Final Report

Report 3

Consultancy Study of

Energy Efficiency Regulations for New Dwellings and Options for Improvement

For the
Department of the Environment, Heritage and Local Government

UCD Energy Research Group
University College Dublin
Richview, Dublin 14
Ireland

In collaboration with

Emerald Energy
Energy Consultants
52 Croyden Green
Marino, Dublin 3
Ireland

Gardiner and Theobald
International Project and Cost Consultancy
43-49 Sir John Rogersons Quay
Dublin 2
Ireland

Esbensen Consulting Engineers
Carl Jacobsensvej 25 D
DK -2500 Valby
Denmark

Acknowledgements

The study team, comprising Vivienne Brophy, Prof J.Owen Lewis and Geraldine O'Daly, UCD ERG, Ciaran King, Emerald Energy, David Myers, Mike McCann and Ciaran Coates, Gardiner and Theobald, and Niels Ulrik Koefoed, Esbensen, wish to thank those who contributed to this study and report.

- The Department of the Environment, Heritage and Local Government - Pat Minogue and the study Steering Group comprising Chris O'Grady, Brian O'Neill, Sarah Neary and Mary Lane

- The architects who provided building design and construction details of current new build dwellings - OMP Architects, DTA Architects and MosArt.

- The construction industry bodies and individuals listed in the Section 3.0.

- The European research collaborators listed in Section 2.1.

Vivienne Brophy
Director UCD ERG
Study Project Manager

Contents

1.0. Introduction

1.1. Background

The Kyoto Protocol came into force in 2005 and the proposed targets of reducing greenhouse emissions by an average 5% compared with 1990 levels by the period 2008 - 2012 became legally binding for those Parties with commitments under the Protocol (UNFCCC, 1997). Under a burden-sharing agreement for the 15 Member States in the EU when the Protocol was agreed in 1997, Ireland's target under the Kyoto Protocol is to limit greenhouse gas emissions to 13% above 1990 levels. That level was reached in 1997. On the basis of current projections and given the full implementation of measures to reduce emissions included in the National Climate Change Strategy 2007-2012 (Government of Ireland DEHLG, 2007), Ireland's greenhouse emissions will be some 19% above 1990 levels by 2012. This Strategy proposes that the balance of Ireland's Kyoto Protocol commitment will be met by the purchase of allowances through the Kyoto Protocol's flexible measures.

The EC Green Paper on Energy Efficiency (EC, 2005), states that it is possible for the EU-25 Member States to achieve energy savings of 20% by 2010, and sees the greatest proportion of these savings (32%) coming from the built environment.

In Ireland the residential sector accounts for 26% of primary energy consumption and 27% of energy related CO_2 emissions (11,376 kt CO_2), and the average existing dwelling emits approximately 8.2 tonnes of CO_2 emissions, 5 tonnes from direct fuel use and 3.2 from electricity use (O'Leary et al, 2005). Improvements in Building Regulation (1997, 2002 and 2005) and fuel switching have resulted in a significant reduction in energy use and related CO_2 emissions associated with new dwellings at a time of exceptionally high housing output (residential new build construction reached 90,000 completed units in 2006) and fuel switching has also contributed to the reduction. The typical new build dwelling, built to current 2005 Building Regulation standards, uses 157 kWh per square metre floor area of primary energy and emits 33.4 kg/m^2 of CO_2 per year.

The National Climate Change Strategy 2000 (Government of Ireland DEHLG, 2000), which provides a framework for achieving emission reductions in an efficient and equitable manner while continuing to support economic growth, identified three key areas with regard to strategies to reduce CO2 emissions in the built environment sector as:

- Increasing efficiency in new homes through revisions of the Building Regulations
- Energy efficiency improvements in the existing stock
- Fuel switching to 'cleaner' fuels.

The National Climate Change Strategy 2007-2012, the Government White Paper "Delivering a Sustainable Energy Future for Ireland" (Government of Ireland DCMNR, 2007a) and the Bioenergy Action Plan for Ireland (Government of Ireland DCMNR, 2007b) include a commitment to continue the process of tightening Building Regulations to aid in the reduction of carbon emissions, through amendment of the Building Regulations in 2008 to deliver a 40% energy reduction and related CO_2 emissions reduction in new build construction.

The EU Energy Performance of Buildings Directive (EPBD) (EU, 2002), transposed into Irish legislation by the Building Control Bill 2005, requires a review of energy regulations every five years, and for dwellings, this next review is due in 2008.

