Combined Heat and Power in Ireland

2010 Update

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SUSTAINABLE ENERGY IRELAND

Energy Policy Statistical Support Unit

Sustainable Energy Ireland

Sustainable Energy Ireland was established as Ireland's national energy authority under the Sustainable Energy Act 2002. SEI's mission is to promote and assist the development of sustainable energy. This encompasses environmentally and economically sustainable production, supply and use of energy, in support of government policy, across all sectors of the economy including public bodies, the business sector, local communities and individual consumers. Its remit relates mainly to improving energy efficiency, advancing the development and competitive deployment of renewable sources of energy and combined heat and power, and reducing the environmental impact of energy production and use, particularly in respect of greenhouse gas emissions.

SEI is charged with implementing significant aspects of government policy on sustainable energy and climate change abatement, including:

- Assisting deployment of superior energy technologies in each sector as required;
- Raising awareness and providing information, advice and publicity on best practice;
- Stimulating research, development and demonstration;
- Stimulating preparation of necessary standards and codes;
- Publishing statistics and projections on sustainable energy and achievement of targets.

It is funded by the Government through the National Development Plan, with programmes part-financed by the European Union.

Energy Policy Statistical Support Unit (EPSSU)

SEI has a lead role in developing and maintaining comprehensive national and sectoral statistics for energy production, transformation and end use. This data is a vital input in meeting international reporting obligations, for advising policy makers and informing investment decisions. Based in Cork, EPSSU is SEI's specialist statistics team. Its core functions are to:

- Collect, process and publish energy statistics to support policy analysis and development in line with national needs and international obligations;
- Conduct statistical and economic analyses of energy services sectors and sustainable energy options;
- Contribute to the development and promulgation of appropriate sustainability indicators.

Highlights

Capacity

- The installed capacity of CHP in Ireland at the end of 2008 was 289 MW_e.
- The operational capacity (units known to be in operation) was 282 MW_e in 2008.

CHP by Fuel

- Natural gas was the fuel of choice for 185 units in 2008. Oil products made up the next most significant share with 6 units while biomass accounted for 2 units. The remainder was solid fuel at 2 units
- Natural gas fuelled 271 MW_e of the installed capacity in 2008. Oil products fuelled 8.1 MW_e, biomass 5.4 MW_e and solid fuel was used by the remaining 5.2 MW_e.

CHP by Sector and Sub-Sectors

- There are a large number of relatively small units in the services sector. The services sector accounted for 84% of the units and 14% of the installed capacity.
- Within the services sector hotels and hospitals account for the majority (61%) of units while the leisure sub-sector (which includes swimming pools, leisure centres, gyms, etc.) accounts for another 18%.
- The food and beverages sub-sector dominates the number of units in industry with 42% of units and 23% of industrial installed capacity.

CHP Electricity Generation

- In 2008, 6.3% of electricity was from CHP installations compared with 6.2% in 2007.
- In 2008, there were 11 units exporting electricity to the grid. These units exported 1,013 GWh of electricity in 2008, an increase of 8.9% on 2007.

CHP Heat Output

- In 2008, approximately 4% of Ireland's total thermal energy demand was from CHP installations.
- The useful heat output was 78% of the total heat generated by CHP plants in 2008.

CHP Fuel Input and Thermal/Electrical Outputs

- In 2008, fuel input decreased by 1%, usefully employed thermal output increased by 2% while electricity increased by 35%. The resulting improvement in the efficiency of CHP was 3.3%.
- The overall stock of CHP installations has become more efficient, increasing by 48% since 2001 to an efficiency of 80% in 2008.

Targets and future growth

- The installed capacity at the end of 2008 was 72% of the Government's 2010 target of 400 MW_e.
- The planned growth for 2009 is 19.6 MW_e, therefore a further 30% (91.4 MW_e) growth in capacity in 2010 is required in order to meet the 2010 target.

Avoided CO_2 Emissions

- There was an increase in avoided CO_2, in 2008, to give a total of 457 kt CO_2 avoided in the year.
- Electricity generated by CHP in 2008 provided a net CO_2 reduction of 248 g/kWh_e to that of marginal generation.

Primary Energy Savings

- There was a primary energy saving of 26% from CHP plants in 2008 compared to separated heat and electricity production.

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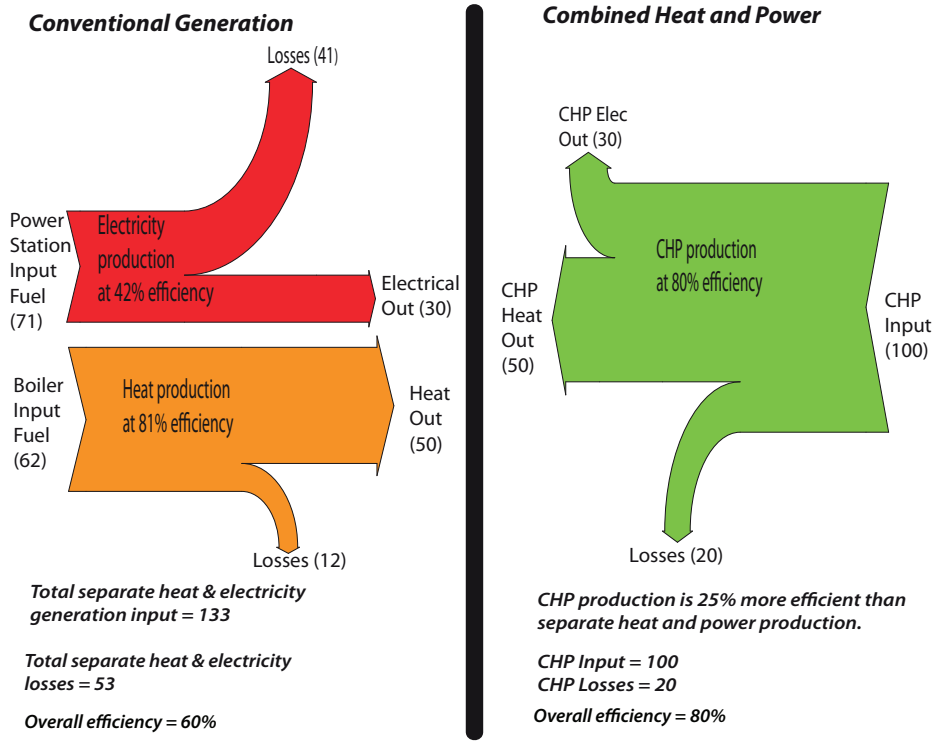
1. Introduction

