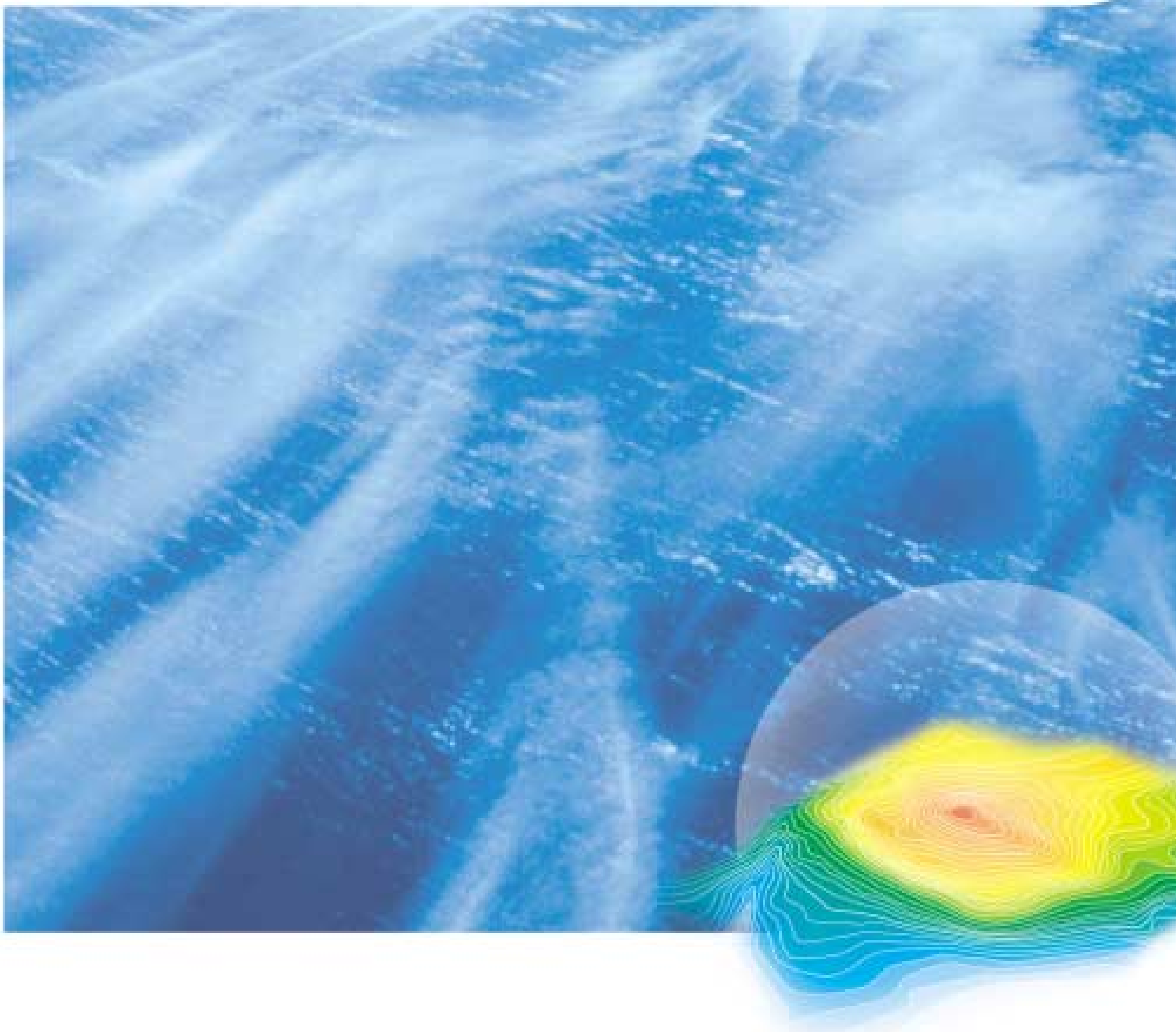

Renewable Energy Resources in Ireland for 2010 and 2020

– A Methodology

Updating the Renewable Energy Resource In Ireland (2004)

FINAL REPORT

Report No. 4P305A-R5

November 2004

Sustainable Energy Ireland,
Glasnevin,
Dublin 9.

ESB International,
Future Energy Solutions,
Energy Research Group,
(University College Dublin)

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Technical Terminology used

Basic unit of Energy : Joule

Basic of Rate of Energy Production or Consumption : 1 Joule/Sec. = 1 Watt

Units of Generator Working Capacity	Units of Energy Generated over time
KiloWatt = 1,000 Watts	1 Kilowatt hour = 1,000 Watts for 1 hour
Mega Watt = 1,000 Kilowatts (kW)	Mega Watt hour = 1,000 Kilowatt hours (kWh)
Giga Watt = 1,000 Mega Watts (MW)	Giga Watt hour = 1,000 Mega Watt hours (MWh)
Tera Watt = 1,000 Giga Watts (GW)	Tera Watt hour = 1,000 Giga Watt hours (GWh)
CCGT	Combined Cycle Gas Turbine
OCGT	Open Cycle Gas Turbine

(Where heat as opposed to electricity is referred to, the above symbols and acryonms have (t) added). No. of hours in year 8,760.

Acknowledgement

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Executive Summary

1. Introduction

This report, prepared by ESB International in association with Future Energy Solutions and Energy Research Group (UCD) forms part of a series commissioned by Sustainable Energy Ireland to assist the Government in developing future policy and programmes on renewable energy for the period beyond 2005.

It takes into account future climate change commitments and the European Directive on the promotion of electricity produced from renewable energy sources in the internal electricity market (2001/77/EC).

The government itself initiated the process and contributed the consultation document “Options for Future Renewable Energy Policy, Targets and Programmes” issued by the Minister for Communications, Marine and Natural Resources in 2003.

This study is intended to update and extend the methodology utilised in earlier studies for estimating the renewable energy resources in Ireland, with a view to providing medium term development potential which could be used to underpin potential targets for future policy options in the deployment of renewables.

It is also intended that the methodology developed for this study should form a consistent mechanism for separate future studies in the electricity and heat markets utilising renewable energy technologies including, inter alia, offshore wind, landfill gas, energy groups, agricultural and forest residues, organic refuse, photovoltaics, solar, thermal and passive design as appropriate for Ireland.

2. Methodology

2.1 Introduction

Particular stages that arose in meeting the overall study objective included:

- Extending methodologies for estimating the renewable energy resources to provide a medium term development potential for the years 2010 and 2020 including the likely resource/cost curve per unit of energy produced.
- Development of a ‘selling price’ allowing for project financing and an adequate return to the developer, from the production costs per unit of energy produced by the resource analysis.
- Application of the methodology and comparison of resulting estimates of resource against historical figures for onshore wind.
- Application of the methodology to landfill gas technology (electrical market) and active solar thermal technology for space and water heating (heat market).
- Use of a scenario approach to identify market contributions under defined basic, minimum and maximum contributions that reflect respectively a continuation of current policies, a relatively slower growth scenario and an accelerated scenario that would provide the highest reasonable levels of penetration for renewables by 2010 and 2020.

While the resource/cost curve concept is a widely used and convenient way of comparing the potential of different renewable energy technologies, it is essential that these curves are developed on a consistent basis so that like is compared with like in both electrical and heat markets.

2.2 General Methodology

The general methodology applied involves bringing together:

(1) Quantification of the accessible resources (using standardised resource definitions) by appropriate means which may vary depending on the particular resource type.

(2) Demand estimation for electricity and heat markets based on growth and commitment scenarios.

(3) Estimation of the levelised costs to the country of bringing these resources on stream, using a computational procedure based on that adopted by CER and tested on a portfolio of renewable type projects. An allowance for financing and profitability is built into the analysis by selection of the appropriate discount rate.

(4) Application of this methodology to create resource cost curves for onshore wind, landfill gas and active solar space/water heating.

(5) Using these resource/cost curves the extent of the viable open market, viable managed market and their sensitivity to fossil fuel price changes, expressed through impact on the Best New Entrant price, can be gauged.

(6) The results when compared with DCMNR consultation document projections and previously available figures immediately focus attention on particular areas.

3. Resource Definition

The first element in this process involves reassessment of resource definitions as used previously in quantifying the available energy at each stage in the attenuation process that exists between the raw theoretical resource as it occurs in nature and the more limited fraction of the resource that is commercially accessible for utilisation.

Thus an agreed set of definitions applicable to both the electrical and heat markets and describing the scale of the renewable resources available to the country was established. These draw on previous work by the present consultants and others and give rise to a unified scale of definitions that range from the Theoretical through the Technical and Practicable resources to the all important Accessible resource.

The market emphasis is underscored by partitioning the Accessible Resource into viable open market, viable managed market and currently non viable segments.

The Viable Open Market (VOM) segment is deemed to occur where the levelised cost per kWh is less than projected for the Best New Entrant technology by the Commission for Energy Regulation. The Viable Managed Market (VMM) extends the viable open market segment to the extent that public policy is willing to underwrite the additional cost of the available energy above that where it would be viable in the open market in its own right. The definitions used are easily conveyed by means of a simple triangular diagram (Figure ES1) and are later applied in establishing the resource levels of three diverse energy sources – onshore wind, landfill gas and solar heating for 2010 and 2020.

4. Demand Estimation in the Electricity and Heat Markets

4.1 Electricity Markets

The capacity of these markets to absorb renewable energy is a function both of their projected size and of the delivery systems and associated constraints that are in place in 2010 and 2020.

The projected national electricity demand has been developed using an ESBI model based on GNP projections correlated with the ESRI Medium Term Economic Forecast to 2020. This correlates well with the Eirgrid median projection of electricity demand (gross generation sent out before losses) which currently extends only as far as 2010 however. The projected electricity demands are 32TWh (2010) and 41TWh (2020). These also match well the levels projected in the government consultation document. Thus reasonably broad based agreement is obtainable on the overall size of the electricity market at the relevant dates.

The actual extent to which this can be met from renewable resources is however an important consideration and is subject to ongoing debate. The accessible landfill gas resource presents no identifiable problem other than one of the price level necessary to bring residual small schemes on stream into the future. The amount of the more plentiful wind resource that can be absorbed is more problematical and levels projected in the consultation document may have to be revised downward. This arises because of operational and economic problems associated with the status of the thermal plant mix, uncertainty over the full implications of new Irish sea connections to UK and results in suggested wind capacity limits of 1000MW (2010) and 3725MW (2020) discussed later.

4.2 Heat Market

Unlike the electricity market the projected heat market in Ireland is more diverse and less well defined. This sector embraces commercial, public, industrial, housing and agricultural elements (excluding process heating). As the solar resource is converted via solar panels, usually wall or roof mounted, it is assumed that the area available for panels is a function of the building floor area; in this way the demand and resource are in fact linked. Housing dominates in this respect with almost 90% of the available area and unit growth rates of 3-3.8% to 2020. It is projected that overall heat demand will grow at a rate of 4% per year to 2020 (excluding the industrial and agricultural areas) leading to thermal energy demands of approximately 68TWh (2010) and 101TWh (2020) for housing, commercial and public sector buildings. While the demand exists, the price of fossil fuels and the Irish climate have discouraged significant investment in active solar heating, particularly where combined space and water heating is concerned. Unit costs of small scale and retrofit installations are recognised as being more expensive than large-scale new developments e.g. new commercial, housing and apartment developments. Three market penetration scenarios are considered with corresponding levels of government support set at 0, 2% and 5% of market turnover as penetration by solar systems is unlikely to be significant without government support. The corresponding levels of CO_2 avoidance are relatively insignificant in relation to the output from natural gas fuelled systems which are still needed as solar back up in any event. The heat market is not discussed in the government consultation document.

5. Resource Estimation

5.1 Onshore Wind

The onshore wind resource was estimated by combining the powerful new Irish Wind Atlas 2003 database of wind accessible speed and distribution with state-of-the-art wind turbine designs of 3MW (2010) and 7MW (2020) capacity. Based on public attitude studies carried out in Ireland and elsewhere it is estimated that the socially acceptable level of wind power capacity in Ireland may lie between 5GW-10GW. The naturally accessible wind resources are 10GW with annual output of 26TWh (2010) and 14GW with annual output of 37TWh (2020) which are about double the socially acceptable levels. (This actually understates the resource as it is based on a reasonably representative tower height of 75m. If 100m tower heights are considered greater output could be expected). These levels are well above all the targets set out in the consultation document, however severe system operation constraints arise in the case of variable resources such as wind power at larger penetration levels.

As the amount of wind power capacity taken onto the system increases the ability of the existing fossil fuelled plant necessary to match the intermittent nature of wind power approaches its limit. This is partly a function of the type of plant mix involved and is closely related to the rate at which plant can be turned down, shut down, restarted from cold and brought back up onto the system. Plant failures are most frequent during the shut down or start-up phases. With intermittent wind generation it is not the short term forecasting that is important (e.g. 0-4 hours) but the medium term (8-12 hours plus) where the fossil plant will be required to start up from cold. Most thermal plant is operated outside any guarantee at this point so while manufacturers guidance is available it is a matter of owners risk analysis and judgement as to what frequency of cold start ups should be permitted and for how long. The bulk of plant installed in Ireland in recent years has been industrial combined cycle turbines which display maximum efficiency and longevity under a relatively stable operating regime. More recently aero derivative gas turbines having improved efficiency (still lower than CCGT) and variable operating characteristics have become available. The amount of wind plant that can be taken onto the system will ultimately be a function of the amount of aero derivative plant (or equivalent) that is added in the future and the number and operational regime adopted for interlinks with U.K.

The position is still complex despite the Ministerial decision in principle to authorise two further Irish sea cables of 500MW capacity each. It is understood that while the position of the first is reasonably fixed, that of the second cable is by no means clear at this stage. Neither is the operational regime and its economics, particularly when tied into the largely thermal UK system and facing the need to maximise CO_2 reduction per unit of power utilised in Ireland. Pending resolution of these issues limits on wind power capacity have been provisionally set at 1000MW (2010) and 3725MW (2020). This poses problems for the targets of the Consultation Document in that as these limits imply wind energy contributions of 3.066TWh (2010) and 10.77TWh (2020). When hydro and landfill gas generation of 1.09TWh (2010) and 1.112TWh (2020) are added, total renewables of 4.156TWh (instead of the desired 7TWh) for 2010 and 12.97TWh (which equates with the desired 13TWh) occur.

Thus unless the shortfall can be made up by biomass or by a switch from CCGT to OCGT in future thermal plant, the targets of 22% (2010) and 33% (2020) of total electrical consumption to come from renewables as set out in the Consultation Document are replaced by 15% and 13.3% respectively, which fall well short of the desired levels. Using OCGT plant could lead to a level of 31.5% being reached by 2020.

This has corresponding implications for CO_2 reduction.

5.2 Landfill Gas

Based on county and regional waste plans and on waste returns made to the EPA, together with consideration of documented EU and Government Directives and programmes, the accessible organic waste resource is projected for 2010 and 2020. The gas yield is assessed and the costs of electricity generation estimated. In this case BNE Discount rate of 6.88% is used as the technology is considered to be mature.

The Accessible additional LFG resource is assessed at 49.7MW (2010) and an incremental 8.5MW (2020) yielding 370GWh and 63.7GWh and CO_2 savings of 215kt and 36kt respectively. Existing plant equivalent to about 30% of this amount is already operational. Comparison with 1997 projection for 2020 should be in context of resource/cost curve at 5.08c and shows an increase in estimated total capacity for 2020 of 46% (58MW total versus 39.8MW).

5.3 Active Solar

The accessible active solar resource was estimated by combining the projected roof areas of the different building types with a mean annual panel performance factor, 350kW (thermal)/m^2/year, for the solar panels that could clad these areas. Allowances are made for reduction in cost and improvement in performance of the panels into the future. The unit costs vary depending on the scale of installation e.g. new large scale mass installations are projected to be cheaper than small, single dwelling and retrofit installations. As the bulk of the building stock (almost 90%) consists of domestic housing and the bulk of this is two storey the roof areas are estimated at 50% of floor area. The directional distribution of the national building stock is not known with certainty. While building guidelines have for many years sought to emphasise a southerly aspect for high occupancy rooms in buildings many roads and towns display a north south axis leading to easterly and westerly roof pitches.

6. Analytical Model

6.1 Discount Rate

Development of an analytical tool for the production of levelised cost/resource data, price conversion and benchmarking against change in reference fossil fuel prices, subject to explicit sets of input assumptions follows.

Particular consideration of the discount rates to be used is necessary. The initially prescribed rates of 8 and 15% actually reflect a built in profit element. It is also important to note that the weighted average cost of capital (WACC) used as the agreed discount rate (6.88%) in estimating resource costs was derived by the CER for the 400MW CCGT reference plant. This is of a scale and level of risk that would be appropriate to development by a large industry player or utility and, from a financier's viewpoint, reflecting the expectation of appropriate income and profit streams (pre-tax profit is 12%). This would not necessarily be valid for smaller renewable project developers where the level of risk would usually be considered higher and where a higher weighted average cost of capital would arise. Thus a higher discount rate appears appropriate when estimating the levelised cost of development of small or developmental renewable resources and the 8% rate is applied. (Pre-tax profit 16% with Debt/Equity 70/30).

6.2 Application of Model to Multiple Technologies

The model was utilised to carry out levelised cost and financial analysis on a representative range of thirteen renewable energy projects of differing size to assess its applicability and allowing ranking of their levelised unit prices against the rates payable under AER6, Best New Entrant, and promotional rates of 15c/kWh nominated in the cases of Ocean Energy and Photovoltaic as developmental technologies.

The model performed as desired and the results are tabulated below. They show that of the three technologies that had lower levelised costs than BNE (4.72 cents/kWh) all were marginal biomass ‘add on’ projects where the bulk of the capital costs had already been provided for reasons other than power generation (e.g. sewage treatment). The developmental technologies e.g. ocean energies have break-even costs 2.5 times those of BNE but apart from the tidal barrage example manage to achieve near positive nett present values at the tariffs allowed.

7. Resource/Cost Curves and their Analysis

7.1 Introduction

The application of the model to the production of resource/cost curves for the three required technologies – Onshore Wind, Landfill gas and solar space/water heating requires estimation of the accessible resource in each case.

7.2 Onshore Wind

A representative resource for 2010 was derived by matching a 3MW wind turbines with the 75m height wind regime throughout the country developed in Irish Wind Atlas 2003. For 2020 the wind regime was matched with 7MW wind turbines. Charges were factored in for network connection. The Theoretical resource was scaled down to give the Accessible resource by deducting areas where turbine installation could be ruled out under well established criteria. As the windier locations yield higher productivity the cost per unit output of the machines located there decreases. Thus the differing wind resources within differing parts of the country can be ranked and costed giving separate curves for 2010 and 2020. The 8% discount rate is used.

7.2.1 Wind Resource/Cost Curves (2010)

The resource/cost curves for the onshore wind resource are shown on Figs. ES2 ES3.

Fig. ES2 shows the significant levels of resource that are accessible at levelised costs of 4c/kWh and upward. With BNE @ 4.72c/kWh the viable open market is virtually zero at 35MW. The AER6 upper limits are 5.216c/kWh for large schemes and 5.742c/kWh for small schemes. These limits would permit viable managed market limits of 105MW and 260MW respectively. The viable open market changes significantly in response to fuel price changes for the BNE. A price increase of +50% leads to an upper bound of viable open market of 490MW while a decrease of -20% simply worsens the position in that there is no viable open market. Thus the viable managed market lying between 105MW and 260MW, reflective of the two

AER6 levelised costs, is the extent of the accessible resource for 2010 using the 8% discount rate to allow for financing and profit. The system constraint of 1000MW applies an upper bound to the 2010 case as discussed.

7.2.2 Wind Resource/Cost Curves (2020)

The corresponding curve for 2020 is shown on Fig. ES3. In this case the BNE levelised cost exceeds that of the accessible wind resource up to several thousand MW. This gives a huge viable open market resource lying below 4.72c/kWh. This is largely due to the assumptions of improvements in wind turbine size and output giving lower unit costs than in 2010. Benchmarking against the impact of fossil fuel (gas) price changes shows that even a price reduction of 20% would not impact on the accessible resource, while an increase in fuel prices of +50% would improve the viable open market resource enormously.

However a system constraint of 1250MW becomes necessary unless the thermal generating plant is reconfigured to include either aero derivative open cycle gas turbines, hydro pumped storage and/or cabled connections to Britain with suitable operating characteristics. This would cause a major shortfall in the amount of renewable wind generation projected by the Consultation Document and as a consequence the level of CO_2 displacement. Reconfiguration of the plant mix as above could permit acceptance of up to 3725MW of intermittent power onto the system. This is shown as an upper constraint. The issue is one for detailed examination and quantification.

7.3 Landfill Gas

The resource/cost curves for landfill gas are shown in Figures ES4 (2010) ES5 (2020).

Because of the fact that LFG installations comprise individual capacity blocks the resource cost curve is not a smooth one but consists of a series of tangible installations each of finite capacity as can be seen on the figures.

7.3.1 Resource Cost Curve : Landfill Gas (2010)

Fig. ES4 shows that by 2010 a series of LFG installations totalling 49MW approximately make up the viable open market capacity, with an energy output of 370 GWh/yr. at a levelised unit price below that of the Best New Entrant (4.72c/kWh). For as long as the AER6 capping price of 6.412c/kWh (or equivalent) remains available as a matter of public policy, the viable managed market extends the range of the viable open market resource by 1 MW in capacity to (50)MW. Above 6.412c/kWh the market is non viable but in fact there are no additional projects available for 2010. The figure illustrates the impact of changes in fossil fuel price by considering the way in which BNE unit cost varies over the range between a fall of 20% to an increase of 50% in its natural gas reference fuel (shown red). A decrease in fuel to 4.13c/kWhr brings the lower bound of the BNE cost into the viable open market region but only sufficiently to reduce the LFG VOM resource by 3.95MW to 45.8MW.

On the other hand an increase of 50% in fuel price when inserted into the model brings the BNE cost up to 6.18 cents/kWh. This has the effect of increasing the viable open market capacity by about 1MW. There is then no difference between the viable managed market and viable open market.

The effect of greater changes in fuel prices can be assessed in a similar way.

7.3.2 Resource Cost Curve : Landfill Gas (2020)

For 2020 the output is estimated to be broadly similar to 2010 although the organic feedstock in the landfills will be declining due to the impact of landfilling regulations. For clarity Fig. ES5 shows only the incremental resource cost curve for 2020. It may be superimposed on that of 2010. The viable open market resource is an additional 5.7MW (BNE 4.72 cents/kWh), while the viable managed market resource extends this to 8.2MW (at the AER6 capped price of 6.412c/kWh).

Again the range of fossil fuel prices from -20% to +50% around the current price level is assessed leading to BNE levelised unit costs of 4.13c/kWh to 6.18c/kWh. The lower BNE level of 4.13c/kWh would preclude any viable open market capacity as it is below the lowest levelised cost of any LFG capacity module. It is clear that based on the currently available information there is relatively little LFG resource likely to be available for 2020 compared with 2010 and that levelised cost has to rise to about 5.6c/kWh to bring an additional 2MW on stream.

In general the LFG resources are not great in a national context but they are reliable and have the merit of consuming methane which is a significantly more harmful greenhouse gas than CO_2.

Relative to the 1997 study the resources are, as noted, projected to be up somewhat with an increase of about 46% in estimated capacity compared with the 39.8MW then projected.

7.4 Solar Thermal

The resource/cost curves for solar space/water heating are shown on Figs. ES6 (2010) and ES7 (2020). The applicable resource cost curves are based on the application of the solar combi system in both large and small scale installations under Irish conditions where a uniform average 350kWh(t)/sq. m/yr. is taken as the solar panel output for 2004. Allowances are made for future increases in panel performance and reductions in capital and maintenance costs over time. The basic resource is the available roof areas of large and small scale structures which are projected for 2010 and 2020. Retrofitting of the existing housing stock is treated at the small scale cost rates which are higher than those for the larger scale apartments, commercial, industrial and future housing estates. The levelised cost analysis uses the 6.88% discount rate and demonstrates the potential effect of economies of scale in the production and installation of panels. The thermal energy produced from the system is costed on the basis of the total accessible resource being developed in 2010 or 2020 respectively at flat rates. The levelised price of the reference fuel for heating (natural gas) is also shown.

7.4.1 Resource/Cost Curve Solar Thermal (2010)

Figure ES6 shows that large scale new installations with an annual aggregate thermal yield level of up to 10TWh have a levelised cost of 6.05c/kWh(t) but that levelised cost of small scale and retrofit installations amounts to 8.24c/kWh(t) for an equal sized aggregate installation. The levelised natural gas price is only 1.41c/kWh(t) and it is clear that this is so far below the solar cost that there is no viable open market. To create a viable managed market levelised injections of at least 6.05c/kWh(t) and 8.24c/kWh(t) for large and small installations respectively would be required. Even gas price increases of +50% would still leave gaps of 4c/kWh(t) and 6.1c/kWh(t) to be bridged. Thus the solar thermal/water heating technology does not appear to be attractive on the basis considered for 2010.

7.4.2 Resource/Cost Curve : Solar Thermal (2020)

Figure ES7 shows that due to improved performance and increased output unit levelised costs are projected to reduce somewhat by 2020, but the gap between the levelised costs at 5.68c/kWh(t) (large installations) and 7.09c/kWh(t) (small installations) each with aggregate outputs of 17.143TWh are too large to allow of a viable open market. A viable managed market would require levelised injections of 4.27c/kWh(t) (large) and 5.68c/kWh(t) (small installations). Although the unit performance is improving it has not yet the level where it would be competitive with natural gas.

8. Conclusions

8.1 A revised generic set of resource definitions, applicable to both the electricity and heat markets, has been developed to assist in ranking the scale of renewable resources that exist at each stage from Theoretical, through Technical and Practicable to Accessible Resource.

8.2 The Accessible resource can be divided into Viable Open Market, Viable Managed Market and Non Viable segments to emphasise the market relationships inherent in the interpretation of resource/cost curves.

8.3 The Viable Open Market resource occurs where the levelised unit price of energy from this resource is less than that of the Best New Entrant technology or competing fuel type. The Viable Managed Market is defined at its upper boundary by the unit price that public policy is willing to underwrite in the interest of developing resources that are more expensive than can be sustained in the viable open market.

8.4 The electricity market is projected to increase at an average annual growth rate of 3% reaching gross generation levels of approximately 32TWh by 2010 and 41TWh by 2020.

8.5 The diffuse heat market, dominated by housing but with an increasing apartment content, is forecast to grow at 4% per annum, resulting in loads of 68TWh (2010) and 101TWh (2020) which are about double the electricity loads.

8.6 In developing and applying a levelised cost analytical model that would incorporate profit and financing charge elements it is important to distinguish between the levels of risk associated with utility scale projects such as Best New Entrant (400MW CCGT) where the discount rate used is 6.88% and smaller renewable projects where a higher (8%) discount rate would be applicable. This was tested by application to 13 renewable technologies in addition to BNE.

8.7 The resource definition technique, projected market levels, and levelised cost model were brought together to provide a methodology for the production of resource/cost curves for onshore wind, landfill gas and solar thermal space/water heating for 2010 and 2020 including benchmarking against changes in fossil fuel (natural gas) price.

8.8 Review of the resource/cost curves shows that landfill gas although a small and probably declining resource is most cost effective in viable open market terms.

8.9 Onshore wind, while the most substantial electrical resource becomes hampered by system operation limitations as its penetration increases. A limit of 1000MW for 2010 is set based on the mix of fossil and hydro plant available to balance the intermittent nature of the wind. By 2020 this would only increase to 1250MW unless a reconfiguration of the thermal mix is put in hand with interlinks, gas and pumped storage capacity added. This is particularly important as by 2020 the falling levelised cost curves for wind place it outside the range where it is likely to be impeded by even falling fuel prices. It is a matter of extreme urgency that the issue of wind/fossil plant balance should be evaluated in detail and appropriate decisions taken.