An Agreed Programme for Government (Government of Ireland DT, 2007) provides A Blueprint for Ireland's Future for 2007-2012. Areas of particular importance include combating climate change and commitments have been outlined across three energy pillars for its achievement – security of supply, environmental sustainability and energy competitiveness. In particular the Government have committed to 'introducing new national building standards in 2007 to ensure that new housing has 40% lower heat energy demand than existing building standards and revise them again in 2010 to achieve a 60% target in further years'.

This has provided the requirement for the timescale of the 2008 review to be revised to facilitate the introduction of new standards in 2007.

1.2. Aim and scope of study

This study relates to the regulation of energy use and CO_2 emissions associated with new dwellings.

The aim of the study, as set out in the DEHLG Request for Tender, is to provide a well-researched and supported basis for the review and amendment of Building Regulations governing the energy efficiency of new dwellings that will:

a. make the maximum practicable contribution to Government CO_2 targets, and, in particular, meet the target of 40% improvement on current standards for new dwellings;
b. be comparable with the best in Europe;
c. be clear, unambiguous, and reflect Government policy on Better Regulation.

The study should

a. evaluate the performance of dwellings complying with current Regulations and compare to the performance of similar dwellings complying with requirements of selected Member States of the European Union;
b. critically assess the format and coverage of the current Regulations, compare with similar Regulations in other Member States leading to specific proposals in form, structure and coverage of amended Regulations;
c. identify a range of measures that could contribute to the achievement of the target of 40% improvement of current standards for new dwellings;
d. propose at lease two optional packages of measures that could be implemented to achieve the stated target. One option should, in addition to meeting the target, focus on the potential of the amended Regulations to incentivise the use of renewable technologies
e. identify and quantify, insofar as possible, the main costs, benefits and impacts of both the measures identified and of the packages proposed.

1.3. Study team

The study has been undertaken, in response to the Request for Tenders entitled Consultancy Study of Energy Efficiency Regulations for New Dwellings and Options for Improvement, as issued by the Department of the Environment, Heritage and Local Government, by UCD Energy Research Group, University College Dublin, in collaboration with Emerald Energy, Energy Consultants, Gardiner and Theobald, International Project and Cost Consultancy, Dublin, and Esbensen A/S Consulting Engineers, Valby, Denmark.

Participant Roles

The aim of the proposed study outlined above and the achievement of its objectives required in depth knowledge of European energy regulatory frameworks, Government strategies and policy, building control and regulations, Irish building stock, Irish construction industry practices, the design and construction process, the energy performance of newly built dwellings and assessment methodologies, together with experience of innovative design and construction and the integration of renewable energies and methods of cost benefit analysis.

A collaboration was formed to provide highly skilled and knowledgeable personnel with extensive relevant prior experience to undertake the study’s defined tasks.

- **UCD Energy Research Group** brought knowledge of European and Irish legislation, the Irish construction industry and the process of delivering energy efficient dwellings
- **Emerald Energy** brought in-depth understanding of residential energy use and assessment procedures
- **Gardiner and Theobald** brought experience in undertaking cost benefit analysis of energy efficient buildings
- **Esbensen** brought 'lessons learnt' from Denmark on the issues to be addressed in achieving design and construction performance and the integration of innovative and renewable energy technologies

1.4. Study Timescale

The timescale for the study was set out in the Request for Tender in April 2007 as approximately 20 weeks to support the DEHLG in the development of an amendment to the building regulation governing energy efficiency in 2008. The subsequent Agreed Programme for Government, published in June 2007, brought forward the amendment to 2007. This necessitated a review of the study programme of work, resulting in the parallel undertaking of certain tasks and deliverables to prioritise the information necessary to support the DEHLG in developing the draft regulation for EC and national consultation by mid-September.

The Draft Report 1 outlined study progress at Week 9, with Draft Final Report 2 providing study outcomes at Week 13. This is Final Report 3. All of the tasks set out in the DEHLG Request for Tender have been completed and delivered.

A single task, in which it was intended to propose mechanisms for achieving higher building energy performance in the future, which was not requested in the Request for Tender but included in the study team's proposal, has not been undertaken due to time constraints and the provision of additional information (see Addendum) to support the DEHLG in their determination of the Draft Technical Guidance Document L (New Dwellings) of 21 September 2007.

2.0. Study Methodology and Recommendations

The Request for Tender proposed the execution of the study in three phases;

a. Phase 1: Current Regulations and International Comparisons
b. Phase 2: Format of Regulations
c. Phase 3: Analysis of Options

2.1. Current regulations requirements and EU Member States comparison

2.1.1. Review of current energy efficiency requirements in Ireland

A review was undertaken of energy use and CO_2 emissions associated with new built dwellings and major renovations to provide a comprehensive overview of the current regulations. The review of energy efficiency requirements took account of Building Regulations 2005, Technical Guidance Document (TGD) Part L Conservation of Fuel and Energy and several provisions of Building Regulations 2002 TGD Part F Ventilation and Building Regulations 1997 TGD Part J Heat Producing Appliances.