In conventional electricity generation much of the input energy is lost to the atmosphere as waste heat. In Ireland 55% of the input energy is lost with just 45% being transformed into electricity. Combined Heat and Power (CHP) systems channel this lost heat to useful purposes so that usable heat and electricity are generated in a single process. In the right circumstances CHP can be an economic means of improving the efficiency of energy use and achieving environmental targets for emissions reduction. CHP usually involves the burning of fossil fuels but heat and electricity are also produced from biomass (including biogas and waste). Figure 1 illustrates how a 25% energy saving can be achieved using CHP compared to the separate production of heat and centralised electricity (which is a 33% increase in efficiency). The efficiency of the CHP units is calculated from the amount of heat usefully employed as opposed to heat generated. There may also be additional efficiency due to eliminating transmission and distribution losses.

Figure 1 Comparing Conventional Heat and Electricity Generation to CHP



Source : SEI

This report examines the contribution made by CHP to Ireland's energy requirements for the period 1991 to 2008, with a particular focus on the years 2007 and 2008. This is SEI's fifth report on the topic. The data is gathered by surveying site operators and CHP unit suppliers.

2. Installed Capacity and Number of Units in 2007 and 2008

The installed capacity[1] of CHP in Ireland at the end of 2008 was 289 MW_e (195 units[2]) up from 287 MW_e (178 units) in 2007, an increase of 1%. The figures above include a number of units that were not operational (5.7 MW_e, 7 units) and a number whose status is currently unknown (3 MW_e, 4 units). Comparing operational installed capacity, there was a 3% increase from 2007 to 2008, an increase of 9 MW_e of installed capacity to 282 MW_e(184 units).

A number of large units, including the sugar plants in Carlow and Mallow, closed in 2005 and 2006. These two plants accounted for 26 MW_e. The Aughinish Alumina plant which accounts for 160 MW_e is operational since 2006 and is the single largest CHP installation. There is an expected growth of at least an additional 16 units with an installed capacity of approximately 19.5 MW_e, which are due to be operational by the end of 2009.[3]

1 Megawatt electrical or MW_e is the unit, by which the installed electricity generating capacity or size of a CHP plant is quantified, representing the maximum electrical power output of the plant.
2 Note that units are distinct from CHP plants or schemes and that there may be more than one CHP unit at a site.
3 The latest data in this report is from the 2009 CHP survey which includes plants in operation at the end of 2008.

3. CHP in Ireland 2008

3.1 CHP by Fuel

It is useful to examine the fuel type associated with CHP plants[4] from the perspectives of both security of supply and environmental impact. CHP is promoted due to the improved efficiencies and reduced emissions that may be achieved relative to the alternatives. In this context, the choice of fuel has a direct impact on the levels of emissions reductions that may be achieved.

Table 1 illustrates the installed capacity and number of units by fuel in 2008. Oil fuels used are liquefied petroleum gas (LPG), heavy fuel oil and refinery gas. Natural gas was the fuel of choice for 271 MW_e (185 units) in 2008. It is worth noting that there is one single 160 MW gas plant which dominates. Oil fuels made up the next most significant share with 8.1 MW_e (6 units) while solid fuels accounted for 5.2 MW_e (2 units). The remainder was biomass at 5.35 MW_e (2 units).

Table 1 Number of Units and Installed Capacity by Fuel 2008

	No. of Units	Installed Capacity MWe	No. of Units %	Installed Capacity %
Natural Gas	185	271	94.9	93.5
Solid Fuels	2	5.2	1.0	1.8
Biomass	2	5.4	1.0	1.8
Oil Fuels	6	8.1	3.1	2.8
Total	195	289	100	100

Source: SEI

3.2 CHP by Sector and Sub-Sector

CHP is more suited to some applications and sectors of the economy than others, depending on how the energy is used, the amount of energy consumption and the split between electrical and heat requirements.

Table 2 presents the number of units and installed capacity for CHP in Ireland in 2008. The majority of units are in the services sector while the bulk of installed capacity is in industry, indicating that there are a large number of relatively small units in the services sector. The services sector accounted for 163 (84%) of the 195 units and 41.8 MW_e of the 289 MW_e installed capacity (14%).

