”.

5.3.3 Kyoto Protocol

At COP 7 in Marrakech in 2002, Parties adopted a decision on the compliance regime for the Kyoto Protocol. It is rather comprehensive and rigorous in the international arena. It makes up the "teeth" of the Kyoto Protocol, facilitating, promoting and enforcing adherence to the Protocol’s commitments. (UNFCCC 2002)

The compliance regime consists of a Compliance Committee made up of two branches: a Facilitative Branch and an Enforcement Branch. The facilitative branch aims to provide advice and assistance to Parties in order to promote compliance. The enforcement branch has the power to apply consequences to Parties not meeting their commitments.

In the case of compliance with emission targets, Annex I Parties are granted 100 days after the expert review of their final annual emissions inventory has finished to make up any shortfall in compliance (e.g. by acquiring AAUs, CERs, ERUs or RMUs through emissions trading).

If a Party’s emissions are still greater than its assigned amount at the end of this 100 days period, it must make up the difference in the second commitment period, plus a penalty of 30% (i.e. 1,3 times the amount in tonnes in excess emissions). It will also be barred from "selling" under emissions trading and must develop a compliance action plan within three months detailing the action it will take to make sure that its target is met in the next commitment period.

6 THE VALUE OF CARBON CREDITS FOR WOOD FUEL PRODUCERS IN IRELAND

6.1 General

The so called *flexible mechanisms* defined in the Kyoto Protocol would create a market value for carbon dioxide emissions reduction, if the protocol entered into force. The Kyoto protocol allows for three kinds of flexible mechanisms to reduce global greenhouse gas (GHG) emissions: *"Clean Development Mechanism" (CDM), "Joint Implementation" (JI), and "Emissions Trading" (ET).*

Through CDM Kyoto protocol parties are able to carry out carbon reduction projects in developing countries and use these reductions in meeting their own GHG reduction targets. Joint Implementation is basically same as CDM, but the projects are implemented in Annex I (developed) countries. The idea behind these systems is that marginal costs of GHG abatement are lower in many Non-Kyoto Protocol party countries and Eastern European countries, and thus CDM and JI would increase the cost efficiency of international climate policy.

JI and CDM systems can also be called as "Baseline-and-credit" type emissions trading systems. In this kind of a system the commodity is a unit of GHG emission reduction (1 tonne of carbon dioxide equivalent). This requires a definition of *baseline*, which represents the business-as-usual scenario, *i.e.* what would the amount of GHG emissions had been without the project. The actual emissions of the project are measured respectively, and the amount of "carbon credits" (or, more precisely, certified emission reductions (CER) in CDM and emission reduction units (ERU) in JI) created by the project are calculated as the difference between baseline emissions and actual emissions.

From the Ireland's wood fuel producers' point of view, Joint Implementation and Clean Development Mechanism, however, are not likely to offer considerable business opportunities, since the GHG reduction projects are carried out abroad. However, the third flexible mechanism, Emissions Trading, may become relevant for Ireland's wood fuel producers. The Kyoto Protocol, if entered into force, would allow for emissions trading within the Protocol party countries. This kind of emissions trading is sometimes called "Cap-and-Trade" type emissions trading system. In this system it is not GHG emission reductions that are the commodities, but rather *emission allowances*. An amount (based on climate chance policy targets) of allowances for GHG emissions are initially allocated to market participants. If a market participant causes less emissions than it has allowances for, it is able to sell these "surplus allowances" to a market participant in need for more allowances. This mechanism should direct the emission reduction activities where they are most cost-efficient. In this respect the most topical issue at the moment is the proposal of the European Commission for a community-wide GHG trading scheme.

6.2 European Commissions Proposal for a Directive establishing a scheme for greenhouse gas emission allowance trading within the Community (COM/2001/0581 final)

The GHG trading proposal by the European Commission arises from the need for the European Union to reduce its emissions of greenhouse gases cost efficiently and meet its obligations under the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

The proposal requires operators of installations undertaking the activities listed in Annex I of the Directive to hold *a greenhouse gas emissions permit* as a condition for emitting greenhouse gases from their installations. The greenhouse gas emissions permit would lay down monitoring, reporting and verification requirements in respect of direct emissions of greenhouse gases specified in relation to those activities, creating the framework for the participation of the installation in the emissions trading scheme.

The permit would further require operators of installations undertaking the activities covered by the scheme to surrender, on an annual basis, *sufficient allowances to match their verified emissions* of the relevant greenhouse gases for the previous calendar year. A failure to surrender sufficient allowances to match verified emissions would result in the imposition by Member States of substantial penalties.

In the beginning of first phase of the proposed scheme (1.1.2005) the allowances would be allocated to companies involved at no cost. Companies that are able to cause less CO_2 emissions than they have allowances for, could sell the surplus allowances for companies, which have need for additional emission allowances. Additionally, not only companies with an emission cap would be able to participate in the trading scheme, but in principle all companies (*e.g.* wood fuel producers), individuals, NGOs etc. would be able to buy and sell emission allowances.

There is, however, a provision made in the Annex III of the proposal increasing uncertainty in profiting from GHG trading by wood fuel producers. In Annex III (4) it is stated that "*[the allocation] plan shall be consistent with other EC legislative and policy instruments. In particular, no allowances should be allocated to cover emissions which would be reduced or eliminated as a consequence of Community legislation on renewable energy in electricity production, and account should be taken of unavoidable increases in emissions resulting from new legislative requirements.*" What this would mean in practice remains unclear at the moment.

However, the provision can generally be interpreted as a measure to prevent the plant operators "double benefiting" from both emissions trading and possible Community-wide support scheme for RES in future, if such will be proposed in coming years. However, the wording does not express any attitude concerning the linkage between Community-wide GHG trading and *national* support schemes, but the national support schemes might be affected by emission trading scheme as well (*e.g.* depending on the opinion the Commission will adopt on the inspection and endorsement of national RES support schemes if GHG trading scheme is in place).

The proposed system is in line with the ET in Kyoto protocol, but would involve only certain industries and only within the EU. At the moment this proposal seems the most likely application of GHG trading to be established and having an impact on Ireland's wood fuel producers. Therefore, in this study, the directive proposal has been chosen as a starting point, based on which the calculations and analysis of carbon credits will be carried out. In Table 6-1 the main features of the proposed GHG trading scheme are summarised.

Table 6-1: Main characteristics of the Proposal for a Directive establishing a scheme for greenhouse gas emission allowance trading within the Community

Geographical scope of the system	The European Union (However, there exists the possibility to link the Community scheme with those of other Parties

	to the Kyoto Protocol by entering into agreements with those other Parties to mutually recognise each other’s allowances.)
Sectors involved	*Energy activities* Combustion installations with a rated thermal input exceeding 20 MW (excepting hazardous or municipal waste installations) Mineral oil refineries Coke ovens *Production and processing of ferrous metals* Metal ore (including sulphide ore) roasting or sintering installations Installations for the production of pig iron or steel (primary or secondary fusion) including continuous casting, with a capacity exceeding 2.5 tonnes per hour *Mineral industry* Installations for the production of cement clinker in rotary kilns with a production capacity exceeding 500 tonnes per day or lime in rotary kilns with a production capacity exceeding 50 tonnes per day or in other furnaces with a production capacity exceeding 50 tonnes per day Installations for the manufacture of glass including glass fibre with a melting capacity exceeding 20 tonnes per day Installations for the manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain, with a production capacity exceeding 75 tonnes per day, and/or with a kiln capacity exceeding 4 m^3 and with a setting density per kiln exceeding 300 kg/m^3 *Other activities* Industrial plants for the production of (a) pulp from timber or other fibrous materials (b) paper and board with a production capacity exceeding 20 tonnes per day
Number of installations involved	Estimated 4000 – 5000 in year 2010 (46 % of CO_2 emissions within the Community)
Coverage of gases	Initially only CO_2. Inclusion of other gases to be considered as monitoring and administration develop: Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur Hexafluoride (SF_6)
Initial allocation of emission allowances	*First phase (2005-2007):* no cost, method of allocation to be decided by the Member States. *Kyoto commitment period (2008-2012):* harmonised allocation method within the Community.
Banking of allowances	Allowed between 2005-2007 and from 2008 onwards. Banking from the first period to the second decided by Member States.
Links to other legislation	Council Directive 96/61/EC concerning integrated pollution prevention and control “IPPC Directive”: GHG emission permit will be tightly linked to national permitting procedures in accordance with the IPPC Directive. Directive 90/313/EEC on the freedom of access to information on the environment: The public should have access to information concerning the results of the monitoring, reporting and verification obligations, information on holdings in national registries and any actions concerning breaches of the Directive Legislation concerning renewable energy: Proposal’s Annex III (4) defining principles of initial allocation of emission allowances: *“The plan shall be consistent with other EC legislative and policy instruments. In particular, no allowances should be allocated to cover emissions which would be reduced or eliminated as a consequence of Community legislation on renewable energy in electricity production, and account should be taken of unavoidable increases in emissions resulting from new legislative requirements;”*

6.3 The effectiveness of a the community-wide GHG trading scheme on the price competitiveness of wood fuel in Ireland

This section considers a GHG trading scheme and compares its effectiveness with the alternative of support measures for renewable electricity generation (RES-E) in selected EU member states. The methodology includes the determination of the value of carbon dioxide allowances expressed in terms of electricity price for a range of generating technologies.

The estimated price per allowance (tonne of carbon dioxide equivalent) is in many studies estimated to fall in a range of 20 – 49 €. However, recent developments have indicated that these figures may be overestimated. The 6th Conference of the Parties in Bonn in July 2001, for example, made a number of decisions that are likely to bring prices down. According to Electrowatt-Ekono's view the price per allowance could rather be around 10 € during the first and second phase of the scheme, *i.e.* between 2005 and 2012. This view is based on active research and market follow-up. The price level is, however, sensitive to suppositions and changes in the market and policies.

Varilek and Marenzi (2001) list most important factors either raising or bringing down the price per allowance. Factors raising the price level include:

- Higher transaction costs due to inefficient trade system structures
- Limited sectoral coverage
- Restrictions on permit banking
- Discounting or elimination of surplus permits in economies in transition (so called *"hot air"*)
- Exercise of market power by some participants
- Failure to harmonise national trading systems
- A compliance reserve
- Voluntary enforcements of supplementary restrictions
- A tax on trade
- Participation of the US in the GHG trading scheme

Factors bringing down the price level include:

- Inclusion of multiple GHG's
- Low penalties for non-compliance
- Application of voluntary rather than mandatory regulations
- Crediting from carbon sinks

Additionally, indicating lower price level, it has to be pointed out that the models used in estimating costs of emissions trading *ex ante* have also earlier over-estimated the price level. (This happened for example in the case of SO_2 emissions trading scheme in USA.)

An example calculation is presented in Table 6-2 and the following figures. It determines an equivalent electricity price for an emission trading scheme based on a 100 MWe condensing power plant. Price levels of 10 €, 20 € and 30 € per emission allowance (tCO_2) have been used in the calculation. The plants are 100 MWe condensing power plants operating 8000 hours per year with efficiency between 0,40 for peat fuelled plant and 0,56 for natural gas fuelled plant[5].

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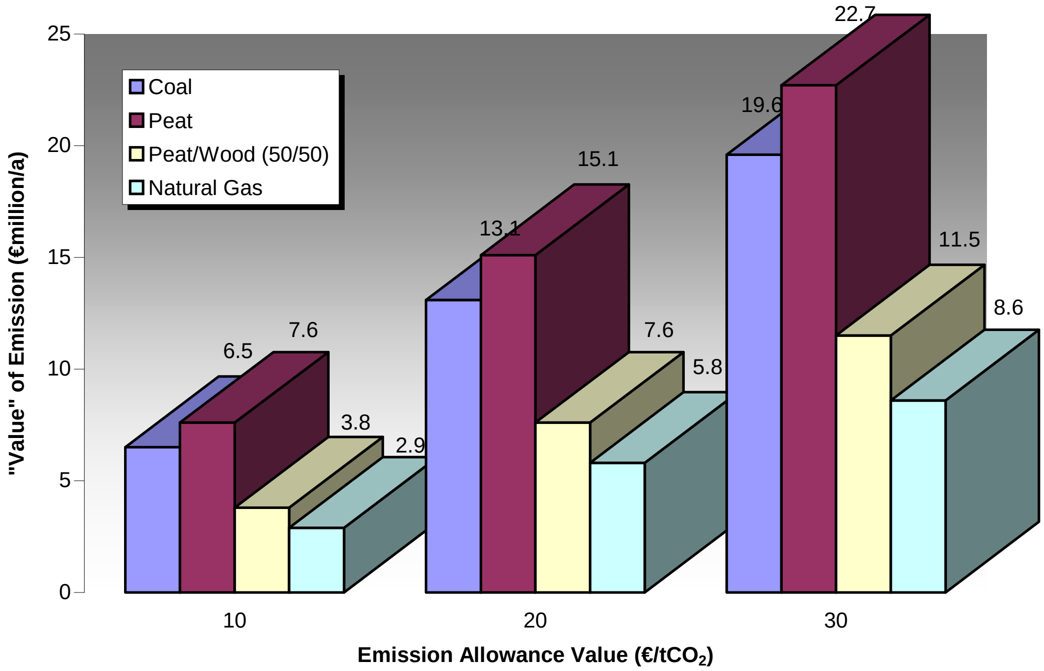
[5] In fact, the calculation is not dependent on plant size or annual production but only on fuel used and efficiency of the plant (and of course the price level of emission allowances).

Table 6-2: Emissions from 100 MWe generating installations based on different fuel types and technologies

SOURCE VALUES	Coal	Peat	Peat/Wood 50/50	Natural Gas
CO_2 emission factor, g/MJ	93	105	53	56
Efficiency	0,41	0,40	0,40	0,56
Electricity Production, GWh_e/a	800	800	800	800
Fuel consumption, GWh/a	1 951	2 000	2 000	1 429
Fuel consumption, GJ/a	7 023 600	7 200 000	7 200 000	5 144 400
Emissions, t/a	653 195	756 000	381 600	288 086

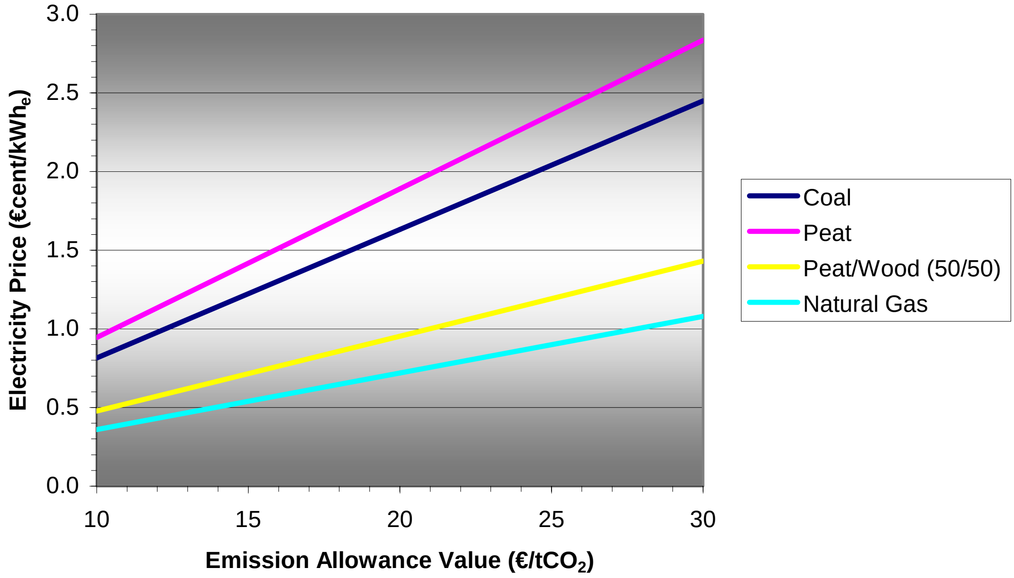
The financial incentive for replacing the current fuel causing CO_2 emissions by CO_2 neutral biofuels in the four different plants is summarised in Figure 6-1. This is calculated by multiplying the annual CO_2 emissions by the emission allowance value. The benefit is valid irrespective of the initial allocation method in the emission trading scheme, since even in the case of no-cost allocation, the plant would benefit by decreasing the amount of incremental allowances to be purchased or increasing the amount of surplus allowances to be sold in the emission allowance market at the given prices.

Figure 6-1 The Potential Value of Emission Allowances for 100 MWe Condensing Power Plants



Due to the CO_2 emission factors and the assumed plant efficiencies, the financial incentive to replace fossil fuel with wood is smallest in the case of natural gas and the greatest in the case of peat. To better illustrate the value of emission allowances, Figure 6-2 shows the allowance price expressed in terms of electricity price. Expressing the allowance in this manner allows for easy comparison with RES support mechanisms. This is especially useful for decision-making where a plant is eligible for either RES-E support or as a participation in an emissions trading scheme.

Figure 6-2 Emission Allowance Price expressed in terms of Electricity Generation Price



For example, assuming an allowance price of 10 €/tCO$_2$, the financial incentive for a plant operator to replace the following fuels expressed in terms of electricity price is:

natural gas,	0.36 €cent/kWh$_e$
peat,	0.945 €cent/kWh$_e$.
coal,	0.816 €/kWh$_e$
peat/wood,	0.477 €/kWh$_e$

With allowance price levels of 20 €/tCO$_2$ and 30 €/tCO$_2$, the incentives are respectively doubled and tripled compared with a price level of 10 €/tCO$_2$.

If this incentive were added on top of a national support scheme when biofuel is substituting fossil fuels, it clearly would make contribution to the competitiveness of biofuels in energy production. However, as stated earlier, “doubl-benefiting” is likely to be prevented by the Commission. If, for example, the incentive provided under a GHG trading scheme and a RES-E supporting scheme where both available to a plant operator or policy maker, it would then be necessary to compare the benefits of each option to determine the most viable choice. The choice however may be ambiguous, since the RES subsidy levels vary widely between the Member Countries.

The cost impact shown in Figure 6-2 can be compared with support levels in countries presented in chapter 9. In fact, from RES-E point of view, the incentive provided by emission trading can be regarded as a kind of price-premium mechanism, for example in Spain (see **Table 9-11**, page 98): if a plant is able to reduce its emissions under the amount of allowances possessed by it, the surplus can be sold to the market thus bringing in extra revenues in addition to electricity sales revenues. If a plant is overrunning its emissions compared with the allowances it possesses, the shortfall would be bought from the market at a the prevailing allowance price. The latter case can thus be compared with carbon tax.

Ireland’s subsidy levels can be calculated comparing the so called “Best New Entrant” (BNE) price and prices of RES electricity in AER 5 competition results. The BNE is currently gas fired CCGT with a reference price of 4,41 €cent/kWh. Respectively the cap price of biomass electricity in latest AER competition was 5.92 €cent/kWh. This difference (1.51 €cent/kWh) – financed by a Public Service Obligation Levy – is thus the “premium-price” for customers to be paid for biomass-based electricity instead of BNE choice. Comparing the level provided by AER 5 and estimated incentive provided by emission trading, it can be seen that contracts awarded in AER 5 are currently more favourable for biomass-based production than the benefit from emission trading only.

Compared to the price-premiums provided in Spain the emission trading incentive seems relatively low at assumed allowance price levels. At the level of 10 € the benefit from replacing peat or coal in emission trading is about 30 % of the incentive provided by the Spanish price-premium levels for biomass. Even at the allowance price level of 30 € the benefit of replacing peat with wood is only around same level with Spanish price-premium for biomass.

However, compared with Finnish subsidies (or tax refunds), the emission trading incentive is higher. In Finland biomass and mini hydro receive a tax refund of 0.42 €cent/kWh, and wind power respectively 0.69 €cent/kWh. In addition, however, renewable energy production receives investment subsidies, and the subsidy level would probably be about the same level for biomass and higher for wind compared to the estimated incentive provided by the emission trading.

In Sweden wind power under 1,5 MW has been able to receive different subsidies of some 3.3-3.4 €cent/kWh on top of electricity price. Support for biomass (only investment subsidy available), however, has been much lower being only around 0.55-0.75 €cent/kWh. Thus in Sweden the GHG trading scheme would give stronger incentive for biomass but weaker incentive for wind energy compared to the existing support schemes. In the proposed certificate system in Sweden the average price level of a certificate is estimated at 1.0 €cent/kWh, and 1.6 €cent/kWh at the maximum. The price is estimated to grow until 2010 and thereafter begin to decrease. The penalty of non-compliance with certificate purchasing – and thus the absolute price gap of a green certificate – would be about 2.0 €cent/kWh.

In Germany, assuming electricity market price being around 2.5 €cent/kWh, the fixed tariffs for biofuels would be around 6.0 – 8.0 €cent/kWh higher, thus being far above the incentive provided by emission trading *plus* electricity price for the use of wood fuel instead of fossil fuels. (A recent study, however, suggests that even the level of fixed tariff is not high enough, giving incentive only for large-scale use of biomass in electricity production.)

To conclude, if the European Commission will prevent the “double benefiting” from both emission trading and RES support schemes, the former might make little contribution to promotion of RES. This is because the emission trading alone, at supposed price level, would not give strong incentive enough for use of RES in many cases, compared to RES support levels in certain countries. The support levels needed by RES and provided by different Member Countries often exceed the incentive provided by emission trading scheme. However, these policy instruments may be integrated in many ways, and whether emission trading contributes considerably to the use of RES, depends on the actual implementation and integration of these instruments. Thus this comparison must be seen as an example only.

7 VALUE OF REDUCTIONS IN SOX EMISSIONS

7.1 General

Sulphur dioxide (SO_2) is produced from the combustion of sulphur-containing fuels, such as coal and peat. In terms of environmental impact, emissions of SO_2 are known to cause acid rain which has an adverse effect on ecosystems and causes damage building fabric. In terms of operational impact, the sulphur content of the flue gas creates a corrosion risk at the cold end of the boiler, i.e. air-preheaters.

Emissions of SO_2 are limited by legislation and, in the case of certain classes of combustion plant, will necessitate the use of desulphurisation systems, especially in large combustion plant.