2.1.2. Comparative analysis of the requirements of current energy efficient requirements for new dwellings with five EU Member States

A comparative analysis of the requirements of current energy efficient requirements for new dwellings in five EU member States was undertaken.

The EU Member States selected for comparison were England & Wales, Denmark, France, Germany, and the Netherlands. All of these EU Member States have energy performance regulations considering transmission losses, ventilation, space and water heating, internal and solar gains, and some have advanced regulations for lighting and integration of renewable energies. More specifically, the factors in selecting these countries included stricter energy performance in buildings, as in the case of current Danish and German regulations for residential buildings; advanced regulations regarding intermittent and demand controlled ventilation, as in the case of France; lighting and renewable energy integration, as in The Netherlands; and climatic similarities, as in England & Wales and Denmark; and similar construction procurement methods in England & Wales. The requirements in Northern Ireland and Scotland regulations were also referred to within the study for comparative purposes.

A network of collaborators throughout Europe, developed through UCD ERG's participation in EU research projects, provided assistance in this task. The energy efficiency regulation requirements were provided by:

Ireland, Northern Ireland and Scotland: UCD Energy Research Group, Dublin
England & Wales: Building Research Establishment (BRE), Watford
Denmark: Esbensen Consulting Engineers, Copenhagen
France: Centre Scientifique et Technique du Bâtiment (CSTB), Paris
The Netherlands: TNO Netherlands Organisation for Applied Scientific Research, Delft
Germany: Fraunhofer Institute of Building Physics, Stuttgart.

A review of the format of current energy efficiency regulations adopted in compliance with EPBD for new dwellings in five Member States is outlined in section 2.2.1. This was the basis of the comparative analysis of energy use and CO_2 emissions in representative dwellings according to Irish and Member States' energy efficiency standards, normalised for climatic differences and outlined in section 2.1.4.

2.1.3. Selection of representative dwellings

A review was undertaken of new build dwelling construction from 2003 to 2006. Sources included the Dept of Environment, Heritage and Local Government Annual Housing Statistics Bulletin, the Central Statistics Office Construction and Housing Statistics, DKM Economic Consultants Ltd Annual Review of the Construction Industry, and Sustainable Energy Ireland's Energy Consumption and CO_2 Emissions in the Residential Sector.

The following representative sample of new dwellings was selected. Dwelling type total percentage (eg. semi-detached 49%) is representative of recent new build dwelling construction, but has been further broken down to facilitate the study procedures.

ID	Type	% new build	Floor area m²	SH fuel
1	Bungalow	9	104	oil
2	Detached small two storey	9	126	oil
3	Detached large two storey	9	280	oil
4	Semi-detached small two storey	16	96	gas
5	Semi-detached medium two storey	17	126	gas
6	Semi-detached large two storey	16	160	oil
7	Terraced three storey	3	105	gas
8	Apartment small mid-storey dual aspect	11	54	electric
9	Apartment duplex two storey dual aspect	10	84	gas

Samples of current new build dwellings were supplied by OMP Architects, DTA Architects and MosArt to confirm typical area, form, glazing ratios, and construction methods and were utilized, in conjunction with notional dwellings, to undertake Dwelling Energy Assessment Procedure (DEAP) assessments.

Average floor area of the above dwellings is 126 m^2. Information on average floor areas of the different dwelling types currently being built was not available. Further details of the representative dwellings are included in Appendix A.

2.1.4. Comparative analysis of energy use and CO_2 emissions in representative dwellings according to Irish and EU member States' energy efficiency standards

A comparative analysis of the energy use and CO_2 emissions of the representative set of dwellings was undertaken with the DEAP methodology applying both the current TGD Part L requirements to confirm compliance and the energy efficiency requirements of the selected five EU member States.

Compliance with current Irish regulations

Each of the selected nine dwellings was made to just comply with current TGD L guidance, using reasonable values for aspects not covered by TGD L. All dwellings were taken to have a regular rectangular shape. For the comparative analysis, all dwellings were assumed to have gas central heating and electric secondary heating as requested. DEAP results were as follows.

	D1	D2	D3	D4	D5	D6	D7	D8	D9	Avg
Primary Energy [kWh/m²y]	169	152	127	152	142	135	135	137	133	143
CDER [kg/m²]	33.6	30.4	25.5	30.3	28.5	27.0	27.0	27.5	26.7	28.6

The average above is the average by dwelling, taking account of the percentage of new construction represented by each dwelling type. It is not the average by floor area.