Traditionally, CHP was more suited to large industrial concerns but the availability of ready made, small scale, reliable gas units in the 1990s (and more recently micro-turbines) meant that the services sector could avail of the technology whereas previously they would not have had the heat and electricity demands to justify the capital investment.

Table 2 CHP Number of Units and Installed Capacity by Sector 2008

	No. of Units	Installed Capacity MW_e	No. of Units %	Installed Capacity %
Services	164	41.8	84.1	14.4
Industry	31	247.6	15.9	85.6
Total	195	289.4	100	100

Source: SEI

Examining the breakdown of services further in Table 3 it can be seen that hotels and hospitals account for the majority (61%, 99 units) of units in the services sector while the leisure sub-sector (which includes swimming pools, leisure centres, gyms, etc.) accounts for another 18% (29 units). These sub-sectors, in particular, benefit from having close to constant demand for heat and electricity but the technology may also be suited to any site that has a simultaneous demand for both heat and electricity.

4 Data for this report originates from surveys conducted by SEI in 1996 to 1998, 2000 and 2002 that were part funded by EUROSTAT. SEI conducted similar surveys for 1999, 2001 and 2002. The ESB undertook the surveys in 1994 and 1996. A survey was not carried out for 1995. An annual survey has been carried out by EPSSU since 2003.

Table 3 Number of Units and Installed Capacity by Services Sub-Sectors 2008

	No. of Units	Installed Capacity kW_e	No. of Units %	Installed Capacity %
Hospital	26	6.5	15.9	15.5
Hotel	73	10.6	44.5	25.3
Public sector	2	1.5	1.2	3.7
Airport	3	4.4	1.8	10.5
Education	8	4.7	4.9	11.3
Office	12	7.3	7.3	17.6
Leisure	29	3.8	17.7	9.1
Retail	6	1.1	3.7	2.6
Services Other	5	1.8	3.0	4.4
Total	164	41.8	100	100

Source: SEI

It is interesting to note that certain sub-sectors have a small number of CHP units but represent a considerable proportion of the installed capacity, notably airports and education.

Table 4 presents the sub-sectoral breakdown of installed capacity and number of units in industry. It can be seen that the food and beverages sub-sector dominates the number of units with 42% (13 units) and 23% (56 MW_e) of industrial installed capacity in 2008. Other refers to enterprises in the non ferrous metals, energy sector, textiles, and sawmills sub-sectors. It also includes the 160 MW installation at Aughinish Alumina.

Table 4 Number of Units and Installed Capacity by Industry Sub-Sectors 2008

	No. of Units	Installed Capacity kWe	No. of Units %	Installed Capacity %
Food	13	56.4	41.9	22.8
Manufacturing	5	9.5	16.1	3.8
Pharmaceutical	5	6.9	16.1	2.8
Other	8	174.9	25.8	70.6
Total	31	247.6	100	100

Source: SEI

4. Policy

The European Commission published a strategy document on CHP in 1997[5] which aimed to double the 1994 CHP penetration by 2010 (from 9% to 18%). This target refers to the EU–15 and in 2007 (the latest year data are available) the proportion of total electrical output that was generated from CHP was 10.3% (10.9% for EU-27), indicating the scale of the challenge for the remaining years.

The European Union CHP Directive[6], approved in February 2004, seeks to create a favourable environment for CHP installations. The Directive contains definitions for micro, small and large scale CHP. Table 5 illustrates how Ireland's installed capacity fitted into those classifications in 2008. It can be seen that units in the over 1 MW_e category account for most of the installed capacity (91%) while most of units are between 50 kW_e and 1 MW_e (78%).

The Energy (Miscellaneous Provisions) Act of 2006 is the transposition of the EU CHP Directive into Irish law. In 2009 two statutory instruments SI 298 and SI 299 were published. SI 298 brought into law section 6 of the 2006 act which relates to CHP. SI 299 gives the Commission for Energy Regulation (CER) the responsibility of calculating Power to Heat Ratios for CHP units

5 Commission of the European Communities (1997), *A Community Strategy to Promote Combined Heat and Power and to Dismantle Barriers to its Development*.

6 European Union, 2004. Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market. Available from: http://europa.eu.int/eur-lex/pri/en/oj/dat/2004/l_052/l_05220040221en00500060.pdf

in Ireland.

Table 5 Number of Units and Installed Capacity by Capacity Size Range 2008

Electrical Capacity Size Range	No. of Units	No. of Units %	Installed Capacity kW_e	Installed Capacity %
Micro <50 kW_e	2	1.0	0.08	0.0
50 kW_e ≤ Small < 1MW_e	152	77.9	25.3	8.7
Large ≥ 1 MW_e	41	21.0	264.0	91.2
Total	195	100	289.4	100

Source: SEI

A government support programme for CHP was announced in December 2005 as part of the 2006 budget. The CHP Deployment Programme, due to run over the period 2006 to 2010, provides grant support to assist the deployment of small-scale (<1 MW_e) fossil fired CHP and biomass (anaerobic digestion and wood residue) CHP systems. The programme provides funding for CHP systems and also includes funding for feasibility studies for micro-CHP generation. The objective of the trial is to assess current technology and identify possible barriers, risks and benefits associated with its deployment. This will inform future policy consideration of micro-generation and the opportunities for further efficiency gains through distributed small-scale generation.[7]

5. Targets and Planned Growth

The Government's *Energy White Paper*[8] published in March 2007, sets out the energy policy directions and targets for Ireland to 2020. The targets of a total of 400 MW_e of installed CHP capacity by 2010 and 800 MW_e by 2020 have been set. The Programme for Government was published in June 2007 and includes a commitment to remove any regulatory barriers to CHP and district heating systems. As seen in section 2 of this report the total operational capacity at the end of 2008 was approximately 289 MW_e. This target is repeated in the National Climate Change Strategy (NCCS)[9] 2007 to 2012, also published in 2007, which states that 0.162 Mt CO_2 equivalent will be saved by 2010, as a result of CHP. The National Energy Efficiency Action Plan[10] published in May 2009 also reflects the targets set out in the government white paper.