8.10 Solar thermal heating using the combi reference system leads to cost/resource curves that reflect the difference in scale between retrofit and small scale developments and possible future large new developments. There is however no viable open market because of the cost of the reference fossil fuel (gas) where the levelised cost would have to rise severalfold for solar to be competitive in levelised cost terms in either 2010 or 2020.

8.11 In the context of CO_2 abatement objectives, landfill gas development is highly beneficial, wind development makes the greatest contribution but could be severely hampered by the projected system limits and solar thermal is unjustifiably expensive at present. If commitments are to be met this issue requires urgent attention.

8.12 As an adjunct to this study the possibility of cocombustion of wood biomass and peat in the three recently constructed fluidised bed peat fuelled generating stations has been adverted to as a means of reducing CO_2 emissions of peat origin and increasing the renewables content in the electricity energy mix.

9. Recommendations

9.1 The resource definition model should be adopted for application and further testing so that a single and broad based set of descriptive ranking definitions exists for both electricity and heat markets.

9.2 The Viable Open And Viable Managed market concepts should be adopted as a means of relating the accessible resource to the market place. The Best New Entrant levelised cost provides a basis for this.

9.3 The discount rate chosen in estimating the levelised unit cost of a particular resource needs to reflect the scale and level of risk and profit associated with development of that resource. Thus it should be somewhat higher for renewable resources than for a fossil fuelled Best New Entrant. It is suggested that a rate of 8% is appropriate at present but this could be subject to further refinement.

9.4 The methodology developed for levelised cost calculation having been tested on a variety of renewable projects should be adopted and input data for renewables gathered to facilitate its application.

9.5 Landfill gas generation is beneficial in every respect and present support measures should continue.

9.6 The potential for the critically important onshore wind technology to develop that resource is threatened by limitations induced by the balance of generation plant on the national system. It is essential that these issues be addressed if the projections of the Consultation Document are not to be undermined.

9.7 The levelised cost of solar thermal resource development so far exceeds that of rival fuel supply that the economic viability of this option is unattractive for 2010 and 2020 and should be treated as discretionary only.

9.8 The methodology developed for this report can be applied to resources and technologies other than those detailed here to determine in depth their potential for future contributions to the electricity and heat markets in Ireland.

9.9 The cofiring of biomass with peat in fluidised bed generating stations should be actively investigated with participation of relevant stakeholders.

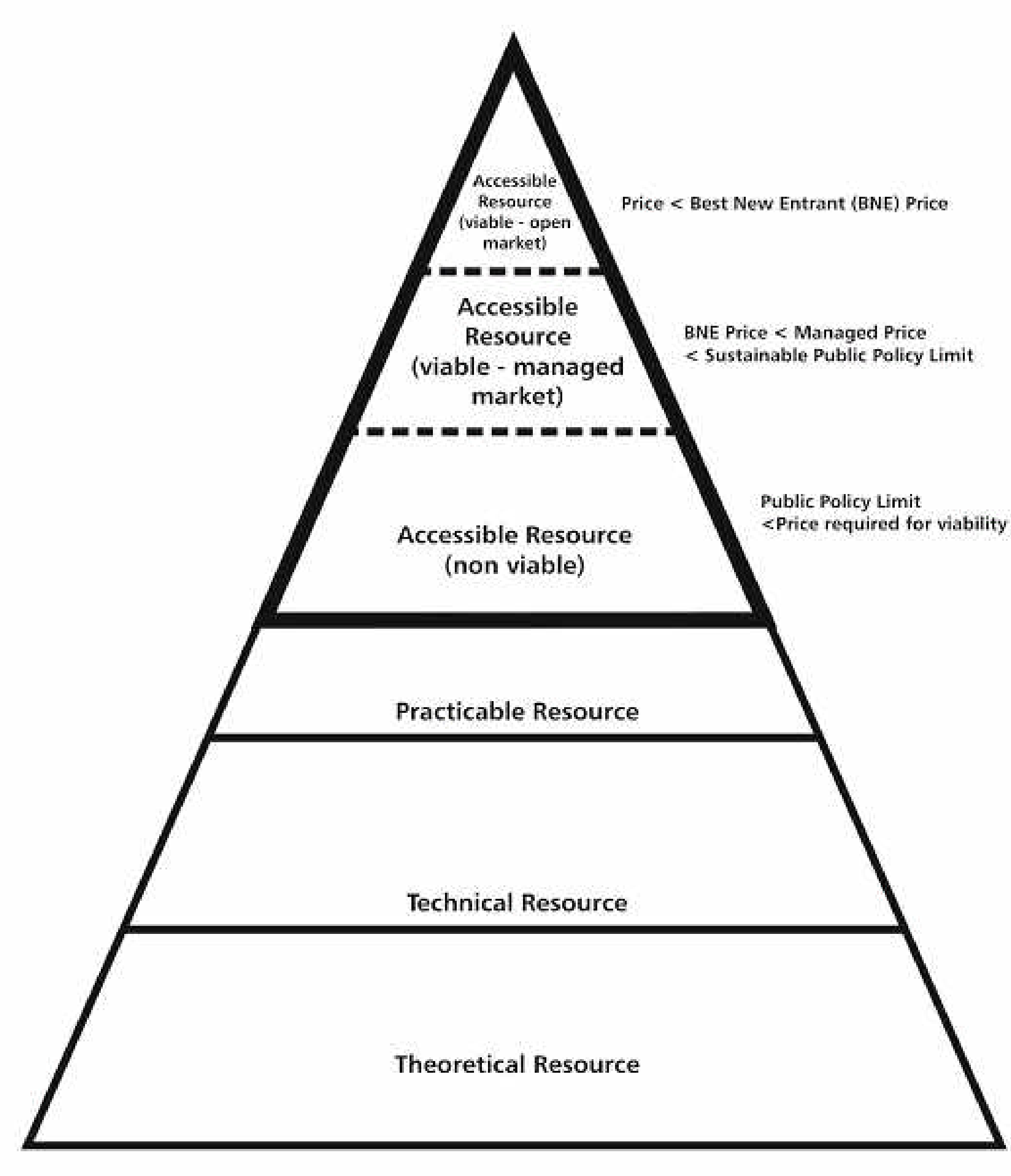


Fig ES.1 Generic Renewable Energy Resource Ranking Diagram (not to scale)

Figure ES.2

Resource Cost Curve

Wind Generation 2010 at 2004 Prices

(8% Discount)

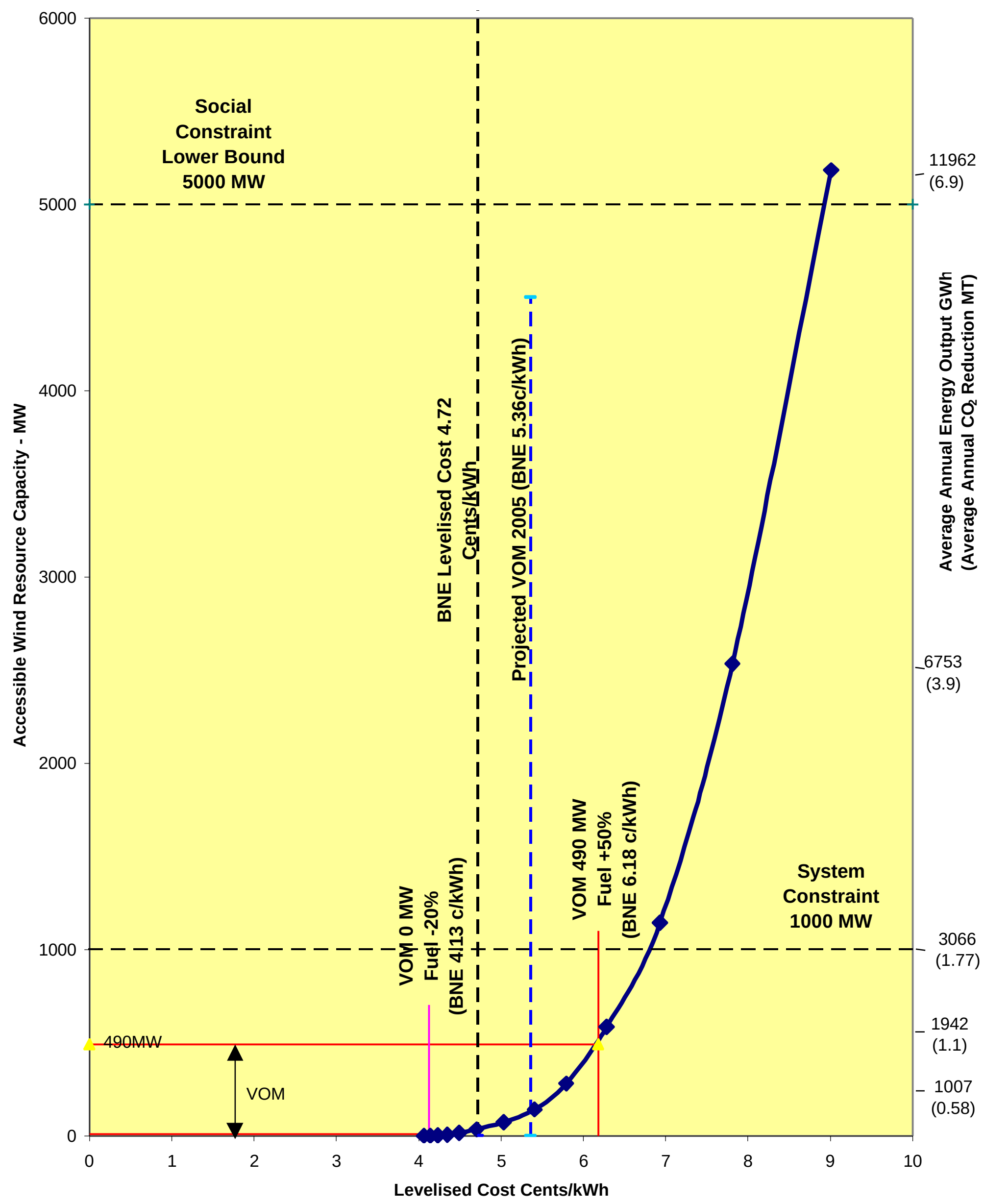


Figure ES.3

Resource Cost Curve

Wind Generation 2020 at 2004 Prices

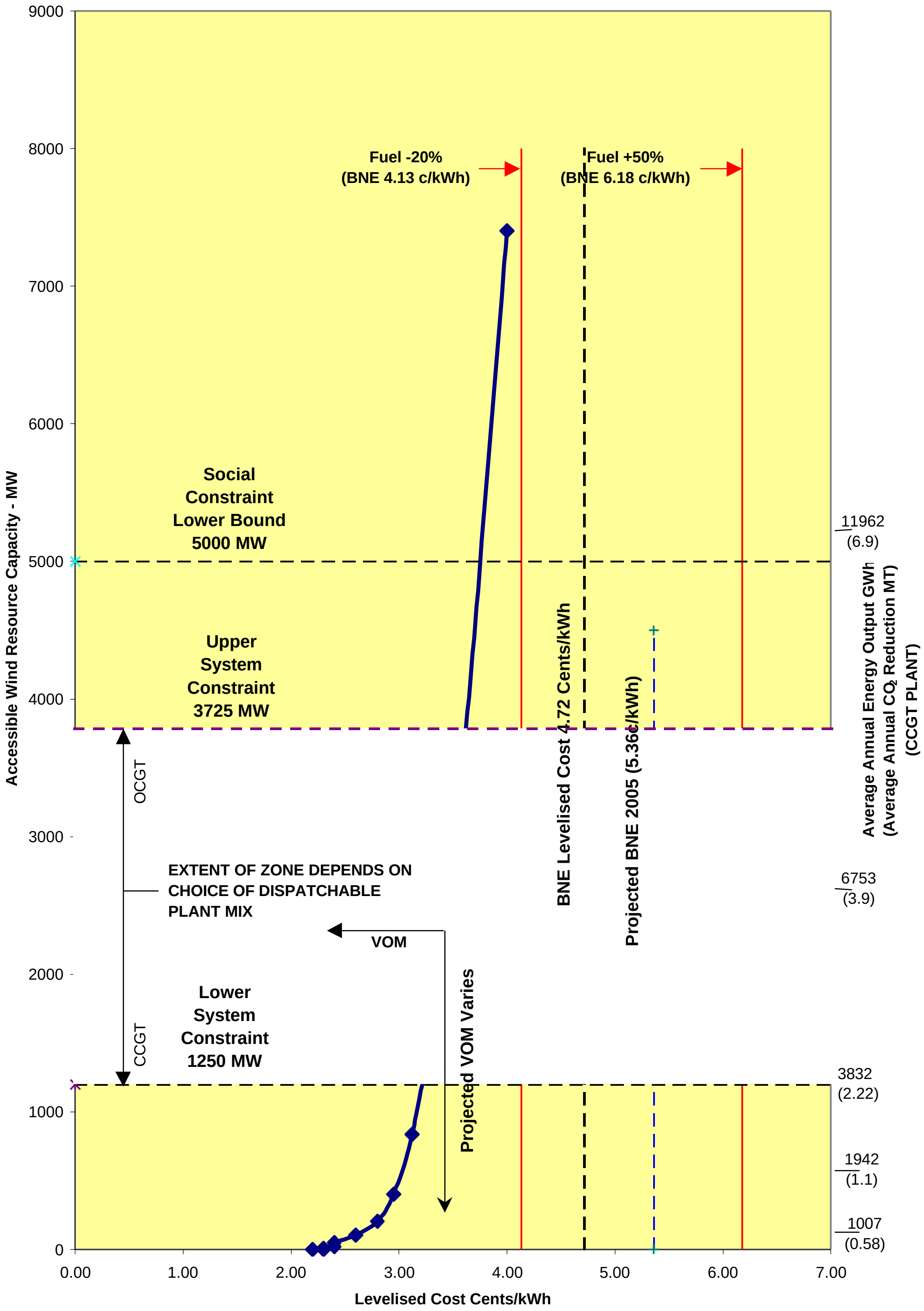


Figure ES.4
Resource Cost Curve Land Fill Gas 2010

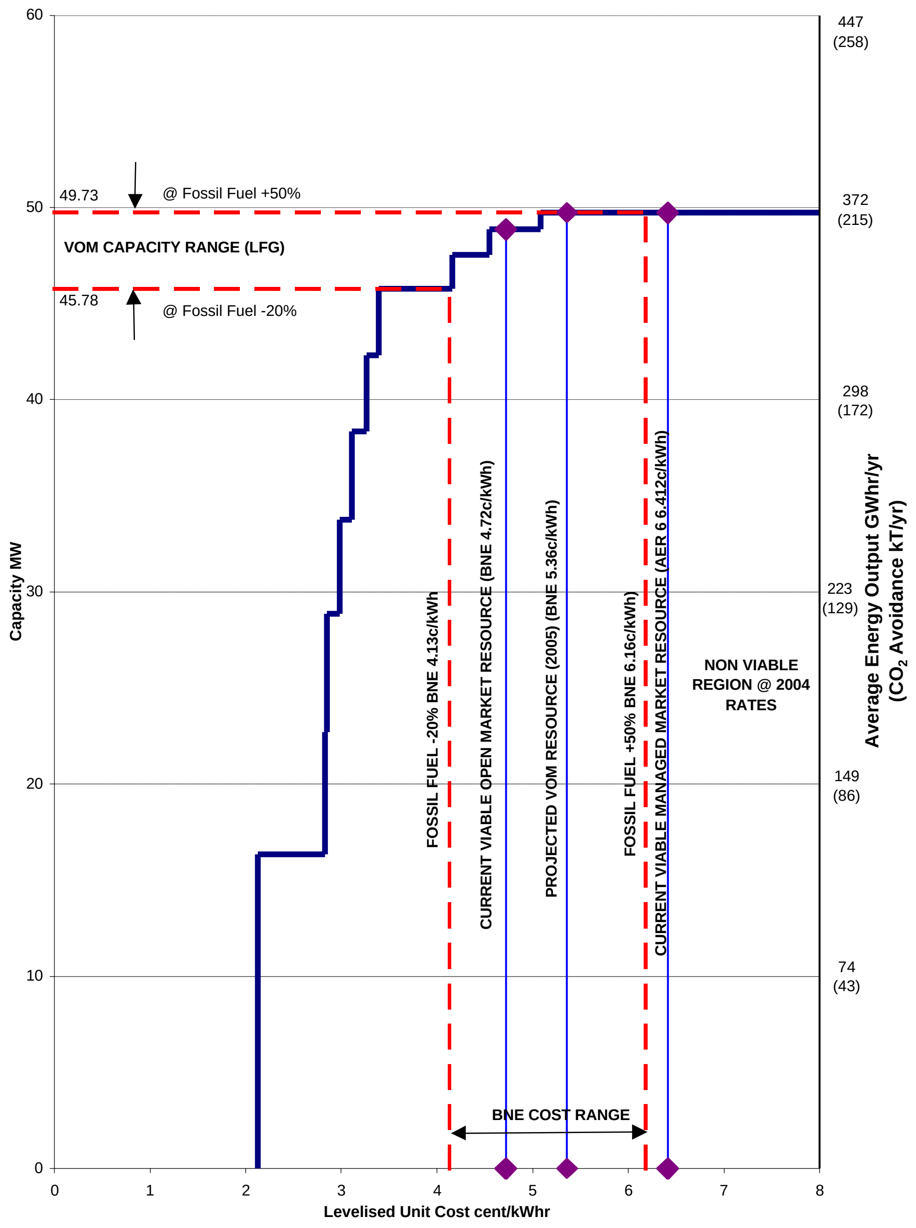


Figure ES.5
Incremental Resource Cost Curve Land Fill Gas 2020

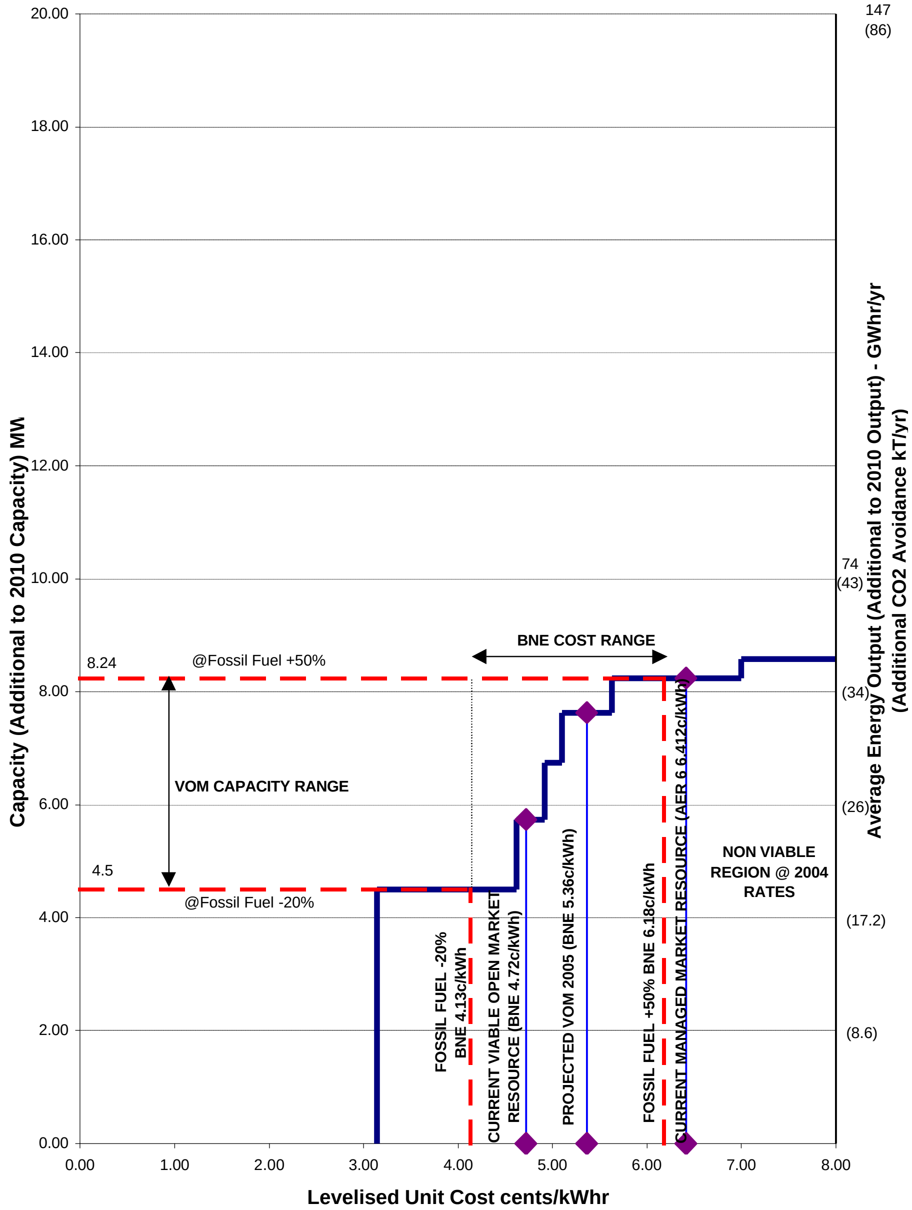


Figure ES.6

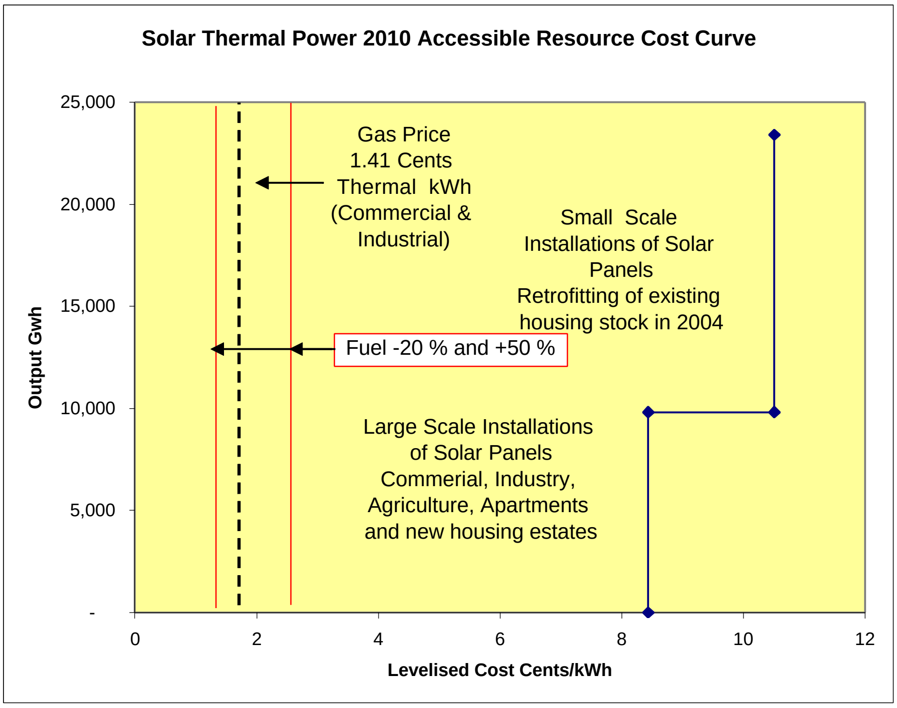
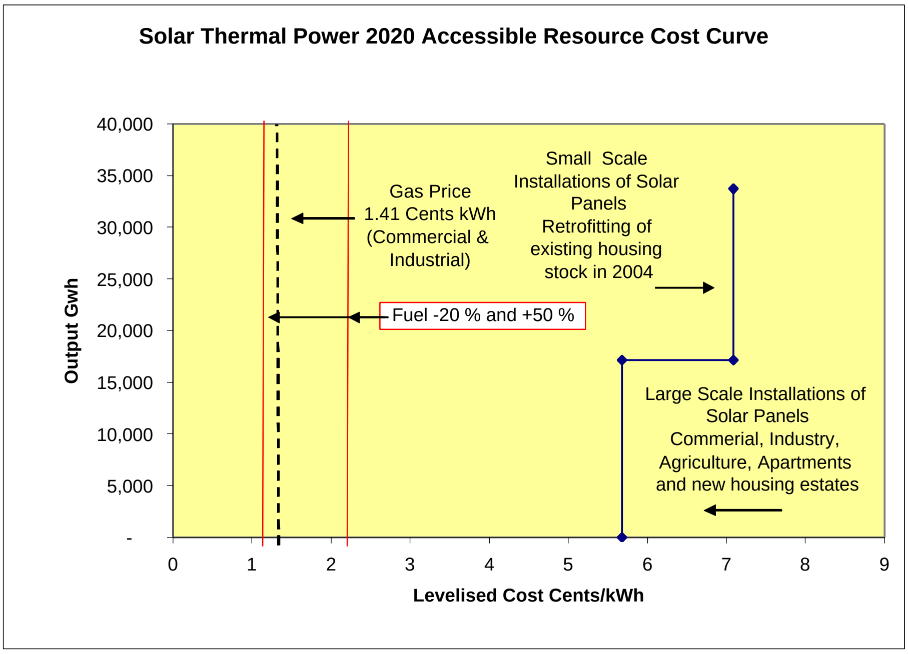


Figure ES.7



1. Introduction

This study forms part of a series commissioned by Sustainable Energy Ireland to assist the Government in considering its future policy and programmes on renewable energy in the context of the challenging future climate change commitments and related European Directives.

The need for this series may be seen to flow from issues raised in a preliminary way by the consultation document “Options for Future Renewable Energy Policy, Targets and Programmes” issued by the Minister in late 2003.

The study updates and extends the methodology utilised in earlier work (Ref. 6) to underpin potential targets for future policy options for the deployment of renewables in the electricity and heat markets. In particular a number of tools have been developed to assist in dealing with different technologies on a consistent basis when discussing renewable resources and the costs and selling prices at which these might be brought to market in the periods to 2010 and 2020.

Resource definitions have been developed and refined from those used previously in renewable energy studies and extended to the Irish heat market.

The study has been underpinned by the development of a comprehensive analytical methodology, now made available to SEI on CD-ROM for use by others, that allows transparent computation of economic, financial and levelised costs per unit of energy delivered from the respective renewable resources. In the case of onshore wind, landfill gas and solar heat the available resources themselves are quantified using the most up to date data currently available.

It is envisaged that the methodology will be extended to other resources such as biomass, geothermal, hydro and ocean energy in a series of later studies that will draw together improved resource information as input material. This will provide the Government with realistic up to date information for informed decision making in relation to the relative market prices and benefits of the respective technologies and their potential roles in CO_2 abatement strategies in the electricity and heat sectors.

In seeking to meet these general goals, this study specifically addresses in separate sections

- Established Strategic Policy Targets for Renewable Energy in Ireland.
- Projected energy markets to 2010 and 2020 respectively.
- An overview of the current status of selected renewable energy technologies.
- Definition of a consistent set of terminologies (with introduction of the concepts of viable open and viable managed markets) for use in both electrical and heat markets, applicable initially to the three reference technologies wind, landfill gas and solar heating prescribed for the report.
- Development of the analytical methodology (available on CD) tested for consistent financial and economic evaluation by application to thirteen renewable technologies at representative scales to provide levelised cost output with reference to the best new entrant technology as advised by the Commission for Energy Regulation.
- Forecast Resource Cost Curve production for renewable energy technologies to 2010 and 2020 – Onshore Wind, Landfill Gas and Solar Thermal Power.

- Identification of social and operational limitations on intermittent technologies such as wind.
- CO_2 Avoidance Potential
- Fossil Fuel Benchmarking with reference to Best New Entrant fuel price variation.
- Conclusions and Recommendations

It is at this point helpful to introduce the cost analysis methodology which incorporates three procedures each of which fulfils a specific purpose. These are incorporated in an EXCEL model for general use by interested parties. The analytical procedures adopted are:

- Financial Analysis

  Here the potential return to a project developer from investment in alternative renewable energy technologies, under stated conditions with inclusion of all life time costs including overheads and revenues, is estimated.