England & Wales regulations

Approved Document L1A includes five compliance criteria, summarised as follows:

1. The annual CO_2 emission rate of the completed dwelling, as calculated using SAP 2005, must not exceed the target set by reference to a notional building.
2. Building fabric and services performance specifications are within reasonable limits.
3. The dwelling should have passive control measures to limit the effect of solar gains on temperatures in summer.
4. The performance of the dwelling, as built, should be consistent with the design performance.

5. The owner should be provided with information on the building and its services to allow it to be operated efficiently.

Regarding Criterion 1 above, the terminology used is that the Dwelling Emission Rate (DER) must not exceed the Target Emission Rate (TER). The target emission rate is obtained using the reference dwelling specified in Appendix R of SAP 2005, adjusted for fuel type and improvement factor. The improvement factor is set at 20%, i.e. a 20% improvement in performance relative to the reference dwelling is required. Lighting is excluded – this requirement includes space heating, ventilation and water heating only.

The fuel factors are set in order to make some allowance for the differences in emission factors for different fuels. The fuel factor for a given fuel is calculated as follows: it is the greater of 1.0 and the square root of the ratio of the CO_2 emission factor of the fuel to the emission factor for mains gas. This tends to make it more difficult to comply using coal than oil, and using oil than gas, providing some incentive to use lower-emission fuels.

Renewable fuels such as wood pellets have the same fuel factor as gas. This would make it very easy to comply with the TER requirement if, for example, a wood pellet boiler was used. Gross inefficiency in other aspects is then prevented by Criterion 2 above.

To allow comparison with the proposal for TGD L in this report, fuel factors are shown below. The "equivalent relaxation factor" (calculated here; not part of the UK regulations) is a measure of the amount of relief given to each fuel regarding ease of compliance, relative to gas. A relaxation factor of 0 provides no relief, i.e. the Target Emission Rate is the same regardless of the fuel used. A relaxation factor of 1 gives full relief; it makes it more or less equally easy for any of the fuels to comply.

Fuel factors in the England & Wales 2006 regulations

Fuel	**CO_2 emission factor**	**Relative to gas**	**Fuel factor**	**Equivalent relaxation factor**
	[kg/kWh]			
Mains gas	0.194	1.00	1.00	
LPG	0.234	1.21	1.10	0.49
Oil	0.265	1.37	1.17	0.46
Grid electricity	0.422	2.18	1.47	0.40
Solid mineral fuel	0.317	1.63	1.28	0.44

For a particular dwelling, the use of electric pumps will slightly modify the relief. Also, the fuel used for secondary heating, if different than that used for primary heating, will affect ease of compliance.

Renewables procured outside the dwelling (wood fuel, biogas) are given a fuel factor of 1.00, hence they are fully incentivised under the CO_2-based compliance criterion.

In Scotland, a separate reference dwelling is specified for each main space heating system fuel, thereby avoiding the need for fuel factors. Pending a more detailed investigation, the effect appears to match that of the England & Wales fuel factors.

In Northern Ireland, the England & Wales fuel factors for LPG, oil, grid electricity and solid mineral fuel are multiplied by 1.14. Resulting fuel factors are as follows.

Fuel	**CO_2 emission factor**	**Relative to gas**	**Fuel factor**	**Equivalent relaxation factor**
	[kg/kWh]			
Mains gas	0.194	1.00	1.00	
LPG	0.234	1.21	1.25	1.23
Oil	0.265	1.37	1.33	0.91
Grid electricity	0.422	2.18	1.68	0.58
Solid mineral fuel	0.317	1.63	1.46	0.72

Requirements under Criterion 2 include limits on fabric U-values, fabric air permeability, heating appliance efficiencies, heating system control, insulation of pipes, ducts and vessels, mechanical ventilation systems, mechanical cooling systems and artificial lighting. These are commented on below.

Fabric U-values

Limits on elemental U-values (given in ADL1A Table 2) are not stringent, in the sense that most elements would need to have considerably better U-values for the dwelling to meet the TER requirement, if renewable energy is not used. U-values for windows take account of inclination, e.g. whether they are vertical or horizontal.

Fabric air permeability

The upper limit of design air permeability is given as 10 m^3 per m^2 of envelope area per hour at an internal-external pressure difference of 50 Pa. Envelope area includes non-exposed as well as exposed envelope elements. In many dwellings, the volume in m^3 and envelope area in m^2 are roughly numerically equal, so that 10 $m^3/m^2.h$ at 50 Pa corresponds roughly to 10 air changes per hour at 50 Pa, or 0.5 ac/h under average ambient conditions. In some aspects of SAP (e.g. the Appendix Q procedure for mechanical ventilation with heat recovery), these are treated as numerically equal.