The Government is due to consider a second CHP target for 2020 in light of further feasibility studies by SEI into CHP applications, a review by CER of potential administrative and regulatory barriers, and decisions on appropriate price support mechanisms for electricity generated from new high efficiency large scale CHP. It is also intended that the public sector will act as an exemplar in relation to CHP.

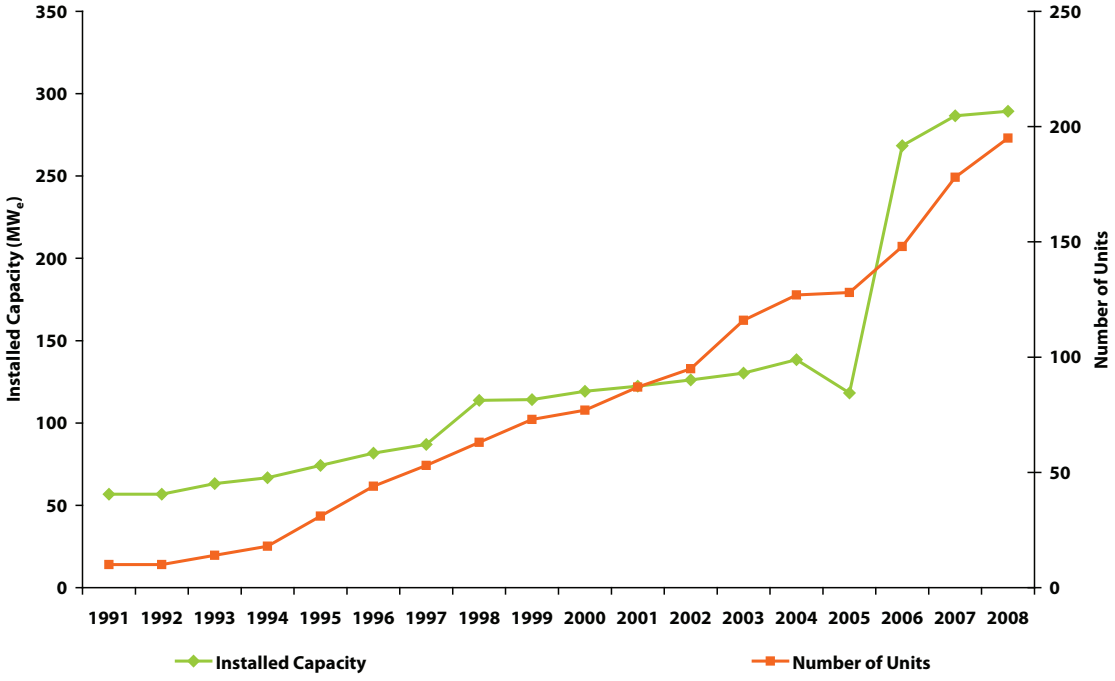
The installed capacity at the end of 2008 was 72% of the government 2010 target. The planned growth for 2009 is 19.5 MW_e, therefore a further 30% (91.4 MW_e) growth in capacity would be required in order to meet the government target. The growth rate in 2008 was 1%.

6. CHP 1991 to 2008

Figure 2 presents the number of CHP units in Ireland over the period 1991 to 2008. The increase in installed capacity over the period was 410% (10% per annum) from a low base. Growth in 2008 was 1%. Growth in 2006 was 227%, largely due to the addition of the Aughinish Alumina plant. The average annual growth rate of installed capacity was 5% prior to the addition of the Aughinish Alumina plant (1991-2005) and 4% after the addition (2006-2008). Figure 2 also presents data for the growth in the number of units (1850%) over the period, representing an average incremental growth of 19% per annum, again from a low base. In 2008 there was a 10% growth in the number of units.

7 Details of the trial are available from http://www.sei.ie/Your_Business/CHP.
8 Full text available from http://www.dcmnr.gov.ie/Energy/Energy+Planning+Division/Energy+White+Paper.htm.
9 Available from http://www.environ.ie/en/PublicationsDocuments/FileDownLoad,1861,en.pdf.
10 Available from http://www.dcmnr.gov.ie/Energy/Energy+Efficiency+and+Affordability+Division/National+Energy+Efficiency+Action+plan.htm/