- Economic (or Levelised Cost Analysis)

  This is a useful first stage screening procedure that permits comparison and ranking of technologies in terms of snapshot economic efficiency expressed in terms of energy output. The method utilises the capital, operating, maintenance and fuel prices together with the annual electrical output to produce a levelised electricity cost in terms of c/kWh and is widely used to compare power plants. It is the present value of all costs divided by the present value of outputs.

- Resource Cost Analysis

  This provides a means of comparing costs of different projects both within and between specific technologies. When plotted as curves the output can be used to determine the energy contribution that each technology can make, bearing in mind its economics and the availability of the resource. Thus national resource cost curves can be built up by summing the resources recorded on a county or other basis. It indicates the cost of bringing different levels of a particular resource into play.

The report discusses the selection of rate of return, discount rate, debt equity ratio assumptions and default values used as inputs in the model analysis for the electricity market.

In the case of the heat market levelised cost analysis and resource cost curves are developed for 2004 with projection of cost reductions for 2010 and 2020.

The project financial analysis profiles for the different technologies are tabulated on 28 screens including that of the Best New Entrant (Combined Cycle Gas Turbine) as estimated by the Commission for Energy Regulation.

These provide cash flows and profit and loss accounts for each project generally under existing AER price caps. The levelised cost analysis provides the corresponding projected cost in cents/kWh for each of the technologies at the representative project size considered.

Resource Cost Curves are developed for onshore wind, landfill gas and solar thermal utilising Irish Wind Atlas 2003, EPA landfill data and three market penetration scenarios for particular solar thermal panels under stated assumptions. In the case of windpower grid constraints are imposed while in the case of landfill gas it is projected that the feedstock supply will diminish due to tighter EU criteria on the disposal of organic waste to landfill.

In terms of CO_2 avoidance the position is salutary. Landfill gas and wind power are the most cost effective but it would effectively require the total accessible wind and solar thermal resources to be developed if the total national CO_2 target for 2010 was to be met. In response to this challenge a method is suggested whereby cofiring of biomass in modern facilities can reduce the CO_2 burden arising from peat fuelled generation.

In general the conclusions arising from this report modify some of the scenarios introduced in the DCMNR Consultation Document by introducing new information and interpretations made possible by the methodology now available.

Introducing the elements of the report chronologically, Chapter 2 discusses briefly the stated EU targets for renewable energy supply insofar as they relate to the Republic and the legislative and administrative mechanisms that have been applied to meet these objectives. The primary contributors have been wind, hydro and landfill gas. The bulk of the hydro contribution is in fact from large rather than the small hydro which is focussed upon in this report. Considerable attention is now directed toward the nature of the most appropriate mechanism to replace the Alternative Energy Requirement (AER) and at the same time to meet the future criteria to be established in respect of the global warming threat.

The energy markets are discussed in Chapter 3. The GNP levels used in the Economic and Social Research Institute Medium Term Review forecast are used with ESBI's own model as a basis for projecting electricity demand forward to 2020. The figures align well with the Eirgrid median line up to the limit of the Eirgrid projection (2010).

The bulk of the heat market is attributable to housing and this is projected to result in an increasing energy demand of about 4% per annum into the future.

Chapter 4 briefly examines the current status of selected renewable technologies in the context of their operational maturity in Ireland and elsewhere and their ability to contribute significantly to the electricity or heat markets. Particular attention is focussed upon technology associated with onshore wind, landfill gas and active solar thermal resource exploitation. The associated Appendix 2 provides supplementary information on these and other technologies by way of updating Ref. (6).

The question of resource definition and quantification is dealt with in in Appendix 7. The important concept of how the accessible resource breaks down into the viable open and managed market resources is introduced and its application to wind, landfill gas and solar thermal power for 2010 and 2020 is discussed in Chapters 3, 4, 5 respectively.

Chapter 6 distinguishes between financial and economic (levelised cost) evaluation of renewable energy conversion technologies. It summarises the detailed analysis carried out in Appendix 1 where a specially developed EXCEL model is applied to thirteen renewable technology cases on representative scales agreed with the client for comparison with a 400MW combined cycle gas turbine which has been determined by the Commission for Energy Regulation as being the Best New Entrant (BNE) having a unit cost of 4.72c/kWh and revenue of 4.79c/kWh. (2004)

A general approach to the construction of resource/cost curves is given in Chapter 7. This illustrates how the unit costs can be plotted against plant capacity or annual energy output for different dates (and different discount rates).

It is projected that (in 2004 terms), where the resource is plentiful, the unit costs should fall with improvement in technology and quantity of production between 2010 and 2020. However with a limited or declining resource or a nature technology, such as landfill gas, this effect is less pronounced.

Resource/cost curves for onshore wind, landfill gas and solar thermal power respectively are developed for 2010 and 2020 in Chapters 8, 9, 10. These show the potential installed capacity (MW) and mean annual energy output (MWhr) plotted against baseline levelised unit costs in c/kWh. For information the Best New Entrant cost and other delimiting lines (e.g. system limits in the case of wind power) are also plotted. The resource having a lower cost than that of Best New Entrant is considered to be the viable open market resource. (Levelised price curves subject to specific assumptions may also be plotted). The landfill gas resource cost curves are step functions reflecting the fact that each LFG installation is of unique size and cost. The solar thermal curve is also a step function that reflects the differing scales of unit costs applicable to small scale and retrofit housing and to large scale new works and commercial developments.

The CO_2 avoidance capacity of the key renewable energy types considered and the corresponding monetary values are noted in the respective chapters while benchmarking against future fluctuation in fossil fuel costs is addressed in the context of its impact on Best New Entrant cost and on the market in the sectors dealing with resource cost curves where the effect can be clearly understood.

Clearly the higher that the latter is forced by rising fuel prices, the greater the region on the respective levelised cost curves for which accessible renewable resources become viable in either the managed or the open market.

Conclusions and recommendations are brought forward in Chapters 11 and 12.

As noted the respective chapters are supported by detailed appendices as required.

2. Renewable Energy and Strategic Targets

2.1 Introduction

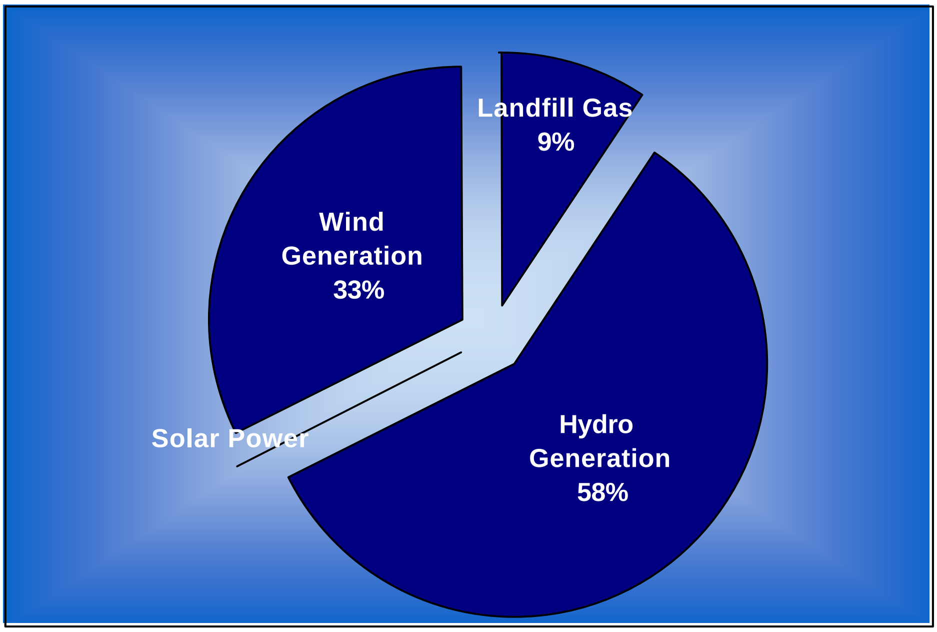
The objective of developing and extending the contribution that renewable energy sources (RES) can make to the production and use of energy in Ireland is set with in the context of Ireland's national and international commitments to climate change management and related EU Directives.

2.2 EU Requirements

The EU RES-E Directive sets a target of 13% of electricity consumption to be generated from renewable energy resources for 2010. There are currently no targets for renewable energy contribution to heat demand. Renewable energy in 2001 provided 6% (1.3 GWh) of total electricity generation (21,000 GWh) mainly from large hydro and wind power as shown in Figure 2.1

Figure 2.1

Profile of Renewable Energy Generation Ireland[1] 2001



The main elements having either the objective or effect of accelerating the uptake of Renewable Energy technologies include

- The Governments Green Paper on Sustainable Energy (1998)
- The Electricity Regulation Act
- The Public Service Obligation
- Proposed introduction of carbon taxation
- The Alternative Energy Requirement Competitions

[1] Eurostat

The Alternative energy requirements (AER) has been the main policy instrument which supports the establishment of additional renewable electricity production capacity in Ireland . A summary of AER VI is provided in Appendix 6.

2.3 CO_2 Emissions Targets

The national target for CO_2 emission levels is 113% of 1990 levels by 2010 or 36 million tons. CO_2 emissions in 1990 were 31.9 million tons (11.6 million tons from power generation) and have risen to 45.8 million tons in 2001 (17.3 million tons from power generation).

Thus the excess over budgeted CO_2 tonnage is 10.0 million tonnes (gross).

There are currently no further published targets for the period following 2012 but preparations are underway to set the scene for further rounds of negotiations and constraints. As part of this process a number of countries including U.K., Germany and France have published documents indicative of their developing thinking in meeting the challenges of CO_2 emissions management over the timespan to 2050.

These indicate a strong commitment to further CO_2 reduction.

The annual potential for reducing CO_2 emissions from wind, land fill gas and solar power summarised in Figs. 2.2-4 below from estimates made elsewhere in the report. The estimates are based on an average mix of input fuels to electricity generation in Ireland in 2010. For every MWh generated by renewable energy 0.578 tons of CO_2 is avoided. In the Heat Market for every MWh Thermal generated from renewable energy 0.22 tons of CO_2 is avoided.

Based on the accessible resources identified in Appendix 3, Wind provides the highest annual potential (21 Million Tons by 2020), followed by Active Solar Thermal Power (7.5 million tons annually by 2020) and Land Fill Gas (251,000 tons annually by 2020).

These gross CO_2 avoidance figures shown are for illustrative purposes only. They are not feasible (with the exception of Land Fill Gas) since the total accessible area in Wind Generation and Active Solar thermal power could not be exploited due to economic, technical and or public acceptability constraints.

Although open cycle gas turbines emit more CO_2 per unit of generation than closed cycle systems, the introduction of the former for intermediate and peak load operation would assist in bringing more wind generation onto the system. In this way it appears possible to meet the 30% CO_2 displacement target for 2020 considered in the Government Consultation Document.

2.4 Conclusions

(1) It should be possible to meet the RES-E Directive Obligations for 2010 in terms of electricity generation.

(2) It will be evident from later sections of the report that the 2020 situation will be more problematic unless measures are put in place to facilitate the entry of an increased element of intermittent power to the system. This is likely to involve significant application of open cycle gas turbines and could pave the way for meeting emission targets raised in the Government Consultation Document.

Figure 2.2

Potential Annual CO_2 Avoidance from Wind Generation Accessible Resource 2010 & 2020

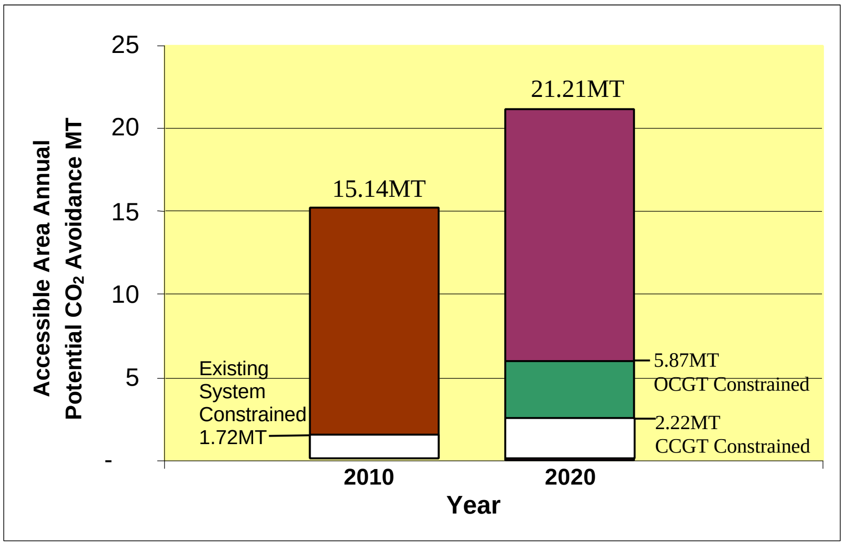


Figure 2.3

Potential CO_2 Avoidance from Land Fill Gas Accessible Resource

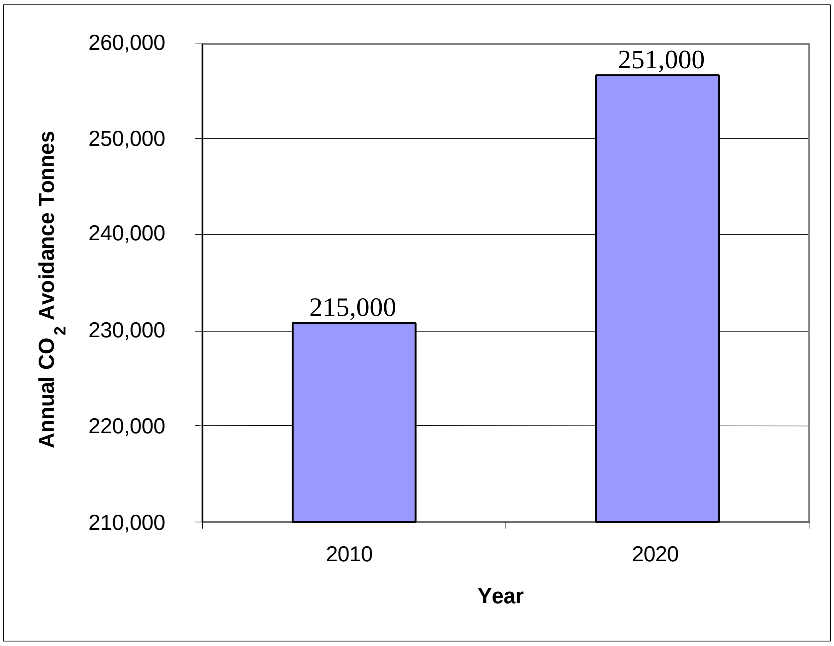
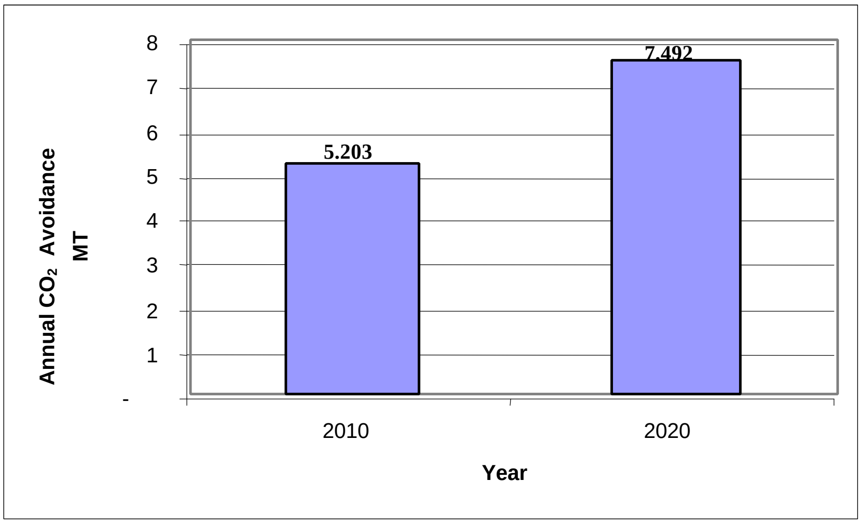


Figure 2.4

Potential Annual CO_2 Avoidance

Active Solar Thermal Power: Accessible Resource



3. Energy Markets

3.1 Introduction

The annual electricity and heat markets in the Republic are approximately (25)TWh and (55)TWh respectively. The electricity market is reasonably well defined but as the market opens up to competition the number of players increases and roles change. This results in an increased dependence on the Commission for Energy Regulation for the security of not only the market but the forward planning and implementation of the generation and transmission infrastructure that make the market possible. In regulating the market the Commission acts on its interpretation of advice and information tendered, in some cases on a statutory basis, by its consultants, other agencies and participants before approving major commitments in terms of generation capacity, infrastructure, and market conditions. In some cases however other influences e.g. financial markets and the local authority planning process may affect the outcome before developments can take place, thereby introducing an element of uncertainty into the process which has at times impacted on the electricity market. It is evident that this process still evolving.

Although aspects of the heat market are regulated by different agencies e.g. insulation levels, CO_2 and other emissions etc. there is no central regulation.

3.2 Electricity

The electricity market is driven by the integrated demand for electricity. Based on demographic and other studies carried out by ESRI, load growth demand curves have been projected forward to 2020 as shown in Figure 3.

Electricity demand growth has shown a more stable relationship with economic growth in Ireland over the period since 1960 than any other energy carrier. This is due to its pervasiveness in every area of economic activity and due to the fact that although the structure of Irish industry has changed substantially in the past thirty years, as subsidiaries of multi-nationals became increasingly important, the change was to electricity-intensive rather than energy-intensive industries. Indeed the most recent growth areas – telesales/service, financial services, software development – use no process energy except electricity.

ESBI's electricity demand projections are developed on the basis of ESRI's economic forecasts and the historic relationship between electricity demand and economic activity. The methodology used has been developed and refined over a fifteen year period and has proven consistently reliable over that period. GNP rather than GDP is used as the measure of economic activity as it is now universally recognised that GNP provides a more realistic measure of economic activity in Ireland, due to the impact of transfer pricing by multinationals.

The GNP projections made in ESRI Medium Term Review, 2003 and contained in its background analysis are used.

The electricity sales projections derived on the basis of the above assumptions are given in Figures 1 and 2. Eirgrid's latest forecasts are also shown. From this it can be seen that electricity sales are projected to increase almost linearly, from 2003 to 2020, with overall sales projected to increase at an average annual growth rate of 3%. The figures are tabulated on Table 3.1.

Although the electricity demand projections undertaken by ESBI and Eirgrid differ in their approach, the results are very close – by the end of Eirgrid's Generation Adequacy Report (Ref. 14) forecast period (2010), Eirgrid predict a total electricity requirement of 32.0 TWh while ESBI predict a requirement of 31.94TWh. The projections for the period between 2010 and 2020 shown here are derived using ESRI long-term GNP forecasts and ESBI's model, as the Eirgrid forecasts are only indicated over a seven-year horizon, as is standard practice amongst many European transmission system operators.

The actual level of electricity generated will be higher than the sales due to losses in electricity transmission and the house load requirements in generating stations. Taking these factors into consideration the projected gross level of generation would be approximately 43 TWh by 2020.

Fig 3.1: Historic and projected electricity sales

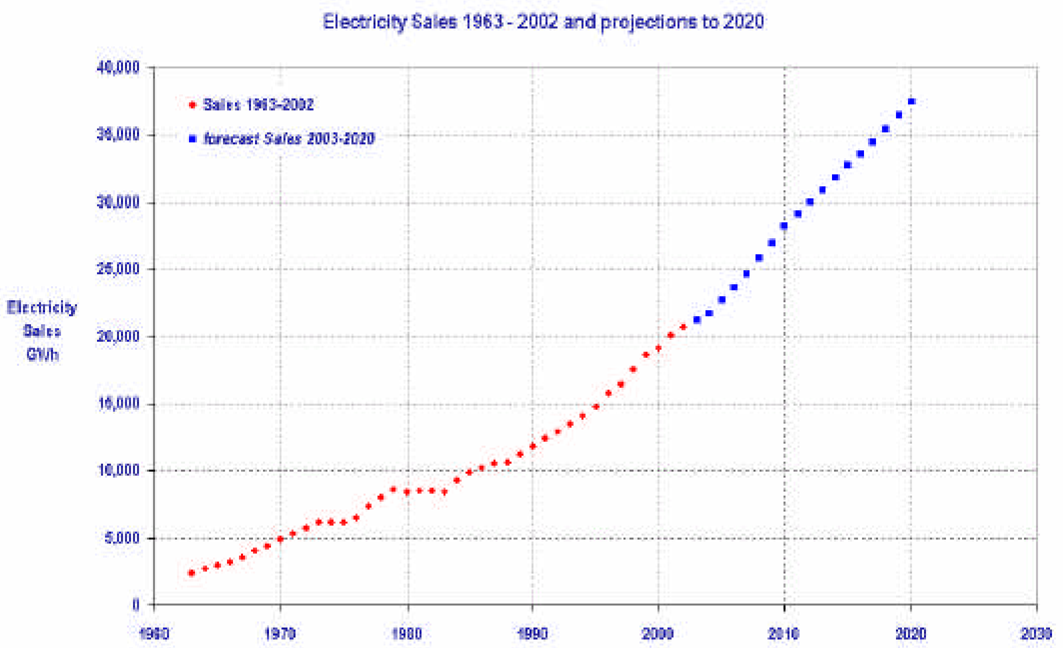
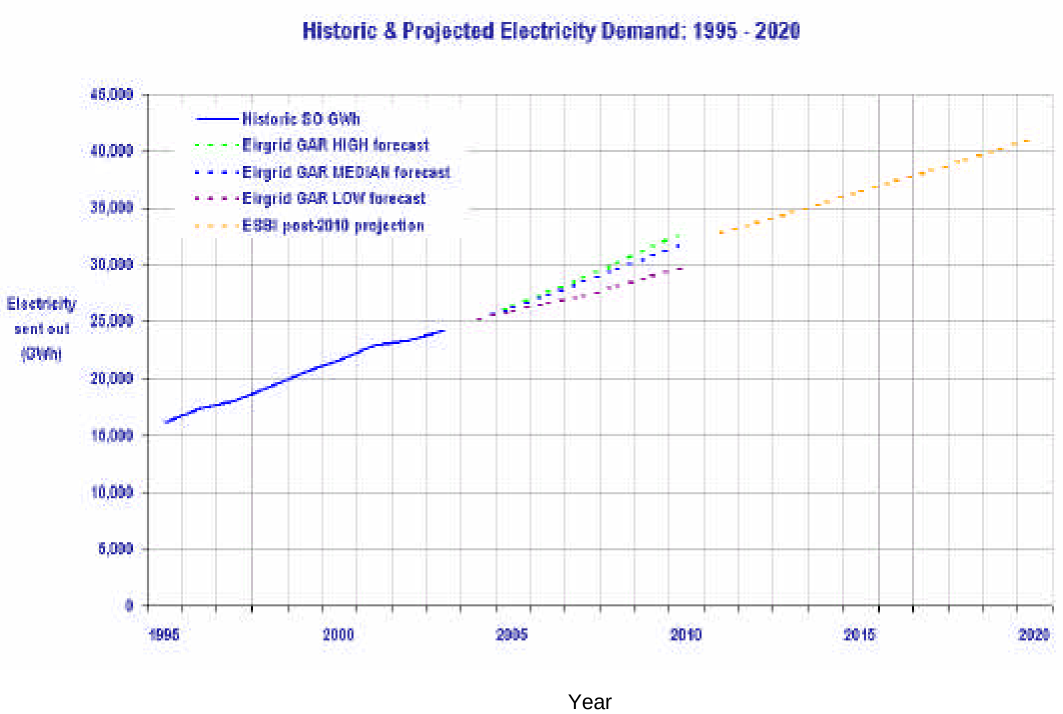


Fig 3. 2: Historic and projected electricity demand (sent-out i.e. before transmission and distribution losses).



(SO : System Operation ESB, GAR : Generation Adequacy Report)

Table 3.1

Historic and Projected Electricity Demand 1995 - 2020

			Eirgrid Projections						
Year	Actual Sales GWh	Actual Export GWh	Annual Growth %	High Export GWh	Annual Growth %	Median Export GWh	Annual Growth %	Low Export GWh	ESBI Export GWh
1995	14699	16206							
1996	15707	17318							
1997	16410	18093							18142
1998	17440	19228							19170
1999	18648	20560							20275
2000	19646	21660							21532
2001	20821	22956							23208
2002	21209	23384							23012
2003		24291							23849
2004	-	-	2.9	25199	2.9	25199	2.9	25199	24743
2005	-	-	4.7	26378	4.1	26223	3.1	25988	25680
2006			4.6	27592	4.4	27376	2.7	26683	26964
2007			4.5	28838	4.1	28506	2.1	27247	27913
2008			4.6	30168	4.1	29677	3.2	28115	28968
2009			4.7	31583	3.9	30839	3.3	29030	30417
2010			4.3	32929	3.8	31997	2.7	29817	31938
2011									32799
2012									33688
2013									34605
2014									35551
2015									36528
2016									37409
2017									38316
2018									39248
2019									40206
2020									41190

Notes:

(1) ‘Export’ denotes energy sent out from power stations (incl. line losses)

(2) Eirgrid projections as per Generation Adequacy Report (Ref. 14)

(3) Annual Growth refers to year on year increase

(4) Consultation Document (Ref. 16) quotes Electricity Export at 24600GWh.

3.3 Heat Market

The estimated heat demand for Ireland (excluding the industrial and Agricultural sectors) is provided in Table 3.2 below. Nearly 90% of heat demand is attributable to housing.

Table 3.2

Heat Demand 2000 Ireland	GWh
Commercial	
Sale Maintenance and Repair of Motor Vechicles	346
Wholesale Trade & Commission Trade	156
	-
Retail Trade	267
Hotels and Restaurents	860
Post and Telecommunications	18
Estate Activities	27
Computer and Related Activities	34
R&D	19
Other Activities	138
Recreational, Cultural and Sporting Activities	80
Other Service Activities	178
Public Sector	-
Central Government (OPW	99
Health	825
Education 3LC	138
Education 2 LC	394
Education 1 LC	292
Education Private	82
Defence	144
Garda Stations	-
Local Authorities	104
State Bodies C&NC	-
Housing	42,053

Heat demand in Ireland (shown in Figure 3.3) excluding the industrial and agricultural sectors is forecast to grow at a rate of 4% per year to 2020 resulting in a 48% and 119% increase in heat demand by 2010 and 2020 respectively. (Table 3.3)

Figure 3.3

Forecast Thermal Energy Demand Ireland to 2020 for Commercial & Public Sector Buildings and Housing

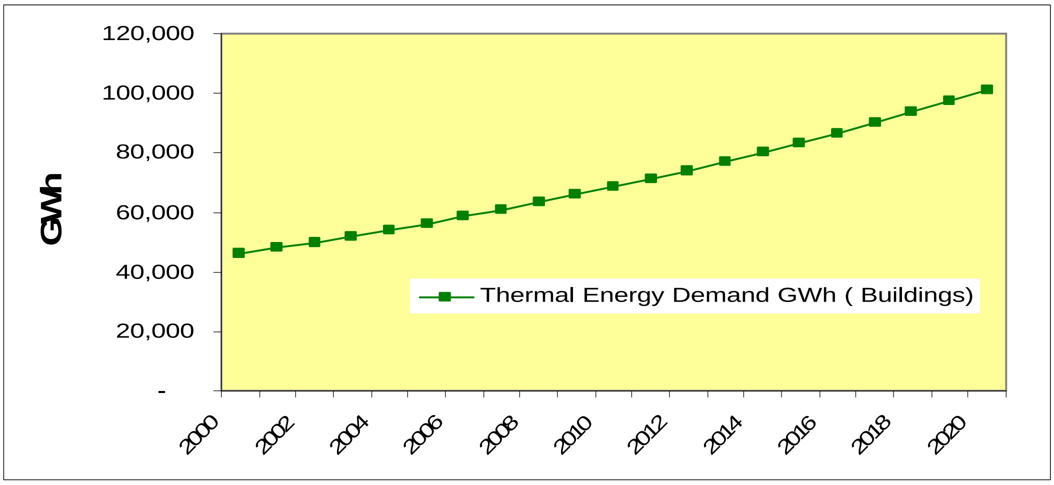


Table 3.3

Forecast Thermal Energy Demand : Ireland : Housing, Commercial & Public Sector Buildings (4% growth rate)

Year	GWh (thermal)	Year	GWh (thermal)
2000	46254	2011	71206
2001	48104	2012	74054
2002	50028	2013	77016
2003	52029	2014	80097
2004	54110	2015	83301
2005	56275	2016	86633
2006	58526	2017	90098
2007	60867	2018	93702
2008	63301	2019	97450
2009	65833	2020	101348
2010	68467	-	-

3.4 Comparative Market Input Data

Input data utilised in this report and Consultation Document (Ref. 16) is contrasted and briefly commented upon below. The DCMNR forecast electricity demand is based on ESRI projections, Eirgrid Generation Adequacy Report (to 2010). The ESBI analysis for 2010 is essentially based on the same input and is extended to 2020 using ESRI data and ESBI correlation with GNP.