Heating systems

Minimum appliance efficiencies, minimum levels of heating system control, and other heating system requirements, are given in the UK Government's Domestic Heating Compliance Guide. Regarding some aspects, the requirements are specified through reference to British Standards documents.

Mechanical ventilation systems

ADL1A references the UK Energy Saving Trust document "Energy Efficient Ventilation in Dwellings", and in addition specifies maximum specific fan power values and minimum heat recovery efficiencies. The SAP Appendix Q procedure supports energy-efficient mechanical ventilation by giving credit for energy-efficient aspects.

Mechanical cooling systems

Mechanical cooling systems are allowed. Their minimum energy efficiency classification is specified via a reference publication.

Artificial lighting

The regulations cover not just the lamps, but the whole light fitting including lamp, control gear, diffuser or shade, etc. Low-energy light fittings are considered to be those having a luminous efficacy of at least 40 lumens per circuit-Watt. The regulations require either one such light fitting per 25 m^2 of floor area, or one per four fixed light fittings. External lighting is also subject to regulation.

Criterion 3: Limiting the effects of solar gain in summer

ADL1A states that a dwelling's risk of overheating should not be "high" when assessed using the SAP Appendix P procedure.

Criterion 4: As-built performance

ADL1A indicates that pressure test results should be submitted to the local authority, and that, if the "approved construction details" approach to continuity of insulation is followed, a report demonstrating adequate site inspection should be produced, preferably signed by a suitably qualified person.

The area of enforcement of Building Regulations in Ireland will be subject to important new provisions in the Building Control Act 2007. Anecdotal evidence would indicate that real challenges exist in ensuring that as-built performance matches the requirement of the regulations.

Comparison with England & Wales regulations

The England & Wales regulations were compared to the current Irish ones as follows. The England & Wales reference dwelling parameters, from Appendix R of the SAP documentation, were entered to the DEAP calculation workbook for each of the nine representative dwellings. As stated above, for the comparison, all dwellings were assumed to be heated by natural gas, with electric secondary heating. As lighting is covered in the England & Wales ADL1A “Limits on design flexibility”, 30% was considered to be an appropriate proportion of low-energy lighting. The specified 20% improvement factor was applied to the results, which were then compared with the Irish ones. The results were as follows.

Ratio of England & Wales performance to Irish performance

(A number < 1 implies a better performance under the England & Wales regulations).

	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**Avg**
Primary Energy	0.79	0.80	0.79	0.80	0.79	0.78	0.78	0.77	0.78	0.79
CO_2	0.78	0.79	0.78	0.79	0.78	0.78	0.77	0.76	0.78	0.78

The result was a performance ratio (England & Wales / Irish) of 0.79 and 0.78 (i.e. 21% and 22% respectively better in England & Wales).

It is more difficult to comply with the England & Wales regulations if the dwelling is heated by oil or electricity rather than gas. When this is accounted for, the England & Wales regulations are stricter than the Irish ones by a larger margin than above. DEAP calculation spreadsheets for Ireland and England & Wales are included in Appendix B.

Northern Ireland regulations

These are quite similar to those of England & Wales, though the fuel factors are different as discussed above. These fuel factor adjustments have the effect of making the required efficiency standard, in terms of CO_2 emission rate, less strict for higher-carbon fuels.

Scottish regulations

Compliance under these regulations is based on SAP as in England & Wales, but instead of using the SAP reference house together with an improvement factor and fuel factors, a different reference house is used for each of six heating system types. The required standards, in terms of CO_2 emission rate, correspond to those of England & Wales.

Danish regulations

Compliance is achieved by using the Danish equivalent of DEAP to calculate the energy per m^2 of floor area for space heating, water heating, ventilation and cooling, and ensuring that this is below a maximum allowable value. Lighting is excluded. The basis is effectively primary energy, as electricity is given a weighting of 2.5 compared to fuels such as oil and gas and heat from district heating schemes.

In addition, there are limits on particular aspects: average U-value of the dwelling excluding windows and doors, U-values of building elements, air tightness, boiler efficiency, and for heat recovery ventilation, specific fan power and heat exchanger efficiency.

Dependence on floor area

The maximum "primary" energy consumption is expressed in terms of floor area A as follows:

$$70 + 2200 / A \ [kWh/m^2y]$$

For apartment buildings, the floor area used is that of the whole building rather than the individual apartment.

Effects of this are that efficient dwelling forms are encouraged, and irregularities such as dormer windows are penalised. Also, the inverse dependence of the target on floor area tends to reduce the inherent advantage of large dwellings over small ones in terms of performance per square metre.