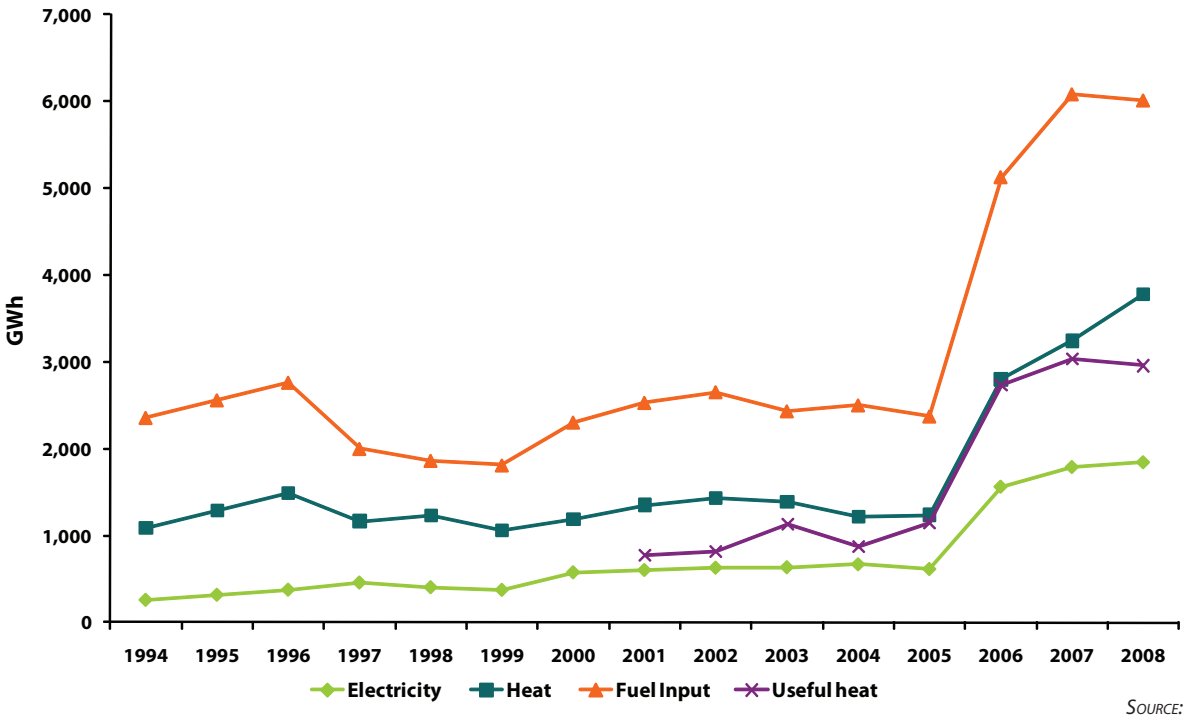
Figure 2 Number of Units and Installed Capacity 1991 to 2008



Source: SEI

Figure 3 illustrates the trends relating to fuel inputs and electricity and thermal outputs for all operational plants over the period 1994 to 2008. Fuel inputs have increased by 155% (7% per annum) while the thermal and electrical outputs have increased by 246% (9% per annum) and 613% (15% per annum) respectively over the period. This suggests that the overall stock of CHP installations has become more efficient over the period. In 2008 fuel input decreased by 1%, thermal output increased by 17% while electricity increased by 35%.

Figure 3 CHP Fuel Input and Thermal/Electricity Output 1994 to 2008



Source: SEI

The data compiled in the CHP survey quantifies electricity and heat generated by all operational CHP plants in Ireland. Data on useful heat, which is the total amount of CHP heat used during the year, as distinct from the total heat produced, is also requested. The useful heat output has increased by 297% since 2001 (22% per annum). The survey responses for useful heat are not always reliable and the overall useful heat values are likely to be overestimating the amount of useful heat. This appears to be a concern for the responses in 2003 and 2005 to 2007 as detailed in Figure 3. SEI are striving to improve the data on useful heat but it will not be possible to update historical values.

Table 6 Useful Heat as a Percentage of Heat Generated

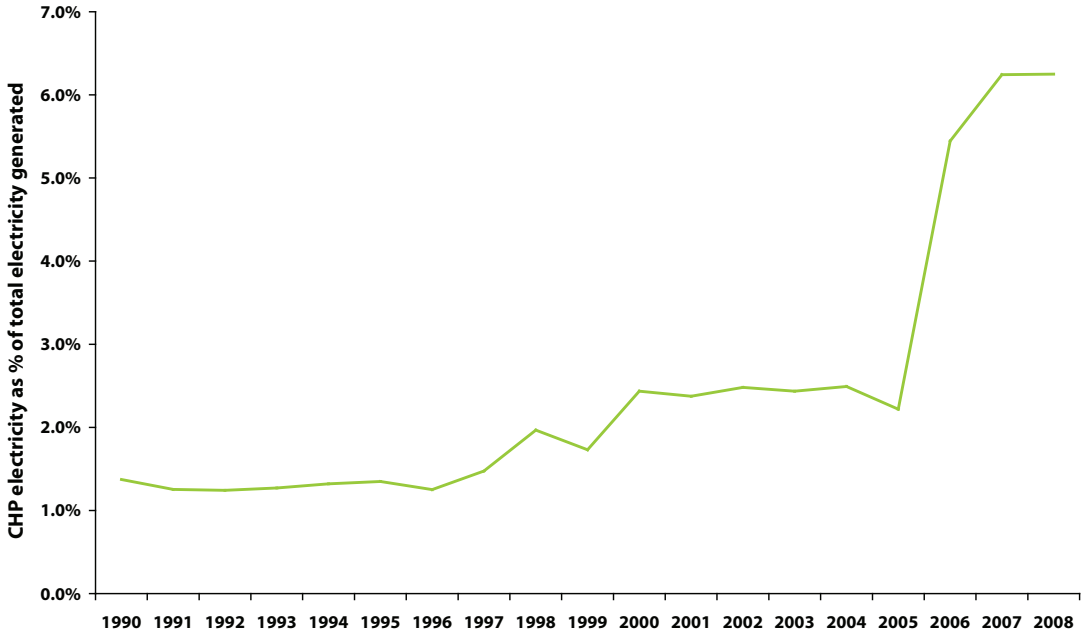
	2001	2002	2003	2004	2005	2006	2007	2008
Heat usefully employed (MWh)	772	812	1,128	872	1,142	1988	3,032	2,958
Percentage of total heat generated	57%	57%	81%	72%	92%	71%	93%	78%

Source: SEI

It is estimated that the CHP useful heat output met approximately 4% of the total thermal demand[11] in 2008.