Table 3.4

DCMNR and ESBI Input Data Comparison

Renewable Technology		DCMNR Ref. (16)	ESBI	Variance % on DCMNR
0	**Market Size (2001)**			
0.1	Electricity Market	24600	22956	-6.7
0.2	Heat Market	60600	48104	-20.6
0.3	Transport Market	50100	N/A	-
1.	**Capacity Factor**			
1.1	Best New Entrant	0.91	0.91	-
1.2	Small Hydro	0.4	0.4	-
1.3	Onshore Wind	0.35	0.35	-
1.4	Offshore Wind	0.35	0.35	-
1.5	Biomass – Residues	0.32	0.42	+31

1.6	Biomass – Energy Crops	0.32	0.85	+165
1.7	Biomass LFG	NA	0.85	+165
1.8	Ocean Wave	0.3	0.35	+16.6
1.9	Ocean Current	0.3	0.3	-
1.10	Solar PV	NA	0.1	NA
2.	**Capital Cost (Ave) €/kW**			
2.1	Best New Entrant		440	
2.2	Small Hydro	1755	1932	+10
2.3	Onshore Wind	990	1139	+15
2.4	Offshore Wind	1454	1990	+37
2.5	Biomass Residue	1900	2357	+24
2.6	Biomass Crops	2050	458	+22.3
2.7	Biomass LFG	NA	1058	NA
2.8	Ocean Wave	4750	2857	+39.8
2.9	Ocean Current	4750	2252	+52.8
2.10	Solar PV	NA	5395	NA
3.	**O&M Cost €/kW/yr.**			
3.1	BNE			
3.2	Small Hydro	63.8	68	+6.6
3.3	Onshore Wind	49.5	42.5	+14
3.4	Offshore Wind	63	63	-
3.5	Biomass Residue	114	1050	+921
3.6	Biomass Crops	150	278	+85.3
3.7	Biomass LFG	NA	139	NA
3.8	Ocean Wave	63	141	+123
3.9	Ocean Current	63	79.5	+2.6
3.10	Solar PV	NA	123	NA

3.5 Key Variances

The principal variances that occur relate to biomass capacity factors, capital costs associated with offshore wind, biomass, ocean energy and O&M costs relating to biomass and ocean energy. The huge variance for 3.5 arises from the dissimilar nature of the projects. In general ESBI attempts to allow for an average network connection cost while DCMNR excludes this.

3.5.1 O&M Costs

Reference (16) utilises a notional O&M cost/kW of capacity installed. It has to be noted that this may be a somewhat misleading way of designating renewable energy converter costs in that it is at a remove from the actual energy delivered and the capacity factors of different renewable conversion systems can be radically different from each other e.g. wind (circa .35 $\pm$ 0.1) and biomass (circa 0.8 – 0.9).

In reality the O&M cost has fixed and variable parts. The fixed part may be related to the capital costs (either proportionately or inversely, depending on how much of the capital cost has been devoted to minimising potential O&M costs e.g. for a low maintenance offshore wind regime) while the variable part is related to the ongoing energy production.

3.5.2 Ocean Energy : Capital Costs : Wave

As this is a developmental area both DCMNR and ESBI ascribe relatively high capital costs at €4,500 – 5,000/kW and €2,857/kW respectively. There is now some evidence that these costs may be too high. A figure of €1,700/kW was given in Ref. (20) as an average of five designs of floating wave converter while Ref. (21) gives 2,100€/kW and Ref. (22) gives the following values for named conversion devices under development abroad at present.

- “Wave Dragon” and “Aqua buoy” 2,000€/kW
- “Pelamis” 2,666€/kW

3.5.3 Landfill Gas Power

- The projected output from the landfill gas resource (ESBI) is relatively small at 0.37TWh (2010) and (0.37 + 0.006) = 0.431TWh (2020). It is not adverted to in the Consultation Document.

3.5.4 Wind Power Capacity Factor

- DCMNR utilises a fixed value of capacity factor (0.35) for both onshore and offshore wind energy. This is not unreasonable for estimation purposes but examination of the wind speed distribution in Irish Wind Atlas 2003 and its combination with the reference wind turbine characteristic curves shows (particularly in the case of the 7MW machine) that the capacity factor varies from 0.26 in areas of low mean wind speed to 0.45 in high mean wind speed areas which once again emphasises the importance of permitting development in high wind speed areas.

3.5.5 Impact of Capacity Limits on Wind Power

- The effect of the suggested 1000MW and 1250MW capacity limits (discussed later) on wind power is most significant. The electrical demand projections of Fig. 3.1 show 28TWh (2010) and 37.5TWh (2020). Given that the existing hydro capacity can contribute 0.839TWh, which is essentially unchanged for 2010 and 2020, and that 1,000MW and 1,250MW of wind power contribute 3.066TWh and 3.88TWh respectively in 2010 and 2020, whle landfill gas contributes 0.25TWh and 0.27TWh respectively, the total renewable contributions for these years are

  2010: (0.251 + 0.839 + 3.066) = 4.156 TWh instead of 7 TWh

  2020: (0.273 + 0.839 + 3.088) = 4.992 TWh instead of 13TWh

  Thus unless the shortfall can be made up by biomass, the targets of 22% (2010) and 33% (2020) of total electrical consumptions to come from renewables as set out in the Consultation Document are replaced by 15% and 13.3% respectively, which fall well short of the targets.

  This has serious implications for CO_2 reduction. The reasons for the windpower limits are discussed elsewhere.

3.5.6 Impact of Biomass Substitution for Peat

This possibility merits consideration as the economics of biomass based renewable generation in Ireland have changed radically in the past year as

- The new generation of peat fired generating plants were also designed for biomass firing.
- The introduction of the single farm payment as part of the latest CAP reform measures coupled with the Minister for Agriculture's announcements that up to 50% of farm area could be devoted to forestry, without affecting rights to the Single Farm Payment

makes the development of Short Rotation Forestry (SRF) a potentially attractive option for farmers previously operating a dry stock or suckler cow enterprise and short rotation forestry is potentially very attractive financially for the many farmers now with off farm employment.

If SRF, delivered to power station, is valued at milled peat prices, it could provide an attractive gross margin relative to other farm enterprises, particularly if SRF establishment grants were available.

- The three new peat stations produce CO_2 at a rate of about 1.18T/MWh and have a total output of about 3 x 10^6 Tons CO_2/yr. Total replacement of this with CO_2 neutral forest biomass would result in a gross saving of 3 x 10^6 tonnes of CO_2/yr. Replacing peat by BNE would save (1.18 - 0.48 (2,965,570) = 2.08 x 10^6 TCO_2/yr.

  Theoretically a full switch of fuel from peat to biomass would also transfer 345MW of non intermittent capacity to the 'renewable' portfolio. This would allow the desired 22% energy target (7TWh) for renewables to be met for 2010. However it is clearly outside the scope of this report to consider the numerous technical and commercial issues that would need resolution before a significant switch could be envisaged.

3.6 Conclusions

3.6.1 Electricity Market Demand

Based primarily on the ESRI mid term review report and having regard to past records and the current Generation Adequacy Report, the projected electricity demands for 2010 and 2020 are estimated to be 32TWh and 41TWh respectively.

3.6.2 Heat Market Demand

The corresponding levels of heat demand for housing, commercial and public sector buildings are estimated at 68.5TWh (2010) and 101TWh (2020) respectively.

3.6.3 DCMNR Consultation Document

A number of variances occur between input data used in the DCMNR Consultation Document and that used in this report. These are adverted to below. (3.10.4 – 3.10.7)

3.6.4 Input Data : Capacity Factors

In general the capacity factor values assumed that the by DCMNR and ESBI are in agreement apart from those for Biomass where it is suggested DCMNR figures (0.32) are unusually low and need review.

3.6.5 Input Data Capital Costs

The ESBI figures (with some exceptions) are higher than those used by DCMNR. This may have arisen because of the inclusion of an element of connection/network upgrade costs in the ESBI figures. Notable exceptions occur in the case of Ocean Energy and Biomass (Crops). In the case of ocean energy there is evidence of a downward trend in projected capital cost while the Biomass (crops) installation was envisaged by ESBI as co-firing on an existing plant with consequently reduced capital costs. The variations indicate the difficulty of ensuring that like is being compared with like in this type of analysis. (The model developed for this report should assist in this regard).

3.6.6 Input Data : O&M Costs

These were largely taken as a percentage of capital costs by DCMNR and consequently the ESBI figures were modified to reflect this. It has been noted that this may not be the best way of representing O&M costs when comparing systems having radically different capacity factors.

3.6.7 Input Data : System Limits

The feasibility of having to work with severe system operation limits was not adverted to in the DCMNR document. Since commencing this report it has become evident that the type and performance of existing generating plant on the system does not provide an effective and economic means of matching further significant tranches of intermittent wind capacity without modification. Limits of 1000MW and 1250MW are advocated for 2010 and 2020 respectively (Republic only) unless a significant proportion of open cycle gas turbines or equivalent plant is introduced.

3.6.8 Impact of Limits

The effect of these limits is to reduce drastically the renewable targets envisaged for the years 2010, 2020 with consequential impact on CO_2 abatement.

A conceptual option for dealing with this in the short term might be to switch fuelling of the three new peat fired fluidised bed generating stations to wood biomass fuel presuming on the availability of such fuel and on option to renegotiate the existing peat supply contracts. The 15 year contract life envisaged for these stations will fall due for renewal about 2020 but an earlier option might be that of phasing in biomass as a cofired fuel with peat which would enhance combustion sulphur control and extend the operating lives of these plants (subject to Planning Permission).

3.6.9 Wind Resource

The importance of the wind resource is underlined but also its future vulnerability to the available generating and transmission infrastructure in Ireland. Likely penetration limits on wind capacity have been suggested and the implications discussed.

3.6.10 Landfill Gas Resource

The benefits of landfill gas recovery have been noted but in national terms the resource is a small one where changing waste management practices are projected to reduce feedstock levels over time, but not significantly before 2010 or 2020.

3.6.11 Solar Heating Resource

Solar water and space heating is a more demanding technology than solar water heating alone. The EU has an ambitious programme for installation in place but this is not being uniformly taken up across Europe and in Ireland the take up has been very low. It is evident that strong government support would appear to be necessary to remedy this position.

3.6.12 Renewable Cofiring Resource

Arising from the difficulties of integrating larger quantities of intermittent (wind) energy into the electrical system, the need to move toward CO_2 avoidance, and the opportunity to focus upon energy crops as a way of profitably utilising land being taken out of agricultural production the merits of utilising biomass as a cofuel in existing modern peat fired generating stations are advanced for further detailed consideration.

3.6.13 Benchmarking Against Fossil Fuel Prices

It is possible to utilise the resource/cost curves developed later in this report to assess the projected market response of a particular renewable resource technology to changes in fossil fuel prices.

4. Overview of Technologies

4.1 Introduction

It has been demonstrated that the resource definitions developed in Appendix 7 can be applied in the cases of electrical and heat energy to the wind, landfill gas and solar thermal resource technologies.

4.2 Current Status of Renewable Energy Technologies

The current status of the renewable technologies is summarised in Table 4.1 in global terms. More extensive information is contained in Appendix 2.

Table 4.1

Current Status of Selected Renewable Technologies – Worldwide

P Operationally Proven (including proven under support rules prevailing in particular managed markets)

P1 Capable of competing in viable open market (2004)

* Applicable to heat market

RDD Small scale Research, Development, Demonstration stage only

(L) Indicates that application of technology is significantly location specific

(D) Indicates that level of measures taken in design is discretionary

(It is taken as given that ongoing R&D is also taking place in fully operational technologies).

Large Scale Operation of Technology	World in General	Ireland
Small Hydro	P (L)	P (L)
Onshore Wind	P (L)	P (L)
Offshore Wind	P (L)	RD, D(L)
Biomass:		

Segregated Mun. Waste to Energy *	P (L)	-
Agri Waste to Energy *	P (L)	-
Forest & Wood waste to Energy *	P (L)	RDD (L)
Biomass Energy Crops to energy *	P (L)	-
Sewage Biogas to Energy	P (L)	P (L)
Landfill Biogas to Energy	P1 (L)	P1 (L)
Passive Solar Design *	P1 (D) (L)	P1 (D)
Solar Water Heating *	P	P
Photovoltaic to Electricity	P	-
Ocean Energy: Tidal Barrage	P (L)	-
Ocean Energy: Tidal Current	RDD (L)	-
Ocean Energy: Wave Shoreline	RDD(L)	-
Ocean Energy: Wave Inshore	RDD (L)	RDD (L)
Ocean Energy: Wave Offshore	-	-
Geothermal: Hotdry Rock *	RDD (L)	-
Geothermal: Aquifer *	P (L)	-
Ambient: Heatpump *	P	P

4.3 Onshore Wind

In the short term, it may be that turbine capacities of up to 2.5MW with hub heights around 75m will be the practical maximum in some parts of the country. Installation of larger machines onshore may be restricted by the difficulties delivering the largest components and suitable infrastructure (cranes etc) to install them. This is likely to be a particular issue where the higher wind speed sites are in mountainous areas with limited road access.

Despite these limitations, a number of machines with capacities in the range 5MW and hub heights of around 100m are currently under development and, in some cases, are already available commercially. It is assumed that onshore wind developments will use 3MW turbines in 2010 and 7MW turbines in 2020.

Some EU studies have quoted reductions in capital costs of over 20% by 2010 and nearly 50% by 2020. The corresponding estimates of reductions of predicted electricity costs are over 30% by 2010 and over 50% by 2020. These estimates may be somewhat optimistic. Wind technology is reasonably mature and costs have already reduced dramatically. Bundesverband Wind Energie (BWE) in 2003 stated that the capital costs of installations in Germany had reduced by 50% from 1990 to 2002. While the factors listed above can be expected to reduce costs it seems unlikely that the same degree of cost reduction can be achieved again over a similar timescale.

It is assumed that a more modest prediction of cost reduction, of the order of cost of energy reducing by 15% by 2010 and 35% by 2020.

Results of public attitude surveys in Ireland and other north European countries have indicated a generally high degree of support for wind farm development particularly among those who already live near them.

Extending the public attitude surveys to examine possible limiting scenarios on public tolerance of wind farm capacity based on experience elsewhere suggests that a range as high as 5-10 GW of capacity might be possible provided that the public are consulted and involved in the developments.

Changing approaches to landuse development planning and energy system issues can represent further opportunities, rather than barriers to wind development. The accessible resource for wind energy is determined on the basis of these issues.

There are particular difficulties in operating a national system with proportionately large amounts of wind or wave power generation connected to it i.e. energy sources that are free, when available, but which are neither storable or controllable.

In Ireland these problems are

- Particularly acute as the electrical system in Ireland, North and South, is small by international standards.
- There is relatively little hydro generation capacity and even more importantly controllable hydro storage in Ireland. This is in marked contrast to the position in the Scandinavian countries or the Iberian Peninsula.
- The new CCGT plants have poorer 'turn down' capability than conventional thermal plant due to their high thermal efficiency and environmental characteristics.
- Frequent starting of industrial as opposed to aero derived gas turbines causes accelerated wear and tear and the total costs of starting an F class GT are estimated to be in excess of €30,000 per start up.
- The lead time to start conventional thermal plant from cold exceeds the time for wind power generation to fall off, across the island.

Thus the capacity of the system to absorb wind power generation is effectively governed by the turn down capability of the thermal plant connected to the system at the time. Technically this limit is related to the system demand at the time but in economic terms the limit is set by the turn down capability available for approximately eight thousand hours per year.

This value is estimated at

- 1000MW in 2010 for the ROI system
- 350MW in 2010 for the N.I. system

Were the existing emphasis on developing large CCGT units, based on industrially derived gas turbines to continue, then the capacity to absorb wind power would grow only slowly between 2010 and 2020, in line with the projected relatively slow growth in system demand in the period.

However a new generation of large aero derived gas turbines with open cycle efficiencies of up to 44% and capital costs as low as €350/kW, when sited in brown field sites with well developed electrical transmission, gas supply and oil storage facilities is now coming to market.

The introduction of this type of generating plant together with gas and pumped storage on the system would allow an increase in wind power generation capacity of up to about 3,725MW onto the system by 2020.

4.4 Landfill Gas

LFG represents a serious risk to the environment both locally and on a global scale. Consequently stringent environmental protection systems are required on modern landfill sites. These are an integral part of the site design and include impermeable liners, a series of migration control wells and a flare to burn off the LFG. However, as explained above, LFG can also be used to generate energy. On well-designed modern landfill sites, the migration system and extraction system for exploitation of energy should be well integrated.

A typical LFG extraction system comprises a series of wells under slight negative pressure. Commonly, a well consists of 250-300mm diameter borehole fitted with an outer 150mm Nominal Bore slotted Medium Density Polyethelene well casing, located 2-3 m above the base of the site. This casing allows gas to be drawn into the pipe. There are a wide range of alternative designs for wells and collection systems available. The system chosen depends on details that are specific to the site, such as the depth of waste and its physical properties.

As well as being used as a fuel for producing electricity LFG can be used as a boiler fuel in conjunction with a steam turbine generating plant. The large scale usually required in the process limits the viability of LFG, due to economic factors. It is also worth noting that steam plants are not as thermally efficient as competing technologies.

LFG conversion to energy is a well-established and mature technology.

The future of the landfill gas market is heavily dependent on future waste management practices. Government Policy in Ireland is aiming to reduce the dependence on landfill and increasing the involvement of the private sector in waste management. The policy is necessary due to the introduction of the EU Landfill Directive.

Projections of municipal waste tonnages and composition have been hampered by poor quality of input data in the past. In more recent times better records prepared under the auspices of the EPA from weighbridge data have become available and allow more realistic projections to be made showing increased waste production for counties and regions.

The total quantity of waste being produced is projected to rise although thermal treatment plants will, if constructed as planned, absorb part of this. EU Directives and Government Policy provide for the diversion of biodegradable waste from landfill, leading to a reduction in methane content of the landfill gas and its energy value. Based on analysis of projected regional waste depositions for 2010 and 2020 the accessible electrical capacity equates to 49MW and 58MW respectively.

4.5 Active Solar Thermal

Active Solar thermal technology can be used for the provision of domestic hot water or space heating. The principal form of the technology involves the heating of domestic hot water. The solar collector is placed in a position of good solar exposure. Fluid is pumped (or can flow by convection) through the solar collector and is heated by the sun. The collector fluid is then used directly as hot water or heats water via a heat exchanger.

Solar collector systems have been in use since the 1970s and can in general be classed as technologically developed. The three general areas of use relevant to the Ireland are domestic water heating, the heating of swimming pool water and low temperature process heating. Solar collector systems can also be used for space heating. Process heating and space heating have only had very limited application in Ireland so far.

Systems for commercial applications (with the exception of outdoor swimming pools) currently have a negligible market due to the low price of fuel and the shorter economic returns required in the commercial sector.

The technology consists of both evacuated tube collector systems and flat plate collector systems. Collector manufacture is often small scale and is at least partly manual. In a mature market rationalised industrial manufacture can be expected to dominate.

5. Renewable Energy Resources to 2010 & 2020.

5.1 Definitions

This chapter sets out the estimated renewable energy resources in Ireland to 2010 and 2020. The report focuses on three renewable energy resources wind, landfill gas and solar thermal power. Each resource has been identified in terms of

- Theoretical Resource
- Technical Resource
- Practicable Resource
- Accessible Resource

A subset of the accessible resource identifies the potential for utilizing the resource in terms of what technologies are likely to be implemented with and with out Government assistance or intervention.

The terms are developed in Appendix 7 and are defined as follows:

Theoretical Resource

This is the gross energy content of the particular form of renewable energy that occurs within a given space (e.g. Ireland) or over a given time e.g. one year)

Technical Resource (Subset of Theoretical Resource)

The technical resource is the theoretical resource as above but constrained by the efficiency of the currently available technology to respectively extract renewable energy from the resource or inject it into an electricity or heat using system. (Slowly variable over time).

Practicable Resource (Subset of Technical Resource)

This is the technical resource as above, constrained by practical physical or other incompatibilities. E.g. where the resource capture or injection systems simply cannot meaningfully be located due to physical interference or other practical reason. (Slowly variable over time).

Accessible Resource (Subset of Practicable Resource)

Practical resource as above is constrained by man made institutional/regulatory deletions that limit energy extraction e.g. environmental, health and safety, energy policy, planning zonation, by-product management criteria etc. In general all of the accessible resource may not be commercially viable (Variable over time)

Viable Resource (Subset of Accessible Resource)

Viable Managed Market Resource

Accessible resource as above, constrained by what is considered to be commercially viable at a particular time in the managed or supported market in terms of development cost, scale, resource distribution, market reward level, timing or other risk (variable over time). Any resource capable of producing power at or below the corresponding AER capping rate is considered to be in the viable managed market.

Viable Open Market Resource

Accessible resource as above constrained by what is considered to be commercially viable without market support in terms of development cost, resource distribution, market reward level, timing or other risk (variable over time). Any resource capable of producing power at or below the rate payable for the Best New Entrant is considered to be in the viable open market.

5.2 Wind

The wind resource for Ireland in 2010 and 2020 is summarised below. The methodology for estimating the resource is provided in Appendix 3 in detail. The height taken as representative was 75m above ground level. (The capacities are indicative only based on a capacity factor of 0.35).

Table 5.1

Summary of Wind Resource in Ireland to 2020

Resource Level	**Capacity TW**	**Energy TWh**	**Capacity TW**	**Energy TWh**
Technical	331	1,015,900	666	2,040,801
Practicable	309	947,969	620	1,902,023
Accessible	8.5	26,207	12	36,701

5.2.1 Theoretical Resource

The gross annual energy content of the wind resource in Ireland was calculated at 75 meters above ground level using the power production curve from a typical Wind Turbine Generator (WTG).

A typical WTG is assumed to be of 3MW capacity for 2010 and 7MW for 2020. The WTG's are geographically placed on a regular grid determined by the minimum practical spacing of the machines. This spacing is determined by using a multiple of five times the blade diameter.

5.2.2 Technical Resource

The technical resource is calculated as above but constrained by the efficiency of WTG technology to extract energy from wind. The constraint used was to neglect all energy content with a long-term annual hourly mean wind speed of less than 7.5m/sec.

5.2.3 Practicable Resource

This is the technical resource as above, constrained further by practical physical incompatibilities. These physical incompatibilities include airports, roads, lakes, canals, railways, electrical infrastructure, and urban settlements. The physical features are removed from the technical resource using the following additional criteria:

- 400m buffer zone around urban settlements
- 6000m buffer zone around airports (Pending agreement from Irish Aviation Authority)
- 100m buffer zone either side of the electricity transmission (110kV, 220kV and 400kV) and distribution (38kV) lines.
- Lakes as they exist. Not buffered

5.2.4 Accessible Resource

Accessible resource is defined as the practical resource but constrained further in two stages:

(1) Constrained by social acceptability of installed wind generating capacity in Ireland. This constraint has been estimated to be a very wide range, that is, 5,000 to 10,000MW of wind capacity installed in Ireland.

(2) Constrained by the total electrical energy system capital, operation and maintenance costs. This results in a resource of 1000MW in 2010 and 1250MW in 2020 if the emphasis on CCGT plant continues.

5.3 Land Fill Gas

The forecast landfill gas resource for Ireland in 2010 and 2020 is summarised below. The methodology for estimated the resource is provided in Appendix 4 in detail.

Table 5.2

Summary of Landfill Gas Resource in Ireland to 2020 (MW)

Resource	*** 2010**	**2020**
Theoretical	331	195
Technical	117	82
Practicable	80	58
Accessible	80	58
Viable Managed Market	49.7	49.7 + 8.24 = 58
Viable Open Market	48.8	48.8 + 4.62 = 53.4

* Includes existing 2004 accessible resource (30MW)

5.3.1 Theoretical Resource

In this instance the theoretical resource is all household and commercial waste that is being sent to landfill.

The National Waste Database Report published by the EPA provides the necessary information on waste arisings and waste disposed of to landfill in 2001. 2001 is the most recent year for which comprehensive national information is available. The waste streams to be considered as part of the study are household and commercial, being referred to as municipal waste when combined. A landfill is deemed a resource for a period of 15 years. The licences being granted at present to manipulate the resource are for a period of 15 years in the majority of cases.

5.3.2 Technical Resource (subset of theoretical resource)

This determined according to:

- Size of site
- Geometry of site
- Gas flow rate
- Waste composition
- Gas engine conversion efficiency

In order to determine many of the above criteria and constraints, detailed site investigations would be necessary. However, for desk study purposes only the constraint of receipt of circa 50,000 tonnes/year/site of municipal waste can be applied with certainty. Landfills that received close to or in excess of 50,000 tonnes of municipal waste were considered.

The technical resource is in the region of 71.04MW producing 529GWh e/yr. for 2010 and 11.4MW producing 85GWh/yr for 2020 (incremental to 2004 and 2010 respectively).

5.3.3 Practicable Resource (subset of technical resource)

The practicable resource is defined as the technical resource as above, constrained by practical, physical or other incompatibilities.

The practicable resource is estimated using industry standard data for landfill gas. This is assumed on the basis that not all of the landfill gas can be collected for use.

If the above constraints are applied to the technical resource figures of 180MW and 950 Gwhe/year, the practicable resource is estimated at 45MW and 395 Gwhe/year for 2010 and 8.6MW producing 64GWh/yr for 2020 (Incremental to 2004, 2010 respectively).

5.3.4 Accessible Resource (subset of practicable resource)

The final resource subset is normally arrived at by deleting those parts of the Practicable Resource that are subject to manmade institutional/regulatory restrictions that limit energy extraction such as environmental, health and safety, energy policy (tariff levels), planning zonation, by product management obligations etc. For the purposes of this study the accessible resource is conservatively equated with the practicable resource in view of the difficulty of forecasting the influence of these factors.

The accessible electrical power capacity is 30 MW for 2001 as against an actual installed electrical power capacity which amounts to a total of 17.8 MW at present. The projected figures for 2010 and 2020 are developed below.

5.3.5 Projected Resource – Electrical Power – for 2010 and 2020

In determining the potential electrical power resource that can be derived from landfill gas by 2010 and 2020 a number of criteria and constraints must be assumed and applied. The Regional Waste Management Plans are currently under review, and when completed should have detailed figures regarding present and forecast waste compositions and thus actual tonnages of packaging waste to be diverted from landfill.