The SO_2 abatement method depends on the combustion technology, which defines whether primary or secondary (or combination of both) abatement methods can be used. Primary methods can be applied with no or minor investment whereas secondary methods may require significant plant modification. Independent of the method, sulphur abatement involves introducing a sorbent material into the combustion process to react with sulphur and produce solid compounds, which are easy to collect in conventional dust abatement systems.

In the case of fluidised bed and pulverised firing technology, a primary abatement method can be applied where sorbent (normally crushed limestone) is introduced into the furnace where it mixes and reacts with sulphur compounds. The reaction is completed in the downstream flue gas passes and the solid reaction product, gypsum, is collected by the conventional dust abatement system, such as an electrostatic precipitator or a bag filter. The primary method has been found to be most effective with fluidised bed technology, and less so with pulverised firing since the sorbent residence time and combustion temperatures above those for the optimal reaction rate.

Replacing part of a high-sulphur-content fuel with a fuel of low sulphur content can be considered as a primary method, as well. For instance, wood contains negligible amounts of sulphur. Environmental and performance tests carried out for power plants operating solely on wood based fuels show that the levels of SO_2 emissions are virtually zero. Displacing proportions of the sulphur-containing fuel with wood fuel in a combustion process would reduce the SO_2 emissions with a corresponding reduction in the running costs of the desulphurisation system.

In regard to secondary sulphur abatement method, there are two main technologies available: dry and wet systems flue gas treatment systems. The dry sulphur abatement method involves injection of reagent to the cold end of the flue gas pass, prior to the dust collector (normally a fabric filter). The reaction between the sulphur and the reagent takes place on the surface of the fabric filter, from where the reaction product solids are discharged to the ash removal system.

Wet abatement technology, such as a spray tower or venturi scrubber, involves washing the flue gas with a mixture of sorbent and water. Wet abatement systems are often used in connection with large-scale power plants firing high sulphur content coal, but in general these systems require large investment, and are more complex to install and operate compared with modern dry injection systems.

7.2 Opportunities in Ireland

There are six plants in Ireland that operate on sulphur-containing fuels and could benefit from wood fuel substitution:

Bellacorick	Peat
Cushaling	Peat
Lanesboro	Peat
Moneypoint	Coal
Rhode	Peat
Shannonbridge	Peat

The Moneypoint coal power station is an older plant whose future is under discussion. It is unlikely to be viable if FGD (flue gas desulphurisation) is required to be retrofitted. This plant is not considered a likely candidate for fuel substitution. Similarly Bellacock and Rhode are both old plants. The former is now closed and the latter is not operating.

The existing Lanesboro and Shannonbridge plants are to be replaced with new fluidised bed plant using limestone to limit SO_2 emissions. Cushaling (Edenderry) is a new peat fired power station that uses limestone addition to the abate SO_2 emissions. These three peat-fired plants could benefit from reduced lime consumption if they are co-fired with wood fuel.

7.3 Technical Issues

The amount of limestone used for SO_2 abatement depends on the sulphur content of the fuel, the quality and reactivity of limestone, and operation of the combustion process (combustion and flue gas temperatures and residence times). For example, for peat with a sulphur content from 0.1 up to 1.0 % (dry basis), the limestone flow into the boiler is about 1 % of the fuel flow. For peat with a sulphur content from 1.0 up to 3.0 % (dry basis), the limestone/lime flow into the boiler and the FGD plant is between 1% and 4 % of fuel flow.

Assuming the wood fuel is in the form of wood chips, then the calorific value (CV) of peat is higher than that of the chips. In order to maintain the same energy supply rate, the mass flow rate of wood fuel supply has to be greater than that of peat according the ratio of CVs, i.e., if the CV ratio of peat:wood is 1.06, then for every 1 tonne of peat displaced by wood, 1.06 tonnes of wood is used; all figures are on a lower heating value.

Trials co-firing wood with peat have been carried out at Edenderry with promising results. Little modification is required to the existing plant, and the expected reductions in SO_2 were achieved.

7.4 Costs

Assuming the cost of limestone is €100/t delivered. For peat with <1.0% sulphur content, 10 kg of limestone is added to every one tonne of peat burnt giving a limestone cost of €1 per tonne of peat burnt.

Replacing peat with wood chips would require 1.06 tonnes of wood chips per tonne of peat displaced. The value of wood chips in terms of it’s the benefit in reducing limestone consumption is €1/1.06 = €0.95 per tonne of wood chips. There would also be further minor savings in limestone supply plant operation such as electricity consumption, operation and maintenance etc., which have not been considered. On the negative side, the increased flue gas volume flow rate would require the induced draft fans to operate at higher load which will create an associated increase in power consumption, maintenance and repair costs.

Assuming wood chips account for 30% by mass of the fuel supplied, then the calculated reduction in the marginal cost of generation due to the reduced limestone consumption is equivalent €cent 0.02 per kWhe.

7.5 Conclusions

Substituting sulphur-containing fuels with wood fuel to reduce the use of sorbent in SO_2 abatement is feasible.

The actual cost savings are small, plant specific and dependant on such factors as fuel sulphur content and calorific values. Each situation must be studied to establish the actual benefits.

8 ENERGY PRODUCTION TECHNOLOGY AND COSTS

8.1 Commercial and Industrial

Electricity production costs of biomass-based combined heat and power production are based on Electrowatt-Ekono`s internal energy cost calculation tool, Power-Cost. Power Cost includes a detailed cost-breakdown of different type and size of boiler investments. In this study, surveyed power plants are:

- Municipal CHP 1/4 MW
- Municipal CHP 3/9 MW
- Municipal CHP 6/17 MW
- Industrial CHP 1/7 MW
- Industrial CHP 7,5/31 MW
- Industrial CHP 15/55 MW
- Industrial CHP 30/97 MW
- Industrial CHP 50/162 MW
- Condensing power 50 MW

A range of wood-fuel prices have been considered and these are represented by a range of curves shown on the graphs given in the figures below which are expressed in green tonnes. The value of heat for the CHP plant has been taken to be 1.0 €/MWh$_{th}$. The utilisation periods at peak load are:

- CHP pant 5000 hours
- Condensing power plant 8000 hours

The calculation does not include any subsidies for investment or energy production, although the AER 6 cap price for biomass of 6.412 EURcent per kWh is shown in the figures for reference. The investment discount rate is 10 % rate and the operating period for the financial appraisal has been taken as 15 years.

Figure 8-1 shows the electricity production costs for condensing power plant, and Figure 8-2 shows the same information for CHP plant.

For example in Figure 8-2, a 10 MWe CHP plant whose fuel cost is €15 per green tonne would generate electricity at €cent 6.1 per kWh.

Figure 8-1 Power Plant Electricity Production Costs

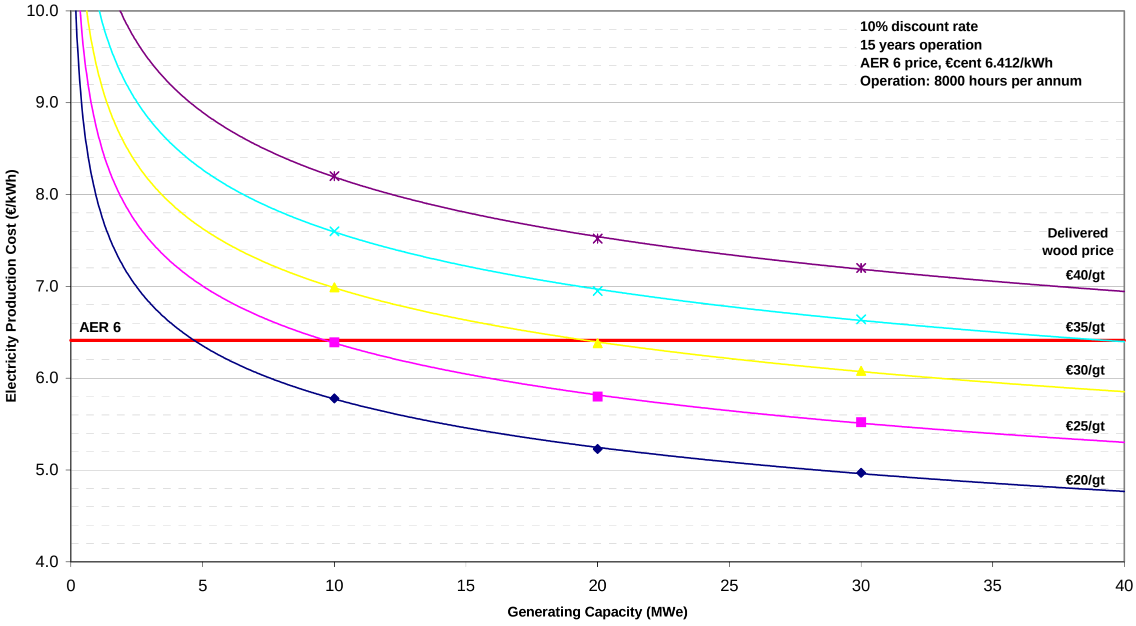
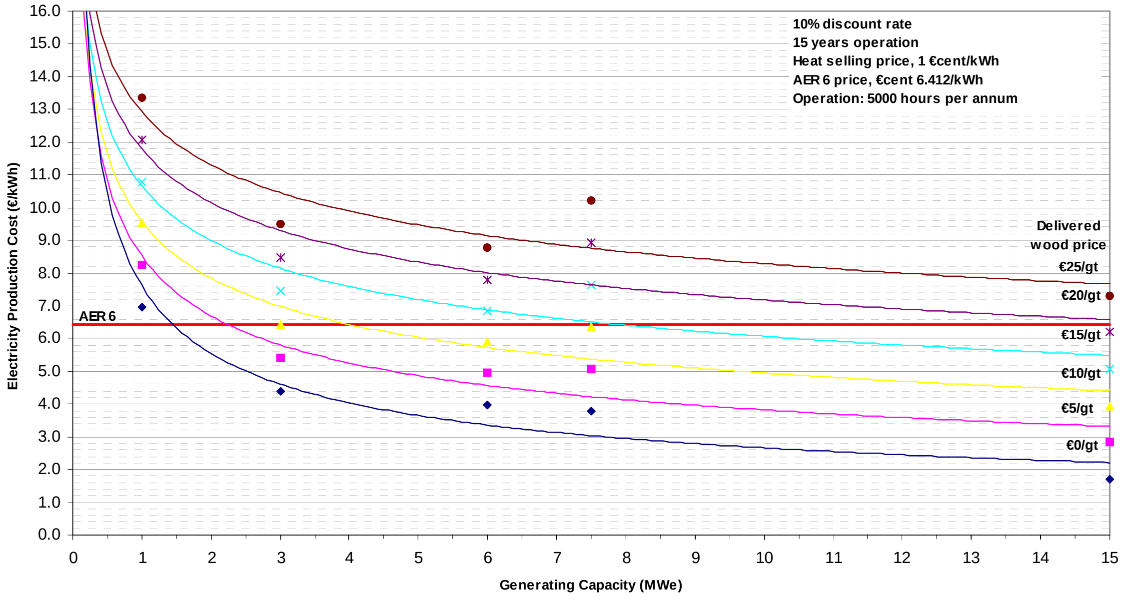


Figure 8-2 CHP Plant Electricity Production Costs



8.2 Domestic Heating System

The following is a description of typical domestic heating systems:

- Open grates and enclosed fireplaces: secondary heating source. Limited effect.
- Tiled stoves: suitable as an additional source of space heating. Efficient way of burning logwood. Low-cost, about €700 upward. Up to 11 kW.
- Pellet stoves: as above, fuelled on pellets. Cost about €2500. Up to 11 kW.
- Pellet boilers: for space and water heating. Performance and size similar to oil boilers. Cost around €7500. Typically 15-40kW.
- Logwood boilers: similar to pellet boilers, although larger for the same performance and operationally less flexible. Need for heat storage tank. Fuel management an issue. Cost around €6000. Typically 6-60 kW
- Woodchip boilers: fully automated fuel-feed systems – similar convenience as oil or gas boilers. Controllable, no heat storage tank necessary. Large wood chip storage facility required. More suited to applications where heat demand is high. Cost around €11 000. 18 kW upwards.
- Hypocaust heating systems: heating systems that distribute heat through flues integrated into the building structure.

8.3 Wood Pellets

8.3.1 Introduction

The following is based on the Finnish experience of wood pellets. The consumer price of pellets is based on production costs, transport costs, taxation and business profit. The production costs can be sub-divided to capital costs, raw material costs and other operating costs. It is difficult to itemise costs exactly, as the pellet producers regard the costs as commercially sensitive.

8.3.2 Capital Costs

The capital costs consist of investment costs and interest charges. The investment costs include buildings, machineries, equipment and transportation equipment. The level of investment in pellet plants in Finland has been kept low to date, as new plants have been constructed in existing buildings. In 1996, Jaakko Pöyry Consulting Oy estimated, on the basis of invitations to tenders, that the capital costs of a factory producing 42 700 t/a of pellets was about 252,500 €, i.e. about 0.34 €/GJ (1.2 €/MWh) [Ebeling 1996].

8.3.3 Raw Material Costs

The raw material for pellets is sawdust and cutter shavings, which are by-products of the wood-processing industries. These by-products have other uses in pulp production, as heating fuels or as litter.

The price of cutter shavings (moisture content 10 – 15%) was about 1.9 €/GJ (6.8 €/MWh) and that of sawdust 1.2 – 2.2 €/GJ (4.3 – 7.9 €/MWh). To produce 1 t of pellets, about 6 m^3 of sawdust (moisture 50 – 55%) or about 7.5 m^3 of cutter shavings (moisture 10 – 15%) are required. For example, the cost of cutter shavings to produce 1 t of pellets is about 8.3 €. At this moment in time in Finland, pellets are produced almost entirely from cutter shavings (Kakkinen 2000).

8.3.4 Other Operating Costs

The fixed costs include wages, salaries and operating staff overhead costs, service, repairs and insurance. The variable costs include (in addition to raw material costs) electricity and auxiliary fuel costs. The variable costs are highly dependent on the capacity, age and construction of the pellet plant. Jaakko Pöyry Consulting Oy estimated the total operating costs of a pellet plant in 1996 producing about 40 000 t/a of pellets at about 2.86 million €, i.e. about 3.9 €/GJ (14.0 €/MWh).

8.3.5 Transport Costs

The transport costs are dependent on transport vehicles and distance. The costs of heavy lorries are the most extensive at about 50 €/h and a distance cost of 0.5 €/km. The transport capacity of the lorry is 40 t. Vapo Oy estimates the share of transport cost is on average 10% of the final pellet price.

8.3.6 Total Costs

According to Austrian evaluations the total production costs of pellets range from 52.2 to 81.3 €/t without drying and from 73.5 to 94.6 €/t if the process needs drying. The distribution of the costs are presented in Figure 8-3 and Figure 8-4. The costs of drying are dependant on the technology and ranges from 25 €/ $t_{pellets}$ to 29 €/ $t_{pellets}$. The production costs are also depending on the annual operation time. If a plant is running in 3 shifts 7 days in a week, costs are 84 €/ $t_{pellets}$, compared with 3 shifts and 5 days a week, 90 €/ $t_{pellets}$, 2 shifts and 5 days a week 101 €/ $t_{pellets}$ and for 1 shift and 5 days a week 133 €/ $t_{pellets}$. [Thek et al. 2001].

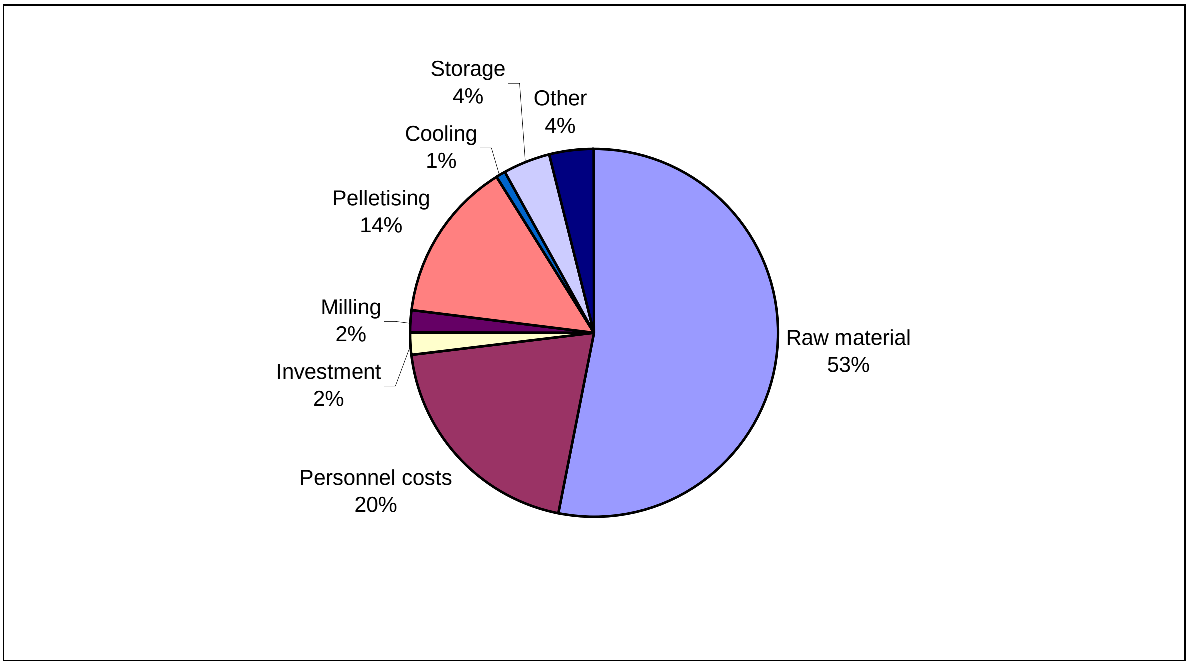


Figure 8-3 Pellet Costs without Drying

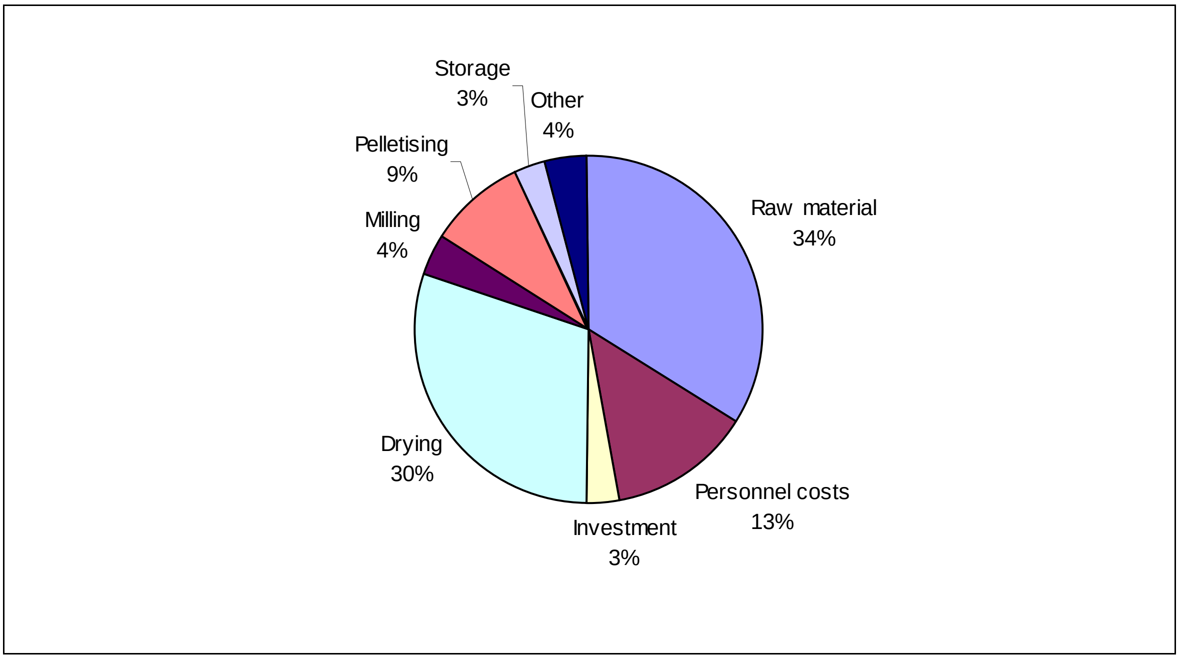


Figure 8-4 Pellet Costs with Drying

8.3.7 Taxation

The competitiveness of pellets is highly dependent on taxation. The Finnish energy taxation system applied since 1998 favours wood fuels. Unlike the combustion of fossil fuels and peat, no energy tax is levied on the combustion of wood. For example, the tax of coal combustion is 41.37 €/t, i.e. 1.6 €/GJ (5.8 €/MWh), and that of heavy fuel oil 0.05 €/kg, i.e. 1.3 €/GJ (4.7 €/MWh). In power generation, the tax financial support on wood is 4.2 €/MWh.

8.3.8 Business Profit

Profit is a part of the final price of pellets and both the producers and the retailers seek profit. The share business profit in the total price of pellets is highly dependent on combustion application.

8.3.9 Case Study

The following table provides a case study of a 8-10 t/h capacity wood pellet manufacture. Prices ex-factory (source: Finland):

Table 8-1 Wood Pellet Case Study

Pellet size	8mm dia, 5-30 mm long
Heat content	4.8 MWh/t
Moisture content	8-10%
Ash content	0.5%
Material	Cutter shavings
Bulk density	660 kg/m^3
Prices 2001 ex factory:	
Bulk supply	€93/t (€19.38/MWh)
Large bags (500-1000 kg)	€113/t (€23.54/MWh)
Small sacks (15 kg)	€3.36 per sack (€46.67/MWh)

9 RENEWABLES IN EUROPE AND IRELAND

9.1 The use of renewables in Europe

In this chapter the use of renewable energy and their support mechanisms in five EU countries will be described. These countries are Germany, Finland, Sweden, Spain and the UK. These countries represent a wide range of support mechanisms and different circumstances for use of renewable energy sources.

Several support mechanisms is used in promoting renewable energy sources, especially in electricity production. The European Commission classifies direct support mechanisms in (1) quota-based systems and (2) fixed price schemes.