Figure 4 focuses on CHP generated electricity in Ireland as a proportion of gross electricity consumption (i.e. electricity generation plus net imports) in the period 1990 to 2008. In 2008, 6.3% of total electricity generation was from CHP installations compared with 6.2% in 2007 and 5.4% in 2006. Some CHP units export electricity to the national grid. In 2008, there were 11 units exporting electricity to the grid. These units exported 1,013 GWh of electricity in 2008, an increase of 8.9% on 2007.

Figure 4 CHP Electricity as a Percentage of Gross Electricity Consumption 1990 to 2008

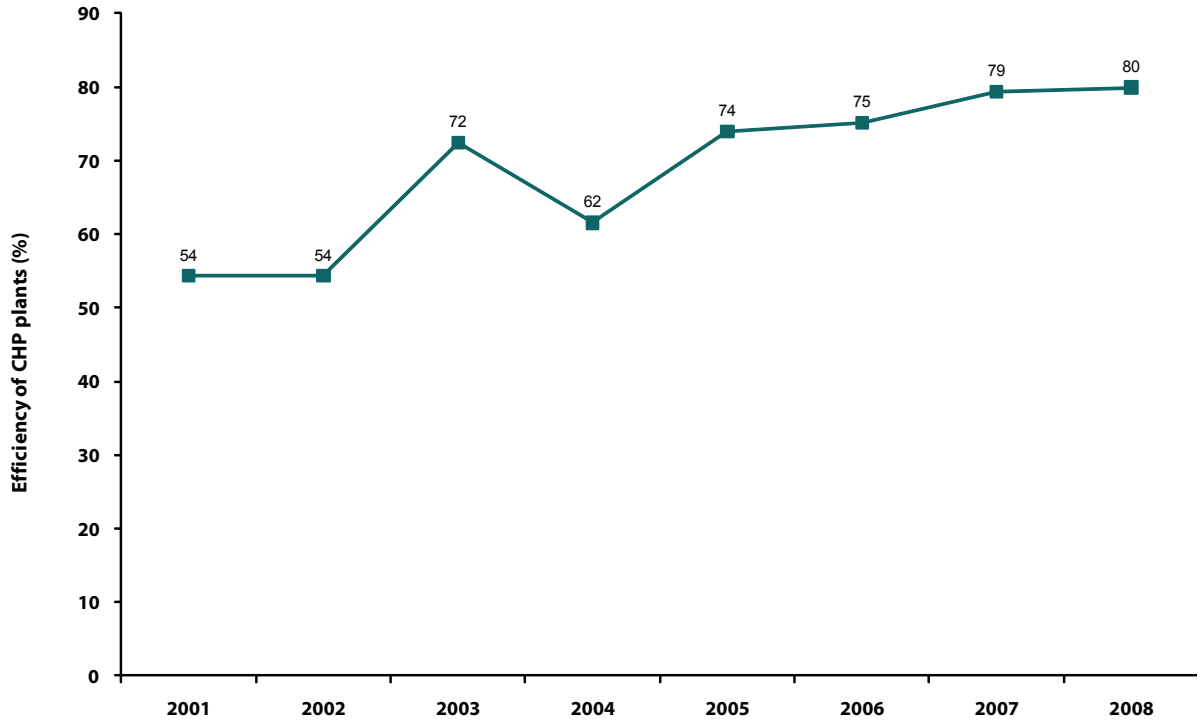


Source: SEI

The overall efficiency of the CHP plants is shown in Figure 5. The overall efficiency of the CHP plants in 2008 was 80%. This figure is strongly influenced by the overestimation of the useful heat responses to the CHP survey. A lot of responses have the exact same figure for heat generated and useful heat. It is unlikely that all of the heat generated is being used.

11 Thermal energy is defined here as energy used for space, process and water heating, cooking, etc. The total thermal demand is calculated as the residual energy requirement when energy use from transport and electricity generation are subtracted from the total primary energy supply.