Table 5.3

Forecast New Landfill Gas Resource as electrical power – 2010 (MW)

Region	Projected waste to landfill (tonnes)	Resource as electrical power (MW)			
		Theoretical	**Technical**	**Practicable**	**Accessible**
Connacht	286,849	20.74	8.78	6.15	As for
Cork	295,659	21.38	9.05	6.34	Practicable
Donegal	42,263	3.06	1.29	0.9	Resource
Dublin	763,143	55.18	23.37	16.38	In this
Kildare	59,151	4.28	1.81	1.27	Instance
Limerick/Clare /Kerry	216,075	15.62	6.62	4.63	-
Midlands	161,980	11.71	4.96	3.47	-
Northeast	185,017	13.38	5.67	3.97	-
Southeast	228,050	16.49	6.98	4.89	-
Wicklow	81,536	5.9	2.5	1.75	-
Total	**2,319,723**	**167.73**	**71.04**	**49.73**	**49.73**

Table 5.4

Forecast New Landfill Gas resources as electrical capacity – 2020 (MW)

Region	Projected waste to landfill (tonnes)	Resource as electrical power capacity (MW) (Incremental to 2010)			
		Theoretical	Technical	Practicable	Accessible
Connacht *	16,000	1.01	0.43	0.32	As for
Cork	222,327	14.06	5.96	4.46	Practicable
Donegal **	31,708	2	0.85	0.64	Capacity
Dublin *	Residual	-	-	-	-
Kildare **	44,087	2.79	1.18	0.89	-
Limerick/Clare /Kerry *	Residual	-	-	-	-
Midlands *	Residual	-	-	-	-
Northeast *	Residual	-	-	-	-
Southeast *	50,000	3.16	1.34	1	-
Wicklow	61,517	3.89	1.65	1.24	-
Total	**425,639**	**26.93**	**11.4**	**8.55**	**8.55**

* *Thermal treatment introduced in Region as outlined in its Waste Management Plan*

** *May not be feasible as it is receiving less than the required 50,000 tonnes per year*

Government policy, as illustrated in (Ref. 10) ‘Changing our Ways’ stresses an overall diversion of 65% of biodegradable waste from landfill from 1998 – 2013. This is based on ‘real’ rather than 1995 figures and therefore is a much more stringent policy than the EU landfill Directive. In hindsight however, the figure of 65% by 2013 is somewhat ambitious as much of the planned infrastructure needed to accomplish this target is not in place and it may be some years before it is. For the purposes of this study it is assumed that there will be a diversion of biodegradable waste of 20% by 2010 and 50% by 2020 from gas production. As already mentioned, it is not possible to accurately determine the impact of the Packaging Directive on the forecast, so the policy as set out in ‘Changing Our Ways’ is used to cover both cases.

5.4 Active Solar Thermal Power Resource Base

The solar heat resource is dependent in the first instance on the insolation falling on the surface of Ireland. The usable power generated by solar panels will vary depending on latitude, time of year and weather conditions. According to the European Solar Thermal Industry Federation, current technology produces per square metre of solar panel between 300 and 450 thermal kWh/year.

The resource base in Ireland for solar heating for hot water and space heating is summarised in Table 5.5 below from the theoretical resource through to the accessible resource for the year 2000. The resource insolation area is based on the roof area of existing and projected future dwellings. The resource is measured in terms of metres squared which is the standard size of solar panels supplied to the Irish Market.

The theoretical resource is predicated on covering the whole country with panels having an average annual output per unit area of 350kW (thermal).

Table 5.5

National Resource Base for

Solar Thermal Power Ireland 2000 (000 M^2)

Summary	Theoretical Resource kmm^2	Total Floor Area $000m^2$	Technical Resource $000m^2$	Practical Resource $000m^2$	Accessible Resource $000m^2$	Accessible Resource %
Commercial		13,988	6,304	3,152	2,384	5%
Public Sector		9,889	5,196	2,598	1,949	4%
Industrial		4,200	2,100	1,050	788	2%
Housing		204,360	102,180	51,080	38,318	89%
Agriculture		1,080	1,080	540	405	1%
Total	69,550	233,517	116,861	58,430	43,823	100%

(Above areas are assumed to yield an average 350kWh/sq. m/yr).

As each square metre of area generates a specific kWh per year it does not incur efficiency deductions that would apply to other generation technologies. For convenience the resources are stated in terms of area.

The practical resource is defined as 50% of the technical resource. The technical resource has been further reduced to arrive at the estimate for the accessible resource taking account of planning and environmental constraints. Planning and environmental constraints are estimated at 25% of the of the practical resource base.

The accessible resource base in Ireland for 2000 is estimated at 44 Million sq. m and 87% of this area is accounted for by the housing stock (1.4 million units) which is estimated to grow at 4% per annum or 55,000 units per year.

Assuming this overall growth rate for the total accessible area, the accessible resource area will increase to 59 and 70 Million square metres by the years 2010 and 2020 respectively.

Table 5.6.

National Resource Base for Solar Thermal Power Ireland 2010 (000 sq. m)

Summary	Theoretical Resource km^2	Total Floor Area $000m^2$	Technical Resource $000m^2$	Practical Resource $000m^2$	Accessible Resource $000m^2$	
Commercial		16,786	7,565	3,783	2,837	5%
Public Sector		11,867	6,236	3,118	2,338	4%
Industrial		5,040	2,520	1,260	945	2%
Housing		282,017	141,008	70,504	52,878	89%
Agriculture		1,296	1,296	648	486	1%
Total	69,550	317,005	158,625	79,313	59,484	100%

(Above areas are assumed to yield an average of 394kWh/sq. m/yr.)

Table 5.7

National Resource Base for Solar Thermal Power Ireland (2020 (000 sq. m)

Summary	Theoretical Resource km^2	Total Floor Area $000m^2$	Technical Resource $000m^2$	Practical Resource $000m^2$	Accessible Resource $000m^2$	
Commercial		19,583	8,826	4,413	3,310	5%
Public Sector		13,845	7,275	3,638	2,728	4%
Industrial		5,880	2,940	1,470	1,103	2%
Housing		333,107	166,553	83,277	62,458	89%
Agriculture		1,512	1,512	756	567	1%
Total	69,550	373,927	187,106	93,553	70,155	100%

(Above areas are assumed to yield an average of 480kWh/sq. m/yr.)

The accessible resource as used for estimating the resource cost curves in Appendix 5 is shown below. The largest resource area is for housing of which 10% is estimated to be apartments in 2004 rising to 14% in 2010 and 20% in 2020.

Table 5.8

Breakdown of Accessible Area (000 Sq M)

for Solar Thermal Panels

Resource Area (000 M2)	2000	2010	2020
Commercial	2,364	2,837	3,310
Public Sector	1,949	2,338	2,728
Industrial	788	945	1,103
Housing		-	0
Total Houses	34,486	45,475	49,966
Total Apartments	3,832	7,403	12,492
Inc. New Houses		10,989	15,480
Inc. New Apartments		3,571	8,660
Total Housing	38,318	52,878	62,458
Agriculture	405	405	567
Total	43,823	59,403	70,165

The trend in accessible area suitable for solar panel installation may be seen on Table 5.8 which is used as a basis for calculation of the resource cost curves later.

5.5 Conclusion

Having quantified the key renewable resources projected to be accessible for 2010 and 2020 the following Section 6 addresses the economic evaluation of the respective technologies.

6. Financial and Economic Evaluation of Renewable Technologies

6.1 Introduction

As previously noted it is a requirement of the assignment that a levelised cost method be used for comparing technologies in a consistent way so that the resource/cost curves will include an appropriate allowance for financing and profitability.

The resource/cost curves are a particularly useful mechanism for identifying the extent of the viable managed and open markets, assessing the impact of constraints and also the market response to changes in fossil fuel prices. They can also be used to make comparisons between resources that contribute to the electrical market and the heat market.

To carry out the computational work involved a customised EXCEL model was developed utilising visual BASIC programming. The model allows the user to carry out levelised cost analysis using a method similar to that of the Commission for Energy Regulation in determining the levelised cost of the Best New Entrant power station. When the accessible resources are factored in, resource/cost curves can be produced and when project construction times, financing charges and energy sales profiles are added, full scale project developer's financial analysis can be provided and the sensitivity to changing conditions determined and recorded. As part of this assignment the model is made available to SEI for use by others in carrying out analysis on these and other renewable energy resources over time. The model and its application are discussed in detail in Appendix 1 and are illustrated in the following sections.

6.2 Scope of Model

Before considering application of the model it is helpful to consider the three types of analysis that it yields in slightly more detail. These are:

- Levelised Cost Analysis
- Financial Analysis
- Resource Cost Curves

Each of the analysis has its own specific features and purpose which are briefly summarised as follows

Levelised Cost Analysis

Power Plants are most frequently compared on the basis of their levelised electricity costs (LEC), which relate the capital cost of the plant, its annual operating and maintenance costs and fuel prices to the annual production of electricity and accounts for the time value of money by discounting using the weighted average cost of capital (WACC). LEC analysis is a useful first stage screening device that provides a means for comparing and ranking the most economically efficient technology in terms of energy output.

The discount rate used in the levelised cost is, by agreement with SEI, the WACC of 6.88%, the rate used by the CER in calculating the the best new entrant price as detailed in Appendix . However for reasons which will be referred to later an 8% discount rate is also used in some cases.

Financial Analysis

The primary focus of the Financial Analysis of alternative renewable energy options is to determine the potential return to the project developer resulting from investing in alternative renewable energy technologies. The financial analysis uses the same capital and O&M cost structures for each technology as those used in levelised cost analysis and combines them with consideration of all the necessary component costs of a project including financing, permitting, equipment integration, construction, operation and maintenance. The financial analysis also differs from the economic analysis in that it includes revenues that are expected to accrue to the developer of the project.

Resource Cost Curves

Resource cost curves provide a means of comparing costs of different projects both within a specific technology and between technologies. The primary value of resource cost curves is in comparing different generating options with each other given similar economic assumptions and evaluation methodologies. They are designed to provide the user with maximum flexibility to compare various options under different conditions. They can be used to determine which technologies can make the greatest energy contribution bearing in mind the availability of the resource and economics of the technology.

6.3 Cost Considerations in Renewable Energy Technologies

The most recent cost and performance data were compiled for electricity generation utilising the following range of plant types.

- On Shore Wind 50 MW
- On Shore Wind 10 MW
- Off Shore Wind 200 MW
- Hydro 1 MW
- Peat 100 MW
- Biomass- Cofiring 15 MW
- Biomass- Wood Waste 20 MW
- Biomass- Landfill Gas 4 MW
- Biomass- Digestion Gas 1 MW
- Ocean Energy Tidal Current 2 MW
- Ocean Energy Tidal Barrage 200 MW
- Ocean Energy Wave 5 MW
- Photovoltaic 1 MW

Because of changing economic conditions, financing assumptions, tax credit considerations and costing methodologies, the values generated should not be used as absolute values outside the context of this report (i.e. for contracting purposes or pricing justification). Similarly the values should not be compared against other non renewable generating options unless the cost of energy is calculated using a consistent approach and methodology.

The economics of renewable-energy technologies are rather different from those of conventional small power systems:

- The capital cost of the equipment is relatively high, especially for larger plants.
- The running costs are generally low
- The output of the system depends the resources available (differs per location) and on the load pattern.
- The reliability is high but capacity factor is often low.
- Renewables with intermittent output become increasingly dependent on the performance of non intermittent plant as their capacity increases beyond a particular threshold level.

6.4 Levelised Cost Analysis Results

Levelised cost analysis based on the varying operating lives of each technology are provided below in Figure 6.1. Both the project cash outflows and plant outputs (kWh) are discounted at the Weighted Average Cost of Capital (WACC) as calculated by the Commission for Energy Regulation (CER) for the BNE at 6.88% real.

In reviewing the following results it should be noted that the various renewable energy technologies are not uniformly mature. In addition the levelised cost analysis is affected by the selected scales of each project which range from 1 MW to 200 MW.

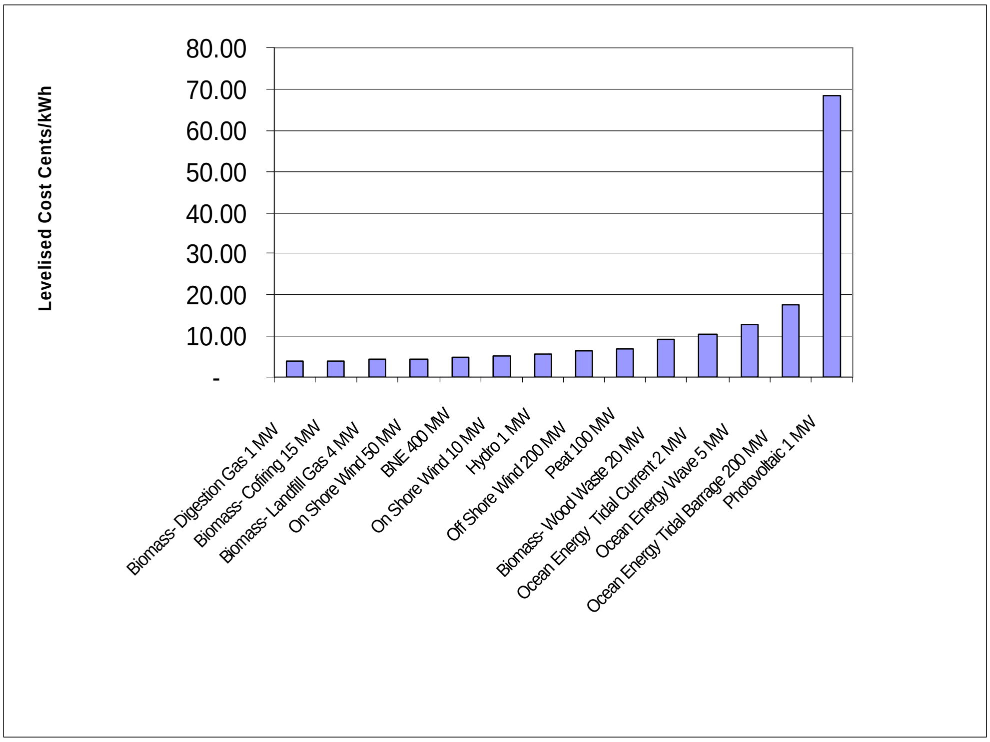
The levelised cost analysis shows the potential cost at which each renewable energy technology could produce energy when operating at maximum technical capacity.

Using the same discount rate (6.88%) as that used for BNE, four renewable energy technologies have the potential to produce energy at a cost which is cheaper that the best new entrant to the Irish Market as identified by the CER (400MW CCGT). Three of the projects are biomass producing gas for conversion to electricity and one onshore wind project at a scale of 50 MW operating at 35% capacity. However as will be seen later if a more appropriate discount rate of 8% is used for onshore wind its levelised cost rises above that for BNE.

It may be noted that all the competitive biomass projects are in the nature of small incremental developments complementing projects where the major expenditure had already taken place for other purposes e.g. sewage treatment, waste disposal, generation using another fuel. Thus they have to carry only incremental capital expenditure. The exception is onshore wind of significant scale (50MW). This does not invalidate the merit of these biomass projects but simply explains how they can be so cost effective.

Figure 6.1 Levelised Cost Analysis

for 13 Renewable Energy Projects and the Best New Entrant



The levelised cost approach identifies the most economically efficient technology in terms of minimising the cost of electricity generation as shown in Figure 6.1. The power sector is scale sensitive so that for any technology the levelised cost will fall as capacity rises. This sensitivity to scale impacts significantly on the commercial viability of some technologies, most notably photovoltaics.

6.5 Financial Analysis Results

A financial analysis (Appendix 1) was also completed on each renewable project listed above, producing cash flows and profit and loss account for each project. The purpose of the analysis is to determine whether the price caps under AER 6 provide sufficient incentives for potential investors in renewable projects and to identify the break even unit revenues required under the selected assumptions for each project discounted at the WACC. Each of the projects is analysed under the same assumptions used by the CER in determining the Best New Entrant Price.

The main assumptions applied in the financial analysis include

- Construction periods vary by project between 1 and 6 years
- Real Interest Rate during Construction 6.1%
- Real Interest Rate post construction 4.7%
- 70/30 Debt/Equity Financing of all projects
- Period of Debt Financing 10 Years
- Inflation rate 2% applied to all costs and revenues
- WACC 6.88% real and 8.88% including inflation as calculated by the CER

- Unit revenues based on AER VI Price Cap where applicable
- Acceleration of revenues allowed by CER under AER VI in the first seven years. Revenue increased by 35% in years 1- 7 and reduced by 35% in years 8 -15.

Each of projects capital and operating costs used for the Financial and Economic Analysis are listed below in Table 6.1 and ranked in terms of unit capital costs (excluding interest during construction).

Table 6.1

Ranked Capital and Operating Unit Costs

Project Costs (excl IDC)	Capital Costs Euro/kW	Unit Operating Costs Cents/kWh
Biomass- Cofiring 15 MW	440	3.74
BNE 400 MW	654	3.76
Biomass- Landfill Gas 4 MW	1,012	1.86
On Shore Wind 50 MW	1,089	1.33
Biomass- Digestion Gas 1 MW	1,170	1.86
On Shore Wind 10 MW	1,226	1.41
Peat	1,759	4.91
Hydro 1 MW	1,853	1.93
Off Shore Wind 200 MW	1,887	1.72
Ocean Energy Dynamic Tidal 2 MW	2,083	3.02
Biomass- Wood Waste 20 MW	2,190	7.05
Ocean Energy Wave 5 MW	2,716	4.59
Ocean Energy Tidal Barrage 200 MW	4,963	3.05
Photovoltaic 1 MW	5,204	14.06

The project revenues applied are based on the Price Cap c/kWh as specified in AER 6 and shown in Table A6.2 below. For comparison purposes the rates 15 Cents/kWh for Ocean Energy and Photovoltaic are used as these are still at the developmental stage. Each of the project revenues are adjusted for inflation in the Financial Analysis.

Table 6.2

Project Revenues

Technology	Cents/kWh
BNE 400MW	4.79
On Shore Wind 50MW	5.22
On Shore Wind 10MW	5.22
Off Shore Wind 200MW	8.40
Hydro 1 MW	7.02
Biomass – Cofiring 15MW	6.41
Biomass – Wood Waste 20 MW	6.41
Biomass – Landfill Gas 4 MW	7.00
Biomass – Digestion Gas 1 MW	7.00
Peat 100 MW	6.41
Ocean Energy Tidal Current 2MW	15.00
Ocean Energy Tidal Barrage 200 MW	15.00
Ocean Energy Wave 5 MW	15.00
Photovoltaic 1MW	15.00

The project results are shown in Table 6.3 below. The project analysis is not concerned with project finance and therefore it is assumed that the project is 100% equity financed. Those projects that have a negative Net Present Value are not generating sufficient funds over a 15 year period to recover the initial investment discounted at a WACC of 8.88%.

As shown in Table 6.3 below, under the cost and operating assumptions discussed above ocean energy, photovoltaic and one biomass project are clearly not financially viable under the unit revenues applied in Table 6.2 above. All others either generate a positive NPV or are close to a positive (NPV).

A total of eight projects in Table 6.3 are not generating sufficient funds to achieve a positive NPV.

The projects Internal Rate of Return (IRR) is closely related to the NPV. The IRR is the discount rate which will set the NPV of projects cash flow equal to 0. The IRR's listed below which are less than the WACC of 8.88% Nominal are not generating sufficient funds using the AER price caps for the project cash flows to break even.

Table 6.3

Project Results

	Project NPV (Nominal)	Project IRR (Nominal)
	000 Euro	%
BNE 400 MW	-1,706	8.8%
On Shore Wind 50 MW	2,432	9.8%
On Shore Wind 10 MW	-1,001	7.1%
Off Shore Wind 200 MW	83,213	13.2%
Hydro 1 MW	-134	7.2%
Peat 100 MW	-51,989	-2.8%
Biomass Cofiring 15MW	23,094	80.6%
Biomass Wood Waste 20MW	-45,259	
Biomass Landfill Gas 4MW	7,178	52.1%
Biomass Digestion Gas 1MW	1,331	30.8%
Ocean Energy Tidal Current 2 MW	-1,482	0.8%
Ocean Energy Tidal Barrage 200MW	-448,313	-0.7%
Ocean Energy Wave 5 MW	1,629	11.4%
Photovoltaic 1 MW	-4,804	

6.5.1 Breakeven Analysis

The unit revenues required for each project to recover initial investments at a WACC of 8.88% are shown in Figure 6.2 and Table 6.4 below. The breakeven selling price for the analysis provided below is that unit revenue required in each project so the NPV of the project cash flow discounted at the WACC is equal to 0. The break even analysis carried out on each project has been developed under the identical assumptions in the financial analysis.

Figure 6.2

Breakeven Analysis €c/kWh

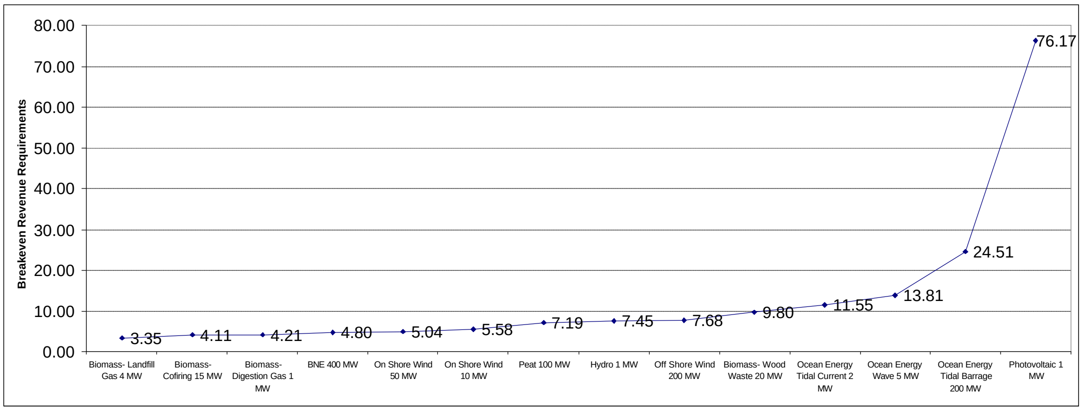


Table 6.4 shows that AER price Caps currently apply to ten of the listed projects. Eight projects (including the BNE) fail to achieve a non Negative NPV on the project cash flow. Some of these projects are close to a non negative NPV. The breakeven analysis identifies the gap between the AER price cap and the unit revenue required (cents/kWh) to a achieve a non negative NPV under the CER's discount rates.

The results show that five of the ten projects in which the CER has identified price CAPs are not financially viable, and the remaining five projects price cap is in excess of that required to make the project financially viable using the WACC for the BNE as the discount rate. However it should be noted that some projects will have different risk than that of the BNE and therefore should have a different discount rate. The higher the risk the higher should be the discount rate and therefore the higher the unit revenue which will achieve a non negative NPV.

Table 6.4

Breakeven Analysis (Cents/kWh)

	AER Price Cap	Project Breakeven Price	Variance
BNE 400 MW	4.79	4.80	-0.006
On Shore Wind 50 MW	5.22	5.04	0.177
On Shore Wind 10 MW	5.22	5.58	-0.364
Off Shore Wind 200 MW	8.40	7.14	1.261
Hydro 1 MW	7.02	7.45	-0.427
Peat 100 MW	6.41	7.19	-0.779
Biomass- Cofiring 15 MW	6.41	4.11	2.31
Biomass- Wood Waste 20 MW	6.41	9.80	-3.390
Biomass- Landfill Gas 4 MW	7.00	3.35	3.65
Biomass- Digestion Gas 1 MW	7.00	4.42	2.58
Ocean Energy Tidal Current 2 MW	15.00	11.55	N/A
Ocean Energy Tidal Barrage 200 MW	15.00	24.51	N/A
Ocean Energy Wave 5 MW	15.00	13.81	N/A
Photovoltaic 1 MW	15.00	76.17	N/A

6.5.2 Profitability Index

The profitability index (PI) is the ratio between the NPV of a project and its initial investment cost. In the financial analysis the BNE generates a profitability index of 1.00 using a price of 4.796 cents per kWh. Hence for every Euro invested in the project 1 unit is returned at a discount rate of 8.88%. This allows for a 10.6 % (post tax) and 11.9% (pre tax) return on equity invested into the project at a debt equity ratio of 70/30.

The price of 4.796 Cents/kWh is the breakeven rate for the BNE. To achieve the same Profitability Index and returns on equity for all projects as that achieved by the BNE under the same discount rate, the breakeven prices in Table 6.4 should be used.

6.5.3 Discount Rate

It is important to note that the weighed average cost of capital (WACC) of 6.88% used as the discount rate was derived by CER for a 400MW CCGT project on a scale and level of risk that might be appropriate to development by a utility or large player and (from a financiers point of view) reflecting the expectation of an appropriate income stream.

The weighed average cost of capital derived by the CER assumed a cost of debt of 4.7% (real) and a pretax cost of equity of 11.96%. Under a debt equity ratio of 70/30 with an equity beta of 1.59 the WACC is 6.88%

This would not necessarily hold true for a renewable project developer where the level of risk would be considered higher and where financiers therefore would demand a higher WACC. Thus a higher discount rate would be appropriate when estimating the levelised cost for development of the resource.

In the case of wind technology the relative impact on profitability of using an 8% discount rate is the model instead of the BNE rate of 6.88% may be illustrated as per Table 6.5 range of values may be tabulated if desired.

Table 6.5

Profitability (Return on Equity) versus Discount Rate

Discount Rate %	6.88	8
Profit (Pretax) % (ROE)	11.96	15.7
Profit (Post tax) % (ROE)	10.6	13.96
Debt/Equity Ratio	70/30	

6.6 Conclusions

(1) This section has introduced the analytical model developed for this assignment and explained its use in economic (levelised cost) and financial analysis of renewable technology projects with examples from a range of technologies. (Application to resource/cost curves occurs in the next section).

(2) Levelised cost analysis provides the best evaluation of the most efficient technologies.

(3) The capital cost of renewable energy technologies is relatively high especially for larger plants and the running costs are generally low.

(4) Biomass represents the most efficient renewable energy technology in levelised unit cost terms. 13 renewable energy technologies were compared to that of the Best New Entrant (BNE) as defined by the CER. Of these four renewable energy technologies generated electricity at a cost less that that of the BNE under the assumptions applied. Three of these were Biomass. The fourth was Onshore Wind which of course is a much greater resource in energy terms.

(5) Provision for finance charges and profit is made by selection of the appropriate discount rate. For renewable technologies this is not necessarily the same as for a CCGT Best New Entrant.

7. Resource Cost Curve Methodology for Renewable Energy

7.1 Introduction

The methodology for constructing the resource/cost curves is basically similar for different resources and technologies. The objective is to produce a function that relates unit cost c/kWh as the independent variable with installed capacity (MW) or by extension quantity of energy produced per year (MWh/yr) as the dependent variable. The resource quantity is drawn from the accessible resource subset and the extent to which it lies within the viable managed or open markets can readily be discerned from the resource/cost diagram. Various constraints and limitations can be incorporated on the curves and the manner in which the markets are projected to respond to changes in fossil fuel costs as these affect the levelised cost of the Best New Entrant can also be gleaned.

7.2 Resource/Price Curves

Although referred to as resource/cost curves the diagrams are readily converted to resource/price curves by incorporation of the appropriate discount rate in the levelised cost base. As energy is a cost to the community the term resource/cost curve will be maintained in this report but the implication is that an acceptable level of profit etc. for the producer is contained within the levelised unit cost to the community. The question of ensuring a “fair” profit to the producer has as its starting point the profit level implied for the Best New Entrant by CER as illustrated in the foregoing Table 6.4.