In **quota-based systems** set the price of renewable energy is formed by competitive process. There is essentially two ways to create a competitive price for renewable energy. Firstly, as is done in Ireland and also in UK until year 2001, a ***tendering procedure*** can be used. Under a tendering procedure, the state places a series of tenders for the supply of renewable energy, which would thereafter be supplied to the local utility on a contract basis at the price which emerged from the tender. The surplus costs generated by the purchase of renewable energy are passed on to the end-consumer of energy.

Secondly, under a ***green certificate system***, renewable energy is sold at market prices. In order to finance the additional cost of producing renewable energy, and to ensure that the desired renewable energy is generated, an obligation is placed on all consumers to purchase a certain amount of green certificates from renewable energy producers according to a fixed percentage, or quota, of their total energy consumption/production. Since consumers wish to buy these certificates as cheaply as possible, a secondary market of certificates develops where renewable energy producers compete with one-another for the sale of the green certificates.

Fixed price schemes, operating presently in several EU countries, and notably Germany and Spain, are characterized by a specific price being set for renewable energy that must be paid by electricity companies, usually distributors, to domestic producers of renewable energy. In such schemes, in principle, there is no quota, or maximum limit for renewable energy set in the Member States. This limit or quota is however set indirectly by the level at which the renewable energy price is set. A variant of the fixed-price scheme is a ***fixed-premium mechanism***, according to which the government sets a fixed-premium or an environmental bonus, paid above the normal or spot electricity price, to renewable energy generators. In cases where the fixed prices are related to the market price of energy there will in reality be little difference between the fixed price and fixed premium schemes. The fixed price or fixed premium may be revised by the government to reflect falling costs.

Close to direct support mechanisms above are ***tax subsidies and exemptions***, when renewable energy is either exempted from an energy tax, pays according to a lower rate, or receives a subsidy equal to the energy tax level, like for example in Finland and Sweden. In addition to output related direct support, also ***investment and interest subsidies*** are often used, the former being an important form of support for example in Finland. Finally, the EU and practically all member countries apply various ***R & D subsidies or programmes and information dissemination*** to promote the development and commercialisation of renewable energy technologies and to strengthen the domestic know-how in these technologies.

9.2 Germany

9.2.1 Use of renewable energy sources in Germany

Table 9-1 Proportion of renewable energy of gross energy consumption and of electricity consumption in Germany

	1990	1995	1999	2010
Gross inland energy consumption, Mtoe	356	340	337	
Electricity consumption, TWh	481	473	488	
RES, % of gross inland energy consumption	1,7	1,8	2,6	
RES, % of total electricity consumption	4,0	4,7	5,3	12,5[1]

[1] Indicative target set in the directive on the promotion of electricity from renewable energy sources in the internal electricity market (COM(2000) 279 final)

Source: EUROSTAT and national sources

Table 9-2 Electricity produced from RES in Germany in 1998

Electricity produced from RES in 1998	**GWh_e**
Biomass	677
Hydro, Small (<10MW)	6 277
Hydro, Large (>10MW)	11 295
Landfill Gas	750
Photovoltaics	35
Wind	4 593
Other RES	123
Total	**23 750**

Source: Eurostat, 2000

Germany is a leading country in wind power utilization. One central reason for high penetration of wind power – both in relative and absolute terms – is the fixed tariff scheme during the 1990s, which gave strong incentive especially for wind power generation. In addition, loft loans and investment subsidies have been available both at the federal and regional level. The new law stating the fixed tariffs for renewable energy sources in electricity production includes considerably higher incentives also for other forms of RES today (see chapter 9.2.2 in more detail).

In addition, Germany has experienced a relatively high increase in photovoltaics and solar thermal. This increase is explained by effective measures not only at federal, but especially on regional and also local level. In addition to federal level fixed tariffs for PV, *e.g.* soft loans and investment grants at regional level and information dissemination and training at the local level have been used to promote the use of PV and also solar thermal production. One important success factor has also been active R&D support at federal level, which has helped in creating strong know-how in PV technology. As a result, over half of the Europe’s PV manufacturing capacity is today located in Germany.

9.2.2 Subsidies for renewable energy sources in Germany

Fixed tariffs

The “Renewable Energy Sources Act” (REA) was approved by the German *Bundesrat* in March 2000 and came into force in the beginning of 2001. Forming the core of German support policy for renewable energy sources (RES) in electricity production, the REA states fixed tariffs for different RES. REA also states a nation-wide cost equalisation scheme, by which the incremental costs of “renewable electricity” purchases are allocated evenly to consumers throughout the country. European Court of Justice has approved the German subsidy system in 13 March 2001. The tariff levels vary between different RES and are affected also by the location and the capacity of the plant. The fixed tariff is made available for plants using RES up to 20 years except for hydro power.

According to the REA, beginning from 1 January 2002 the minimum compensation levels for different RES in electricity production shall amount as shown in the Table 9-3.

Table 9-3 Minimum fixed tariffs for renewable energy sources in electricity production in Germany as of 1.1.2002

Energy Source	Capacity (MWe)	€/MWh
Hydro and biogas	< 0,5	76,7
	0,5 – 5	66,5
Biomass	< 0,5	101,2
	0,5 – 5	91,0
	5 – 20	85,9
Wind	Depending *i.e.* on location, on average during 20 years period	68,0 – 86,9
Solar	< 5 (until a total installed capacity of 350 MW has been reached in Germany)	481,1
Geothermal	< 20	89,5
	> 20	71,6

Beginning from 1 January 2002 the tariff levels are lowered for biomass (1%), wind (1,5%) and solar (5%) annually.

Tax exemptions

The so called “ecological tax reform” was adopted in Germany in 1999. The aim of the reform is a considerable but revenue neutral increase in energy taxation by decreasing pension insurance premium respectively over the time period 1999 – 2020. At least in the short term the tax increases are directed mainly to motor fuels. According to the Energy Report of the German Federal Ministry of Economics and Technology (BMWi, October 2001) the energy taxes between 1999 – 2003 are as follows (€c):

Table 9-4: The increase of “eco tax” and the total excise tax on energy in Germany 1999 – 2003 (BMWi 10/2001)

Year	Petrol (€c/l)		Diesel (€c/l)		Fuel oil (€c/l)		Natural gas (€c/kWh)		Electricity (€c/kWh)	
	eco tax	total tax	eco tax	total tax	eco tax	total tax	eco tax	total tax	eco tax	total tax
1999	3,1	53,2	3,1	34,8	2,0	6,1	0,18	0,35	1,0	1,0
2000	6,1	56,2	6,1	37,8	2,0	6,1	0,18	0,35	1,3	1,3
2001	9,2	59,3	9,2	40,9	2,0	6,1	0,18	0,35	1,5	1,5
2002	12,3	62,4	12,3	44,0	2,0	6,1	0,18	0,35	1,8	1,8
2003	15,3	65,4	15,3	47,0	2,0	6,1	0,18	0,35	2,0	2,0

The manufacturing industry, agriculture and rail transport are partly exempted from excise taxes on fuel oil, natural gas and electricity. The electricity from renewable energy sources is exempted from electricity tax.

The combined heat and power plants with a monthly utilisation rate of at least 70 % are exempt from the existing tax on fuel oil. The CHP plants which are achieving a conversion efficiency of at least 57,5 % and which have been put in operation after 31 December 1999 are proposed to get exemption from fuel oil tax for a period of 10 years. However, the European Commission has so far accepted exemption only for 5 years.

Other support mechanisms

In addition to fixed tariff system stated in the REA there are many other, more specific programmes that give support for renewable energy sources in forms of investment, interest and R&D subsidies. Two most considerable programmes are “100.000 Roofs Solar Electricity Programme” and “Market Incentive Programme”. The former is “soft loan” subsidy intended to give support for investments in solar energy equipment in households and small and medium sized enterprises. The latter provides investment and interest subsidies for use of RES especially in heat production. Together around 1 billion € support has been given through these programmes since year 1999.

9.3 Finland

9.3.1 Use of renewable energy sources in Finland

Table 9-5: Proportion of renewable energy of gross energy consumption and of electricity consumption in Finland

	1990	**1995**	**1999**	**2010**
Gross inland energy consumption, Mtoe	29	29	323	
Electricity consumption, TWh	59,5	66,0	75,0	
RES, % of gross inland energy consumption	18,9	21,3	22,3	
RES, % of total electricity consumption		27,0	26,3	31,5[1]

[1] Indicative target set in the directive on the promotion of electricity from renewable energy sources in the internal electricity market (COM(2000) 279 final)

Source: EUROSTAT and national sources

Table 9-6 Electricity produced from RES in Finland in 1998

Electricity produced from RES in 1998	**GWh_e**
Biomass	7 492
Hydro, Small (<10MW)	1 328
Hydro, Large (>10MW)	13 723
Sewage & bio gas	509
Wind	24
Total	**23 076**

Source: Eurostat, 2000

In 1999 over 22% of the total primary energy was covered with renewable energy sources, mostly biomass. This is understandable, since approximately half of the industrial energy consumption, that is 25% of the total energy consumption of the country, was caused by the pulp and paper sector. In this sector wood residuals form a significant share of the energy production. Beside biomass also hydropower is important, whereas other technologies such as wind power, solar energy or heat pumps play a marginal role.

The Ministry of Trade and Industry launched in 1999 an Action Plan for Renewable Energy Sources. The program objective is to enhance the penetration of various RES technologies on the market and increase the consumption of renewable energy sources in absolute terms by 50% from year 1995 until 2010. Additionally a vision has been set for the year 2025.

9.3.2 Subsidies for renewable energy sources in Finland

Taxation

Before 1997 the carbon content of primary energy carriers has played a crucial role in energy taxation policies both in heating and electricity sectors. Within the heating sector this situation still is valid. The liberalisation of electricity markets in the beginning of 1997 lead to a situation, where Finnish conventional condensation power based on coal lost in the competition and hence changes in the basis of taxation policies applied to electricity were unavoidable. According to the new law (having gone into effect in the beginning of 1997), electricity taxes are based on the total electricity consumption, not on the carbon content of the primary energy carriers used for electricity production. However, in the case of electricity generated with wood based biomass, wind power and mini hydro power (< 1MW) the electricity taxes are returned back to the producer (6,9 euro/MWh for wind power and 4,2 euro/MWh for bioenergy and micro hydro power). A major change with respect to the present taxation model proposed in the new action plan deals with value added taxes on small-scale bioenergy consumption: the present level of 22% should be reduced. Also small-scale hydro power production up to 10 MW should receive electricity taxes returned.

Subsidy schemes

Ministry of Trade and Industry hands out subsidies of up to 30% of the investment costs to renewable energy technologies. For wind energy the subsidy level is 40% at maximum. Commercial installation, however, get seldom investment subsidy at the maximum rate. The investor is required to be a legal entity in order to receive subsidies. In the Action Plan the subsidies will remain at the present level, however, the possibility of including private persons or households in the subsidy scheme will be investigated. This would affect mainly the markets for heat pumps, small-scale wood burners as well as solar systems.

9.4 Sweden

9.4.1 Use of renewable energy sources in Sweden

Table 9-7: Proportion of renewable energy of gross energy consumption and of electricity consumption in Sweden

	1990	**1995**	**1999**	**2010**
Gross inland energy consumption, Mtoe	48	51	51	
Electricity consumption, TWh	131	127	129	
RES, % of gross inland energy consumption	24,7	25,4	26,8	
RES, % of total electricity consumption		47,1	46,2	60[1]

[1] Indicative target set in the directive on the promotion of electricity from renewable energy sources in the internal electricity market (COM(2000) 279 final)

Source: EUROSTAT and national sources

Table 9-8 Electricity produced from RES in Sweden in 1998

Electricity produced from RES in 1998	**GWh$_e$**
Biomass	2 573
Hydro, Small (<10MW)	4 448
Hydro, Large (>10MW)	69 894
Landfill gas	14
Wind	316
Total	**77 245**

Source: Eurostat, 2000

The use of renewables in Sweden accounted for over 26 % of the primary energy supply in 1999.The main renewable contributions come from hydropower and biomass. In 1998, electricity from hydropower amounted to 76 TWh. This is 48% of the country's electricity production. During 1998, use of bio-fuels, peat etc. amounted to 92 TWh. Bio-fuels now meet more than 50% of the supply to the district heating grids.

9.4.2 Subsidies for renewable energy sources in Sweden

In Sweden there is currently investment, production, tax and network charge subsidies available for renewable energy. Wind energy has been in the most beneficial situation among renewable energy sources, since it has been able to benefit from all forms of subsidy mechanisms mentioned.

Investment subsidy of 25% is available for biomass-based CHP production. In 2001 there was also an investment subsidy of 15% for wind energy and small-scale hydro (under 1,5 MW). In 2002 the latter subsidy was reduced to 10%, and according to a Swedish newspaper “Dagens Nyheter” (9.3.2002) the government is proposing a cancellation of the latter subsidy.

Production subsidy of 9,8 €/MWh is available for hydro and wind energy production under 1,5 MW.

Tax subsidy, or “environmental bonus”, of equal to the consumers’ electricity tax is available for wind power under 1,5 MW. In year 2002 the electricity tax for consumers is 21,6 €/MWh. Additionally renewable energy sources are exempted from energy taxes on fuels for heat production.

Network charge subsidy is available for all small-scale electricity production under 1,5 MW, including fossil fuels. In practice this subsidy is, however, emphasized on renewable energy sources. It varies between 1,1 and 5,5 €/MWh.

A proposal for a *green certificate system* has been given in Sweden (SOU 2001/77). The system is proposed to start in the beginning of 2003. Consequently all current subsidies would be phased out gradually by 2010 (exempt the network charge subsidy). As a result the system would support all renewable energy sources equally instead of emphasizing on certain forms of renewables. The demand for renewable electricity would be created by introducing a purchase obligation for end users of electricity. The quota, initially 6,4% of purchased electricity, would increase annually, reaching 15,3% in 2010.

9.5 Spain

9.5.1 Use of renewable energy sources in Spain

Table 9-9: Proportion of renewable energy of gross energy consumption and of electricity consumption in Spain

	1990	**1995**	**1999**	**2010**
Gross inland energy consumption, Mtoe	91	103	118	
Electricity consumption, TWh	129	146	182	
RES, % of gross inland energy consumption	6,7	5,7	5,2	
RES, % of total electricity consumption		14,3	12,8	29,4[1]

[1] Indicative target set in the directive on the promotion of electricity from renewable energy sources in the internal electricity market (COM(2000) 279 final)

Source: EUROSTAT and national sources

Table 9-10 Electricity produced from RES in Spain in 1998

Electricity produced from RES in 1998	**GWh$_e$**
Biomass	841
Hydro, Small (<10MW)	5 231
Hydro, Large (>10MW)	26 656
Landfill Gas	44
Photovoltaics	4
Wind	2 149
Other RES	117
Total	**35 042**

Source: Eurostat, 2000

In 1999 the electricity generation from RES accounted for 32.795 GWh, with a total capacity installed of 19.735 MW. The major contribution in the electricity sector comes from hydropower plants. Taking into consideration the perspectives of wind energy in the medium term, this sector could reach the level obtained by the hydropower. Electricity generation using biomass and municipal solid waste now accounts for over 300 MW of installed capacity, while photovoltaic is experiencing an increase of the market.

The thermal production from renewable accounted for 3.533 ktoe in 1999, from which 99.1% came from biomass comprising very different applications. Solar thermal provides 28 ktoe, mostly in low-temperature installations, while geothermal provides 5 ktoe in little installations of low-temperature, generally for tourism or agricultural uses.

9.5.2 Subsidies for renewable energy sources in Spain

In Spain there are fixed prices offered for electricity from biomass. In 2002, the situation is as follows: the plant can sell the electricity to the grid with a fixed price (62

€/MWh if it uses energy crops, or 59 €/MWh for other kinds of biomass), or with a bonus added to the market price (28 €/MWh or 26 €/MWh for the two cases mentioned above). Nowadays, with a market price usually over 36 €/MWh it is more profitable to choose the second option, the gap between fixed tariffs and price-premiums being around 33-34 €/MWh. The law supporting the scheme is R.D. 2818/98, and the tariffs change every single year. The price-premiums and alternative fixed tariffs for renewable energy sources are presented in Table 9-11.

Table 9-11: Price premiums and fixed tariffs available for renewable energy sources in electricity production in Spain

	Price premium (on top of electricity price)	**Fixed tariff (total price) producers may choose**
Energy Source (national cap is 50 MW)	**€/MWh**	**€/MWh**
Solar, <5 kW	361	397
Solar, rest of installations	180	216
Wind	29	62
Geothermal, waves, tide, hot and dry rocks	30	64
Small hydro (< 10 MW)	30	64
Primary biomass: vegetables growing < 1 year, used directly or after a transformation (min. 90% of LCV)	28	62
Secondary biomass, residues after a 1st utilisation (min 90% of LCV)	26	59

According to the national and EU laws, the liquid biofuels produced in pilot plants can achieve a fiscal exemption on hydrocarbons specific taxes.

9.6 UK

9.6.1 Use of renewable energy sources in UK

77 per cent of the renewable energy produced in the UK in 2001 was transformed into electricity. This was an increase from 75 per cent in 2000 and 71 per cent in 1999. Whereas in 2001, waste and landfill gas appear to dominate the picture when fuel inputs are being measured, hydro electricity dominates when the output of electricity is being measured. This is because on an energy supplied basis, hydro (and wind and wave) inputs are assumed to be equal to the electricity produced. For landfill gas, sewage sludge, municipal solid waste and other renewables a substantial proportion of the energy content of the input is lost in the process of conversion to electricity.

Table 9-12: Proportion of renewable energy of gross energy consumption and of electricity consumption in the UK

	1990	1995	1999	2010
Gross inland energy consumption, Mtoe	213.6	218.4	231.4	
Electricity consumption, TWh	284.4	303.9	332.4	
RES, % of gross inland energy consumption	0.5	1.0	1.2	
RES, % of total electricity consumption	0.28	0.75	1.25	10[1]

[1] Indicative target set in the directive on the promotion of electricity from renewable energy sources in the internal electricity market (COM(2000) 279 final)

Source: DUKES

More comprehensive tabulation of UK

9.6.2 Subsidies for renewable energy sources in UK

The UK Government's initiative the promotion of renewables until year 2000 was the Non-Fossil Fuel Obligation (NFFO) Orders for England and Wales and for Northern Ireland (NI-NFFO) and Scottish Renewable Obligation (SRO). These were collectively known as the NFFO Orders. These aimed to assist the renewables industry by allowing premium prices to be paid for electricity for a fixed period. A summary for the NFFO Orders status is given in Table 9-13 and the average contract prices are given in Table 9-14.

Table 9-13 Status of NFFO Orders (March 2000)

Technology	Contracted Projects		Commissioned Projects (31 March 2000)	
	Number	**Capacity (MWe DNC)**	**Number**	**Capacity (MWe DNC)**
Biomass	32	256.0	6	64.3
Hydro	146	95.4	55	37.1
Landfill gas	329	699.7	151	302.7
Municipal and industrial waste	90	1,398.2	14	182
Sewage gas	31	33.9	24	25.0
Wave	3	2.0		
Wind	302	1,153.7	67	150.9
Total	**933**	**3,638.9**	**317**	**762.0**

Table 9-14 Summary of Average NFFO Prices

	Price p/kWh
NFFO 1 (1990)	7.51
NFFO 2 (1991)	8.78
NFFO 3 (1994)	4.84
NFFO 4 (1997)	3.59
NFFO 5 (1998)	2.71

Since February 2000 the UK's renewables policy has consisted of four key strands:

- A new Renewable Obligation (RO) on all electricity suppliers in Great Britain to supply a specific proportion of electricity from eligible renewables;
- Exemption of electricity from eligible renewables from the Climate Change Levy (CCL);
- Exemption of electricity from renewables[6] from the Climate Change Levy;
- An expanded support programme for new and renewable energy including capital grants and an expanded research and development programme;
- Development of a regional strategic approach to planning and targets for renewables.

The aim of the RO is to increase the contribution of electricity from renewables in the UK so that by 2010, 10% of licensed UK electricity sales should be from renewable sources eligible for the RO.

The RO (and the analogous Renewables (Scotland) Obligation) eligible sources are:

- Energy from waste (biodegradable fraction)
- Landfill gas
- Sewage gas
- Agricultural and forestry wastes
- Energy crops (capital grants available)
- Co-firing biomass (phased out by 2006 unless from energy crops which is in turn phased out by 2011)
- On and off-shore wind (capable grants available for off-shore wind)
- Hydro less than 20 MWe (new and refurbished)
- Wave power, tidal and tidal stream power
- Photovoltaics
- Geothermal power

9.7 The use of Renewables in Ireland

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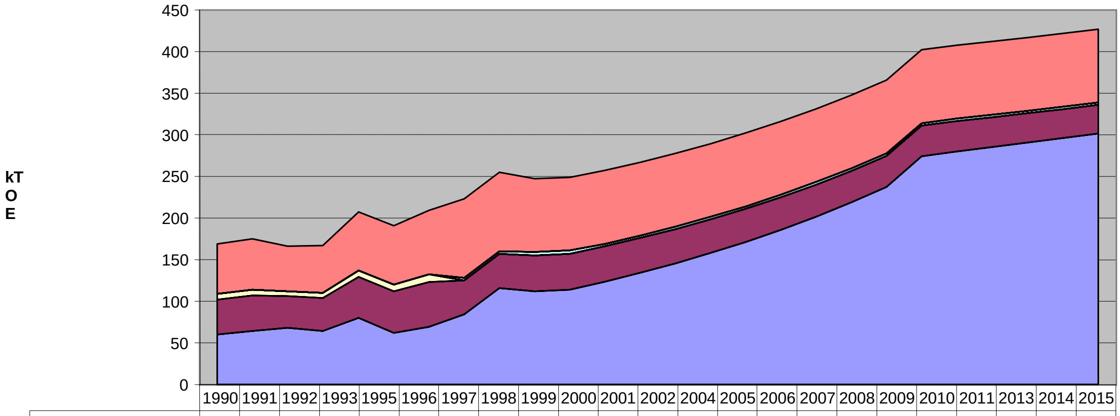
[6] Electricity generated by hydro stations with a declared net capacity (DNC) greater than 10 MWe is not exempt from the Climate Change Levy.