Air tightness

The maximum air leakage rate is 1.5 l/s per m^2 heated floor area at 50 Pa. It is noted that this is based on floor area rather than envelope area as in England & Wales. 1.5 l/s is equal to 5.4 m^3/h. In a dwelling of normal room heights, this translates into an average air-change rate under ambient conditions of 0.11 air changes per hour. This level of air-tightness is consistent with whole-house mechanical ventilation, which is standard in new dwellings in Denmark.

Comparison with Danish regulations

The comparison was carried out by Irish and Danish participants in the project team. Details of a typical Irish semi-detached house were entered to the Danish energy calculation software, Be06. The house initially just complied with the Irish regulations, and was then improved until it just complied with the Danish "energy frame" requirement. The result was a performance ratio (Danish / Irish) of 0.69 (i.e. 31% tighter in Denmark).

If further comparisons were carried out with other dwelling characteristics and other dwelling types, somewhat different results would be expected. Also, as the Irish and Danish regulations do not cover exactly the same aspects of a dwelling, the results would depend on assumptions made regarding aspects not covered by one or other. With these factors in mind, uncertainty in this estimate is considered to be plus or minus 5%.

Regulations of Germany, The Netherlands and France

Information on building regulations in each of these countries was obtained from collaborators in each country, and in particular, details on compliance requirements for a typical semi-detached house were obtained. Based on this information, an analysis was carried out to form an impression of how these regulations compare to current Irish requirements.

Comparison of regulations in different countries is difficult, as compliance in each of these countries is based on an energy assessment procedure, and the results of these are not directly comparable. Also, the “small print” can have significant effects.

The results obtained are tentative, but they suggest that the energy performance of dwellings just complying with the regulations in Germany and Netherlands are each in the region of 20 % better than that in Ireland, and that in north-eastern France (the region with the coldest winters) about 5% better, with an uncertainty of plus or minus 10%.

2.2. Current regulations format and EU Member States comparison

The EU Directive on the Energy Performance of Buildings, of which Articles 3, 4 and 5 refer to new build construction, requires that Member States set, either at national or regional level, energy performance requirements for new buildings; apply, at national level, a methodology of calculation expressing energy performance in a transparent manner; and ensure that in buildings over 1,000m² the feasibility of alternative energy systems is considered. Overall measures can be backed up by additional requirements.

Different Member States use various methods of specifying minimum energy performance requirements, including CO_2, primary energy requirements, final or net energy requirements, component and system requirements (U-values, mean U-values, service system efficiencies)and special indicators (for prevention of overheating in the summer). The minimum requirements may be expressed as a specific number (eg in the case of maximum U-values), a function of some indicators (maximum energy demand dependent on the surface-to-volume-ratio and/or the floor area) a comparison with a reference building or the ratio between the calculated energy performance and the reference energy requirement.

A review of the format of the regulations adopted in the selected EU Member States – Denmark, France, Germany, The Netherlands and England & Wales was undertaken. The findings are included in Appendix C. A summary of the findings is outlined below.

2.2.1. Review of the format of current energy efficiency regulation for new dwellings in five EU Member States

Ireland

In Ireland the 2005 amendment to Part L (Conservation of Fuel and Energy) of the Building Regulations and Technical Guidance Document (TGD) L, provide for the implementation of Articles 3, 4 and 5 of the EPBD. The aim of TGD Part L is to limit the use of fossil fuel energy and related CO_2 emissions arising from the operation of buildings. For dwellings the primary method of demonstrating compliance is to show that the calculated rate of CO_2 emissions associated with the operation of the dwelling does not exceed a specific target value. The carbon dioxide emission rate (CDER) is calculated using the DEAP methodology for a reference dwelling of the same size and shape as the dwelling to be assessed with relevant characteristics as specified. There are requirements in the regulations in relation to space and water heating controls, insulation of hot water cylinders and pipe work as well as thermal bridging. Requirements in relation to natural and mechanical ventilation of buildings are detailed in TGD Part F 2002 and in relation to heat producing appliances are detailed in TGD Part J 1997.

Denmark, France, Germany, The Netherlands and England & Wales

All five Member States have transposed the EPBD requirements regarding new build construction into law. In all cases government departments are responsible for its implementation. Current building regulations in Denmark, France, Germany the Netherlands and England & Wales are revised to comply with the EPBD.

Each Member State has national building regulations and different methodologies for showing compliance. Denmark, Germany and The Netherlands compare results to an energy target while France and England & Wales compare results to a reference building.