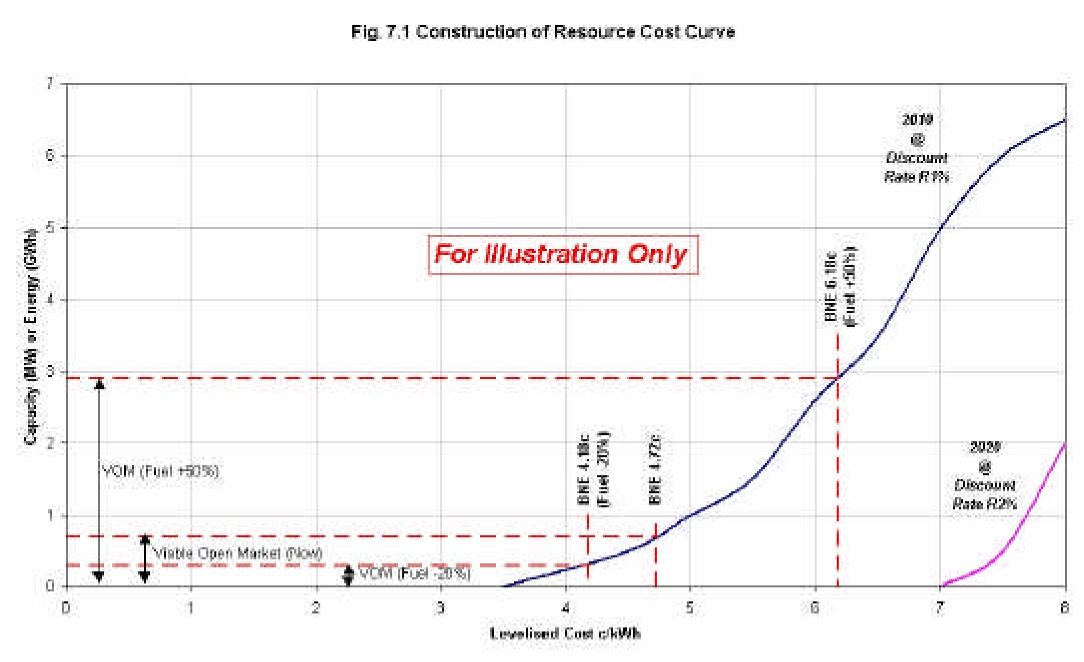
Where a technology has maturity, large scale and a utility level developer together with a secure market position its risk level allows the use of a relatively lower discount rate than one which may be still evolving, is smaller in scale, intermittent and with a smaller developer. Thus a higher discount rate is appropriate to allow for higher financing charges and risk takers profitability.

For the purposes of this report a discount rate of 8% is taken in the case of onshore wind and the profitability implications are shown in Table 6.4. Depending on economic circumstances discount rates can change and the model can be used to evaluate the implications in profit terms.

7.3 Development of Curves

A further requirement of resource/cost curves is a means of discriminating between levelised costs of the components of the resource that are most cost effective to develop and those that are not. In general costs are inversely proportional to the scale of development, distance between resource location and point of network connection, efficiency of technology that can be used and similar factors. Thus the resource cost curve is built up as a cumulative series of increments starting with that having the lowest levelised unit cost and progressing towards the most expensive. This is shown in Fig. 7.1.

Figure 7.1 Construction of Resource Cost Curve



A movement along the resource cost curve in any one period shows the varying quantities of energy that can be supplied at varying costs.

A shift in the supply curve is caused by a change in investment costs or a technological innovation or other productivity related change. This is shown above for illustrative purposes in 2020 where the cost curve shifts downwards resulting in a cost increase of supply energy at all output levels. This might also show a diminution in supply into the future.

In general the resource/cost curve is not a smooth line as each power station or increment of plant has a tangible capacity. In the case of wind power because the individual turbines form a small fraction of the overall potential the function approximates to a smooth curve. In other cases, e.g. landfill gas, it is a stepped function.

7.4 Curve Utilisation

The viable open market is defined as the capacity or energy level that occurs below the levelised cost of BNE. The viable managed market share lies between the BNE unit cost and whatever upper levelised unit cost limit the community is prepared to bear for wider reasons of policy.

Finally it will be borne in mind that the levelised cost of BNE is vulnerable to variations in the fossil fuel that it consumes. Thus the BNE unit cost variation can be plotted on the resource/cost curve as a consequence of projected fuel price changes and the consequential changes in size and price ranges of viable open and managed markets observed.

Resource/cost curves can be prepared showing levelised costs and amounts of CO_2 displacement in addition. It is important to stress that the CO_2 displacement is a consequence of energy production which is already being paid for as energy rather than double counting the levelised costs for both energy production and CO_2 avoidance. The resource/cost curves for onshore wind, landfill gas and solar thermal are developed and discussed in the following sections.

8. Resource Cost Curves Wind 2010 & 2020

8.1 Introduction

The resource cost curves for the important wind resource in Ireland have been developed on a levelised cost basis assuming technology developments will advance such that a 3 MW turbines will be in use in 2010 and 7 MW turbines will be in use by 2020.

The outputs in MWh for the accessible resource and the number of wind turbines have been generated using the Wind Atlas for Ireland (2003) focussing on the 75m. height above ground level only and are shown on Tables 8.1, 2.

8.2 Resource Cost Curves

The accessible resource cost curves for wind are shown in Figures 8.1 and 8.2 below. The accessible resources for 2010 and 2020 shown on Table 8.1, 2 reflect the turbine sizes utilised, 3 MW and 7 MW respectively, and the cost curves have been generated using levelised cost analysis for each of the mean wind speed levels detailed below. Details are given in Appendix 3.

The cost curves below are based on the accessible resource before system and market constraints are taken into account. The system and market constraints could have a significant impact on the amount of wind resource that could be exploited. Because of its importance the issue of constraints is discussed in detail in Appendix 3.

Basically for 2010 the system as currently existing and planned could permit the installation of 1000MW of wind or other intermittent power capacity. However the position beyond 2010 is more fluid. One option is to continue installation of efficient combined cycle gas turbine plant. This would result in a system that was dominated by relatively inflexible plant, poorly equipped for load following which is a pre-requisite for the acceptance of a large quantity of wind power onto the system. A second option is to adopt the emerging large open cycle aeroderivative type of gas turbine plant which is marginally less efficient but more suitable for load following. By 2020 this could permit the acceptance of up to 3,725MW of wind power onto the system.

This is represented by the upper constraint shown on Figure 8.2. The addition of appropriate amounts of pumped storage could improve the flexibility of the system in either event.

Thus the upper limit to the amount of wind energy that can be accepted onto the system by 2020 depends on the mix of thermal plant that is selected for installation in the intervening years as retiring current plant is phased out.

The resource cost curves clearly show that under the forecast cost reduction used in the analysis, wind power is becoming more competitive than the BNE in 2010 and could be particularly so by 2020.

8.3 Onshore Wind Resource

8.3.1 Resource Summary

The onshore wind resource for Ireland in 2010 and 2020 is summarised below. The methodology for estimating the resource is provided in the following section in detail.

Table 8.1

Summary of Wind Resource in Ireland to 2020 GWh

GWh	2010	2020
Technical	1,015,900	2,040,801
Practicable	947,969	1,902,023
Accessible	26,202	36,701

8.3.2 Theoretical Resource

The gross annual energy content of the wind resource in Ireland was calculated at 75 meters above ground level using the power production curve from a typical Wind Turbine Generator (WTG). The wind distribution throughout the country is that developed for the Irish Wind Atlas 2003 (Ref. 12).

The Atlas maps the mean wind speed among other variables at heights of 50m, 75m and 100m above ground level throughout the country on a digital database. The national database can be subdivided into counties or other geographical regions. In this instance it was agreed with the client that a suitable representative height for computing the wind resource would be 75m.

A typical wind turbine generator (WTG) is assumed to be 3MW for 2010 and 7MW for 2020. The generators will be geographically placed on a theoretical regular grid determined by the minimum practical spacing of the machines. This spacing is determined by using a multiple of five times the blade diameter.

8.3.3 Technical Resource

This is the theoretical resource calculated as above but constrained by the efficiency of WTG technology to extract energy from wind. The constraint used was to neglect all energy content nationally with a long-term annual hourly mean wind speed of less than 7.5m/s.

8.3.4 Practicable Resource

Technical resource as above, constrained further by practical physical incompatibilities. These physical incompatibilities include airports, roads, lakes, canals, railways, electrical infrastructure, and urban settlements. The physical features are removed from the technical resource using the following additional criteria:

- 400m buffer zone around urban settlements
- 6000m buffer zone along airports (Pending agreement from Irish Aviation Authority)
- 100m buffer zone around the electricity transmission (110kV, 220kV and 400kV) and distribution (38kV) lines.
- Lakes as they exist are not buffered.

8.3.5 Accessible Resource

Accessible resource is defined as the practicable resource but constrained further by social acceptability of installed wind generating capacity in Ireland. This constraint has been estimated to be in the range 5,000 to 10,000MW of wind installed in Ireland. It is further subdivided into the viable managed market and open market resource segments.

8.3.6 Resource Assumptions

The wind resource for Ireland for 2010 and 2020 is detailed in Table 8.2 below which provides a summary of the national accessible wind resource as a function of turbine size utilised. The energy output for each of the mean wind speed regions (made up from a summation of sub areas having this mean wind speed) across the country is abstracted from the national database of grid points that cover the country in the Irish Wind Atlas. It was inappropriate to partition this further in a national study although the potential exists to do so in the future if required.

Table 8.2

National Accessible Wind Resource

	MWh	
Speed Metres/Second	2010	2020
7.75	11,961,842	17,350,138
8.25	6,753,267	9,454,744
8.75	3,434,721	4,661,358
9.25	1,941,621	2,561,574
9.75	1,007,317	1,296,814
10.25	545,473	688,054
10.75	299,686	373,173
11.25	152,652	187,855
11.75	68,221	82,784
12.25	27,037	32,716
12.75	7,895	9,447
13.25	2,205	2,590
13.75	593	691
Total	**26,202,530**	**36,701,938**

8.3.7 Wind Turbine Technology

Resource cost curves have been constructed based on the use of 3MW wind turbines in 2010 and 7 MW wind Turbines in 2020. Note that the capacity factor varies throughout reflecting the usual increase with mean wind speed.

8.3.8 Cost Assumptions

Table A8.3 below provides the capital and operating cost structures for a 10MW, 7MW and 3MW wind Turbine in 2004 prices.

- The capital costs provided in Table 8.3 have been adjusted for real cost decreases for the year 2010 and 2020.
- The capital costs in 2010 are forecast to decrease (15%) to €4.6 Million (excluding interest during construction) for a 3MW Wind Turbine resulting in a unit cost of €1,546 per kW at 2004 prices.
- The capital costs in 2020 are forecast to decrease (35%) to €6.3 Million for a 7MW Wind Turbine resulting in a unit cost of €902 per kW at 2004 prices.
- The unit costs of Table 8.3 (discounted at 8%) are combined with the accessible resource figures of Table 8.2 to yield Tables 8.4 and 8.5 leading to the resource/cost curves of Figures 8.1, 2.

It remains to provide a basis for the constraints incorporated on these figures.

Table 8.3

Cost Structures for 10, 3 and 7MW Wind Farms

Project Capacity	**MW** **€**	**10** **10**	**7** **78%**	**3** **43%**
Site Procurement	000	20	16	9
Pre Financial Close Costs:	000	40	31	17
EIA	000	40	31	17
Engineering	000	40	31	17
Financial and Legal Costs	000	80	62	34
Post Financial Close Costs	000			
EPC Contract:	000			
Plant	000	8,200	6,388	3,530
Civil Works	000	1,100	857	474
Engineering	000	600	467	258
Contingency	000	594	386	300
Interconnectors:	000			
Electrical Interconnection	000	1,000	779	431

Other Costs:	000			
Owner Engineering, Project Mgt.	000	250	195	108
O&M Mobilisation	000	5	4	2
Contingencies	000	594	482	256
Spares	000	10	8	4
Total Investment Costs excl. IDC	000	**12,474**	**9,718**	**5,457**
	000			
Unit Cost	Euro/MW	1,247	1,388	1,819
Total Investment Costs	000	**12,474**	**9,718**	**5,457**
O&M				
	Cents/therm & Euros per GJ			
Lend Lease Payments	000	50	39	22
Salaries and Owner Maintenance Costs	000	120	93	52
Insurance	000	62	49	27
Rates	000	87	68	38
Owners General and Administrative Costs	000	10	8	4
TUOS Maintenance Charge	000	16	12	7
TUOS Charge	000	88	69	38
Annual O&M Costs	000	434	338	187
		2004	2020	2010
Capital Costs as proportion of 10MW		12,474	9,718	5,457
Capital Cost Reduction Time over 2004 prices			35%	15%
Forecast Capital Cost		12,474	6,316	4,638
Forecast Unit Cost (Euro/MW)		1,247	902	1,546

8.3.9 Outputs

Outputs in MWh for the accessible resource and the number of wind turbines have been generated using the Wind Atlas for Ireland (2003) for each of the thirteen mean wind speed levels. The outputs for each level are shown in Table 8.4 and 8.5 below for 2010 and 2020 respectively.

Table 8.4

Resource Cost Data 2010 – 2020

Resource Cost Curve Data - 2010 (3MW)				
Wind Speed	Cents		MW	MWh
	6.88%	8%		
7.75	8.46	9.01	5,182	11961,842
8.25	7.33	7.81	2,535	6,753,267
8.75	6.51	6.93	1,145	3,434,721
9.25	5.89	6.28	586	1,941,621
9.75	5.43	5.79	280	1,007,317
10.25	5.08	5.41	142	545,473
10.75	4.72	5.03	72	299,686
11.25	4.41	4.70	34	152,652
11.75	4.21	4.49	15	68,221
12.25	4.08	4.35	6	27,037
12.75	3.98	4.23	2	7,895
13.25	3.88	4.14	0	2,205
13.75	3.81	4.06	0	593

Table 8.5

Resource Costs by Wind Speed Category (2020)

Resource Cost Curve Data - 2020 (7MW)				
Wind Speed	Cents		MW	MWh
	6.88%	8%		
7.75	3.8	4.0	7,401	17,350,138
8.25	3.4	3.6	3,620	9,454,744
8.75	3.1	3.3	1,635	4,661,358
9.25	2.9	3.0	836	2,561,574
9.75	2.7	2.9	400	1,296,814
10.25	2.6	2.8	203	688,054
10.75	2.5	2.6	103	373,173
11.25	2.3	2.4	49	187,855
11.75	2.3	2.4	21	82,784
12.25	2.2	2.3	8	32,716
12.75	2.2	2.3	2	9,447
13.25	2.2	2.3	1	2,590
13.75	2.1	2.2	0	691

The resource cost curve for 2020 shows a significant shift downwards compared to that for 2010. The accessible resource however after system and market constraints would increase by only 250 MW by 2020 to 1250 unless significant changes in future thermal plant type were to be contemplated. This could permit wind penetration of up to 3725MW.

8.4 Constraints

The question of constraints to be imposed on the accessible wind resource for social or other (possibly temporary) reasons such as conventional generation plant balance or system operation requirements is considered at some length in Appendix 3 and more briefly in the following.

8.4.1 Social Acceptability of Wind Farms

In addition to the physical and economic constraints that have been used in the standard resource definition sequence there are other perception related factors that influence (at a remove) the likelihood of permitting for both the projects themselves and in some cases connection to the electricity network.

Surveys (3, 4, 5) in Ireland, UK, Germany and Denmark have shown positive attitudes toward the development of wind farms among those living near them providing that particular criteria are observed. Considering these four countries it is evident that in terms of installed capacity per unit of population and of area, the density already achieved in Germany and Denmark is significantly higher than in UK or Ireland. Bearing in mind the higher windspeeds and lower population density available in Ireland relative to Danish and German regions (where development is still ongoing) it is suggested that the publicly acceptable onshore wind capacity in Ireland is likely to be in the range 5,000 to 10,000MW provided that an informed public is consulted and involved in developments.

Thus the lower of these limits is shown on the wind resource cost curves for 2010 and 2020 where it draws attention to the possible existence of a level of installed wind turbine capacity above which the public might be expected to grow increasingly uncomfortable at the prospect of further development of onshore wind farms.

8.5 Electrical System Integration Issues

8.5.1 Introduction

The extent to which wind power can be accommodated on electricity systems is determined by

- The scale of wind power development in relation to system size.
- The extent to which wind power output is correlated with peak demand or periods of otherwise high loss of load probability.
- The mix of other plant on the system i.e. nuclear, hydro, conventional thermal, combined cycle, open cycle gas turbine.
- The ability to modulate demand.
- The degree of interconnection with other systems and the characteristics of those systems.

These issues are examined in the following sections.

8.5.2 Scale of Wind Power Developent in Relation to System Size

This is at present a key issue in relation to wind power development in Ireland. The issues involved have been clearly identified by ESBNG (18).

In that presentation the size of the various independent synchronous networks in Europe was identified as follows.

Table 8.6

Relative European Network Capacities

System	Coverage	Generation Capacity MW
Ireland	Island of Ireland	7,000
G.B.	England, Scotland, Wales	76,000
NORDEL	Norway, Sweden, Finland & Zealand (DK)	83,000
UCTE	Remainder of EU 25 excl. Baltic States & Greece	550,000

From this it is clear that the Irish system is less than one tenth the size of the GB and NORDEL systems and totally insignificant in relation to the UCTE system.

Thus while Ireland has undoubtedly one of the best wind regimes in N. Europe with the potential to generate in excess of 75,000MW at sites with mean wind speeds in excess of 7.0m/s. The ability to exploit that capacity is clearly limited by system size and the overriding need to ensure continuity of supply in periods of low wind output.

8.5.3 The extent to which Wind Power Output is correlated with Peak Demand or Periods of Otherwise High Loss of Load Probability

In some locations wind power output is closely correlated with periods of high electricity demand. This is particularly true where wind speeds reflect high daily temperature variations and periods of maximum wind speed in specific locations correlate with high electricity demand in the region, particularly air conditioning demand. These conditions are found in areas of California, the Panhandle States in the US and Crete.

Such conditions may also arise in N. West Europe where wind chill unquestionably affects space heating requirements. But the contribution of electric heating to space heating needs has declined very substantially in many countries, with the widespread installation of fossil fuel based central heating systems. Thus electricity demand is now more closely correlated with sunlight than wind speed.

Nonetheless wind speeds in N.W. Europe are generally higher in winter than in summer and thus partially correlated with periods of peak demand. Thus there would appear to be good grounds for accepting the argument put forward by Milborrow (19) that capacity credits for wind power should be based on the mean capacity available during periods of peak demand i.e. the winter months in N.W. Europe. This argument is valid for larger systems where the loss of load probability is highest during periods of peak demand and as a result, on those systems, generation planning is wholly focussed on the ability to meet demand at peak demand periods.

However the combination of a comparatively very small system size in Ireland, coupled with the fact that the unit size for new CCGT plant is the same as used elsewhere, for economic reasons, gives rise to the situation that the LOLP is as high in Ireland during the summer as during the winter, as the tripping of a large unit can coincide with unavailability of other large units, due to forced or maintenance outages.

Thus in Ireland at present the capacity credit for wind power should be based on the annual capacity factor rather the winter capacity factor. This situation could change with the development of HVDC interconnection to Great Britain provided the interconnectors are operated with that in mind.

8.5.4 The Mix of Other Plant on the System

The need to meet the day to day and minute to minute requirement to match production with demand is unique to the electricity sector.

Over the years the electricity sector has developed various approaches to satisfying this need. These include:

- Demand Management
- Pumped storage systems
- Turbine control systems

But there is still a requirement to match the mix of plant on the system to the need to provide the responsiveness to daily, weekly and seasonal demand changes and to provide the necessary spinning reserve capacity to cover for the loss of the largest infeed to the system.

The wind turbines now in service make no contribution to meeting spinning reserve requirements. Thus the ability to cover spinning reserve needs at periods of high wind speeds is particularly problematic. This problem is exacerbated by the fact that although CCGT's have a very good capacity to increase output rapidly, in time periods in excess of 10 seconds, their ability to provide primary spinning reserve in the short term i.e. 5-10 sec. is quiet limited and may thus impose limits on wind power output in certain conditions.

This problem could be eliminated if the existing and planned HVDC links were operated in a manner which allowed their technical capacity to increase power flows in very short time frames to be exploited. But this is not the case at present in relation to the Moyle interconnector, for commercial reasons.

The introduction of proportionately large amounts of wind power generation whose output is both intermittent and unpredictable, in the medium term i.e. one day to one week, creates particular problems as wind power is essentially free when available and should thus displace other sources of generation.

In the case of hydro plant this is generally relatively straightforward as hydro output can generally be reduced to minimum levels in the medium term, provided storage facilities are adequate to cater for the inflow in the period. In general ESB's hydro output could readily be reduced to very low levels to accommodate wind output but the installed capacity of ESB's conventional hydro plants in Ireland is only 220MW. Thus if wind power generation were to reach 1350MW on the island there would be a need to displace substantial additional generation at times.

Pumped storage hydro schemes are designed to facilitate load following, but many schemes such as Turlough Hill are designed to even out daily peaks and troughs and thus their storage capacity is only equivalent to eight hours operation at full output. Thus pumped storage schemes such as Turlough Hill can help even out hourly wind power fluctuations but they are of little use in smoothing medium term wind power output variations unless sized for longer term storage.

Thermal plants have differing load following capability, depending on their design.

ESB's conventional thermal plants were generally optimised at 80% of rated output i.e. they achieved their optimum efficiency at that power level. As a result they can be turned down to 50% of rated output with relatively little loss in efficiency and in some cases could be operated at as low as 25% of rated output, although difficulties with NO_x emissions may limit such operation.

In contrast natural gas fired CCGT plants are off the shelf units optimised at 100% rated output and as a result their efficiency falls off relatively sharply as their output is reduced. Furthermore the NO_x emission rate/m^3 rises with declining output and these units are generally unsuitable for operation below 60% of rated output.

The performance of open cycle gas turbines depends on their design. Industrial type units have similar characteristics to large scale CCGT's, aero derived units are more suited to load following.

Nuclear units are generally relatively inflexible as operators generally wish to run these units at base load to minimise the risk of tripping.

The significance of the above in relation to the ability of the electricity system in Ireland to accommodate high levels of wind power output is that post 2005 our projections indicate that natural gas fired CCGT plants will be the marginal generating plant for most of the year.

Thus wind powered generation will have to displace plant with relatively poor turndown capability. As a result in periods of high wind power generation it would be necessary to take CCGT plant off the system if the level of wind power generation exceeding the turn down capability of the hydro and CCGT plant.

Thus ESBNG in its analysis of Feb. 2004 indicate that for the ROI system alone up to 5% wind energy penetration could be accommodated without any adverse impact on the number of starts required p.a. for either base load, mid load or peaking plant. But for higher levels of wind power penetration the number of starts of mid load plant, i.e. the plant at the margin for most of the year expands considerably. This is both costly, as the total cost of starting an F Class CCGT is estimated at in excess of €30,000 and damaging for the plant, in terms of availability and lifespan.

ESBI while agreeing with the modelling approach adopted by ESB NG has concluded that up to 1000MW of wind power could be accommodated on the RoI system by 2010 without seriously increasing the number of starts required of mid load plant.

This divergence of views is believed to be due to a difference in the assumptions made in relation to

- Interconnectors
- The turn down capability of coal fired plant.

8.5.5 The Ability to Modulate Demand

Electrical utilities have traditionally sought to discourage demand at peak periods and encourage off peak demand by means of pricing incentives.

The peaking penalties were targeted at larger customers who had the capacity to reduce demand at peak periods. However the development of a competitive market for these customers and the introduction, by CER, of a "top up and spill" pricing regimes which did not reflect peak generation costs resulted in the break down of the peak penalty pricing regime and resulted in a significant decline in system load factor in 2002/03.

Since then ESB NG, at the request of CER has introduced an incentive system designed to restore the incentive to reduce demand at peak periods. However the capacity to modulate demand has declined significantly in recent years as many of the larger, price sensitive electricity customers have ceased operations.

8.5.6 The Degree of Interconnection with Other Systems and the Characteristics of Those Systems

As indicated earlier the size of the synchronous system to which wind power generation is connected is a critical factor in relation to the ability of the system to accommodate that generation. But asynchronous connection with other systems helps as is clear from the experience in W. Denmark, which is asynchronously connected with the NORDEL system as well as being synchronously connected to the UCTE system.

An important point in this regard is that the NORDEL system, which has a total capacity of 85,000MW includes 47,000MW of hydro powered generation.
As indicated earlier hydro generation is an ideal complement to wind power generation as for systems with a considerable proportion of hydro power the key problem is meeting the annual MWh demand rather than the peak demand.

Thus the incorporation of intermittent wind power generation in such a system generally presents no system issues.

In contrast the electricity system in England, Scotland and Wales has proportionately very little hydro. Thus were wind power in Great Britain to be developed as now proposed by the U.K. Government the system problems would be similar to those in Ireland, except that the provision of spinning reserve is not a significant problem in a system of that size.

Thus interconnection with Great Britain could eliminate spinning reserve difficulties in Ireland and would reduce any within day problems of accommodating wind, due to improved geographic dispersion. But the medium term problems of accommodating wind, including its impact on daily gas demand and requirements, particularly in summer months, would not be resolved by interconnection, as wind output in Great Britain is likely to mirror that in Ireland in the medium term.

8.5.7 Constraints on Inter System Electricity Trading

There is sometimes perception that interconnection is the solution to all system constraints on wind power development in Ireland.

However to date there appears to have been little analysis of how the output from wind farms in Ireland would be treated in an All Islands System.

One view in the wind industry appears to be that Britain would provide

- A potentially very large outlet for Irish wind power generation
- A highly lucrative market for Irish wind power generation, given the Renewables Obligation.

Both these views could be valid provided

- The output from some wind farms is designated as being hypothecated to the British market.
- The U.K. authorities accept that wind power output in Ireland is treated as satisfying the renewable obligation in British markets.

While the former could clearly be arranged, to date the U.K. Government has refused to accept that renewable output from any jurisdiction which does not have a Renewable Obligation, similar to that originally in place in England and Wales, would qualify under the Renewable Obligation regime. Indeed the original Statutory Instrument setting down the Renewable Obligation rules specifically excluded renewable generation from N. Ireland as it did not then have a similar regime in place. Thus access to the U.K. market is conditional on the Irish authorities introducing an effectively identical scheme.

In addition the operation of the New Electricity Trading Arrangements in England and Wales has created significant cost barriers for individual generators, or those unable to accurately forecast their hour by hour output before gate closure.

Thus while the provision of an East-West interconnector may technically facilitate the development of wind farms in Ireland to supply the demand for renewables in Britain it is clear that there are significant institutional and commercial barriers encountered in converting the potential to reality.

An alternative approach is to assume that the provision of an East-West link would permit the level of wind power generation to be increased beyond the turn down capability of the thermal plant on the system and that electricity could then be imported from Great Britain in periods of low wind output.

This approach would be feasible if the level of wind power penetration in Great Britain was low but would not apply if the U.K. Government's current targets for wind power development in Great Britain were achieved, as the problems of turning down thermal plant output, to accommodate wind power generation, would be the same in that market as in Ireland.