	1990	1991	1992	1993	1995	1996	1997	1998	1999	2000	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011	2013	2014	2015
Industry	60	61	54	57	71	77	95	95	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88
Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0	3	3	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3
Commercial & Public	7	7	6	6	8	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Residential	42	43	38	40	50	54	41	41	43	43	42	42	40	40	39	39	38	38	37	36	35	35	34
Electricity generation	60	64	68	64	62	69	84	116	112	114	124	134	158	171	186	201	219	237	274	280	290	296	302

Year

The above figure summarises projections for renewable usage from the ESRI energy forecast. Analysis of the data and assumptions reveals the following:

- Only three sectors make significant use of renewables: Industry, Residential, and Electricity.
- The figures for the Industry sector are for the use of wood and other biomass for heat. There are at present no biomass fuelled CHP plants, and none are assumed in the forecast. Future projections are based on the assumption that usage will not change from 2000 onwards, the justification for which is not clear.
- The figures for the Residential sector are for firewood. Future projections are based on the assumption that usage will reduce by 1.5% per annum. However section A.2 shows that the use of geothermal energy is increasing in the Residential sector.
- The figures for electricity generation include ‘large hydro’ as well as the newer renewables: wind, ‘small hydro’, Landfill Gas (LFG).
- There is effectively no scope for the further development of large hydro in Ireland, but the existing capacity equivalent to around 60kTOE per annum will continue.

The projected increase in use of renewables for electricity generation is based on the assumption that in 2010 10% of electricity generated comes from renewables, with interpolation for other years. It is worth noting that this is not consistent with the target set in the ‘Green Paper on Sustainable Energy’ of 12.4% in 2005, nor with the target set in the EU Renewable Energy Directive of 13.2% by 2010.

Usage of Different Renewable Energy Sources

In March 2002 the Government responded to a questionnaire from the European Parliament providing a breakdown of energy generated from renewable resources by type of renewable in 1999 and 2000, with an estimate for 2001. These are given below:

Table 9-15 Energy Generated from Renewable Resources 1999-2000

		GWh 1999	GWh 2000	GWh 2001 (estimate)
Hydro		846	850	800
Wind		187	244	359
Solar PV		0	0	0
Solar Thermal		3	3	4
Solar Collectors		0	0	0
Biomass		1583	1660	1744
Biogas		165	133	170
Liquid Biofuels		0	0	0
Wave & Tidal		0	0	0
Geothermal		390	465	512
Total		3174	3355	3589
of which:				
	Heat	2011	2165	2430
	Electricity	1163	1190	1289
	Fuels	0	0	0

The main points to note are:

- The very rapid rise of wind generated electricity (92% in 2 years)
- The rapid rise of geothermal (31% in 2 years), due to growing installation of ground-coupled heat pumps

Note that when the totals are converted from GWh to kTOE (using the conversion (11.63 GWh = 1kTOE) they do not precisely match the ESRI model. It is understood that this may be due to the latest figures not yet having fed through to the ESRI model.

Table 9-16 Comparison between ESRI Energy Model and EU Return

	kTOE 1999	**kTOE 2000**	**kTOE 2001 (estimated)**
EU Return	273	289	309
ESRI Model	247	249	257

Renewable Energy Capacity for Electricity Generation

At the start of 2001, the following renewable electricity generating capacity was connected to the network (source – Eirgrid Forecast Statement 2001/2 –2007/8):

Table 9-17 Renewable Electricity Generation Capacity (Start 2001)

Type	**Capacity (MW)**
Large Hydro[7]	215
Small Hydro[8]	21
Wind	120
LFG/waste	15
Total	**371**

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[7] Transmission system connected

[8] Embedded (distribution system connected)

Planned Capacity Increases

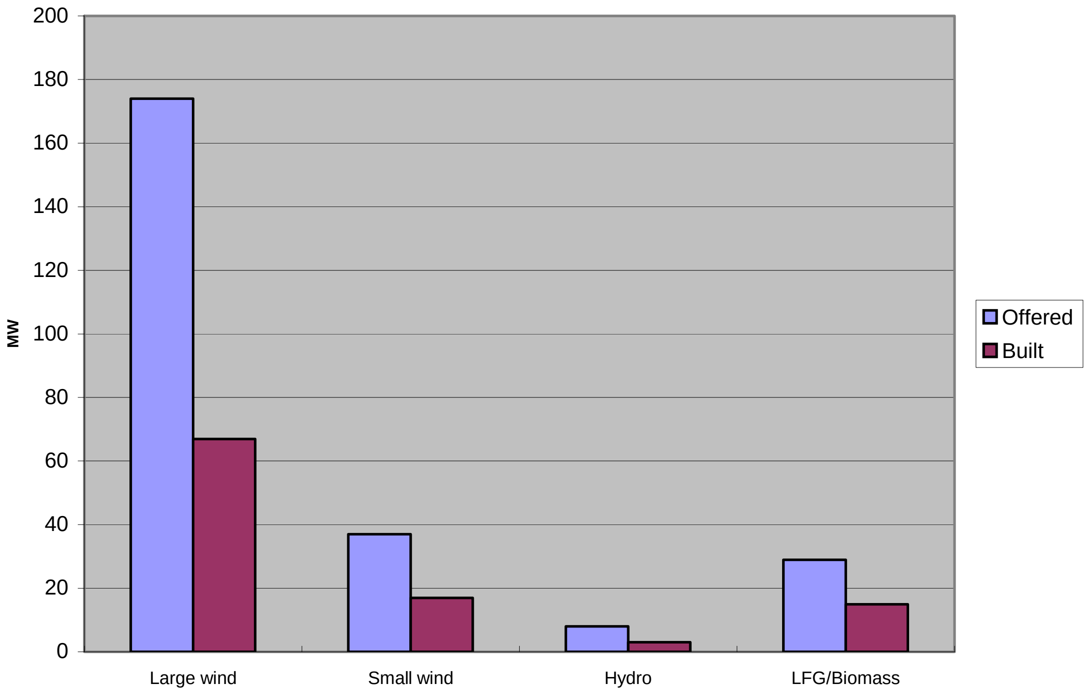
The main route for renewable energy projects to obtain support is the Alternative Energy Requirement (AER) competitions, organised by the former Department of Public Enterprise (now Department of Communications, Marine and Natural Resources). These involve projects tendering to provide capacity. Successful projects are guaranteed the offer of a power purchase agreement (PPA) by ESB Public Electricity Supply (PES). The results of the latest AER5 competition were announced in February 2000, as follows:

Table 9-18 AER5 Competition Results by Type

Type	Capacity (MW)	No of Projects
Large Wind	318.3	21
Small Wind	35.3	19
Biomass	8.0	5
Hydro	0.9	3
Total	**362.5**	**38**

However, it is likely that not all of this capacity will be built, taking the track record of the previous AER rounds into account.

Figure 9-1AER 1...4 Results to December 2001



Mr Dermot Ahern, Minster for Communications, Marine and Natural Resources announced on Thursday 14 November 2002 the general rules for AER 6. The key points affecting wood-energy are:

- The purchase price for electricity will be split. 30% will be at the price cap for the technology band. 70% will be decided by competitive bidding.

- Project not built before 1 May 2001 will be permitted to enter AER VI.
- The biomass technology band capacity will be up to 25 MWe.
- The biomass cap price will be 6.412 eurocent per kWh.
- The Minster is exploring the possibility of targeting particular technologies within the biomass class. In particular, consideration may be given to biomass CHP with a tailored price cap.

The Department of Communications, Marine and Natural Resources have established a database of potential renewable energy projects, their location and grid access requirements, for the purpose of Grid Update Programme planning. The database contains information provided by potential project developers following an advertisement by the Department. Details for individual projects are confidential. The Department kindly provided a statistical summary for the purpose of this study. Because the response in some technologies was so low, a breakdown by technology could identify individual projects. Therefore the Department provided the following data, noting that wind the is "predominant" technology in all the regions outlined:

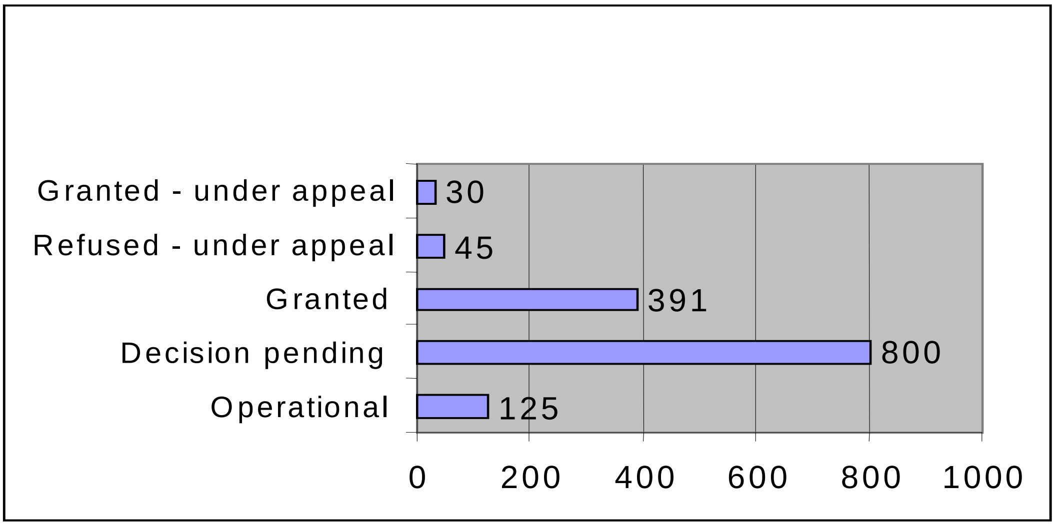
Table 9-19 Potential Renewables Capacity

Area	Potential Capacity (MWe)	Capacity with Full Planning Permission (MWe)
Connacht and Donegal	1,245	127
Leinster, Cavan, Monaghan	194	47
Munster	613	135

Planned Wind Capacity

A key indicator of future capacity for wind is the status of applications for planning permission, which at December 2001 were as follows for on-shore wind projects (source Renewable Energy Information Office):

Figure 9-2 Wind Energy Planning Status Dec 2001 (MWe)



In addition a Foreshore Lease was granted to SURE Partners in January 2002 to develop an offshore wind farm of 520MW on the Arklow Bank. The first phase of 60MW is scheduled to be operational by December 2003, and the full 520MW by December 2006. A further 6 Foreshore Licences have been granted for wind energy investigation work, and another 14 applications for licences have been submitted.

Planned Solid Biomass Capacity for Electricity

Currently no electricity is generated from solid biomass (as opposed to Landfill Gas), and none has been awarded a PPA under the AER programmes. A small number of projects are under consideration, including in Carlow, Limerick, Monaghan and Tipperary. The fuels under consideration include wood (sawmill residues, forest residues and short rotation coppice), poultry litter and spent mushroom compost.

9.8 Summary

Table 9-20 summarises the policy measures taken in above mentioned member states. Only the primary policy instruments promoting renewable energy is presented. Usually other measures are also implemented in member countries as complementary instruments to the primary instruments. These include *e.g.* focused investment and soft loan programmes. In addition, practically every member state and the EU apply R&D programmes and information dissemination to speed up the commercialisation and diffusion of renewable energy innovations.

Table 9-20: Summary of primary support mechanisms on certain member states

	Germany	Finland	Sweden	Spain	UK
Fixed tariffs	X			X	
Fixed price premiums or production subsidies			X	X	
Green certificate system			(X)[1]		X
Investment subsidies		X			
Tendering procedure					(X)[2]
Interest subsidies					
Tax refund or exemptions	X	X	X		X

[1] Planned to be introduced in the beginning of 2003.

[2] In place until early 2002, replaced by a green certificate system since 1.4.2002.

The main factors affecting the success of renewables in the countries studied are:

Germany

- The main success factor for increase of biomass use has been the high fixed tariff provided for biomass in electricity production, and the obligation of distribution network operators to buy the RES-E within its operation area. Previously the law favoured smaller installations (< 5MW), but the new subsidy scheme presented in the EEG law favours larger installations (20 MWe, which is the upper limit for eligibility for biomass installations in EEG law).

- The subsidy scheme gives incentive to increase waste wood use, and there are a great number of theses installations in planning phase. The forest and industrial wood residues do not seem to be profitable fuels even with the EEG law (there are few of these types of installation in the planning pipeline)
- It is estimated that some 25% of planned installations will be built, which would mean the existing capacity of 280 MW in Germany is increased to some 600 MW by 2004. This is solely due to EEG law.
- Last year the biomass use in Germany was 2,8 Mt/a, and the economically potential is currently about 4,5 Mt/a. Thus the availability of wood fuel at competitive prices will be the main factor limiting the construction of biomass capacity.
- The progress of biomass-based power production: 1993: 419 GWh, 1999: 677 GWh, 2001: about 1000 GWh
- It is also worth mentioning that many "Bundesländer" have their own support schemes in addition to the federal level support (i.e. mainly the EEG).
- Climate policy is an important driving force for biomass and other RES in German energy policy.

Spain

- The main success factor is similar to Germany: regulation providing high fixed tariff (or alternatively production subsidy), DSOs' obligation to buy the RES-electricity and guaranteed grid connection for RES-E.
- There has been also capital grants available for biomass during 1990s.
- In addition to the national level support, the regions are active in RES support.
- The planning and permitting procedures are handled on a regional level, which allows for good local involvement and appropriate treatment of applications.
- Main biomass sources have been grape/wine residues, rice husks, wood wastes and wood residues.
- Important users include the residential sector and various industrial sectors (e.g. pulp and paper industry).The progress of biomass-based power production: 1993: 485 GWh, 1999: 677 GWh.**Finland and Sweden**

The main success factors have been:

- The availability of raw-material: there is an abundance of forests / biomass in the country. It is of national interest to secure the availability of large quantities of high quality raw-wood for industry (at sustainable bases) and several companies have been established (e.g. Vapo, Biowatti) whose business is to compile biomass, further process it to commercial fuels and to sell it to users The industrial structure is based forestry: forest industry / and forestry are cornerstones of the Finnish economy which is energy intensive. Biomass is the natural choice of fuel for the industry. The largest increase in wood based energy use has been related to forest industry and there is easy/ready access to wood fuels (mainly wood processing by-products)

- Energy production structure in general and competing fuels favour biomass. The guaranteed supply of fuel peat at affordable price has made it possible for large scale power plants to use wood based fuels flexibly as much it has been available at affordable prices.
- Many industries have solid wood based boilers
- Biomass addresses environmental concerns and its use conveys a positive image. As a consequence, incentives to promote wood fuel production, plant investments and wood use in energy production have made wood fuel "wanted"

UK

The main success factor in respect to renewable development has been Government obligation for electricity supply companies to purchase electricity generated from renewable sources through the award premium price contracts in open competition. This was known as the non-fossil fuel obligation (NFFO). The only major biomass development resulting from NFFO was large scale (15-40 MWe)chicken litter and straw fired power stations. There were no wood fuel developments because they were not competitive against other eligible technologies (wind, landfill gas, energy from waste etc).

NFFO has been replaces with the Renewable Obligation which requires licensed electricity suppliers to supply stimulated percentages of electricity supply from RES-E. Capital grants are available for biomass project in recognition that biomass will be uncompetitive against other forms of RES-E.

9.9 Subsidy options for wood fuels and wind in Europe

In this section, an analysis of different RES supporting mechanisms based on economic theory and empirical evidence will be presented. The empirical evidence has been gathered mainly from the countries analysed in the previous sections, but also other EU Member Countries have been included in the analysis when relevant. The analysis will be focused in the direct support mechanisms for RES-based energy production, *i.e.* fixed tariffs, price-premiums, investment subsidies, tendering procedure and green certificate trading, as these mechanisms are in focus of discussion at the moment and traditionally the primary measures used in increasing the use of RES.

Two important concepts are worth clarifying when analysing the benefits of different support mechanisms, namely *effectiveness* and *cost-efficiency*. The former refers to the ability of a measure to contribute to the increase in the amount of RES used in energy production. With the latter it is meant, how much costs must be sacrificed by the society for each MW or MWh increase in the RES capacity or production from RES. As will be shown, these important objectives are often contradictory, and some kind of compromise must usually be found between these objectives. An ideal support scheme would be effective and cost-efficient, *i.e.* allow for rapid expansion in the use of RES in energy production with lowest possible costs.

9.10 Theory and practice of different support mechanisms available for RES-based energy production

Fixed tariffs

Fixed tariffs are simple in principle, are argued to provide the best incentive to invest in RES technologies and thus to be the most effective support mechanism. However, the measure itself is not effective, but it depends of course on the level of the fixed tariff compared to actual production costs. The effectiveness properties of fixed tariffs can exist only if the tariff is over the total unit costs of energy. If fixed tariffs have been set at high level enough, and they are provided for a long period enough (*e.g.* 10-15 years) they are effective in principle. In this case there is little uncertainty, since the revenues of the investment are stable and can be estimated with high probability. Thus the investor may get a reasonable return on investment associated with low risk.

The effectiveness of fixed tariffs can also be evidenced in practice. The countries applying fixed tariffs reached the most rapid expansion in RES use during 1990s. For example Spain and especially Germany have used fixed tariff systems effectively. In Germany the law from 1992 introduced high fixed tariff for wind power in particular, and this has been the main factor leading to high penetration of wind energy in Germany during the 1990s. In 2000 a new law was introduced including considerably increased fixed tariffs also for other forms of RES. The stable investment environment provided by fixed tariffs in Germany and Spain have also helped in creating strong domestic know-how and wind power manufacturing industry, which has created new jobs and increase in exports. Additionally, in Spain and Germany national and also strong regional support in form of R&D, investment subsidies and soft loans have helped wind power penetration. As the technology has developed and experience has been gained, the other forms of support are not needed to same extent as earlier, and the fixed tariff systems have all the more important role in promoting further wind capacity building. In Spain investment subsidies have been reduced because of the developments made in wind capacity building.

One reason for effectiveness of fixed tariffs is the simplicity of the system. The rules and the rates are transparent and easily available for every interested party. The transaction costs for investors are lower in the beginning lowering the threshold to begin with project planning. An actual evidence of this is the former Italian fixed tariff system, which despite the attractive tariff levels did not forge considerable increase in RES use. The system was considered too complex, and was therefore simplified. After the amendment of the system the RES use begun to grow in Italy.

From the societal costs (consumers) point of view the situation is contrary to the investor’s one when it comes to risks associated with fixed tariffs. Since the society has guaranteed a certain price for the electricity producer for each unit, the actual incremental costs of the support scheme depend on the development of electricity price. If electricity prices hike, the gap between a fixed tariff and “what would have been paid for the electricity without the scheme” narrows. Respectively, if electricity prices fall, the additional costs of the fixed tariff system rise for the society.

Thus fixed tariffs can be an effective incentive in case of risk-averse investors, or if the investors have lower estimations about the development of electricity price than the regulator (or if the regulator sets the tariffs at generously high level).

Fixed tariffs, however, are not regarded as cost-efficient measure, since they do not introduce competition between producers. Moreover, due to the asymmetry of information, in case of fixed tariffs there is likely to be producers gaining extensive profits, *i.e.* they would invest and produce with lower compensation level too, since the regulator can't know the marginal costs of producers as exactly as the producers themselves.

There are several ways to improve the cost efficiency and reduce the risks of over-subsidising in case of fixed tariffs. In Germany it is stated already in the Renewable Energy Act that the tariff levels will decrease annually to anticipate falling costs of these technologies. Thus potential investors are able to calculate well in advance also the future (lower) tariff levels. Another way to cope with the risk of over-subsidising is to set upper limit for the capacity of a RES technology. For example in Germany the fixed tariff for solar power applies only up to 350 MW installed capacity through the fixed tariff system. When this limit is exceeded the regulator will re-evaluate the need and rate for further support for solar power. Also stepped fixed tariffs may be applied. In this method the tariff depends on the efficiency of a plant. More efficient plants will be provided with higher tariffs than less efficient ones. In theory this should allow for the new plants being installed at most feasible locations and conditions first and the subsequent plants would be less and less efficient, receiving lower and lower tariffs. In some stage the incentive to invest in new capacity should be so low that no increase through the fixed tariff system occurs. The last option, however, includes also more administration costs than other forms of fixed tariff systems, and it might also hamper the simplicity of the system thus constituting an extra barrier from the investors' point of view. Also R&D support is usually applied together with fixed tariffs to enhance technological development. This helps not only to bring costs down but may also contribute to technological know-how in new technologies and thus creating jobs and increasing exports.

Price-premium system

Second price-driven choice for policy makers is the so called price-premium incentive (or rate-based incentive) where the revenues for the investor are composed of the conventional electricity price *plus* the price-premium paid by the society (customers) on top of electricity price. Thus the premium is fixed but the total revenues for the investor vary according to the electricity price. Hence, the price risk associated with this instrument is opposite compared with the fixed tariff. The additional costs of support scheme are constant for the society, since the additional incentive is fixed, but the investor faces electricity price risk. If the electricity price rises, investor's revenues increase, and if the price falls, the profits of the RES-based production fall as well.

Thus, in theory, price-premium system would be effective in case of risk-tolerant investor having higher expectations of electricity price than the regulator (or if the regulator sets the tariffs at generously high level). Denmark has been successful in using price-premium in promoting wind energy. Denmark gave strong support for R&D efforts in wind energy during the early phases of wind technology development in late 1980s. Thereafter the emphasis of support has moved more on price-premium for wind power. This has given Denmark a leading international position in wind power technology.

Concerning cost-efficiency properties of price-premium system the same principles apply as in case of fixed tariffs. If the rate of a price premium is too high, it may lead to unexpected high penetration and consequently higher electricity prices. For example Denmark decreased recently the subsidy for wind power, since the level was considered unnecessary high. (Moreover, the country is planning introduction of tradable green certificate system.)

Comparable instrument to price-premiums is introducing energy tax exemptions or refunds for renewable energy sources. In the Nordic Countries tax incentives have been effective in contributing to increase of RES in heat production. For example in Sweden exemption of RES from energy, carbon dioxide and sulphur oxides taxes has considerably improved the competitiveness of RES in district heating. Also R&D support in harvesting supply programmes, fuel production and combustion technologies have been crucial factors of success. (See also the Finnish case in chapter 9.3.)