Assessment methodology

Denmark uses a standardised method developed by the Danish Building Research Institute. It is based on a maximum energy consumption target which stipulates that the total weighted energy consumption shall not exceed 70+2200/A where A = total heated area. France has three different climatic zones and has different energy consumption requirements for each zone, although all are calculated and related to a reference energy consumption value (CEP). The CEP must be lower than the reference (CEP ref) and lower than maximum values. Germany calculates primary energy demand which should be equal to or lower than a defined maximum value based on a surface to volume ratio. The Netherlands was an overall energy performance target based on surface area. The England & Wales Standard Assessment Procedure (SAP) calculates CO_2 emissions in comparison with a target CO_2 Emissions Rate (TER) for the whole building. Energy consumption is measured in $kWh/m^2/y$ and CO_2 emissions in $kgCO_2/m^2y$.

Each country inputs information on the building envelope including U-values, thermal bridging and infiltration, ventilation, heating and hot water systems into their calculations.

Countries which have specific requirements for the following include:

Heating controls: Denmark, Germany, England & Wales.

Minimum insulation levels for water tanks / pipework: Denmark, Germany and England & Wales

Boiler efficiencies: Denmark and England & Wales

Minimum natural ventilation: Denmark, France, England & Wales

Minimum mechanical ventilation: Denmark, France, Germany, England & Wales

Thermal bridging: Denmark, Germany, England & Wales

Energy efficient fixed lighting: England & Wales

Fuel type: No country has specific requirements

Renewable technologies: No country has specific requirements

Ban on artificial cooling: No country has specific requirements

Maximum U-values (The Netherlands EPC calculates min. U-values)

	Denmark	**France**	**Germany**	**Netherlands**	**Eng & Wales**
Walls	$0.4W/m^2K$	$0.26W/m^2K$	$0.23W/m^2K$	_	$0.35W/m^2K$
Floors	Unheated 0.4 Heated 0.3	Ground floor 0.27	Ground floor 0.24	_	0.25
Roofs	0.25	0.18	0.18	_	0.16
Windows & doors	Before Jan 2008 2.3 After Jan 2008 2.0	Windows 2.2 Doors 2.73	1.3	_	2.0

Conformance result

Energy rating expressed in kWh/m^2y: Denmark, France, Germany

Cost based: England & Wales

Primary energy: Denmark, France, Germany and The Netherlands

Testing

Post construction testing: Denmark, England & Wales

Air-tightness testing: England & Wales. Occasionally in Denmark, France, The Netherlands

Thermography: No country has requirements.

Other testing: None

Responsibility for enforcement of regulations

Denmark: Danish Enterprise & Construction Authority. A permit is issued to allow occupation of the building following proof of compliance with the energy requirements

France: Ministry of Dwelling. Verification of compliance required by the regional state technical centre - CETE

Germany: The Federal States of Germany. Energy performance calculations and energy performance certificates collected by the cities' administration.

The Netherlands: The Municipality checks that the calculations are correctly carried out and that they correspond with the drawings

England & Wales: The Building Control Authority enforces compliance either directly or through Approved Inspectors.

Inspection

On site inspection: Germany, England & Wales.

Both Denmark and The Netherlands issue a permit for building use following completion of the building which is based on the finished building being shown to conform to the original specification. In France the architect and contractor carry responsibility for the building and are obliged to hold appropriate insurance.

Building Energy Rating

Provisional and Final BER for dwellings: Denmark, Germany.

France is planning a provisional BER. The Netherlands relies on the information supplied for the Building Permit. England & Wales will introduce BER before January 4th 2009. Meanwhile the Target CO_2 Emissions Rate is being used.

2.3. Proposal for Technical Guidance Document (TGD) Part L

2.3.1. Proposal for DEAP related compliance criterion in TGD L

A compliance criterion for dwellings in TGD L that will achieve a 40% improvement in performance is required. Two measures of performance have been specified – primary energy consumption and carbon dioxide emissions, and DEHLG has requested a 40% improvement in each, when averaged nationally across new dwellings. DEHLG has also requested that renewables be incentivised, and the reduction of carbon dioxide emissions has been accorded a high priority in policy documents.

The current DEAP-related compliance criterion in TGD L, the Maximum Permitted Carbon Dioxide Emission Rate (MPCDER), is based on CO_2, but generally excludes heating systems. When these are included, it will become difficult for high-carbon fuels to comply with a more challenging MPCDER target. The England & Wales regulations address this difficulty, without getting rid of it entirely, by means of a “fuel factor”. However, such fuel factors have disadvantages that are discussed later, and a more robust method of dealing with this fuel issue was sought. Also, there are significant savings to be achieved through incentivising an efficient dwelling form. A workable means of implementing this was also sought.

Proposal summary

The proposals in this document fall into two categories – the framework and the values. The values may be adjusted while retaining the framework.