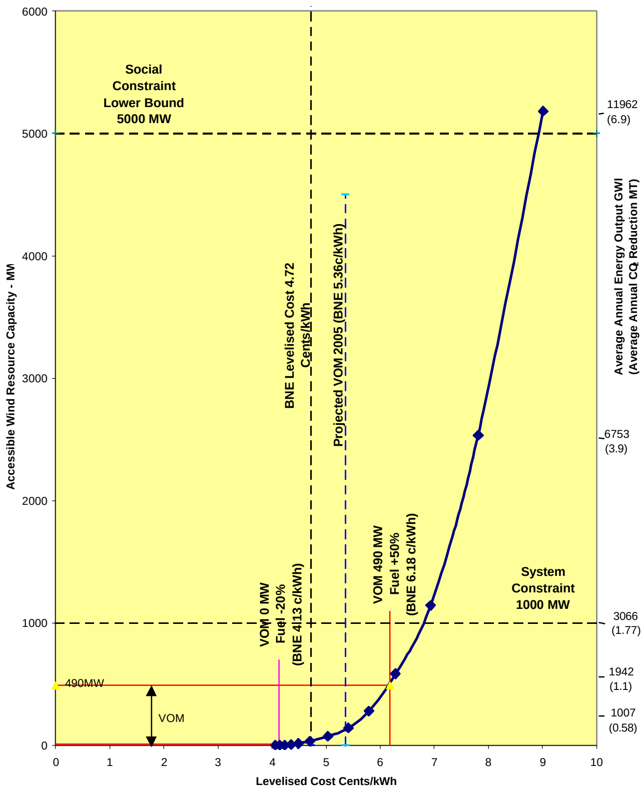
Arising from the above projected capacity constraints of 1000MW (2010) and 1250/3725MW (2020) are carried forward for incorporation on the resource/cost curves being developed in the next section. Revised constraints can, if necessary, be incorporated at a later date.

Figure 8.1

Resource Cost Curve

Wind Generation 2010 at 2004 Prices

(8% Discount)



8.6 Wind Resource/Cost Curves 2010

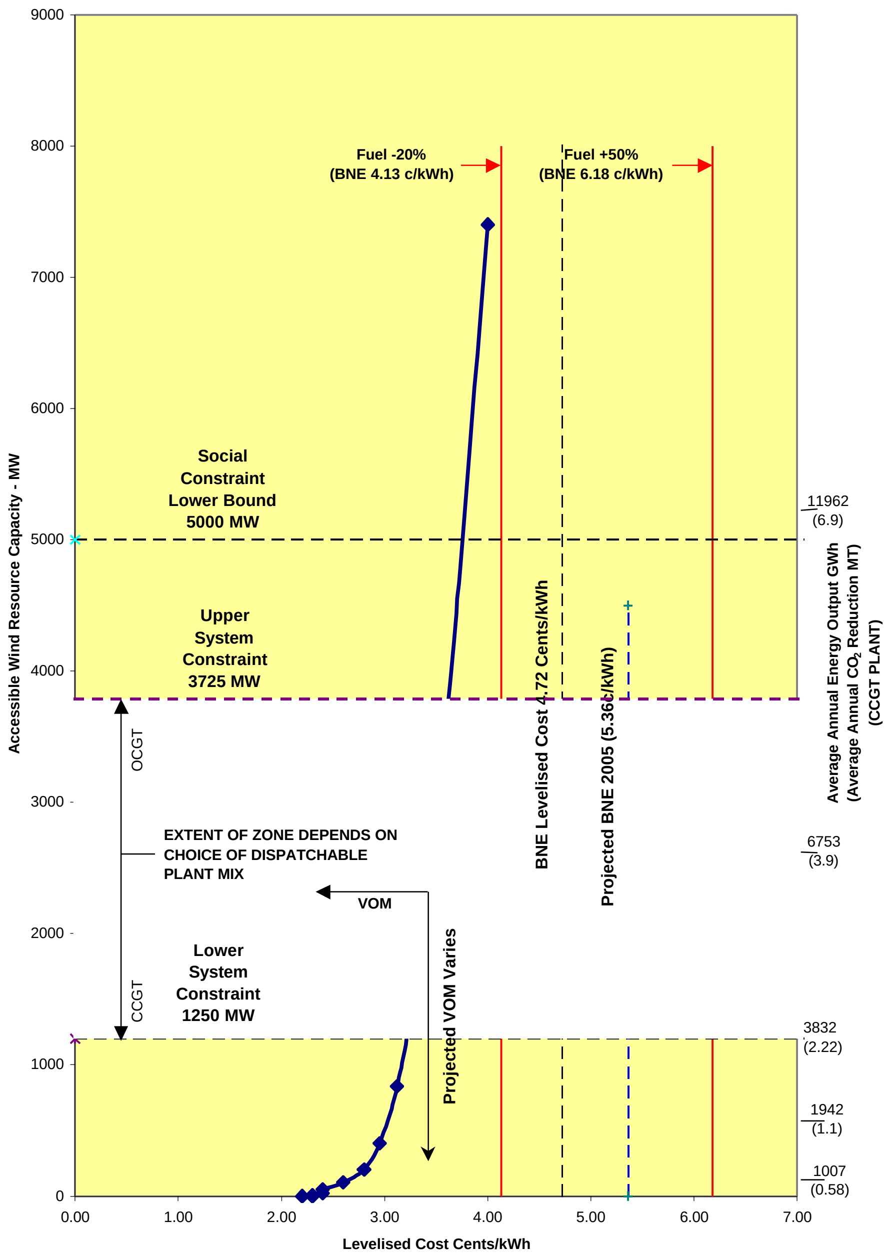
The resource/cost curves for the onshore wind resource are shown on Figs. 8.1 and 8.2.

Fig. 8.1 shows the significant levels of resource that are accessible at levelised costs of 6c/kWh and upward. With BNE @ 4.72c/kWh the viable open market is virtually zero at 35MW. The AER6 upper limits are 5.216c/kWh for large schemes and 5.742c/kWh for small schemes. These limits would permit viable managed market limits of 105MW and 260MW respectively. The viable open market changes significantly in response to fuel price changes for the BNE. A price increase of +50% leads to an upper bound of viable open market of 490MW while a decrease of -20% simply worsens the position in that there is no viable open market. Thus the viable managed market lying between 105MW and 260MW, reflective of the two AER6 levelised costs, is the extent of the accessible resource for 2010 using the 8% discount rate to allow for financing and profit. The system constraint of 1000MW applies an upper bound to the 2010 case as discussed.

Figure 8.2

Resource Cost Curve

Wind Generation 2020 at 2004 Prices



8.7 Wind Resource/Cost Curves 2020

The corresponding curve for 2020 is shown on Fig. 8.2. In this case the BNE levelised cost exceeds that of the accessible wind resource up to several thousand MW. This gives a huge viable open market resource lying below 4.72c/kWh. This is largely due to the assumptions of improvements in wind turbine size and output giving lower unit costs than in 2010. Benchmarking against the impact of fossil fuel (gas) price changes shows that even a price reduction of 20% would not impact on the accessible resource, while an increase on the accessible resource, while an increase in fuel prices of +50% would improve the viable open market resource enormously.

However the lower system constraint of 1250MW becomes necessary unless the thermal generating plant is reconfigured to include either aero derivative open cycle gas turbines, hydro pumped storage and/or cabled connections to Britain with suitable operating characteristics. This would cause a major shortfall in the amount of renewable wind generation projected by the consultation document and as a consequence the level of CO_2 displacement. Introduction of a more favourable thermal plant mix could permit acceptance of wind and other intermittent capacity of up to the upper system constraint level at 3,725MW. The issue is one for detailed examination and quantification, but is outside the scope of this report.

8.8 Conclusions

(1) The resource cost curves provide a useful means of visualising the viable open and viable managed market resources and their sensitivity to changes in the cost of the reference fossil fuel used by the Best New Entrant.

(2) Utilising an appropriate discount rate (8%) the resource/cost curve becomes in effect a resource/price curve reflecting necessary provision for financing charges and profit.

(3) The resource cost curve can be used to illustrate the effect of operating limits projected for operational, system or other reasons.

(4) Wind energy has the potential to compete in terms of cost with fossil fuel electricity generation by 2010 and its cost competitiveness is projected to increase over the period to 2020 depending on the rate of capital cost reduction and on gas price increase.

(5) In theory the potential electricity that could be generated on an intermittent basis from wind is sufficient to provide all of Ireland's generation requirements. However this is not feasible because of the additional costs associated with standby generation facilities and the additional operation and maintenance costs of the total energy system.

(6) The accessible resource becomes very small when system and market constraints are taken into account reducing the potential resource to 1000 MW in 2010 and 1250 MW in 2020 for the Republic if the current commitment to combined cycle gas turbine plant as best new entrant continues to 2020. These figures could both be increased by 350MW on an all island basis.

(7) The emergence of large open cycle aero derivative gas turbine plant with more flexible load following characteristics, coupled with the provision of gas and pumped storage opens up the possibility of a much larger acceptance of intermittent resources onto the system by 2020. An upper limit of 3,725MW is therefore suggested.

(8) Intensive assessment is now necessary to validate the projected capability of these open cycle gas turbines which are as yet unproven in the market place and to examine in an integrated way the costs and options that will underpin the system generation mix to 2020.

9. Resource Cost Curves Landfill Gas 2010 & 2020

9.1 Introduction

Landfill gas conversion is a well established and mature technology but its long term future is dependent on future waste management practices. Diversion of household waste away from landfills and reduction in the level of biodegradable waste going to landfill as planned will reduce the feedstock available for landfill gas production in the medium term. (Because of the lag between waste disposal and decline in gas production it is unlikely that much fall off will occur within the period to 2020 covered by this review).

The resource cost curves developed for land fill gas resource are based on the accessible resource identified in Appendix 4 of this report. The cost curves have been constructed using the levelised cost analysis approach discussed in earlier sections. The efficiency of the technology for landfill gas is 36%. In developing the annual outputs it is assumed in the analysis that the plant life is 15 years and will operate at 85% capacity factor.

9.2 Land Fill Gas Resource

The many variables involved in the estimation of landfill gas resources available in the Republic for 2010 and 2020 are discussed in detail in Appendix 4. The biodegradable waste quantities arising by county and region are derived from the Environmental Protection Agency database and their gas production and electrical generation potential are assessed using gas collection efficiencies improving from 70% (2010) to 75% (2020). The impact of current and future policy directions on the disposal of biodegradable waste, the credibility of existing waste plans and related factors are considered.

In general it is assumed that a site must be in receipt of at least 50,000 t/year of waste to be considered viable.

9.3 Resource Cost Curves

The annual outputs of each landfill site as shown in Table 9.1 below will vary with scale, composition of the gas, diversion of biodegradable waste, recycling initiatives and introduction of thermal treatment. Each of these variables have been incorporated in the forecast practicable and accessible resource.

The accessible resource cost curves for landfill gas are shown in Figures 9.1 and 9.2 below. The outputs shown for 2010 will continue to be produced in 2020 resulting in a cumulative output of 229,000 MWh for that year.

The resource cost curves for 2010 and 2020 show that, as might be expected, the cost of generation is sensitive to the scale of the landfill.

The forecast cost of developing landfill sites to generate energy will increase between 2010 and 2020 due to the forecast reduction in the scale of sites available for energy production between 2010 and 2020.

Table 9.1

Landfill Gas : Accessible Resource/Costs

2010

MW	Cents/kWh	Average Annual Output MWh
16.36	2.13	121,807
6.34	2.83	47,208
6.15	2.85	45,793
4.9	2.98	36,485
4.6	3.11	34,252
3.96	3.26	29,486
3.47	3.39	25,836
1.75	4.16	13,031
1.3	4.55	9,680
0.9	5.08	6,701
49.73	Totals	370,291

Table 9.2

Landfill Gas : Incremental/Accessible Resource/Costs

2020

MW	Cents/kWh	Average Annual Output MWh
4.5	3.14	33,507
1.24	4.62	9,233
1.0	4.92	7,446
0.89	5.1	6,627
0.64	5.63	4,765
0.32	7.0	2,308
8.59	Totals	63,888

9.4 Resource/Cost Curve : Landfill Gas 2010

Fig. 9.1 shows that by 2010 a series of LFG installations totalling 49MW approximately make up the viable open market capacity, with an energy output of 370 GWh/yr. at a levelised unit price below that of the Best New Entrant (4.72c/kWh). For as long as the AER6 capping price of 6.412c/kWh (or equivalent) remains available as a matter of public policy, the viable managed market extends the range of the viable open market resource by 1 MW in capacity to (50)MW. Above 6.412c/kWh the market is non viable but in fact there are no additional projects available for 2010. The figure illustrates the impact of changes in fossil fuel price by considering the way in which BNE unit cost varies over the range between a fall of 20% to an increase of 50% in its natural gas reference fuel (shown red). A decrease in fossil gas fuel to 4.13c/kWhr brings the lower bound of the BNE cost into the viable open market region but only sufficiently to reduce the LFG viable open market resource by 4MW to 46MW.

On the other hand an increase of 50% in fuel price when inserted into the model brings the BNE cost up to 6.18 cents/kWh. This has the effect of increasing the viable open market capacity by about 1MW. There is then no difference between the viable managed market and viable open market.

The effect of greater changes in fuel prices can be assessed in a similar way. The projected BNE price for 2005 is shown on the figure for information.

9.5 Resource/Cost Curve : Landfill Gas 2020

For 2020 the output is estimated to be broadly similar to 2010 although the organic feedstock in the landfills will be declining due to the impact of landfilling regulations. For clarity Fig. 9.2 shows only the incremental resource cost curve for 2020. It may be superimposed on that of 2010. The viable open market resource is an additional 5.7MW (BNE 4.72 cents/kWh), while the viable managed market resource extends this to 8.2MW (at the AER6 capped price of 6.412c/kWh).

Again the range of fossil fuel prices from -20% to +50% around the current price level is assessed leading to BNE levelised unit costs of 4.13c/kWh to 6.18c/kWh. The lower BNE level of 4.13c/kWh would preclude any viable open market capacity as it is below the lowest levelised cost of any LFG capacity module. It is clear that based on the currently available information there is relatively little additional LFG resource likely to be available for 2020 compared with 2010 and that levelised cost has to rise to about 5.6c/kWh to bring an additional 2MW on stream.

In general the LFG resources are not great in a national context but they are reliable and have the merit of consuming methane which is a significantly more harmful greenhouse gas than CO_2.

Relative to the 1997 study the resources are, as noted, projected to be up somewhat with an increase of 46% in estimated capacity.

9.6 Conclusion

(1) Landfill gas is the most competitive of electricity generation based on a levelised cost comparison of CCGT, Wind, Hydro, Photovoltaics, Peat and Wave energy.

(2) It provides a steady source of power and unlike wind should not be the subject of any capacity constraint.

(3) The competitiveness of landfill gas is likely to remain, however landfill gas as a resource will reduce significantly with the reduction the methane content of the gas which is assumed at 51% for 2010 and 32% for 2020 due to the decrease in biodegradable waste going to landfill in accordance with EU Directives.

(4) The projected energy outputs are however rather small at 370GWh (2010) and 434GWh (2020).

Figure 9.1
Resource Cost Curve Land Fill Gas 2010

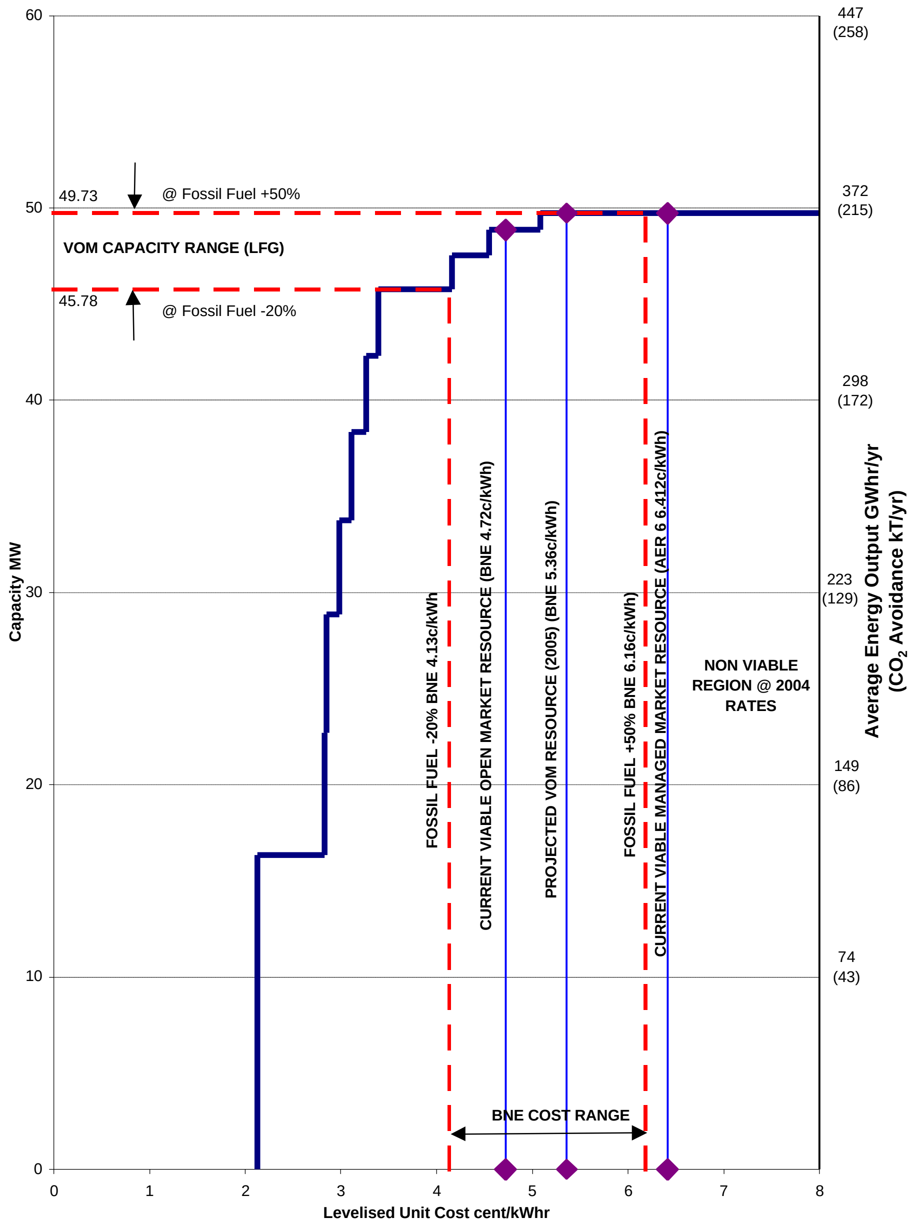
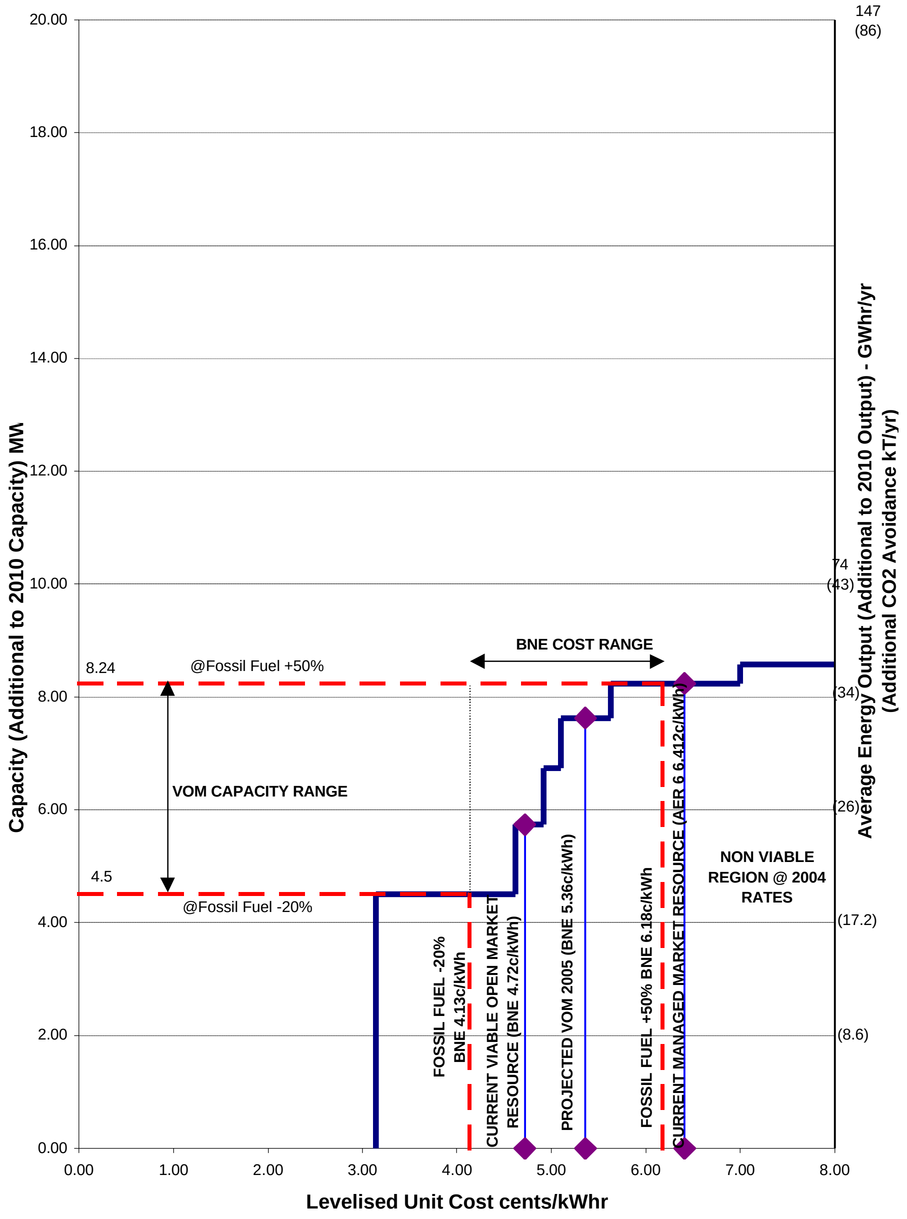


Figure 9.2
Incremental Resource Cost Curve Land Fill Gas 2020



10. Resource Cost Curves Active Solar Thermal Power 2010 & 2020

10.1 Resource and Technology

This technology can be used for the provision of domestic hot water or space heating via fluid circulating through collector plates. The systems, both on a domestic and commercial scale, have had limited application in Ireland to date unlike in other parts of Europe. It is likely that market stimulation will be required to sustain significant growth.

The resource costs curves developed below for active solar thermal power are based upon the accessible resource in terms of the levelised cost of generation of thermal electricity in cents/kWh. The technology evaluated is the Solar Thermal Combi Power System which can be used for space and water heating in conjunction with conventional heating systems. The calculations are fully developed in Appendix 5.

10.2 Resource Estimation

10.2.1 Basic Considerations

The resource base in Ireland for Solar Heating for hot water and space heating is summarised in Table A5.1 below from the theoretical resource through to the accessible resource for the year 2000. The resource area is based on the roof area of existing and future dwellings. The resource is measured in terms of metres squared which is the standard size of solar panels supplied into the Irish Market.

The starting point for determining the theoretical resource is the total surface area of the country, which if covered by solar panels is taken to yield a mean annual output of 350kWh (thermal)/sq. m based on averaged figures quoted by panel suppliers.

Table A10.1

National Resource Base for

Solar Thermal Power Ireland 2000 (000 sq. m)

Summary	Theoretical Resource km^2	Total Floor Area $000m^2$	Technical Resource $000m^2$	Practical Resource $000m^2$	Accessible Resource $000m^2$	
Commercial		13,988	6,304	3,152	2,364	5%
Public Sector		9,889	5,196	2,598	1,949	4%
Industrial		4,200	2,100	1,050	788	2%
Housing		204,360	102,180	51,090	38,318	87%
Agriculture		1,080	1,080	540	405	1%
Total	69,550	233,517	116,861	58,430	43,823	100%

(All above figures x 350kWh (thermal)/sq. m/yr)

It is assumed in the analysis, that in the absence of a new technology there will be no large stepwise increase in the efficiency of the solar panels. Rather there will be an annual increase in the efficiency of the solar panels of 2% (compounded) per year of manufacture resulting in a 37% efficiency increase by 2020 over 2004 levels as shown in Table 10.1.

Table 10.2

Active Solar Trends

	2004	2010	2020
Annual Output kWh (t)/sq. m.	350	394	480
% Change on 2004		13%	37%

10.2.2 Technical Resource

The technical resource is based on the assumption that roof area is a fraction of the total floor area of the five categories of existing buildings throughout the country. It is assumed that each square metre of area generates a specific kWh per year and does not incur efficiency deductions that would apply to other generation technologies.

10.2.3 Practicable Resource

The practical resource is defined as 50% of the technical resource. The technical resource has been further reduced to arrive at the estimate for the accessible resource to take account of planning and environmental constraints. Planning and environmental constraints are estimated at 25% of the practicable resource base.

10.2.4 Accessible Resource

The accessible resource base in Ireland for 2000 is estimated at 44 Million sq. m and 87% of this area is accounted for by the housing stock (1.4 million units) and is estimated to grow at 4% per annum or 55,000 units per year on average.

Assuming this overall growth rate for the total accessible area, the total resource area will increase to 59 and 70 Million square metres by the years 2010 and 2020 respectively.

The estimated resource base for solar power is shown in Table A5.2, 5.3 for 2010 and 2020 respectively.

In forecasting the resource area for 2010 it is assumed that

- New housing construction will continue until 2010 at a rate of 3.8% on 2000 levels of 50,000 units per annum.
- New housing construction will continue at a rate of 3% on 2000 levels between 2010 and 2020.
- All other dwellings will increase at a rate of 2% on 2000 levels per year from 2004 to 2020.

Table 10.3

National Resource Base for

Solar Thermal Power Ireland 2010 (000 sq. m)

Summary	Theoretical Resource km^2	Total Floor Area $000m^2$	Technical Resource $000m^2$	Practical Resource $000m^2$	Accessible Resource $000m^2$	
Commercial		16,786	7,565	3,783	2,837	5%
Public Sector		11,867	6,236	3,118	2,338	4%
Industrial		5,040	2,520	1,260	945	2%
Housing		280,017	141,008	70,504	52,878	89%
Agriculture		1,296	1,296	648	496	1%
Total	69,550	317,005	158,625	79,313	59,484	100%

(All above figures x 394kWh (thermal)/sq. m/yr)

Table 10.4

National Resource Base for

Solar Thermal Power Ireland 2020 (000 sq. m)

Summary	Theoretical Resource km^2	Total Floor Area $000m^2$	Technical Resource $000m^2$	Practical Resource $000m^2$	Accessible Resource $000m^2$	
Commercial		19,583	8,826	4,413	3,310	5%
Public Sector		13,845	7,275	3,638	2,728	4%
Industrial		5,880	2,940	1,470	1,103	2%
Housing		333,107	166,563	83,277	62,458	89%
Agriculture		1,512	1,512	756	567	1%
Total	69,550	373,927	187,106	93,563	70,156	100%

(All above figures x 480kWh (thermal)/sq. m/yr)

The accessible resource is used for estimating the resource cost curves in Appendix 5 is shown below. The largest resource area is for housing of which 10% is estimated as apartments in 2004 rising to 14% in 2010 and 20% in 2020.

10.2.5 Cost Assumptions

The cost of the Solar Thermal Power Combi systems is shown in Table 10.5 below.

Table 10.5

Active Solar Thermal Combi System (2004)

	Units	
Existing House (Euro per House)	Euro	8,000
New House (Euro Per House)	Euro	9,500
Area Heating (sq. metre)	Sq. Metres	100
Roof Area	Sq. Metres	50
Number of Solar panels	Sq. Metres	20
Average Cost Square Metre	Euro	438
Output square metre	kWh per year	350

- The development of the total accessible area for solar thermal power in Ireland (70 million sq. metres in 2020) would require mass production of the solar panels on an unprecedented scale which would result in significant economies of scale in the cost of manufacture.
- It is assumed in the analysis that between 2004 and 2020 the capital and maintenance costs of the solar panels would reduce by 2% per year. This would result in a cost reduction of 39% by 2020 as shown below.
- A further reduction of 20% in capital and maintenance costs have been applied to large scale installations of solar panels. These costs apply to all sectors with the exception of retrofitting existing houses.
- Retrofitting of existing houses (2004 levels) is assumed to be undertaken on an individual basis and therefore would result in a higher unit capital, maintenance and installation cost than for large installations. Therefore the small scale costs detailed below have been used for retrofitting existing houses. This excludes apartment blocks where the large scale cost structure has been applied.