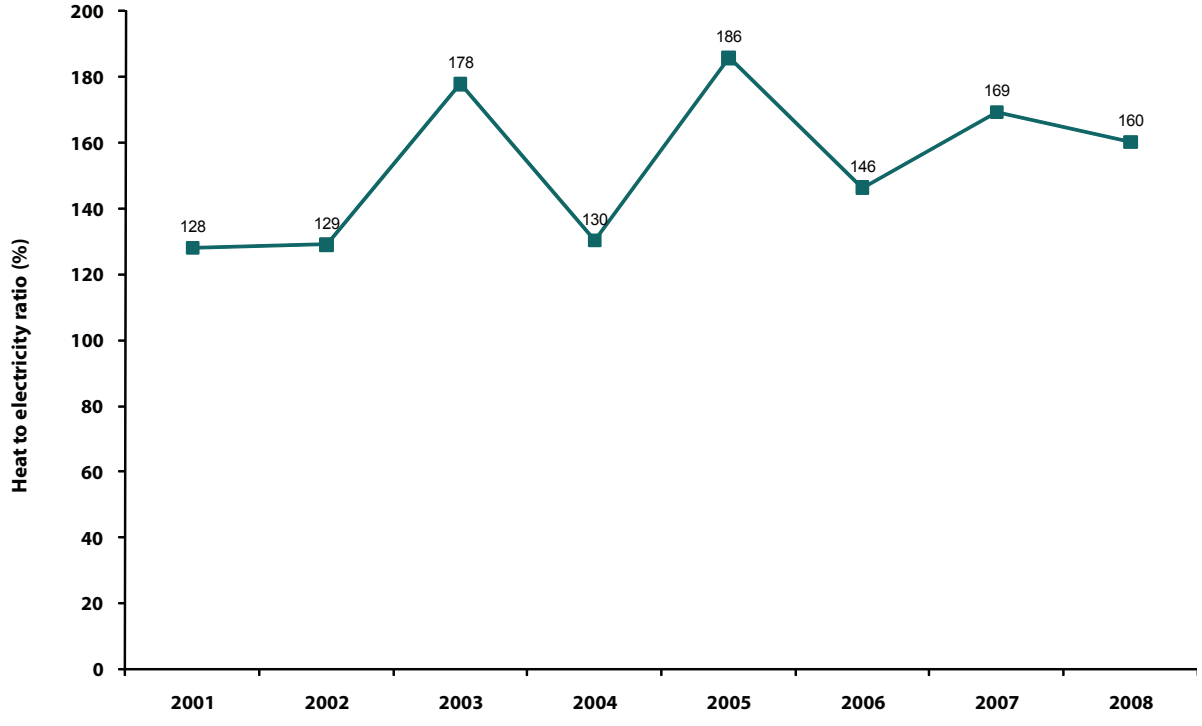
Figure 5 Efficiency of CHP Plants



Source: SEI

The heat to power ratio is plotted in Figure 6. The spikes in the ratio in 2003 and 2005 are due to unreliable responses to the CHP survey for the useful heat values in those year. In 2008 there was 60% more heat produced from CHP than electricity.

Figure 6 Heat to Power Ratio of CHP Plants



Source: SEI

7. Avoided CO_2 from CHP

As mentioned at the beginning of this update, CHP can be used to achieve environmental targets for emissions reduction. Specifically, by utilising the heat that would otherwise be lost in electricity generation, the efficiency of a CHP plant can typically be 20 to 25 percentage points more efficient than the combined efficiency of heat-only boilers and conventional power stations. Also, if embedded in the network close to the point of electrical consumption, CHP can avoid some of the transmission losses incurred by centralised generation. Consequently CHP can bring environmental benefits in the form of CO_2 savings.

The amount of CO_2 avoided by employing a CHP unit is difficult to determine and is widely debated. It requires assumptions relating to the electricity generation in the absence of CHP plants, i.e. relative to a specific baseline. One perspective suggests that CHP displaces the marginal fuel of electricity generation, as less marginal plant electricity is required if additional electricity is generated from CHP. This is typically referred to as the *operating margin approach*[12,13]. For example, if additional CHP electricity is produced, less single cycle (oil or natural gas) electricity will be generated. The *operating margin approach* is the approach adopted in this report for calculating the historical avoided emissions by CHP plants.

The assumptions regarding displacement of heat depend on the fuel used and are detailed in Table 7.

Table 7 Displacement of Heat – Assumptions

Fuel	Displacement fuel	% efficiency
Natural Gas	Natural gas	80%
Biogas	Fuel oil	80%
Biomass	Fuel oil	80%
Peat	Milled Peat	70%
LPG	Gas oil	80%
Coal	Fuel oil	80%
Refinery Gas	Fuel oil	80%

Source: SEI

A number of factors influence the quantity of avoided emissions in using the operating margin approach. These include the carbon intensity of the operating margin fuel mix, the overall efficiency of the installed CHP plants and the absolute CHP capacity. The carbon intensity of the marginal generation mix will have a significant impact on the quantity of avoided CO_2. Detailed in Table 8 this varies annually depending on the composition of the marginal generation in any particular year.

Table 8 Carbon Intensity of the Marginal Generation

	2001	2002	2003	2004	2005	2006	2007	2008
Intensity CO_2 g/kWh (Operating Margin Mix)	645	600	552	546	552	559	524	515
Annual Improvement		7.0%	7.9%	1.1%	-1.1%	-1.2%	6.3%	1.6%