Investment subsidies

Investment subsidies can also be granted for investors in order to enhance the use of RES in energy production. If the investment costs form considerable share of production costs (as in case of wind, hydro and solar power), the investment subsidy may be justified. However, if there are considerable production costs, the effectiveness of investment subsidy cannot be assured. This is because the producer selling on conventional electricity market will produce only when price is higher than producer's variable costs. If for example the price of electricity decreased or price of biomass increased dramatically, the biomass-based operator would not have incentive to produce, which would reduce the demand for biomass. From wood fuel producers' point of view the investment subsidy includes thus more risks than fixed tariffs or fixed price-premiums. Therefore, in case of RES-based energy production having significant variable production costs, fixed tariffs may be more effective than investment subsidies.

Competitive tendering

In competitive tendering procedure a state introduces a competitive bidding for certain capacity of RES-based energy production. The capacity is usually split according to different technologies. The interested investors are able to submit tenders including the type of production technology, the capacity, the annual amount, and for which price they would be willing to produce energy. The state then chooses the most cost-efficient alternatives, which will be provided with a long-term supply contract at fixed price suggested in the tender. Due to competition, this arrangement may not seem as attractive for investors as for example fixed tariffs. In tendering procedure the price risk is low, actually the same as it is in case of fixed tariffs. However, there are other risks and barriers in tendering procedure for investors. The success in bidding is uncertain for technology developers and investors during pre-contract period. Compared to fixed tariff system investors must bear high risk during project development in tendering procedure, since in a fixed tariff system the investor knows already during planning phase that there will be guaranteed revenues in future if the investor will start production. The uncertainty during technology development and project planning may hamper the development of know-how and domestic manufacturing in countries applying tendering procedure.

For example concerning the UK's NFFO programme it has been argued that the successful wind power technology has been imported mainly from Denmark – a country using price-premiums. It seems that (partly because of tendering system) the UK has not been able to develop such strong manufacturing industry in RES technologies compared to the countries applying fixed tariffs. Further, the tendering systems in the UK and also in France have suffered from other barriers than simple price-related. For example licensing/permitting procedures and problems in grid connection have caused that not all successful tenders have led to a new installed capacity. Also the statistics show that increase in RES use has been slower in tender procedure countries than in fixed tariff (or price-premium) countries. Since France and UK have replaced their competitive tendering systems with other support mechanisms, Ireland remains the only country within the EU applying competitive tendering in promotion of RES.

However, from the society point of view, the system is good, since it in theory minimises the incremental costs of RES energy production, by enforcing the companies to compete and thus to “reveal” the magnitude of marginal unit costs.

Tradable Green Certificates

Tradable Green Certificate systems (TGCs) are a more recent policy instrument in RES policy (see section 5.3.2 Proposal for GHG trading directive). Consequently not much empirical evidence of its advantages and weaknesses is available at the moment. Also in this case the cost efficiency is achieved by compelling the RES producers to compete, which would be beneficial from the society point of view. This system gives a more continuous circumstances to develop and invest than tendering procedure. As in price-premium mechanism, also in TGC producer will sell the electricity on conventional market and get a premium on top of electricity price in this case, however, by selling the green certificates on certificate market. Producers can thus plan and implement projects continuously, in contrary to competitive tendering. However, compared to price-premium system, the effectiveness might be restricted since the price of green certificates vary according to market situation making the estimation of future revenues more complex thus increasing risk for the investor.

So far TGC systems have been implemented for example in Belgium, Netherlands and the UK. The discrepancy between theory and practice is becoming evident in the UK, where the quota obligations might not been met. In the beginning the system has not proven to be very effective, since not enough new RES-based electricity generation is brought on line. Consequently, the price of certificates is hiking. In theory this should provide investors with an incentive to build new capacity. However, for other reasons this has not taken place at least in short term. There may be several reasons for this. Firstly, problems with licensing, land use planning, grid connections etc. might exist that prevent new capacity to be built. Secondly, the system itself may still suffer from lack of confidence by potential investors, since it is still in its infancy. The lack of confidence causes volatility in the market. There are, however, measures to set limits for volatility of certificate prices.

Usually TGC systems include a penalty charge if the obligation is not met. This penalty forms in practice the price ceiling for certificates: if the certificate prices rise over the penalty level, it is cheaper for consumers to pay the penalty instead of buying certificates. This leads in practice higher electricity price with no effect on RES production. The price ceiling is thus intended to reduce price risk of customers.

In order to reduce risks for electricity and fuel producers a “guarantee price” for green electricity can be introduced. In practice this means integrating a TGC system and price-premium system. If certificate price level is estimated to be at 15 €/MWh, the regulator may introduce an alternative price-premium available for RES electricity fixed at 10 €/MWh. If certificate prices fall under 10 €/MWh, the producers choose the price-premium. This can be seen as a compromise to increase effectiveness by reducing cost-efficiency of a TGC system; the reduced risk should enhance more investments.

9.11 Concluding remarks and suggestions from wood fuel producers' point of view

In the previous chapter the most important theoretical and empirical strengths and weaknesses of different supporting mechanisms were presented. This chapter aims at discussing and listing appropriate solutions in alleviating weaknesses and maintaining theoretical benefits from the wood fuel producers' point of view. In summary, it can be said that the fixed tariff system would be the best solution if the aim is to increase the energy production from RES-E (*i.e.* effectiveness is good). On the other hand, the TGC system might be the best measure to bring the RES-E prices down. (*i.e.* it is a cost-efficient measure). Fixed price-premium system and tendering procedure might fall somewhere between these two mechanisms in respect of effectiveness and cost-efficiency. Thus the most desirable support mechanism therefore depends on the primary goal of a planned system: effectiveness or cost-efficiency?

A country with a relatively high RES-E potential compared with actual use might be more interested in effectiveness, whereas a country with a high penetration of RES-E compared to the RES potential (for example as a result of successful fixed tariff system) might prioritise cost-efficiency.

Figure 9-3, provides a classification of the support mechanisms according to relative effectiveness (i.e., mechanisms towards the top left-hand side of the box) and cost-efficiency (i.e., mechanisms towards the bottom right-hand side of the box):

- The fixed tariff makes available a stated price for the duration of the project: the characteristics are low producer risk, given price.
- In contrast, the electricity price under a TGC system is continuously subject to market forces to ensure the price remains competitive but the risk to the producer is high because of market uncertainties: the characteristics high producer risk, competitive price.
- With the tendering procedure, the price is awarded by competition and is fixed for the contract life irrespective of external affects. The price is competitive at the competition stage, but fixed thereafter. The characteristics are: a limited degree of producer risk at the bid stage, competitive initial price.
- Price premiums/tax incentives offers a certain amount of fixed price, with the balance being subject to electricity market changes. The characteristics are: part of the electricity price is given, but the balance is subject to electricity market forces which creates some risk for the producer.

The decisive factors in the classification are the risk for producer and the price mechanism.

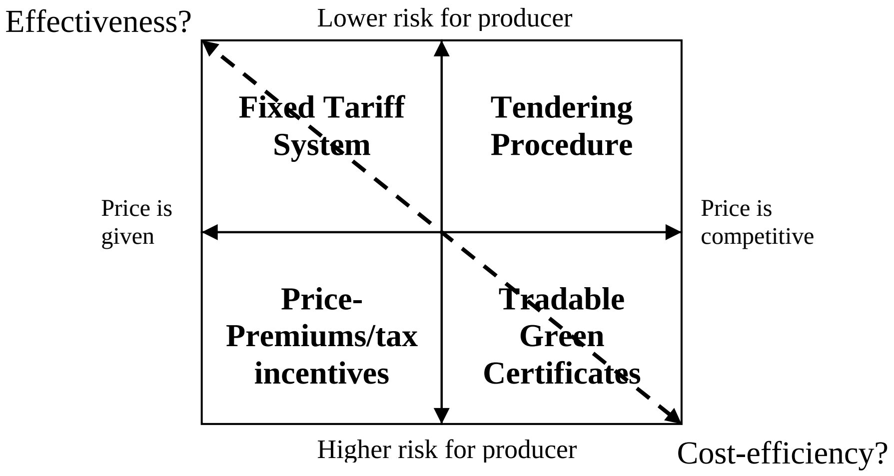


Figure 9-3: Classification of support mechanisms according to effectiveness and cost-efficiency

Since it is in interest of fuel producers to increase the demand for the fuel, effective support mechanisms are preferred rather than cost-efficient ones. The experience so far indicates that fixed tariff systems have been most effective providing the producers with a stable investment environment with appropriate revenues. In the case of fixed tariffs, however, the technological development must be assured, so that the national technologies and producers will remain competitive also in international context, since the liberalisation of the electricity markets within the Community will enable producers compete more and more on international arena. This can be enhanced by implementing specific R&D and information dissemination programmes for specific technologies. Investment subsidy might not be as appropriate form of support as fixed tariffs in case of wood fuels, at least as the main support mechanism. However, investment subsidies are important in respect of technological development and should be considered as complementary mechanisms.

A certificate trading scheme is a new mechanism and it is difficult to make firm statements concerning its appropriateness from wood fuels producers point of view. Theoretically, the negative feature for producers is that the mechanism continuously narrows the certificate prices and thus profits all the time: When technological development increases the cost-efficiency of new installations, it decreases all others' revenues via market mechanism. To increase the effectiveness of a TGC system a guarantee price can be provided.

Continuous competition, however, may increase the competitiveness of producers in international context. International development has to be observed as well. In some studies Ireland's indicative target in RES-E directive is said to be rather low compared to the EU level. Therefore, the certificate prices in national TGC system could be lower than in an international TGC system. From producers' point of view an international TGC system would in this case be more desirable than national TGC system.

When introducing support mechanisms for RES, not only price-related problems should be solved but emphasis has to be put also on other factors such as grid connection issues, land use planning, permitting procedures etc. These problems are often more difficult for RES production because of their often small size and sometimes remote locations. The empirical findings above confirm that these factors have in many cases ruined the effectiveness of a basically appropriate financial direct support mechanism.

9.12 Support mechanisms for Ireland

The previous section identified five possible support mechanisms: fixed-tariff, premium-price system, investment subsides, competitive tendering and tradable green certificates. The support mechanism for wood-energy in Ireland is considered under two categories which is in accordance to the national targets set by the EU for CO_2 reduction and electricity generation targets:

- Electricity generation from renewables sources (RES-E), including CHP;
- Sustainable heat supply.

The criteria for any mechanism should ensure:

- Benefit for the national environmental inventory;
- Cost-efficiency for the support providers;
- Acceptable risk for potential investors;
- Due account is given to the significant operating costs of wood-energy projects;
- The competitive position of wood-energy projects is maximised compared with other renewable energy sources.

The term *wood-energy* is coined rather than the use of the generally excepted name *biomass* which would include agricultural wastes and residues such as straw and chicken litter. Being wastes, these materials have little or no value and could undermine any value being sought by wood-energy suppliers.

RES

The existing support for RES is the AER which is a competitive tendering mechanism. From a Government prospective, this is more cost-effective than the fixed tariff and premium-price alternatives and it is therefore most improbable that Government would consider promoting the latter two systems.

Investment subsidies are not particularly effective on biomass projects because the operating costs of biomass RES is far more influential parameter on the viability than the capital costs. The existence of a successful AER would also deter from support based on the use of investment subsidies.

This leaves two options; retaining the existing arrangements, or using tradable green certificates. The tradable green certificates:

- Do not recognise the technology and consequently the most competitive renewable technologies will be most successful;
- The price of green certificates is subject to demand and supply; future prices are not certain as this will create a barrier to project financing the more ‘risky’ technologies such as biomass. Early experience of the UK’s Renewable Obligation (RO – a green certificate system) has seen this to be the case.

Continuation of the AER’s competitive tendering support is recommended, however lobbying for a *wood-energy* technology band should be considered:

- It would remove the competitive barriers with other renewable technologies;
- Provision for co-firing should be made within any *wood-energy* technology band since this is the most cost-effective approach to wood-energy generated electricity.

Ireland is in a unique position in have three new state-of–the-art peat fired power stations capable of co-wood firing.

A further band of *wood-energy with CHP* could be considered. This needs to be separate from the *wood-energy* technology band as the energy production costs are different. Such a band would:

- Create an opportunity for those existing industrial wood-fired heat only boilers to convert to CHP;
- Be contiguous with any national promotion of CHP as energy efficient technology.
- From a Government perspective, a *wood-energy* technology band would:
- Stimulate rural development and employment;
- Help develop fuel diversity;
- Promote an environmentally acceptable form of fuel that could perfectly complement the use of peat as a fuel;
- Help in enhancing the security of national fuel supplies;
- Add firm base-load electricity production (in contrast to wind) on to the networks

Heat Supply

There is no heat market as there is an electricity market so the options for support would focus on the wood-fuel supply or investment support.

Gaining Government support for wood-fuel supply would be difficult because of the lack of any developed supply structure, fuel standards or accreditation surrounding the use of wood as a fuel. Under these circumstances, Government would view such support as impractical to implement. Investment support is the only practical alternative.

In the UK, heat related initiatives have been aimed at the domestic and public sectors either as part of energy efficiency initiatives or sustainable development policies involving district heating. On this basis, it is recommended that investment support should focus on the domestic and public sectors which could be delivered by the Sustainable Energy Authority of Ireland.

Domestic Sector

Domestic sector investment subsidy could subsidise the installation cost of domestic wood boilers. At a cost of €5000…€7500 for a domestic wood pellet boiler depending on capacity, these boilers are about 4 to 5 times more expensive than that of a comparable oil or gas boiler. The level of subsidy required would be equivalent to the difference in installation cost between a wood pellet boiler and the equivalent fossil fuel boiler. This approach would be most effective where the cost of competing heating is high, i.e., oil or all electric heating.

Public Sector

District heating (DH), with or without CHP, is often a public sector initiative. As well as the potential cost savings, DH can deliver many social and environmental benefits. Its uptake is often prevented by the high initial investment requirement and the fact that organisations do not adequately account for the through-life benefits.

DH is extremely fuel-flexible, and in conjunction with wood-energy, has the potential to deliver cost savings to end-users and significant environment benefits in terms of CO_2 emission reductions by displacing the use of fossil fuels and electric heating.

The two barriers of high initial investment requirement and the significant operational costs can be addressed by considering investment support based on the whole life costs of the project. This approach has been adopted the UK's Community Energy Programme for supporting the uptake of community (district) heating by making available GBP 50m for the promotion of community energy including schemes with CHP.

The approach is to invite public sector organisations to tender their project for capital grants based on the level of support required to make the tendered scheme a commercial proposition. The evaluation criteria includes factors such as tonnes of CO_2 saved per GBP of grant awarded, value of savings per GBP of grant awarded etc. A wood-energy scheme would be highly advantaged in terms of CO_2 saved.

Other Initiatives

Other initiatives should be pursued to boost *wood-energy* opportunities:

CO_2 *Tax Exemption*

Government is considering the introduction of Greenhouse Gas Taxation. It is important that the benefits of wood-fuel use is recognised by those formulating the tax to ensure that its use is made exempt from any CO_2 tax by virtue of its CO_2 neutrality;

Tax Concessions

An Enhanced Capital Allowance Scheme to enable businesses to claim 100% first year capital allowances on investments in wood-energy technologies and products. Businesses would be allowed to write off the whole cost of their investment against their taxable profits of the period during which they make the investment. A similar scheme has been in operation in the Netherlands and is now being implemented in the UK.

10 THE BASIS OF TRADING WOOD FUELS

10.1 General

Measures to maintain biofuel competitiveness

Production and utilisation of renewable energy have been promoted for a fairly long time by providing funds for research and development and by introducing financial and fiscal measures, such as energy taxation of fossil fuels and grants for investments or support for electricity production from renewable energy sources. In 1990 Finland was the first in Europe to introduce CO_2 taxation. In heat generation biofuels are not taxed, because net CO_2 emissions from their use are small, even including the harvesting and transport. To maintain biofuel competitiveness in power generation, a tax subsidy was introduced in 1997, when fuel taxes were replaced by taxes on electricity consumption.

Better competitiveness with intensive R&D

In Finland, great emphasis has been given to wood based fuels in the development of energy technology. As a result of these R&D activities, the production cost of fuels from forest residues has been reduced considerably, resulting in a rapid increase in the use of forest chips in recent years. In addition to machine development, the focus has been on reducing harvesting and transportation costs by improving logistics and applying modern information technology solutions within the supply chain.

Also, increased know-how in combustion technologies has enabled efficient and environmentally acceptable utilisation of low-grade fuels. The development of fluidised bed combustion technology during the last 20 years provides a good example. Finland is a trendsetter in combined heat and power production, with CHP plants accounting for over 30 per cent of the total electricity production both in industry and larger municipalities.

Fuel flexibility with co-firing

Quite often, energy production based on biomass is hampered by limitations in the supply and/or fuel quality. That is why co-firing with two or more fuels is widely used. This is especially true in large-scale electricity production, where the biomass can seldom meet the total fuel demand in a cost- efficient way.

Successful co-firing of biomass requires attention to the fuel properties and mixing techniques. Various types of biomass are frequently burnt together with peat or coal. In some Finnish power plants, up to five different fuels are combusted together. Fuel flexibility ensures the economical operation of the plant even when there are seasonal limitations with some sources of the fuel supply.

Fluidised bed technology is applied to a wide range of fuels, from very moist fuels like bark and sludges up to high-grade fossil fuels. Multi-fuelled fluidised bed boilers achieve fuel efficiency rates over 90 per cent even with difficult, low-grade fuels.

Retrofitting of old pulverised fuel fired boilers to burn biofuels increase the fuel range and flexibility.

Separate biomass gasifiers, which can also use wet biofuels and REF, are one of the tested solutions for existing pulverized coat fired plants. Fluidised bed gasifiers can make efficient use of locally available fuel with low investment costs. Gasification of biomass and co-combustion of the biomass derived product gas in existing coal-fired boilers offer several advantages: minimal environmental impact with low investment and operation costs.

Local fuels efficiently used for heat supply

In Finland, space heating accounts for about 20 per cent of the primary energy consumption. Most of the heat is generated by CHP technology or by loca1 district heating plants. Especially in rural areas and in one-family houses, however, separate heating systems are needed. There is increasing interest among municipalities and industry to heat their own buildings and facilities by locally available fuels. This is a question of boosting the local economy, too.

In Finland, cooperation between industrial plants and municipalities has been a success when the partners have been organising heat supply together utilising biomass fuels. In these cases, the plant together with the local agricultural businesses provides the fuels. The power plant and the required other investments are financed by the municipality or other partners. Raw material use and energy recovery are kept in balance in the wood procurement chain.

Biomass is typically a local fuel, limited in supply and cost-effective only within a restricted distance. Given suitable combustion technology, the conversion of oil- fired boilers to burn locally available biomass constitutes a bioenergy niche with considerable potential in many countries.

Cooperation, the key to success

Good cooperation between Finnish companies, research organisations, universities and public authorities has been the key to the success of the Finnish energy technology sector. The energy cluster of energy producers, consumers, equipment manufacturers and specialist organisations in the energy sector provides synergetic advantages. The cluster is particularly important for business chains and technology development.

Emphasis on the chain of research, development, demonstration and commercialisation has been fruitful. The development of FBC technology, from bubbling fluidised bed to circulating fluidised bed combustion and on to advanced gasification, is a good example of this.

Cooperation between industrial companies and municipalities regarding the heat supply is also very common. A municipal plant may provide process steam to a local factory, or conversely an industrial heating plant may supply district heat to local consumers.

Finnish companies tend to work together to implement projects both with domestic partners and local foreign partners. In large export projects, close cooperation, from consultancy and planning to final delivery of the plant, enables the client to find the most efficient and environmentally sound solution.

The forest industry, the main provider and user of wood based energy

In Finland, the main provider and user of wood based energy is the forest industry, which gets the wood fuels at a competitive price in connection with raw material procurement or as a by-product of wood processing. This creates a natural context for the development of bioenergy technology.

About 6.5 Mtoe of wood based fuels (35 million m3 solid, calculated as wood) are used in Finland annually for energy production, covering 20 per cent of the total consumption of primary energy. Most of the wood based energy is recovered from liquid and solid industrial wood residues. Only a modest share comes from the forest chips and traditional firewood.

The total share of wood based energy in Finland is higher than in any other industrialised country in the world. Nevertheless, our goal is to increase the energy use of wood fuels. In the Finnish conditions, this is considered one of the most efficient ways to reduce greenhouse gas emissions. Since all industrial wood residues are already used either as raw material or to produce energy, any increase must be based primarily on the recovery of unutilised biomass reserves in the forests.

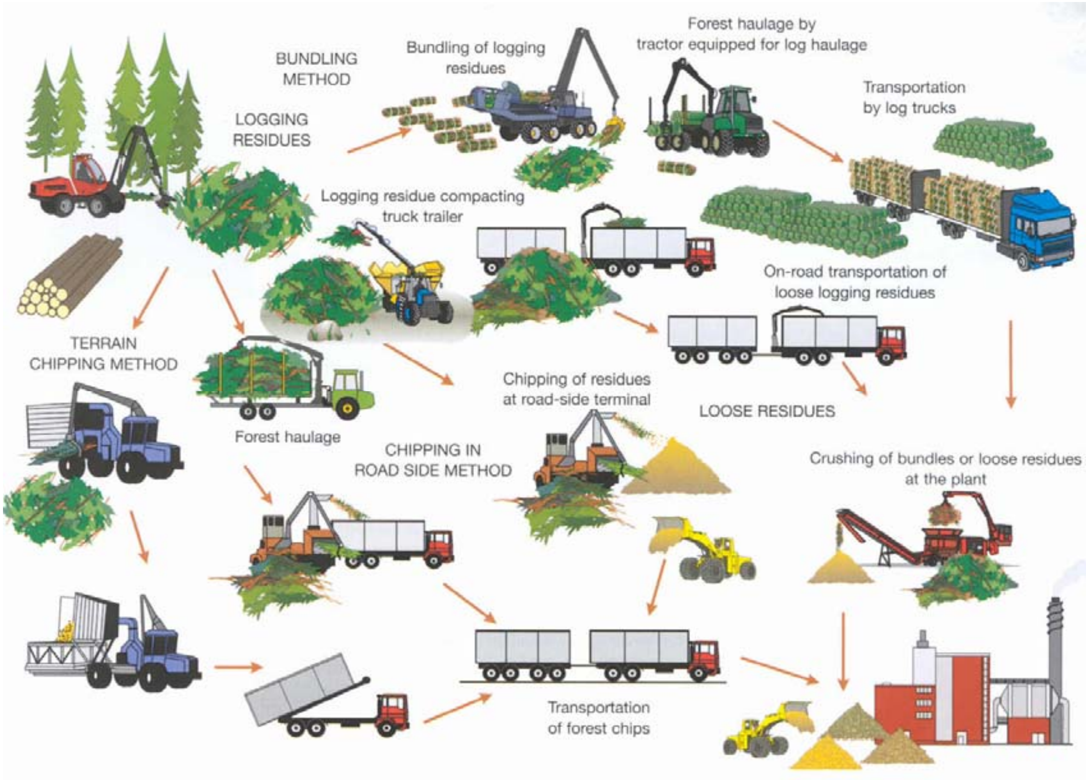


Figure 10-1 Different methods in the wood procurement of forest chips

Finnish timber harvesting organisations apply modem technology and efficient logistic chains to supply the raw material to the industry. By integrating wood fuel production with the industry's raw material supply chain, it is possible to achieve economies of scale and reduce transportation and overhead costs.