Table 10.6

Forecast Real Price Decrease in Capital and Maintenance costs of Active Solar Thermal Panels

	2004	2010	2020
Small Scale Installations			
Unit Capital Cost Euro	438	388	317
Unit Maintenance Cost Euro p.a.	10	9	7
% reduction on 2004		11%	28%
Large Scale Installations			
Unit Capital Cost Euro	350	310	253
Unit Maintenance Cost Euro p.a.	10	9	7
% reduction on 2004		11%	28%

10.3 Resource Cost Curves

The accessible resource cost curves shown below demonstrate the potential effect of economies of scale in the production and installation of solar panels and efficiency increases.

The cost curves below show the cost of developing the total accessible resource area in 2010 or 2020 assuming there is no development of the resource in previous years. The methodology for identifying the unit costs (Cents/kWh) is based upon the levelised cost analysis and is compared with the levelised cost of a 50MW CHP plant. The forecast capital and operating costs have been discounted at the Weighted Average cost of Capital (WACC) 6.88 % as used by the CER and divided by the present value of the annual output of the panels over an estimated life of 20 years.

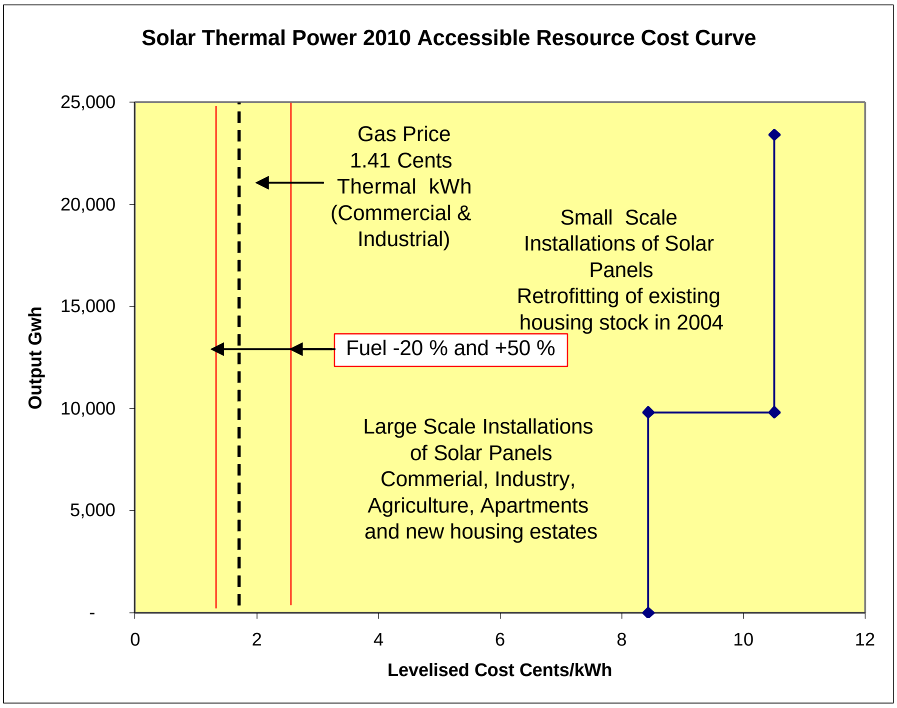
10.4 Solar Thermal (2010)

The resource cost curve for 2010 as shown in Figure 10.1 under the assumptions detailed above shows that at 2004 prices both large scale and small scale installations of the solar combi systems could have the potential to compete with electricity for that proportion of thermal energy that can be supplied by Active Solar Thermal Power assuming there is no real price reduction in electricity over the period.

Solar Thermal Resource/Cost Curve (2010)

Figure 10.1 shows that large scale new installations with an annual aggregate thermal yield level of up to 10TWh have a levelised cost of 6.05c/kWh(t) but that levelised cost of small scale and retrofit installations amounts to 8.24c/kWh(t) for an equal sized aggregate installation. The levelised natural gas price is only 1.41c/kWh(t) and it is clear that this is so far below the solar cost that there is no viable open market. To create a viable managed market levelised injections of at least 6.05c/kWh(t) and 8.24c/kWh(t) for large and small installations respectively would be required. Even gas price increases of +50% would still leave gaps of 4c/kWh(t) and 6.1c/kWh(t) to be bridged. Thus the solar thermal/water heating technology does not appear to be attractive on the basis considered for 2010.

Figure 10.1



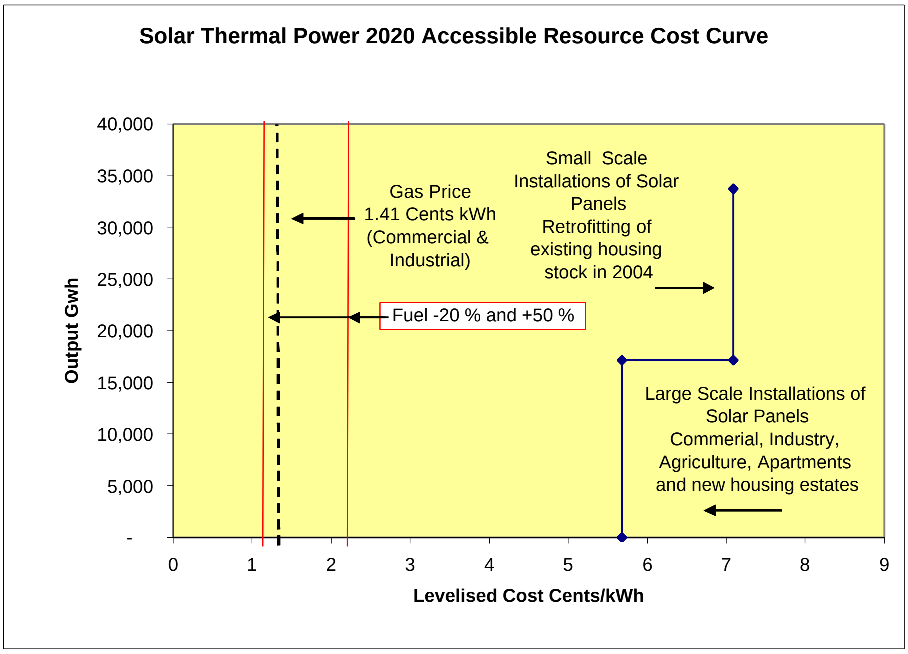
10.5 Solar Thermal (2020)

In 2020 as shown in Figure 10.2 below the Resource Cost Curve shifts downwards so that at all output levels solar thermal power can be produced at a lower cost. The cost of producing thermal power from natural gas will continue to be more competitive however than solar thermal power in 2020 even without any real price decrease or technical innovation in CHP by 2020.

Solar Thermal Resource/Cost Curve (2020)

Figure 10.2 shows that due to improved performance and increased output unit levelised costs are projected to reduce somewhat by 2020, but the gap between the levelised costs at 5.68c/kWh(t) (large installations) and 7.09c/kWh(t) (small installations) each with aggregate outputs of 17.143TWh are too large to allow of a viable open market. A viable managed market would require levelised injections of 4.27c/kWh(t) (large) and 5.68c/kWh(t) (small installations). Although the unit performance is improving it has not yet the level where it would be competitive with natural gas.

Figure 10.2



10.6 Conclusions

(1) Levelised cost analysis in this section shows that Active Solar Thermal combi systems produce thermal energy at a cost or 14 Cents/kWh in 2004 compared to a levelised cost of 1.4 cents/kWh for natural gas.

(2) The proportion of thermal energy that could be supplied by active Solar Thermal power may have the potential to compete with electricity assuming there is no real price reduction in electricity over the period of analysis and there is significant real price decreases in Active Solar Thermal Technology and significant productivity increases.

(3) The on a purely cost basis potential impact of Active Solar thermal Power on the Irish Market is limited as

  (1) Active Solar Thermal Applications must be used in conjunction with conventional heating systems as technology cannot replace conventional space heating systems.

  (2) There would need to be a significant reduction in production costs and significant productivity increases in the technology to make it competitive with electricity or natural gas.

  (3) The potential for Active Solar thermal power systems to be competitive may be eroded with technical innovations in competing technologies such a micro CHP.

(4) The highest market penetration scenario is less than 1% of total Thermal Demand by 2020

11. Fossil Fuel Benchmarking

11.1 Introduction

It is useful to summarise briefly the impact of fossil fuel price changes on the prospect for the three key renewable resources discussed in this report as shown in the foregoing resource/cost curves.

11.2 Price Impacts

Fuel prices affect electricity planning in two primary ways. They influence electricity demand because they are substitute sources of energy for space and water heating and some other end-uses as well. They also influence electricity supply and price because they are potential fuels for electricity generation. Natural gas, in particular, has become the most cost-effective generation fuel when used to fire efficient combined-cycle combustion turbines.

Review of the past history and projected trends in fuel prices to 2020 allows two conclusions to be drawn:

- Past trends have been extremely erratic and provide little guidance in future price predictions other than to indicate the vulnerability of fossil fuel prices to world events.
- An underlying upward trend exists particularly in the cleaner fuels.

Increased fossil fuel prices have two basic impacts. Primarily they increase the unit price of electricity supplied by the Best New Entrants (BNE) as well as increasing heating costs. Pushing the BNE price upward normally enlarges the size of the viable market for renewables unless other constraints exist in the market place.

The secondary effect is to add to the capital and operating costs of renewable generation but to a much lesser degree than the impact on the Best New Entrant.

Thus the sensitivity of the BNE unit price to fuel price serves as a useful way of benchmarking renewables in the context of their resource/cost curves.

In this case the model has been used to develop a sensitivity curve for BNE price as a function of fuel price. This ignores the secondary adjustments necessitated by impact of fuel price rises on renewables themselves or any attempts to internalise external costs that may be associated with the reference Best New Entrant which is currently a combined cycle gas turbine as advised by CER.

The results may be as tabulated below using 2004 prices. Reference can be made to the resource cost curves Figs. 8.1, 2., 9.1, 2., 10.1, 2 for the data on Table 11.1.

Table 11.1

Benchmarking of Renewables to Fossil Fuel Prices

			Implied Increased Capacity (MW)		
Fuel Type	Unit Fuel Price %	BNE Output Price c/kWh	Wind	LFG	Solar
Oil	As Gas	As Gas	As Gas	As Gas	As Gas
Coal	NA	NA	NA	NA	NA
Gas 2010	-20%, +50%	4.13 – 6.18	+0 to + 490	-3 to + 1	No change
Gas 2020	-20%, +50	4.13 – 6.18	Limit 3725	-1.2 to +8.2	No change

In application an ordinate is projected upwards on the appropriate figure at the new BNE unit price resulting from the change in fossil fuel price, until it intersects the resource cost curve. This gives the new capacity and output levels at which the renewable technology is now viable in the open market, if at all. A falling fuel price extends the range over which the market must be managed for viability. A rising fuel price may obviate the need for market support.

Coal being a base load fuel unused for gas turbines is not applicable. Distillate oil although more expensive than gas is really a standby fuel with intermittent use, so that gas may be taken as the representative fossil fuel.

The results indicate that gas prices will be the primary determinant of the price of power supplied by the BNE and that as these increase the viable market for renewables increases. This has little impact in the case of LFG which is resource limited in any event. It is of direct benefit to wind but only insofar as the network is capable of accepting further inputs of wind power. It also is of benefit to solar where heating is derived from electricity.

More particularly solar heating benefits from the increased cost of direct fossil fuel heating, with which it is in competition.

Without storage however solar heating still carries the penalty of the need for installation of duplicate systems. Thus there are constraints on the degree to which each of the renewable resources – wind, LFG and Solar may benefit from increased prices of the competing fossil fuels. Biomass although dependent on fossil fuels for harvesting, transportation and processing is more likely to benefit from price rises in competing fossil fuels.

Table 11.1 summarises the effects noted from the respective resource cost curves of sections 7, 8, 9 of the report. In both 2010 and 2020 the cost of gas is allowed to fluctuate between 20% below its levelised market value (2004) and 50% above that value. The Best New Entrant unit price/kWh (at 6.88% discount rate) varies correspondingly from 4.13c to 6.18c.

At the lower limit of 4.13c/kWh the price would be so low as to preclude any wind power in the open market while landfill gas would still manage about 46MW in the open market and would depend on a managed market (through AER) to obtain a further 3MW of capacity. The solar position would not be directly affected as it is already outside the immediate influence of changes in gas price.

At the upper limit of 6.18 cents/kWh representing a 50% rise in fuel price, the effect on wind power is to allow viable open market to reach 490MW and the need for a managed market for LFG disappears and all available resource becomes viable in the open market. Solar thermal is still unchanged.

By 2020 it is projected that the unit price for wind has fallen such that its viable open market resource is outside the influence of the fuel price fluctuations listed and it is only limited by system constraints. Landfill gas is able to contribute only an additional 8.2MW for a 50% rise in fossil fuel price. A reduction in natural gas price precludes any additional LFG input above a 4.5MW increase on 2010 figures (i.e. a drop of 1.2MW on current VOM capacity of 5.74MW).

12. Conclusions

12.1 Introduction

The following conclusions are drawn from the foregoing sections and supporting appendices.

The resource definitions of Appendix 7 can be used for both electricity and heat markets in the context of this and associated reports where resource ranking frameworks for renewable energy resources are required.

Most of the twenty renewable energy technologies reviewed are operationally proven elsewhere in the world even if research and development of these technologies also continues. About half are operationally proven in Ireland at this stage. Many renewable technologies are limited in scale or require particular circumstances e.g. availability waste feedstocks, or supported markets for success.

12.2 Analytical Model

(1) A comprehensive and portable analytical model has been developed for use in the production of levelised (economic) costs when comparing technologies, resource cost curves for technologies and financial analyses of power generation projects. The model has a number of default values for use where specific information may be lacking. It conforms with the analytical approach adopted by the Commission for Energy Regulation (CER).

(2) The model was successfully proven by application to 13 renewable energy technologies at scales agreed with Sustainable Energy Ireland as being appropriate for 2010 and 2020. It was also applied to the Best New Entrant (CCGT) notified by CER for reference purposes.

(3) The modelled projects included Biomass, Onshore and Offshore Wind, Small hydro, Peat, Wave, Tidal and Photovoltaic resources.

(4) Any model is only as good as the assumptions made and quality of the input information. It is evident that the selection of appropriate input values requires careful consideration and an informed understanding of project costs if the most realistic output is to be achieved. The project scales used in this instance were those agreed with SEI as representing a realistic spread for implementation under the timing and conditions relevant to Ireland.

(5) As discussed in Appendix 1 (sub-section 12) it is concluded that the resource/cost analytical model with suitable inputs, is applicable to 15 renewable technologies that were outside the immediate scope of this report. The model can show projected resource/prices by selection of appropriate discount rate to allow for profit and financing charges.

12.3 Electrical Market

(1) For many years electricity demand growth has shown a more stable relationship with economic growth than any other energy carrier. Based on consideration of ESRI projections of GNP (incorporating demographic analysis) electricity sales projections forward to 2020 have been made. These agree well with Eirgrid median projections which extend only to 2010 at this stage.

(2) The overall sales are projected to increase at an average annual growth rate of 3%. This would result in projected gross generation levels of approximately 32TWh by 2010 and 43TWh by 2020.

12.4 Heat Market

(1) The heat market, dominated by housing but with an increasing apartment content, was estimated to require 42TWh in 2000 and is forecast to grow at a rate of 4% per annum resulting in demands of 62TWh (+48%) in 2010 and 92TWh (+119%) in 2020 respectively.

(2) The heat market outweighs the electricity market by a factor of 2.5 but the latter attracts more attention because it is less diffuse, more quantifiable and more controllable.

(3) A system of resource definitions applicable to the heat market has been developed analogous to those used in the electricity market. These have been applied in the case of the solar thermal resource and will be applicable to later studies relating to biomass.

(4) Levelised cost analysis shows that Active Solar Thermal combi systems still require significant real price decreases and increases in productivity to be competitive with fossil fuels.

(5) The active solar technology is limited by the requirement to retain conventional space heating systems and complications of system integration.

(6) The highest market penetration scenario envisaged accounts for less than 1% of the total thermal demand projected for 2020.

(7) The heat market is primarily served by fossil fuels but efforts are being made to introduce biomass (primarily wood pellets) solar and ambient geothermal heating via heat pump and all of these systems are available in the market place at a price.

(8) The prospect of co combustion of biomass in peat fired generators as introduces a potential alternative market for biomass feedstock. It remains to be seen whether this would divert biomass from the heat market. As large quantities of biomass required for power station use will probably be constrained by transportation and cost to be supplied from within a particular radius of the plants, it may be concluded that bulk biomass will be supplied from midland sources and pellet production may utilise material arising in the east and south, adjacent to major domestic markets.

12.5 Wind Resource

(1) It has been demonstrated that the resource definitions developed in Appendix 7 can be applied in the cases of electrical energy to the onshore wind resource technology.

(2) Although onshore wind is reaching technological maturity further improvements are projected as size of turbines increases, network and system needs demand higher quality of performance and quantity production reduces costs albeit at a declining rate of decrease.

(3) There is evidence of a stronger government lead in focussing on the need to develop beneficial resources where they exist both in the local and national interest. Public attitude surveys suggest that this view is likely to be mirrored by the larger part of the population in general.

(4) There are significant technical and economic limits to the amount of variable wind power development that can be accommodated on the total Irish network. These arise from the technical and economic characteristics of the existing and

planned thermal plant mix on the system and the market arrangements for handling intermittent generation. This set of real issues associated with the capability of the total Irish electrical systems ability to accept input from intermittent sources (such as wind) has raised the real likelihood of enforced limitations on permissible wind power capacity to 1,000MW in 2010 and 1,250MW in 2020. An additional 350MW would be possible on a whole island basis. A plant mix incorporating aeroderivative gas turbines could, however, allow wind penetration to rise to 3,725MW by 2020.

(5) The key weakness of the wind resource is its variability when juxtaposed with the current and projected transmission and generation systems and the absence of long term hydro storage. The possibility of large-scale pumped hydro may merit attention in its own right to see whether an economic solution may exist to complement viable energy sources.

(6) The levelised unit cost of wind energy is projected to continue falling particularly if capacity can increase. It is projected to halve between 2010 and 2020 given the assumptions made.

(7) The broadly favourable public attitude to modern wind farm development is conducive to ongoing responsible development.

12.6 Landfill Gas Resource

(1) The resource definition model and the analytical cost model were successfully applied to the Irish landfill gas resource.

(2) The resource is not large in the national context but its utilisation has significant positive impact in the removal of methane from the biosphere. The resource is scheduled to decline as the disposal of biologically degradable materials in landfill sites is phased out in line with EU and Government Policy.

(3) Based on a levelised cost comparison, this resource is currently the most competitive renewable method of electricity generation the bulk of the residual LFG resource can be developed to produce power flexibility at or below the reference unit price for the Best New Entrant CCGT, without taking into account any external costs for that technology.

(4) The AER VI Biomass rate cap of 6.41c/kWh would appear to extend the viable (managed) market umbrella to all LFG likely to be available by 2010 (50MW) and an incremental 8.2MW by 2020 unless issues associated with particular sites serve to increase costs beyond those considered in this report.

(5) Because of the statistical data compiled under the auspices of the Environmental Protection Agency in recent years this resource lends itself well to the analytical procedure. While there may be some doubt as to how valid some of the original existing regional waste plans will prove to be into the future the fact that good data control will exist will assist in measurement of change.

12.7 Solar Resource

(1) The resource definition model and the analytical cost model were successfully applied to the Irish solar heat resource.

(2) In the absence of a database dealing with all structures the country, available statistical data compiled by the Irish Energy Centre and other organisations was used in this analysis. This data is however rather incomplete and will require to be augmented in the future if a fully comprehensive analysis is to be carried out.

(3) The Irish Theoretical solar resource is estimated at an average annual panel output of 350kWh (thermal)/sq. m acting over the whole country area.

(4) The bulk of the accessible resource base lies in housing stock which is estimated to be growing at 4% per year. Taking this figure as the driving rate for the whole accessible resource leads to projections of 59×10^6 and 70×10^6 sq. m in roof area by 2010 and 2020 respectively.

(5) The Solar Combi system is used as the reference system. Reductions in unit capital and operating costs were projected for 2010 and 2020 and three market penetration scenarios were considered to give a spread of possibilities for 2010 and 2020. Costs for small scale (existing housing) installations exceeded those for large-scale (new buildings).

(6) The costs to government of the three market penetration scenarios are 0% (low), 2% of turnover (medium), 5% of turnover (high), respectively.

(7) Each scenario leads to corresponding CO_2 avoidance levels for 2010 and 2020 respectively. The value of the CO_2 avoidance (is not) matched by the promotional costs noted in (5) above.

(8) The levelised costs of solar heating exceeds those of natural gas heating which has been nominated as the competing heat source by agreement with the client.

12.8 CO_2 Avoidance

(1) Assessment of potential for CO_2 avoidance relative to the projected future plant mix on the Irish system showed that wind had the highest potential and lowest unit cost, solar had a nationally high potential if the accessible resource was fully developed. However it is very expensive and only a tiny fraction of that resource can be considered likely for development by 2020.

(2) LFG development is doubly useful in that it consumes methane and provides a study power supply but the resource is of limited extent and is scheduled to decrease over time.

(3) The possibility of utilising cocombustion of biomass wood crops with peat in recently constructed generating stations having fluidised bed boilers merits further attention as a means of moderating CO_2 output.

(4) The possibility of utilising cofiring of biomass wood crops with peat in recently constructed generating stations having fluidised bed boilers merits further attention as a means of moderating their CO_2 output.

12.9 Fossil Fuel Benchmarking

(1) The first order impact on the key renewables of changes in fossil fuel prices may be readily estimated by operating the analytical model with a range of fuel costs for the Best New Entrant. The range of BNE unit costs produced may be plotted on the resource cost curves of the respective renewables to obtain their corresponding new viable open market limits (for capacity) and threshold rate/kWh if they are paid the same as BNE.

(2) As the fuel cost to BNE ranges from -20% to +50% above the current level viable open market wind capacity varies from 0MW to +490MW, the viable managed market (under AER criteria and with existing fuel cost) would lie between 105MW and 260MW in 2010 and viable open market (and viable managed market) remains at 1250MW (due to the system limit imposed) in 2020, (Figs. 8.1, 8.2), LFG varies from -5MW to +4MW in 2010 and from 0MW to 2.5MW (incremental in 2020 (Figs. 9.1, 9.2) relative to the existing capacity levels. Solar thermal remains unchanged throughout as it is still too expensive for these changes in the cost of gas to bring the levelised solar cost into the viable range (Figs. 10.1, 10.2).

13. Recommendations

13.1 Resource Definitions

(1) The resource definition model should be applied, tested and modified in detail where found necessary so that a single acceptable and broad based set of descriptive definitions exists for both electricity and heat markets.

13.2 Analytical Model

(1) Given that the analytical model developed for this project is applicable to a wide range of technologies and scenarios the emphasis should now switch to ensuring that there is a suitable database of representative input information available for applications.

(2) This implies that improved information will be necessary in respect of resource scales, technology costs, appropriate discount rates (since these reflect both risk levels and expected profits), constraints and limitations. As this information may be commercially sensitive in individual cases it appears desirable to develop a parametric study. A discount rate of 6.88% considered appropriate by CER for current Best New Entrant should be replaced by 8% for wind under present conditions. For LFG the 6.88% rate is retained.

13.3 Electrical Market

(1) Developments in the electrical market should be monitored to assess the validity of the projections made in this study, going forward.

(2) Any expectation that the electrical market can carry CO_2 reduction targets other than those relating to its own sector should be avoided. (This does not of course imply that the benefits of CHP or cocombustion for heating should not be shared).

(3) Support the possibility of utilising cocombustion of wood biomass with peat in recently constructed generating stations via a feasibility study involving stakeholders.

13.4 Heat Market

Recognising the relative size and dispersed nature of the Irish heat market, the relative dominance of the housing sector and its projected rate of growth, it is recommended that SEI should

(1) Apply and test the system of resource definition developed in this report and modify in a controlled way if necessary to ensure that they are appropriate to the needs of the sector.

(2) Continue its support for incorporation of good design, high standards of insulation and energy saving features in domestic commercial and industrial structures and processes.

(3) Consider implementation of a pilot scheme of micro CHP, heat pump and ground storage projects with a view to the introduction of a 'learning by doing' culture, targeting both new build and retrofit cases.

(4) Continue support for CHP and wood pellet fuel developments in the Irish market.

(5) Refocus attention on solar water heating rather than space heating.

13.5 Onshore Wind Resource

(1) Given the results of public attitude surveys the message behind the projected revised planning guidelines needs to be strongly sold to ensure that there is no weakening of resolution to bring significant quantities of wind energy on stream for 2010 and 2010.

(2) It is essential for decision makers to recognise the well flagged system operation limitations that arise with increasing penetration of wind energy into the system and to initiate optimisation studies that would allow the relative merits of fossil fuelled open cycle gas turbines and or long cycle hydro pumped storage to be assessed as a vehicle for increased wind penetration and reduced CO_2 emission. (This will also be relevant to intermittent offshore wind and ocean energy technologies).

(3) Wind development costs should continue to be monitored so that progress toward the projected low levelised costs for 2020 can be assessed.

13.6 Land Fill Gas Resource

(1) Recognising that this is a relatively small but valuable resource that both absorbs methane and produces useful energy while assisting responsible landfill management it is recommended that SEI should

(2) Represent to EPA the importance of continued classification of municipal waste stream by type and weight to prevent recurrence of erroneous data records at Local or Regional Authority Level.

(3) Monitor EPA reports on extent and nature of resource feedstock stream to allow projection of resource decline.

(4) Assess possibilities for extending life of existing resource, evaluating points at which waste flows less than 50,000t/yr. may become commercially viable.

(5) Consider slight reduction in future tariffs for projects larger than 1.5MW to see if a tier of smaller projects can be brought in at enhanced tariffs.

13.7 Solar Resource

(1) Consider initiating a process of gathering the necessary raw material for a more comprehensive study of the potential of solar heating bearing in mind the relative lack of fully verifiable data on the building resource, suitability for retrofit, system performance, and costs encountered during the present study.

(2) Press for incorporation of roof area data including ridge line orientation, if any, in planning application documentation and the summarising of such data by planning authorities in returns to DOELG or EPA.

(3) Examine the possibility that existing satellite image based geographical information system databases used for addresses may contain sufficient information on existing building stock to allow assembly of data similar to that proposed in (2) above for new buildings via desk study.

(4) Consider which level of market support may be sustainable or desirable commensurate with the returns projected for active solar thermal power bearing in mind the low market penetration and CO_2 avoidance envisaged by the highest scenario.

(5) Ensure that proven standard methods of test and validation are available for application to solar water and space heating systems intended for use in the Irish market, with availability of corresponding performance data.

13.8 CO_2 Avoidance

(1) It should be noted that the wind resource if allowed to develop further has the realistic potential to make the most significant contribution to CO_2 displacement of the renewables considered in this report at the lowest cost.

(2) The merits of cofiring Short Rotation Forestry in modern fluidised bed peat plants as a means of redressing the high CO_2 output per kWh should be actively pursued.

13.9 Fossil Fuel Benchmarking

(1) Bearing in mind the volatility of the premium fuel market (distillate, gas) and the fact that BNE owner would probably operate using a policy of hedge and spot, the method of using resource cost curve ordinate as dependent variable to BNE unit cost/kWh provides an acceptable first order means of benchmarking renewables against fossil fuel prices in future.

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