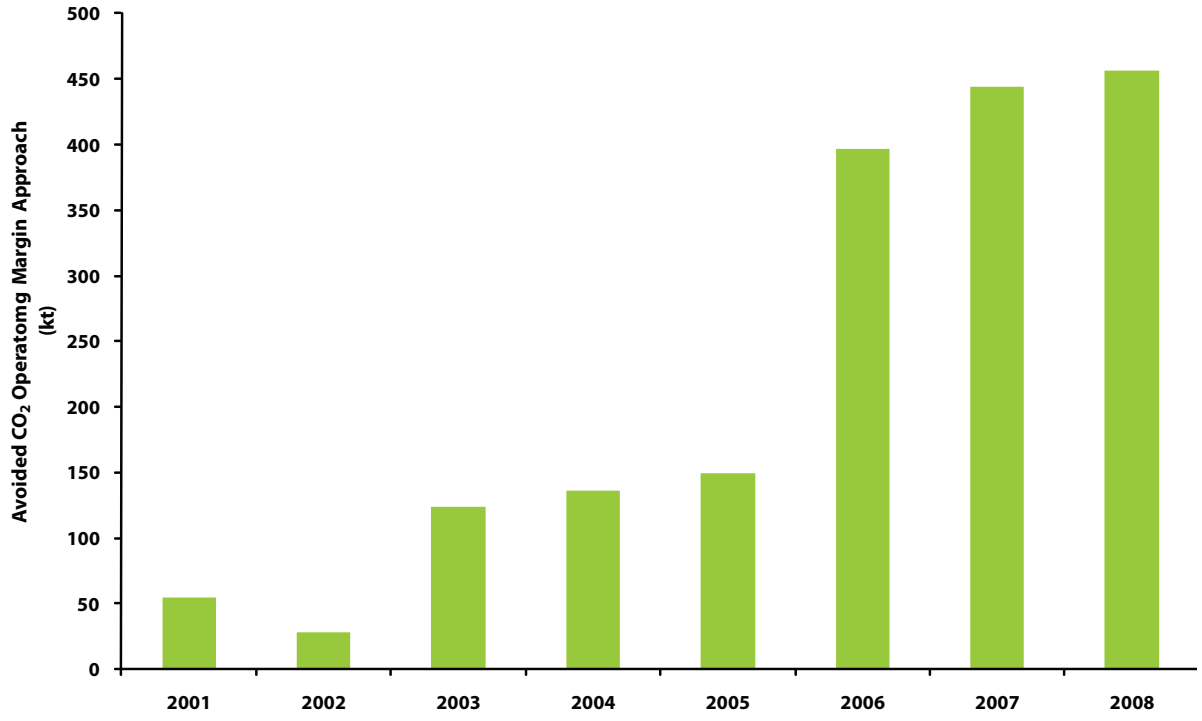
Source: SEI

The results from the operating margin approach are illustrated in Figure 7 and Table 9.

12 Kartha S., Lazarus M. and Bosi M. *Baseline recommendations for greenhouse gas mitigation projects in the electric power sector*. Energy Policy 2004, 32, 545-566.

13 Ó Gallachóir B. P., O'Leary F., Bazilian M., Howley M. & McKeogh E. J. 2005 *Comparing Primary Energy Attributed to Renewable Energy with Primary Energy Equivalent to Determine Carbon Abatement in a National Context*. Journal of Environmental Science and Health.

Figure 7 Avoided CO_2 Operating Margin Approach 2001 to 2008



Source: SEI

It can be seen in Figure 7 that the avoided CO_2 from the operating margin approach increased from 55 kt CO_2 in 2001 to 149 kt CO_2 in 2005[14], an increase of 171% (28% per annum on average). During this time there was a 14% reduction in the CO_2 intensity (CO_2 g/kWh) of the electricity generated from the marginal generation fuel mix, so the increase in emissions is due to the increase in the number of CHP plants. The sharp reduction in 2002 was due to the reduction in the avoided emissions due to the 7% improvement in the overall electricity emissions and an increase in the actual emissions from the CHP plant due to changes in the fuel mix and volume increases (overall 4%) which resulted in lower avoided emissions in that year. In 2006 there was a sharp increase (266%) in the avoided emissions to 397 kt CO_2, mainly due to the additional capacity added that year. There was a 3% increase in avoided CO_2 in 2008 to 457 kt. This increase in avoided emissions was due to the improvement in the overall efficiency of the CHP plants, which is also plotted in Figure 5.

Table 9 Avoided CO_2 Operating Margin Approach

	2001	2002	2003	2004	2005	2006	2007	2008
Avoided CO_2 (kt)	55	29	124	137	149	397	444	457

Source: SEI

The cumulative avoided CO_2 emissions by CHP plants since 2001 is 1,791 kt CO_2. Apportioning all of the CHP CO_2 emissions savings in 2008 to the electricity generated by CHP in that year results in the net reduction of 248 g/kWh compared to the electricity generated by the operating margin mix.

14 Note that the historical figures for the avoided CO_2 emissions were revised for this update. The heat output used is the amount of heat useful employed.

8. Primary Energy Savings

Primary energy savings are the savings in primary energy achieved when CHP is used to provide the heat and electricity outputs, instead of separate production. The amount of primary energy savings (PES) provided by CHP is calculated according to the formula specified in the European Directive on the promotion of cogeneration.[15] Using this method the primary energy savings are calculated as a percentage of the overall primary energy use for separate heat and electricity generation. The results are shown in Table 10. The directive specifies that there must be primary energy savings at least 10% compared to separate production of heat and electricity. This calculation is based on useful heat only, so the result is determined by the accuracy of the useful heat responses in the annual CHP survey. There have been primary energy savings in each year since 2001, but the European Directive level of 10% was achieved only in 2003 and each year from 2005 to 2008. However, in these years the level was surpassed, with savings ranging between 20% and 29%.

Table 10 Primary Energy Savings

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Primary Energy Savings	0%	7%	4%	21%	9%	20%	29%	23%	27%
PES (GWh)	-	-	-	631	-	576	2,075	1,859	2,054

Source: SEI

15 European Union, 2004. Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market. Available from: http://europa.eu.int/eur-lex/pri/en/oj/dat/2004/l_052/l_05220040221en00500060.pdf