The nominal price of forest chips has declined by 35 per cent over the past two decades, thanks to a general decline in procurement costs of industrial timber, technological advances in forest chip production technology and the related procurement logistics as well as increased production volume.

When logging residues are recovered from regeneration areas, fuel transport makes up almost half of the total cost. Compacting logging residues to bundles makes it possible to apply standard forwarding and trucking equipment for off-road and on-road transportation of forest biomass. Modern information and satellite technologies will be applied in the future to make the logistics more economical.

10.2 Wood fuel specifications

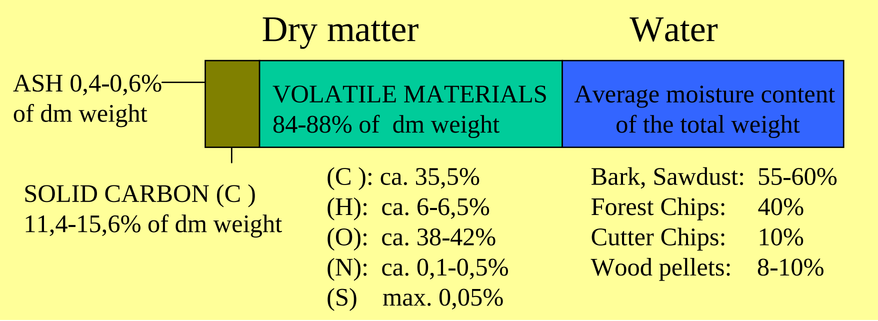
10.2.1 General aspects of wood as a fuel

The characteristics affecting the properties of wood as a fuel are: heating value, chemical composition, moisture content, density, hardness, the amount of volatile matters, the amount of solid carbon, ash content and composition, the melting behaviour of ash, the slagging behaviour of ash and the amount of impurities, dust and fungi spores.

Wood fuel chips, for instance, are often made of various tree species with various proportions of wood, bark, foliage, branches, buds, and even cones. This causes variation in the fuel properties.

Approximately one half of fresh, just fallen tree is water. The other half consists of dry matter of wood, approximately 85% of which consists of volatile matters, 14,5% of solid carbon and 0,5% of ash. When wood is combusted, its components will change into steam of water (H_2O), carbon dioxide (CO_2), nitrogen oxides (NO_2), sulphur oxides (SO_2) and ash. Wood has practically no sulphur at all, as its share in wood is 0,05% at the highest. The average chemical content of wood fuels is shown in Table 10-1.

Table 10-1 Average Chemical Contents of Wood Fuels



(C): ca. 35,5%
(H): ca. 6-6,5%
(O): ca. 38-42%
(N): ca. 0,1-0,5%
(S) max. 0,05%

Bark, Sawdust:	55-60%
Forest Chips:	40%
Cutter Chips:	10%
Wood pellets:	8-10%

10.2.2 List and values of Wood fuel parameters

Wood Fuel Characteristics

A summary of Finnish wood fuel characteristics is presented in Table _.

Table 10-2: Finnish wood fuels with typical ranges of variation

	Logging residue chips[a]	Whole tree chips	Log chips	Stump chips	Softwood bark	Birch bark
Moisture content, w-% (fresh chips)	50-60	45-55	40-55	30-50	50-65	45-55
Net calorific value in dry matter, MJ/kg	18.5-20	18.5-20	18.5-20	18.5-20	18.5-20	21-23
Net calorific value as received, MJ/kg	6-9	6-9	6-10	6-11	6-9	7-11
Bulk density as received, kg/loose m^3	250-400	250-350	250-350	200-300	250-350	300-400
Energy density, MWh/m^3 of bulk volume	0.7-0.9	0.7-0.9	0.7-0.9	0.8-1.0	0.5-0.7	0.6-0.8
Ash content in dry matter, w-%	1-3	1-2	0.5-2	1–3	1-3	1-3
Hydrogen content in dry matter (H), w-%	6-6.2	5.4-6	5.4-6	5.4-6	5.7-5.9	6.2-6.8
Sulphur content in dry matter (S), w-%	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Nitrogen content in dry matter (N), w-%	0.3-0.5	0.3-0.5	0.3-0.5	0.3-0.5	0.3-0.5	0.5-0.8

[a] Logging residue chips or Harvesting residues (today usually recovered in bundles) have been used in Finland in industrial scale for about 5 years and have been established as a normal fuel component in Finland today. However, it is more expensive than wood wastes originating from forest industries and peat. Harvesting residues are used in amounts that are available at competitive prices. There are many small (< 2 MWth) heating stations in Finland that are using only harvesting residues. Power plants fuel supply is always based on a fuel mix consisting typically of forest industry by-products, peat and harvesting residues to the amounts available at competitive prices.

Table 10-3: Finnish wood fuels with typical ranges of variation (continued)

	Wood residue chips	Saw residue chips	Sawdust	Cutter chips	Grinding dust	Plywood residue	Uncoated wood
Moisture content, w-%	10-50	45-60	45-60	5-15	5-15	5-15	15-30
Net calorific value in dry matter, MJ/kg	18.5-20	18.5-20	19-19.2	19-19.2	19-19.2	19-19.2	18-19
Net calorific value as received, MJ/kg	6-15	6-10	6-10	13-16	15-17	15-17	12-15
Bulk density as received, kg/loose m^3	150-300	250-350	250-350	80-120	100-150	200-300	150-250
Energy density, MWh/m^3 of bulk volume	0.7-0.9	0.5-0.8	0.45-0.7	0.45-0.55	0.5-0.65	0.9-1.1	0.65-0.8
Ash content in dry matter, w-%	0.4-1	0.5-2 0	0.4-0.5	0.4-0.5	0.4-0.8	0.4-0.8	1-5
Hydrogen content in dry matter (H), w-%	5.4 -6.4	5.4 –6.4	6.2 -6.4	6.2 -6.4	6.2 -6.4	6.2 -6.4	6-6.4
Sulphur content in dry matter (S), w-%	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.1
Nitrogen content in dry matter (N), w-%	0.1-0.5	0.1-0.5	0.1-0.5	0.1-0.5	0.1-0.5	0.1-0.5	0.1-0.5

Moisture Content

The moisture content of wood significantly influences the net calorific heating value since vaporising water requires energy. The moisture content of fresh wood fuel varies from 50 to 60 percent of the weight of the total mass. In general, the moisture content of wood fuels varies usually from 20 to 65 percent and is influenced, among other things, by the climatic conditions, the time of year, tree species, the part of stem in question and by storage phase. The effect of moisture content on the heating value of wood is clearly defined in Figure 10-2.

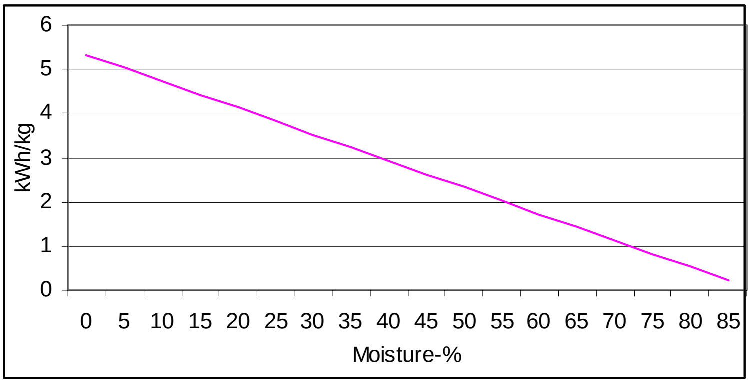


Figure 10-2: The effect of moisture content on the heating value of wood (kWh/kg)

It is thus obvious that the acquisition of energy per m^3 of wood fuel increases as the dry matter content per m^3 increases and the moisture content decreases. The dry matter content of the chip measure varies considerably. This is influenced by the basic density and the solid volume content of chips. Basic density (kg/m^3) indicates the relationship of dry mass to solid volume measure, or how much dry wood weighs per a solid measure of wood.

If a plant has been designed to use moist fuels, no technical problems will occur but high moisture content will impact the overall feasibility of the energy production:

- the more water fuel contains -> lower heating value -> fuel efficiency is lower
- the more water fuel contains -> bigger boiler volume needed -> more expensive boiler
- transportation of water is not feasible

Further, most automation systems cannot react to rapid variations in moisture content resulting in incomplete combustion, which increases emissions.

Heating Value

The calorific heating value of dry matter does not vary a great deal from one tree species to another (18.7 -21.9 MJ/ kg), but it is slightly higher in coniferous species than in deciduous tree species. This is caused by the higher lignin and resin contents in coniferous species.

A summary of heating values for Nordic woody biomass is shown in Table 10-4.

Table 10-4: Effective heating values of Nordic woody biomass (MJ/kg)

Species	Stem without bark	Bark	Whole stem	Crown	Whole trees
Scots pine (Pinus sylvestris)	19,31	19,53	19,33	20,23	19,52
Norway spruce (Picea abies)	19,05	18,8	19,02	19,77	19,29
Downy birch (Betula pubescens)	18,68	22,75	19,19	19,94	19,3
Silver birch (Betula pendula)	18,61	22,52	19,15	19,53	19,29
Grey alder (Alnus incana)	18,67	21,57	19	20,03	19,18
Alack alder (Alnus glutinosa)	18,89	21,48	19,31	19,37	19,31
Trembling aspen (Populus tremula)	18,67	18,57	18,65	18,61	18,65

Particle Size Distribution

The particle size and moisture content of direct wood fuels or forest fuels are often very heterogeneous. The particle size varies from sawdust-like needle and bark material to sticks of wood and branch pieces. The size of the wood particles is influenced both by the original raw material being chipped and by the chipper types. The more stern wood the raw material contains, the more even the particle size distribution will be. The condition of chipper knives as well as the aperture size of the screen in the chipper also influence the particle size. Chips produced with crushers have typically coarser particles compared to the chips produced with chippers.

There is a large variety of different chippers available. Wood chip users always define the size and quality. Usually size is defined so that 95 % of chips must fall under diameter of 30 mm, 45 mm or 60 mm. Maximum moisture content (w-%) allowed is usually defined for chips to be under 40%, 50% 60% or 65%.

It is the fuel supplier’s responsibility to deliver the size and quality of chips that he has signed a delivery contract for.

Density

The solid volume content of chips indicates the relationship between the masses of so-called bulk measure and solid measure, that is, how many solid m^3 one bulk m^3 will yield. The solid volume content of chips is influenced mostly by the technical specifications of the chipper, such as particle size distribution, blowing power and loading method. The drying time of chips and the compacting that occurs during long-distance transport, however, have no decisive effect on the solid volume content value. Solid volume content (the portion of solid measure) is needed for converting bulk measure into solid measure. The bulk density of the Northern woody biomasses is in the range of 200- 350 kg / loose m^3.

The density and ability to control it will affect fuel handling systems (e.g. conveyor designed).

Ash Content and Properties

The fuel contains various impurities in the form of incombustible component parts ash. Ash itself is undesirable, since it requires purifying of the flue gas for particles with a subsequent ash and slag disposal as the result. The ash contained in wood comes primarily from soil and sand absorbed in the bark. A minor proportion also comes from salts absorbed during the period of growth of the tree.

The ash also contains heavy metals, causing an undesirable environmental effect, but the content of heavy metals is normally lower than in other solid fuels.

A special characteristic of ash is its heat conservation property. For wood stoves, the ash layer at the bottom of the stove forms a heating surface, transferring heat to the final burnout of the char. For heating systems using a grate, the ash content is important in order to protect the grate against heat from the flames.

Wood also contains salts that are of importance to the combustion process. It is primarily potassium (K) and partly sodium (Na), based salts resulting in sticky ash, which may cause deposits in the boiler unit. The Na and K content in wood is normally so low that it will not cause problems with traditional heating technologies.

Typical mineral fractions in wood chips expressed as percentage of the dry matter (DM) of the wood is shown in Table 10-5. Compared to straw, the K content in wood chips is approx. 10 times lower.

Table 10-5: Typical Mineral Functions

	% of DM
Potassium (K)	0.1
Sodium (Na)	0.015
Phosphorus (P)	0.02
Calcium (Ca)	0.2
Magnesium (Mg)	0.04

The typical ash formation is shown in Table 10-6.

Table 10-6: Ash formation

	Ash,%dm	P	K	Ca	Mg	Mn	Fe	Zn	S	B	Cu
Birch											
+log chips	0,68	4,3	16,4	20,8	4,1	1,1	0,6	0,5	1,8	0,05	0,04
+whole tree chips	0,79	4,1	15,1	21,9	3,9	0,9	0,6	0,5	1,7	0,05	0,04
+bark	2,18	2,4	8,0	29,1	3,0	2,6	0,3	1,2	0,8	0,09	0,02
Alder											
+log chips	0,92	5,8	19,3	19,3	2,9	0,7	0,6	0,3	2,3	0,05	0,05
+whole tree chips	1,08	5,6	18,3	20,7	2,9	0,6	0,6	0,3	2,2	0,05	0,05
+bark	3,5										
Aspen											
+log chips	0,92	1,9	21,4	20,9	3,2	0,5	0,5	0,2	1,8	0,06	0,04
+whole tree chips	1,09	2,1	20,5	22,0	3,1	0,5	0,4	0,2	1,6	0,06	0,04
+bark	3,4										
Pine											
+log chips	0,74	2,2	11,5	2,2	5,1	2,1	0,7	0,2	2,8	0,05	0,03
+whole tree chips	0,8	2,4	12,2	22,2	5,0	1,9	0,7	0,2	2,6	0,05	0,03
+bark	2,55	2,5	8,9	26,9	2,7	0,9	0,7	0,2	1,4	0,04	0,02
Spruce											
+log chips	1,01	2,7	12,3	24,5	3,0	3,3	0,7	0,3	1,3	0,05	0,04
+whole tree chips	1,25	2,8	11,0	24,7	2,8	3,0	0,7	0,3	1,3	0,05	0,04
+bark	3,2	1,5	6,0	32,4	2,2	1,7	0,4	0,4	0,6	0,04	0,01

If ash is exposed in the boiler to over 1200 C^0 temperature, this causes the melting of ash which has several negative influences (e.g. sintering of ash, -> bed sand material would not work as supposed to). The typical ash melting points are shown in the table below.

Table 10-7: Ash melting point (^{o}C)

	Wood chips	Clean bark
Softening point	1200	1340-1405
Melting point	1250	1650
Complete melting	1275	1650

In general, however, the ash content of wood based biomass is very low (< 2%) and highest in bark (2-5%), which collects sand and other impurities.

Altogether ash should not be a major issue for a properly designed biomass plant.

COFORD is currently funding research to develop a marketable fertiliser from wood ash. This could eliminate the disposal costs for wood ash and create another advantage over other fuels.

Volatiles

Wood and other types of biomass contain approx. 80% volatiles (in percentage of dry matter). This means that the component part of wood will give up 80% of its weight in the form of gases, while the remaining part will be turned into charcoal. This is one reason why a sack of charcoal seems light compared to the visual volume. The charcoal has more or less kept the original volume of the green wood, but has lost 80% of its weight.

The high content of volatiles means that the combustion air should generally be introduced above the fuel bed (secondary air), where the gases are burnt, and not under the fuel bed (primary air).

Structural Elements of Wood

The structural elements (ultimate analysis) of the organic portion of wood are carbon (45 - 50 percent), oxygen (40 - 45 percent), hydrogen (4.5- 6 percent) and nitrogen (0.3 - 3.5 percent). The distinct advantage of woody biomass over fossil fuels is the small amount of sulphur. The ultimate analysis of some tree species show that carbon and hydrogen contents are rather uniform among species. Bark has a higher percentage of carbon and hydrogen than wood. This is most visibly the case with birch and alder.

In the proximate analysis the amount of volatiles is 65- 95 percent, fixed carbon 17 -25 percent and ash content 0.08- 2.3 percent. Please note that the information of the properties of wood fuels has been collected from several different sources. The most comprehensive data of wood fuel properties was available from ECN laboratories from Netherlands.

10.3 Quality control at the power plant

Fuel supply contracts

The definition of biomass quality and the fuel supply contract should be made prior the implementation of the power plant project. Commonly agreed fuel characteristics are the starting point of a design of the power plant. Further, they have continuous impacts on operational performance of a plant including the final energy output from the delivered fuel.

The wood fuel supply contract is the result of negotiations between the buyer and the seller. Typical contract durations are around one year as prices change according to demand and supply. Framework agreements of up to five years are also used between parties. These agreements have the provision to review prices at regular intervals, typically one year, to ensure the supply of wood remains competitive.

The wood fuel supply contract size depends on the seller's size and the buyers demand. The aim is to keep the number of contracts to as few as possible to minimise the administration burden.

Biomass fuel pricing is usually made according to the real energy content, taking into consideration calorific value of dry matter, moisture content and weight. In practice the net calorific value of dry matter is quite independent on the tree species, being 19.0 – 20.5 MJ/kg.

Accuracy and definition of a pricing system depends on size of the power plant, smaller the plant a more simplified a system is appropriate.

A wood fuel contract form, according to Finnish experiences, could have the following structure (table of contents):

1. Parties involved
    - Identification information of the buyer and seller
2. Objective of the contract and power plant(s) subject to the fuel supply
    - Supplier delivers agreed quantities and qualities of wood fuel to the place agreed according to the delivery terms specified in this agreement
3. Supply period
    - Length of the supply period (usually one calendar year)
4. Definition of fuel types and quantities
    - Typically a table showing the fuel types, quality classes and quantities is provided
    - Average fuel characteristics and allowed variation

Table 10-8 Fuel Type Classification

Fuel type	Quality class	Quantity, MWh
Logging residue chips		
Stump chips		
Whole-tree chips		
Bark		
Sawdust		

5. Terms of fuel delivery

  - Destination (address) of the deliveries
  - Delivery equipment specifications (type of trucks to be used etc.)
  - Delivery frequencies
  - Security of supply
6. Determination of fuel energy content and quality
    - Methods to be used to verify energy content and quality
    - Level of accuracy to be used
    - Quality standards to be used
    - Fuel sample analysis procedures
7. Pricing of the fuel and terms of invoicing
8. Force major
9. Discrepancies
    - Actions in case of deviations in deliveries
10. Validity time and denouncing of the contract
11. Transferring of the contract
12. Signatures

Fuel quality control

Quality definition and control are especially important in case of use of biomass fuels without previous experience. The system adopted for fuel quality control will depend on size of the biomass-fuelled boiler plant. In case of small plants (1-10 MW), less sophisticated quality control system is appropriate. Basic parameters for biomass fuel quality assessment can be classified in terms of:

· energy density as received MWh/m3
· moisture content w-%
· ash content
· particle size

For an energy density as received, a minimum value (MWh/m^3) is usually given, whereas for the moisture content, a maximum value (w-%) is usually given. For a particle size, major part of the delivered fuel (for instance 95%), should be less than agreed maximum size.

Finnish Bioenergy Association published Quality Assurance Manual for Solid wood Fuels in Finland in 1998. This publication covers, inter alia, sawmill and forest residues. The manual is a practical guide, defining the methods, by which the quality and energy amount can be reported and stated unambiguously and appropriately between a power company and a biomass fuel supplier.

The methods and information applied in the Finnish quality assurance manual can well be adapted to Ireland’s conditions. The manual is recommended to be used in all delivery agreements of wood fuels. As regards the agreements in force, the buyers and the sellers may agree upon the possible application of the manual case by case.

11 ANALYSIS

11.1 Wood-Energy Potential

The annual energy potential from all pulpwood, sawmill residues and harvestable forest residues produced in Ireland is estimated to be over 17.3 PJ (2.3 million green tonnes[9]) in 2001, rising to 26 PJ (3.5 million green tonnes) by 2015. The price afforded by the energy market will determine how much of this potential is acutally realised in energy production.

The estimated energy potential of pulpwood, sawmill residues and forest residues surplus to the present market demand and therefore available for energy production is 3.6 PJ (424 green ktonnes) in 2001 rising to 9.4 PJ (1,106 green ktonnes) by 2015.

Depending on the fossil fuel wood displaces, the amount of surplus wood identified could save about a third of a million tonnes of CO_2 every year increasing to just under one million tonnes per year by 2015. This represents 3%, increasing to 8%, of Ireland's present commitment to the EU for reductions in CO_2 greenhouse gas emissions.

Assuming the same surplus wood resource is used to generate electricity, 50 MWe increasing to 132 MWe of renewable generating capacity could be created using similar technology to a modern peat fired plant. This would satisfy between 10%, increasing to 26% of the Green Paper on Sustainable Energy working target of 500MWe of additional renewable generating capacity.

In terms of annual RES consumption, the potential of the surplus wood resource could meet 9%, increasing to 23% in 2015, of Ireland's annual EU RES target of 4.5 TWh.

In terms of heat supply, the energy potential of the surplus wood resource (86 kTOE in year 2001 rising to 227 kTOE by 2015) could:

- Meet the entire estimated annual commercial and industrial consumption of solid fuel of 4 kTOE;
- Supply about 27%, rising to around 75% by 2015, of the estimated annual domestic use of coal (316 kTOE) or peat (290 kTOE). (NB: the forecast is for a fall in domestic coal and peat consumption over this period).

11.2 Wood-Energy Competitive Position

11.2.1 RES-E (Electricity Generation)

The following power generation options have been studied over a 15 year period based on a 10% discount rate. The results are summarised in the figure below and are compared with best new entrant electricity prices for 2002 and 2003 and the AER maximum biomass project electricity price for AER V and an indicative price for AER VI.

Co-Firing in Edenderry Peat-fired Power Station – 30MWe

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[9] Green wood, 50% moisture content, based on lower heating value

Co-firing wood-fuel in Edenderry peat-fuelled power station would require the wood to compete directly with the delivered cost of peat on a net heat supplied basis and contribute to the investment return in proportion to the wood-generated electricity. The assumption is that virtually no plant modifications are required as has been demonstrated at recent co-firing trials at Edenderry Power station. The price of peat supplied to Endenderry Power is €22/energy tonne[10] (€2.86/GJ).

There would also be a cost benefit in terms of reduced limestone consumption as a result of displacing peat fuel, which is highly plant specific. The benefit has been calculated to be insignificant.

The Client has had discussions with Edenderry Power Station to establish their interest in co-firing wood. They confirmed that they would not consider co-firing because of the obligations under their existing peat supply contracts.

Co-Firing in Moneypoint Coal-fired Power Station – 30 MWe

The lowest cost option (*van den Broek et al*) for co-firing wood-fuel in Moneypoint coal-fired power station would require plant modifications to pulverise the wood-fuel prior to mixing with the coal fuel stream. The proportion of electricity generated from wood-fuel is required to contribute to the investment return to both the main plant and the modification investment.

The Client has had discussions with Moneypoint power station to establish their interest in co-firing wood. They confirmed that they would not consider modifying the plant to co-fire wood because of the strategic importance of the plant as part of the nation's portfolio of generating assets.

Power Only Projects – 10…30 MWe

A new wood-fired power stations sized at 10, 20 and 30 MWe have been studied based on fluidised bed technology and a condensing steam turbine.

Combined Heat and Power

The following CHP plant configurations have been studied:

- 1 MWe/4 MWth
- 7.5 MWe/31 MWth
- 15 MWe/55 MWth

The value of heat supply used was 1.0 eurocent/kWh.

Results

1. The results of the analysis are presented in the Figure 11-1 below. Support for wood is required at the point where the line for each option crosses above the relevant BNE line. The level of support required is determined from:

   cost of electricity for the option - BNE cost

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[10] An energy tonne is equal to 7.7 GJ

2. The maximum feasible support is given at the intersection with the relevant AER line.
3. It can be seen that the electricity prices from the co-firing and power only options are very similar and lower than CHP plant options. This is because:
   - The study assumed that all the options are required to payback the main plant investment in addition additional investment for plant modifications, and;
   - CHP is disadvantaged because the plant is not optimised for power generation. A proportion of the heat is used for heat supply (which generates a low value income stream) at the expense of power generation (which high generates a higher value income stream).
4. There is a certain amount of error between the curves for CHP given in Figure 11-1 Relative Competitiveness of different Power Generation Options and Figure 8-2 CHP Plant Electricity Production Costs. The reason for the difference is that the curves for the latter are ‘best-fit’ curves based on a range of data for CHP plant designed to meet different duties including industrial and municipal plant. In contrast, the Figure 11-1 curves were determined from plant specific models.

   The comparison of power-only plant curves (Figure 8-1 Power Plant Electricity Production Costs) is far more consistent as the design basis of power plants does not widely vary.

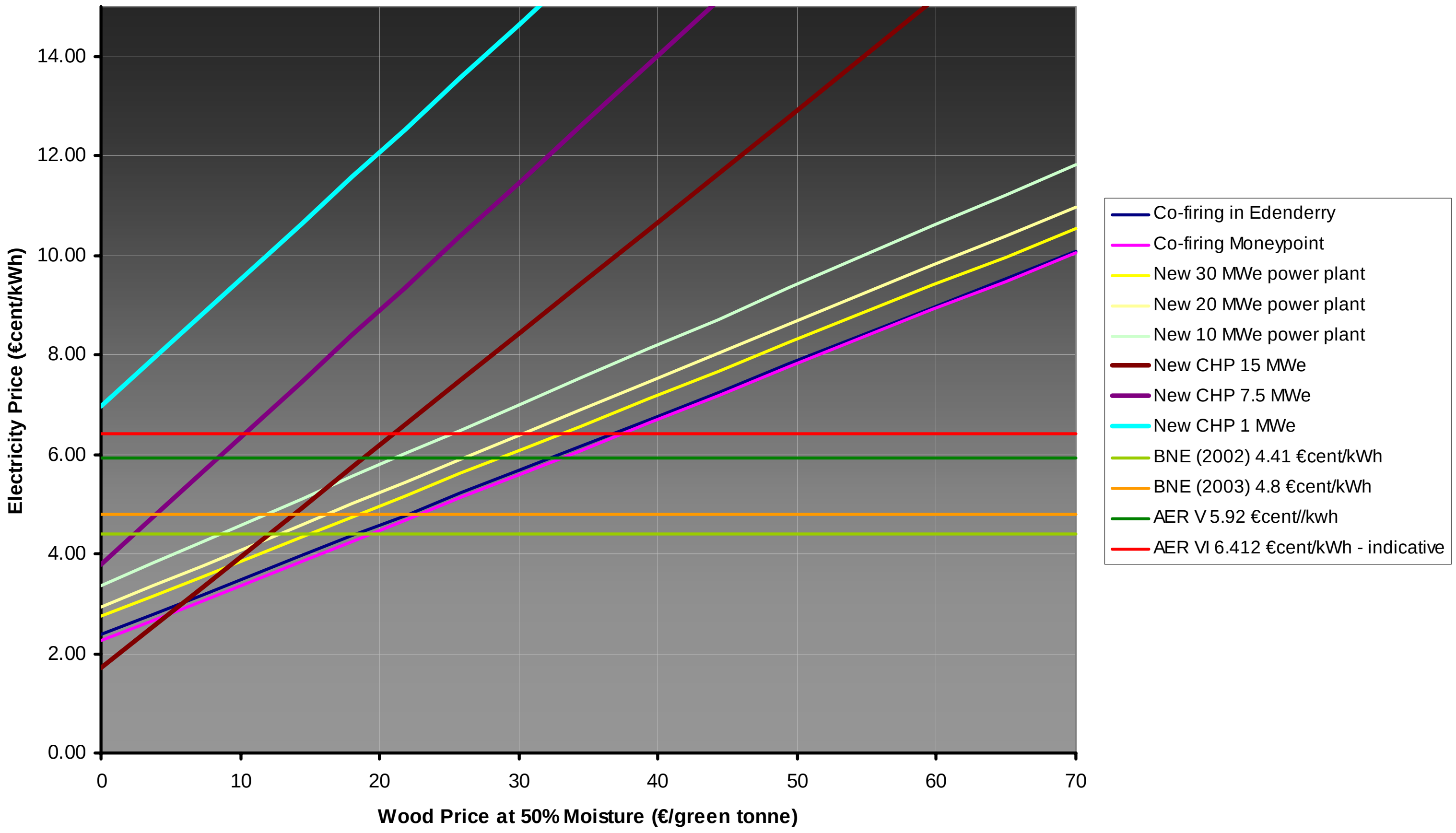
Conclusions

Co-firing offers the best value in terms of support investment in power generation from wood fuel. Non-technical barriers mean that the likelyhood of these options being implemented are highly unlikely.

New power-only plants are only slightly more costly than co-firing as a option. The larger the generating capacity of the plant, the lower is the electricity cost as this is a function of economy of scale.

CHP plants produce electricity at considerably higher costs compared with the same capacity power-only plant. CHP plant needs significanly higher levels of support than the same capacity of power-only plant inorder to be viable.

Figure 11-1 Relative Competitiveness of different Power Generation Options (15 year period, 10% IRR, CHP heat = 1 €cent/kWh)



11.2.2 Heat Supply

Public, Commercial and Industrial Sectors

The study has recognised that the potential for heat supply based on wood in the public, commercial and industrial sectors is very limited because of:

- The very low use of solid fuels in the sectors, and;
- The low cost of competing fuels such as gas and oil, combined with the operational convenience of these fuels (see the fuel analysis in the following section).

Section 9.12 Support mechanisms for Ireland, Heat Supply, *Public Sector,* outlines a possible support mechanism for wood-fired district heating based on the capital support required using a whole life costing approach.

However the small potential of these opportunities are unlikely to justify the cost of developing and implementing such a programme. An alternative approach would be to support individual projects through a demonstration grant scheme.

Domestic Heat Supply

This study has recommended that wood-fuelled heat supply to the domestic market should be supported by means of grant to subsidise the installation cost equivalent to that of a competing oil-fired boiler installation.

The equivalent price of green wood and wood pellets in the domestic market has been determined and is presented in Table 11-1 below. The same equivalent price for the commercial fuel market is also given.

Table 11-1 Equivalent Wood and Pellet Selling Prices

	€cent/kWh	€/GJ	Equivalent wood selling price @ 50% MC €/t	Equivalent pellet selling price @ 8-10% MC €/t
Domestic Tariff				
Peat	1.57	15.7	43.56	75.36
Peat briquettes	3.54	35.4	98.21	169.92
Coal	2.88	28.8	79.90	138.24
Kerosene	4.06	40.6	112.64	194.88
Gas	2.23	22.3	61.87	107.04
Electric	10.71	107.1	297.13	514.08
Electric Night Saver	4.05	40.5	112.36	194.40
Commercial Tariff				
Peat	1.56	4.33	43.28	74.88
Coal	0.7	1.94	19.42	33.6
Gas Oil	0.873	2.43	24.22	41.90
Gas	2.44	6.78	67.69	117.12

Wood pellets would be the most attractive form of domestic wood fuel because the convenience of handling; a such a system is easier to manage than peat and coal fired boilers and only marginally less user-friendly than oil (kerosene) fired heating.

It is unlikely that wood pellet domestic heating would replace oil and all-electric heating systems because of the ease-of-use issues. The all-electric system would require the installation of a wet radiator system. Wood pellet boilers are most likely to compete where solid fuels are presently used, i.e., coal and peat, and especially where existing solid fuel boilers are being considered for replacement with oil fired systems, which is becoming increasingly the case. It has been estimated that some 400,000 households used coal and peat for heating in 2001. This figure is expected to fall to around 20,000 by 2015 due to fuel switching to oil and, as it becomes more widely available, gas.

Examining the fuel cost issues, and based on the price of large-bag and bulk supply of wood pellets in the range €93…€113/t at 8-10% moisture content (**Table 8-1 Wood Pellet Case** Study), wood pellets could successfully compete on price in the domestic market with peat briquettes, coal, kerosene and electric heating assuming the cost of conversion to wood-pellet boilers was met elsewhere.

Wood pellets would not be competitive in the commercial market. The competitive position against gas is marginal, however the convenience of gas fired heating systems is likely to outweigh the small cost advantage of wood-pellets over gas at the prices stated in Table 11-1.

The strategy for a domestic wood pellet boiler subsidy is considered in the context of competing with oil fired systems. Assuming the cost of a wood pellet boiler installation for the average domestic application is €7500, and the equivalent oil fired boiler costs €2500, then the maximum level of subsidy would be €7500-€2500=€5000 per house hold.

Targeting 5% of the forecast solid fuel users in 2015, i.e., 1000 households, the subsidy would cost Government:

$$1000 \times €5000 = €5{,}000{,}000$$

The average annual domestic heat demand is 12,000 kWh/a. Assuming the wood pellet boiler replaces either a coal or peat fired boiler operating at 76% efficiency, then the annual savings in CO_2 emissions per household would be approximately:

- Coal: 5.4 tCO_2/a per household
- Peat: 6.0 tCO_2/a per household

The total annual emission savings for 1000 households assuming either coal or peat is displaced would be:

- Coal: 5,400 tCO_2/a, or
- Peat: 6,000 tCO_2/a

11.3 Cost/Benefit

The cost/benefit analysis determines the therotecial cost to Government in terms of number of euros of subsidy spent and the unit reduction in tonnes of CO_2 achieved, i.e., €/tCO_2 reduction. The results expressed in these terms not only provides a useful value-for-money comparison between the RES-E technologies and the heat supply alternatives, but also offers a direct comparison with the market value of CO_2 in emissions trading schemes.

RES-E

The cost/benefit of electricity generation from wood-fuel assumes that the generated electricity displaces 'grid' electricity. Grid electricity generation in Ireland emits 0.73 kg of CO_2 for every kWh of electricity generated, therefore every kWh generated in a wood fired power station will reduce the national CO_2 emissions by 0.73 kg.

Where Government provides support to that wood fired power station in terms of a premium price electricity contract, the benefit of the support is easily calculated in terms of € of subsdiy per reduction in CO_2 emission. Figure 11-2 illustrates the results of that calculation; for a wood fired power station contracting with Government at say the proposed AER VI price of €cent 6.412 per kWh, the intersection with the condensing power plant line in Figure 11-2 determines a cost of about €89/tCO_2, i.e., the Government is effectively buying CO_2 reductions at €89/tCO_2, although what is acutally happening is that Government is buying RES-E to meets it's EU RES-E obligation.

The case for wood fuelled CHP is different. Not only does the generated electricity displace grid electricity in the same manner as the power station decribed above, but the waste heat displaces heat production in a conventional boiler. The analysis assumes that the CHP heat displaces natural gas burn in a boiler. Based on an average industrial boiler efficiency of 76% and a natural gas emission factor of 0.19 kgCO_2/kWh, the emission factor for boiler heat supply is 0.25 kgCO_2/kWh. Given a CHP heat to power of 3:1, the overall emission factor for wood fuelled CHP expressed in terms of kWh eletrical is:

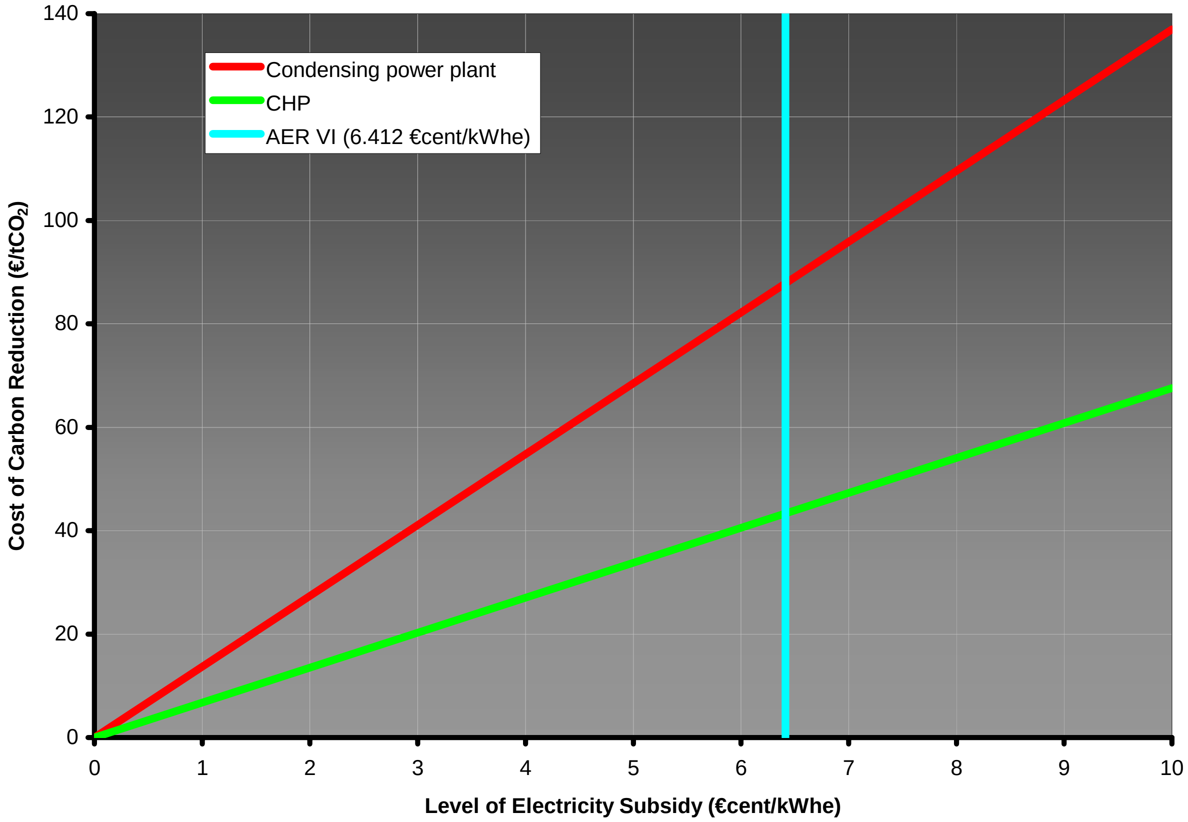
$$0.73 + 3 \times 0.25 = 1.48 \text{ kgCO}_2\text{/kWhe}$$

The CHP line in Figure 11-2 illustrates the cost of the resulting CO_2 reductions. Assuming the proposed AER VI price of €cent 6.412/kWhe, the intersection with the CHP line indicates a price of about €43/tCO_2, which is over half the cost of the power station result (€89/tCO_2).

This result demonstrates the energy efficiency of CHP and that if CO_2 reductions where the objective, then the money spent CHP is over twice as effective in producing CO_2 reductions than the same amount spent on condensing power stations. However the objective is RES-E generation, and it has already been established that CHP requires far higher subsidy to be viable compared with the same capacity power station.

It does however open up the argument that in supporting CHP RES-E, Government could also claim the GHG reductions from the heat supply element as contributing towards the national target. This gives a strong case to lobby for a special band for wood fuelled CHP under the AER.

Figure 11-2



Heat Supply

The recommended heat supply strategy is to subsidise the installation of domestic wood pellet boilers to replace existing solid fuel (coal and peat) boilers. The recommended level of subsidy aimed to achieve parity with the installation cost of oil fired boilers which has been estimated to be €5000 per household.

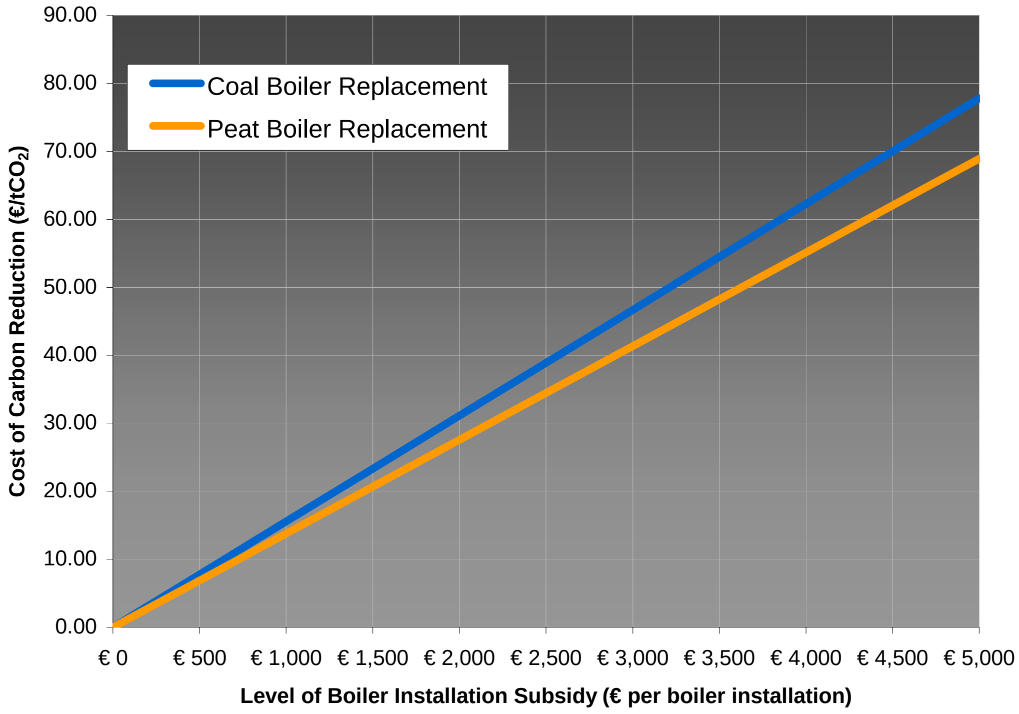
The cost/benefit analysis has been calcualted for a single household as follows:

- The following emission factors where used:
  - Coal: 0.33 $kgCO_2/kWh$
  - Peat: 0.38 $kgCO_2/kWh$

  For example, for every kWh of coal or peat wood pellets replace, 0.33 or 0.38 kg of CO_2 emissions is saved.
- The amount of CO_2 saved is calculated over an average boiler life which is assumed to be 12 years (tCO_2 calculated in previous section) , i.e.,
  - Coal: 12 x 5.4 tCO_2 = 64.8 tCO_2
  - Peat: 12 x 6.0 tCO_2 = 72 tCO_2

- The cost per tonne of CO_2 saved is calcualted by dividing the subsidy by the life time CO_2 savings. Figure 11-3 shows the results for different levels of subsidy from 0 to €5000.

Figure 11-3 Cost to Government of CO_2 Reduction according to Level of Subsidy



The results show that at the recommeded subsidy of €5000 per household, the cost of carbon savings is:

- €69/tCO_2 where peat is replaced and
- €78/tCO_2 where coal is replaced.

Although not as cost effective as CHP at the proposed AER VI price (€43/tCO_2), it represents better value for money than power only projects (€89/tCO_2).

11.4 Sequestration Value of Forestry

The nation's forestry contributes to GHG reduction by absorbing CO_2 from the atmosphere. Barry, Clinch and Convery, 2001 state that applying figures [for sequestration] to Forest Service data and predictions on forest growth, the average CO_2 reduction over 2008-2012 would be 1.29 Mt CO_2yr^{-1} or 9.9% of Ireland's reduction target. In addition, 15,000 ha planted in 2001 will provide for a sequestration of 38,000 tonnes of CO_2 equivalent per annum during the Kyoto period 2008-2012, and increasing the planting rate to 20,000 ha per annum will increase the sequestration rate to 50,000 tonnes CO_2 equivalent per annum during the Kyoto period." (Department of the Environment and Local Government, 2002).

11.5 Fuel Import Substitution

The former Minister of State at the Department of Public Enterprise, Mr. Joe Jacob, T.D., announcing the results of AER V, stated that the competition would reduce Ireland's dependence on imported fossil fuels by more than 2,000,000 barrels of oil annually, redirecting over €40 million back into the Irish economy.

On that basis, using the additional wood fuels available now would redirect €1.7 million back into the Irish economy, rising to €4.5 million in 2015 (at 2002 prices).

11.6 New Employment Potential

EUFORES (2000) estimate that the increase in energy provided from renewable sources can result in the creation of over 900,000 new jobs in the EU15 by 2020. 385,000 jobs are predicted to be created by 2020 from provision of renewable energy, and a further 515,000 jobs from biomass fuel production. This increase takes account of the direct, indirect and subsidy effects on employment, and jobs displaced in conventional energy technologies. Table 11-2 below gives the figures for the Republic of Ireland (net new full Time Equivalent employment relative to base year 1995).

Table 11-2 Net New Employment Creation from Renewables in Ireland, 2005 to 2020

Year:	2005	2010	2020
Ireland (IRL)	4,446	7,981	11,184

Based on data contained in EUFORES (2000), it has been estimated that the net new employment creation from "available" wood energy (and not including production of energy crops) could be 1,500 jobs or more by 2015.

12 SUMMARY AND CONCLUSIONS

The follow summary and conclusions are presented:

1. The annual energy potential from all pulpwood, sawmill residues and harvestable forest residues produced in Ireland is estimated to be over 17.3 PJ (2.3 million green tonnes[11]) in 2001, rising to 26 PJ (3.5 million green tonnes) by 2015.
2. The estimated amount of surplus wood available from the Irish market has the potential to supply some 3.6 PJ (1 TWh) rising to 9.4 PJ (2.61 TWh) by 2015 GWh of energy for heating and electricity supply.
3. The surplus wood could save about a third of a million tonnes of CO_2 every year increasing to just under one million tonnes per year by 2015. This represents 3%, increasing to 8%, of Ireland's present commitment to the EU for reductions in CO_2 greenhouse gas emissions.
4. Used for heat supply, the energy potential of the surplus wood (86 kTOE in year 2001 rising to 227 kTOE by 2015) could supply about 27%, rising to around 75% by 2015, of the estimated annual domestic use of coal (316 kTOE) or peat (290 kTOE).
5. Alternatively, condensing power plant technology could use the wood to generate 50 MWe of electricity, increasing to 132 MWe BY 2015. This would satisfy between 10%, increasing to 26% of the Green Paper on Sustainable Energy working target of 500MWe of additional renewable generating capacity. In terms of annual RES consumption, the potential of the surplus wood resource could meet 9%, increasing to 23% in 2015, of Ireland's annual EU RES target of 4.5 TWh.
6. The use of wood can provide significant national benefits by:
    a. Contributing significant environmental benefits by displacing the use of fossil fuels in heat and electricity supply. Estimates indicate that between third to just under one million tonnes of CO_2 emission savings could be achieved every year depending on the energy conversion technology.
    b. Stimulating rural development and employment as wood fuel supply chains develop to meet market demands;
    c. Helping to increase fuel diversity;
    d. Promoting an environmentally acceptable form of fuel that would perfectly complement the use of peat as a fuel;
    e. Enhancing the security of national fuel supplies;
    f. The displacement of imported fossil fuels with wood fuel from national resources €1.7 million would be redirected back into the Irish economy.
    g. Generating firm base-load electricity on to the national electricity network in complete contrast to the highly variable generation characteristics of wind power generated electricity.
7. The use of wood for energy supply is very well established throughout the world and including European Union member states

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[11] Green wood, 50% moisture content, based on lower heating value

8. In all but a few particular cases in Ireland, the cost of wood fuel technology and it the supply of the fuel cannot compete with existing fuels such as coal, gas, oil and peat. Government support is required to remove this barrier to the uptake of wood for energy supply.

9. Any approach to Government for support must be aligned with current national strategies. The key strategies identified in the study are the Government's commitments to achieving targets set by the European Union for:
    a. The reduction in greenhouse gases and;
    b. The generation of electricity from renewable energy sources (RES-E).

10. A range of different mechanisms is available for supporting RES-E which have been used in EU member states to promote biomass RES-E. The appropriate mechanism for Ireland for wood-energy generated electricity is the competitive tendering arrangement which would be a continuation of the existing AER. Compared with the alternatives, this arrangement is highly cost-effective for the supporting Government and provides the necessary long-term income assurance for potential investors.

11. Different to the previous AERs, there should now be a wood-energy technology band. This would help remove the competition barriers with other renewable technologies.

12. An additional technology band of *wood-energy with CHP* should be considered. This would be separate from the *wood-energy* technology band as the energy production costs are significantly different. Such a band would:
    a. Create an opportunity for those existing industrial wood-fired heat only boilers to convert to CHP;
    b. Be contiguous with any national promotion of CHP as an energy efficient technology.

13. Heat supply from wood fuel is most feasible for the domestic sector. Support is required and should be in the form of capital subsidy for the installation of wood pellet boilers; wood pellet boilers have been selected because of the convenience of operation. The level of subsidy would need to be set at the difference in price between the installation of the wood pellet boiler and the equivalent oil or gas fired boilers, i.e., approximately €5000 per installation.

14. Heat supply from wood fuel for the public, commercial and industrial sectors based on district heating and district heating with CHP is unlikely to be effective because of the small heat demand. Projects in these sectors should be encouraged through demonstration schemes.

15. Other initiatives should be pursued to ensure *wood-energy* is not disadvantaged by any future climate change initiatives, i.e.;
    a. Exemption of wood-energy from any CO_2 tax by virtue of its CO_2 neutral position;
    b. Tax concessions for renewable energy investments; this could include enhanced capital allowances, which would allow exemption from first year corporation tax for all renewable energy plant and equipment investments.

16. Financial analysis has shown that:
    a. RES-E is the most effective means of establishing a demand for wood-energy;
    b. Domestic wood-fuel supply offers the best opportunity for the highest wood prices because of the price levels of competing fuels;
17. The environmental cost/benefit analysis (expressed in terms of support money spent and CO_2 reductions achieved) has ranked the wood-energy technologies as follows in terms of best value:
    1. CHP offers best value, followed by;
    2. Domestic heating, and finally;
    3. Condensing power plant.

13 RECOMMENDATIONS

The following recommendations are made in order to stimulate the development of wood for use in energy supply:

1. A specific term, such as *wood-energy*, should be coined to differentiate this renewable energy source from other forms of biomass especially those involving wastes such as straw and chicken litter. The principal is that *wood-energy* should be recognised as sustainable resource with development capacity which would trigger rural development and employment, increase fuel diversity and security of national fuel supply etc. On this basis, wood-energy should be treated as separate case in terms of support.
2. Government support for wood-energy should be sought, specifically:
   i. The AER should be extended to include:
      1. A *wood-energy* technology band. The band should make provision to include co-firing.
      2. A *wood-energy with CHP* technology band.

   ii. Investment support should be sought from the Sustainable Energy Authority of Ireland to encourage the development of heat supply from *wood-energy* by:
      1. Directly subsidising the installation of domestic wood-fuel boilers to a level comparable with that of domestic oil boilers.
      2. Promoting a demonstration programme for wood-fuelled boilers aimed at the public, commercial and industrial sectors.
3. Other initiatives should be pursued to ensure *wood-energy* is not disadvantaged, namely:
   i. Exemption of wood-energy from any CO_2 tax by virtue of its CO_2 neutral position;

   ii. Tax-breaks for the investment in renewable technologies and plant.

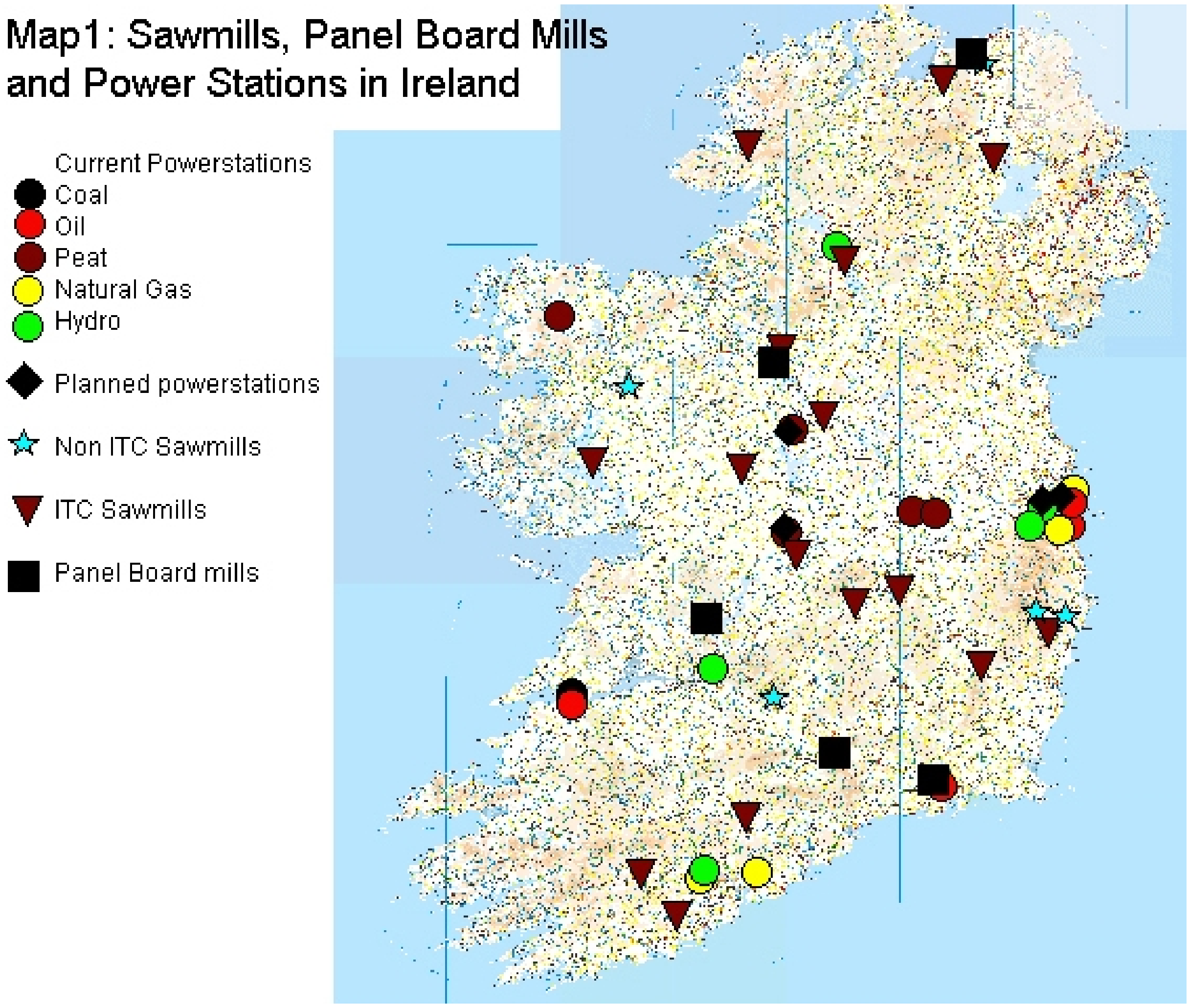
It is also recommended that the following promotional activities be adopted:

4. Work with the Department of Communications, Marine and Natural Resources and other relevant Government Departments to ensure that the barriers to wood energy identified in this report are removed as quickly as possible, and that suitable support mechanisms are put in place.
5. Link the work of the COFORD Wood for Energy Strategy Group to ongoing work on transport and logistics in the wood industry (e.g. the COFORD sponsored OPTILOG project; and any Supply Chain Management initiative established as a result of the Timber Industry Development Group report). Geographic Information System technology would be of value in optimising the supply of wood for energy.
6. Ensure as far as possible, through co-operation with ESB and Bord na Móna, that the new peat fired power plants to be developed at Lanesboro and Shannonbridge are compatible with the use of wood fuel for co-firing.
7. Continue the trials work on whole tree chipping commenced by COFORD this year. Whole tree chipping offers good potential for the production of low cost wood fuel from thinnings.

8. Commence trials work on the use of integrated harvesting on sites harvested using skylines. These trials should include the use of the Timberjack Fibrepac bundling machine.
9. Roadside residuals have the potential to provide low cost wood fuel. Their availability and cost for wood fuel production should be assessed in a pilot area.
10. There is considerable variation in published estimates of the breakdown on sawmill residues into chips, sawdust, bark and other. A comprehensive and reliable dataset on sawmill residues should be established and maintained (including information on quantity and moisture content).
11. A dataset on the moisture content of potential sources of wood fuel (including sawmill residues, pulpwood and forest residues) should be established and maintained, as the delivered cost of energy from wood is quite sensitive to moisture content. Strategies to reduce the moisture content of wood fuel should be developed and implemented
12. Establish and maintain co-operation between COFORD, Sustainable Energy Ireland and its Renewable Energy Information Office, the Irish Bioenergy Association and the Local Energy Agencies on the promotion of wood for energy. A focus of this co-operation should be on the sustainable production and use of high quality wood fuel in the domestic sector, including in the form of wood pellets.
13. A Strategic Environmental Assessment on the use of wood for energy should be undertaken to evaluate the environmental impacts of this Strategic Plan. Such a process would be a valuable component of integrating wood for energy into Sustainable Forest Management and forest certification. A comprehensive inventory of the private forest resource has not been undertaken since 1973. The development of an adequately detailed National Forest Inventory for private forests is urgently required to provide reliable information on the future volumes of wood that are likely to become available for wood energy from the private sector. It is important that such an inventory can detail roundwood volume forecasts on a meaningful regional basis and also outline species, roundwood sizes, accessibility and other qualitative and quantitative information. Infrastructure constraints on the exploitation of these resources should also be identified in any inventory.
14. The quantity of harvestable forest residues has been calculated as an additional 9% of the roundwood production from spruce plantations in Ireland (based on expert opinion from the UK). This assumption should be tested by undertaking trials on spruce harvesting sites in Ireland

APPENDICES

APPENDIX 1 LOCATION MAP OF SAW MILLS AND POWER STATIONS



MAPPING BY RURAL DEVELOPMENT DEPARTMENT, TIPPERARY INSTITUTE

APPENDIX 2 UK RENEWABLE ENERGY USAGE

Renewable sources used to generate electricity and heat in the UK

Thousand tonnes of oil equivalent

	1,996.0	1,997.0	1,998.0	1,999.0	2,000.0	2,001.0
Used to generate electricity						
Wind:						
Onshore *(2)*	41.9	57.4	75.4	73.1	81.3	82.5
Offshore	0.0	0.0	0.0	0.0	0.1	0.4
Solar photovoltaics		0.0	0.0	0.1	0.1	0.2
Hydro:						
Small scale	10.1	14.1	17.7	17.8	18.4	18.1
Large scale *(3)*	281.6	344.4	422.3	441.0	418.8	330.7
Biofuels and wastes:						
Landfill gas	232.1	301.1	388.8	558.4	717.6	822.2
Sewage sludge digestion *(4)*	134.6	133.7	126.5	134.6	120.4	119.0
Municipal solid waste combustion *(5)*	205.3	258.2	346.5	345.0	352.7	408.2
Other *(6)*	67.1	67.9	76.3	157.0	300.1	405.5
Wastes *(7)*	184.8	222.0	273.8	238.5	220.9	210.3
Total biofuels and wastes	823.9	982.8	1,211.8	1,433.6	1,711.6	1,965.2
Total	**1,157.5**	**1,398.6**	**1,727.2**	**1,965.5**	**2,230.3**	**2,397.1**
Used to generate heat						
Active solar heating *(8)*	8.7	8.9	9.1	9.4	11.1	13.2
Biofuels and wastes:						
Landfill gas	16.6	15.5	13.6	13.6	13.6	13.6
Sewage sludge digestion *(4)*	58.5	58.2	54.1	54.2	48.3	49.4
Wood combustion - domestic *(9)*	204.2	204.2	204.2	204.2	204.2	204.2
Wood combustion - industrial	505.5	506.1	436.9	367.7	298.6	264.6
Straw combustion, farm waste digestion and short rotation coppice *(10)*	71.7	71.9	72.0	72.2	72.2	72.2
Municipal solid waste combustion *(5)*	50.6	14.3	24.1	32.0	40.6	46.5
Other *(11)*	44.7	47.0	40.6	37.5	37.3	37.1
Total biofuels and wastes	951.7	917.2	845.6	781.4	714.6	687.4
Geothermal aquifers *(12)*	0.8	0.8	0.8	0.8	0.8	0.8
Total	**961.2**	**926.9**	**855.5**	**791.6**	**726.5**	**701.5**
Total use of renewable sources						
Solar heating and photovoltaics	8.7	8.9	9.1	9.5	11.2	13.4
Onshore and offshore wind	41.9	57.4	75.4	73.1	81.4	82.9
Hydro	291.7	358.5	440.0	458.8	437.2	348.8
Biofuels and wastes	1,775.6	1,900.0	2,057.4	2,214.9	2,426.5	2,652.7
Geothermal aquifers *(12)*	0.8	0.8	0.8	0.8	0.8	0.8
Total	**2,118.7**	**2,325.5**	**2,582.7**	**2,757.1**	**2,956.8**	**3,098.6**

(1) Includes some waste of fossil fuel origin.

(2) For wind and hydro, the figures represent the energy content of the electricity supplied but for

biofuels the figures represent the energy content of the fuel used.

(3) Excluding pumped storage stations.

(4) No estimate is made for digestors where gas is used to heat the sludge.

(5) Biodegradable part only.

(6) Includes electricity from farm waste digestion, poultry litter combustion, meat and bone combustion, and short rotation coppice.

(7) Non-biodegradable part of municipal solid waste plus waste tyres.

(8) Based on a survey carried out in 1995 and updated using data from the Solar Trade Association.

(9) An approximate estimate of domestic combustion based on a survey carried out in 1989; a moisture content of 50% is assumed.

(10) Straw is based on an approximate estimate based on a limited survey carried out in 1994 and on information collected in 1990.

(11) Includes heat from waste tyre combustion, hospital waste combustion, and general industrial waste combustion.

(12) Based on information collected by the 1994 RESTATS questionnaire.

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GLOSSARY OF TERMS

AAU	Assigned Amount Unit
AER	Alternative Energy Requirement
AMWS	Annual mean wind speed
BFB	Bubbling fluidised bed
BNE	Best New Entrant
CCGT	Combined cycle gas turbine
CDM	Clean development mechanism
CER	Commission for Energy Regulation
CER	Certified emission reductions
CFB	Circulating fluidised bed
CHP	Combined heat and power
cm	Centimetre
CO_2	Carbon dioxide
COP	Conference of Parties
DCMNR	Department of the Communications, Marine and Natural Resources
DM	Dry matter
EC	European Commission
ERU	Emission Reduction Units

ESB	Electricity Supply Board
ESRI	Economic and Social Research Institute
ET	Emissions trading
EU	European Union
FBC	Fluidised bed combustion
GBP	Pounds, sterling
GHG	Greenhouse gas
GJ	Gigajoule
GW	Gigawatt
GWh	Gigawatt-hour
h	Hour
Ha	Hectare
IGCC	Integrated gasification combined cycle
IPP	Independent Power Producer
IPPC	Integrated Pollution Prevention and Control
ITC	Irish Timber Council
JI	Joint implementation
kg	Kilogram
kTOE	Kilo tonnes of oil equivalent (see also conversions below)
kW	Kilowatt
kWe	Kilowatt electrical
kWh	Kilowatt-hour
LFG	Landfill gas
LPG	Liquid petroleum gas
m	Metre
MJ	Megajoule
Mtoe	Millions of tonnes of oil equivalent

MW	Megawatt
MWe	Megawatt electrical
MWh	Megawatt-hour
MWth	Megawatt thermal
NCCS	National Climate Change Strategy
NFFO	Non-fossil fuel obligation
NGO	Non-government organisations
NO_x	Oxides of nitrogen
POW	Office of Public Works
PPA	Power Purchase Agreement
PSO	Public Service Order
R&D	Research and development
REA	Renewable Energy Sources Act
RES	Renewable energy source
RES-E	Renewable electricity source – electricity
RMU	Emission Removal Unit
SO_x	Oxides of sulphur
t	Tonne
TFC	Total Final Consumption
TGC	Tradable green certificate
TPER	Total Primary Energy Requirement
TWh	Terawatt-hour
UNFCC	United Nations Framework Convention on Climate Change
V	Volt
VAT	Value added tax

CONVERSION FACTORS

k = kilo = 10^3 = 1 000

M = mega = 10^6 = 1 000 000
G = giga = 10^9 = 1 000 000 000
T = tera = 10^{12} = 1 000 000 000 000
P = peta = 10^{15} = 1 000 000 000 000 000

CONVERSION FACTORS FOR ENERGY

To convert from the units in the left hand column to the units on the top row, multiply by the values in the table

from / **to**	**GJ**	**MWh**	**toe**
Gigajoules (GJ)	1	0.2778	0.02388
Megawatt hours (MWh)	3.6	1	0.08598
tonne of oil equivalent (toe)	41.87	11.63	1

TYPICAL AS RECEIVED NET CALORIFIC VALUES

Fuel	**Unit of Measure**	**GJ**	**MWh**	**toe**	**t/m^3**
Sod peat	m^3	5.04	1.40	0.124	0.38
Milled peat	m^3	3.24	0.90	0.080	0.32
Wood pellets	Tonne	17.3	4.9	0.472	0.67
Saw dust	m^3	2.16	0.60	0.053	0.30
Wood chips	m^3	2.88	0.80	0.071	0.30
Green wood (50% moisture content)	Tonne	8.5	2.36	0.203	
Wood - dry	Tonne	19-20.5	5.3-5.7	0.45-0.49	0.7[1]

[1] Density based on softwood - Norwegian Spruce