The dwelling is assessed using DEAP. The proposed criterion of energy performance for TGD L compliance is based on an average of primary energy and CO_2 emissions, and is determined as follows:

- A reference dwelling related to the actual dwelling is also assessed using DEAP
- The primary energy requirement of the actual dwelling is divided by that of the reference dwelling to give a “Primary energy Performance Coefficient” (PPC)
- **-**The carbon dioxide emission rate of the actual dwelling is divided by that of the reference dwelling to give a Carbon dioxide Performance Coefficient” (CPC)
- **-**The average of PPC and CPC is determined, and is called the Energy Performance Coefficient (EPC) of the dwelling
- **-**To comply, the EPC must not exceed a Maximum Permitted EPC (MPEPC).

It might be reasonable for one to ask if it is correct for an “energy” performance coefficient to include CO_2 emissions. The response is that here the term “energy performance” is taken to include the environmental as well as resource consumption aspects of the dwelling’s energy use.

In averaging the PPC and CPC to calculate the EPC, the weighting given to the CPC governs the degree of incentivisation of renewable fuels and the corresponding level of penalty for higher-carbon fuels. This issue is discussed below. Here a weighting of 50% is given to each, so the EPC is a straight average.

Initially, the reference dwelling will be set to match current standards, and the MPEPC will be set at a level giving the requested improvement; the calculation of this level is described below. In subsequent revisions of TGD L, the MPEPC value may be reduced without changing the reference dwelling; for example, reducing it from 0.80 to 0.60 will yield a 25% improvement in performance.

To incentivise efficient dwelling forms, the reference dwelling does not have the same shape as the actual, but has an exposed envelope area based on its volume. It is thus easier for a compact dwelling to comply than an irregularly-shaped one. It is also easier for an apartment to comply than a detached house, by virtue of its lower exposed-surface-to-volume ratio.

Basis: primary energy vs. carbon

There are different ways of defining primary energy, and of evaluating CO_2 emissions. The following discussion is based on the DEAP primary energy and CO_2 factors.

Basing the compliance criterion on primary energy, as in Denmark, Germany, The Netherlands and France, ensures that the specified standard of energy efficiency is met, but does not incentivise low-carbon fuels.

Basing the compliance criterion on carbon dioxide emissions, as in England & Wales, provides an incentive to switch from higher-carbon to lower-carbon fuels (e.g. oil to gas), and from fossil fuels to renewable fuels such as wood pellets. However, this incentivisation works by relaxing other efficiency requirements, so too much incentivisation can lead to poor energy efficiency standards in other aspects of a dwelling heated by wood fuel. Furthermore, some such aspects are subsequently more difficult to change than the boiler type, e.g. insulation levels, dwelling shape, orientation.

Also, basing the compliance criterion on carbon dioxide can make compliance quite difficult for dwellings not on the gas grid and heated by higher-carbon fuels. In England & Wales, a "fuel factor" was introduced to relax the requirement for such fuels and electricity. However, apart from being cumbersome, this has the side-effect that heat pumps benefit. Heat pumps are not an existing high-carbon technology, and therefore fall outside the heating system types that the fuel factor is intended to support. This side-effect allows lower energy standards in other aspects of a dwelling heated by a heat pump. It has been suggested (UK DCLG, 2007) that the fuel factor for heat pumps be set to that of gas in 2010.

In England & Wales, the gas grid serves a greater proportion of new dwellings than in Ireland or Northern Ireland. In Northern Ireland, the fuel factor for higher-carbon fuels and electricity was increased above that in England, presumably to provide further relaxation for heating systems using such fuels.

The supply of agricultural land for growing wood fuels is not infinite; this is an issue that will become increasingly important in coming years. For this reason also, it is considered that a compliance criterion based purely on carbon gives too much incentive to wood fuels, at the expense of efficiency.

The use of a weighted average of PPC and CPC as the basis for compliance can allow an appropriate level of incentivisation of low-carbon fuels to be specified. The weighting for CO_2 proposed here is 50%, i.e. equal weighting to primary energy and CO_2. If this were to make compliance excessively difficult at this stage for dwellings not on the gas grid and heated by higher-carbon fuels, given that the wood pellet supply industry is not yet well-established in Ireland, a lower weighting for CO_2 could be specified initially, then raised to 50% in a subsequent revision of TGD L. However, the investigations described below suggest that the 50% weighting can be achieved at present without excessive difficulty for such dwellings.

A 50/50 weighting to the PPC and CPC is proposed because in principle, it reflects the seriousness of the problems of both finite energy resources and climate change, and in practice it gives what is considered to be an appropriate level of incentivisation of lower-carbon fuels.

With reference to the section of this report on the England & Wales regulations, in which relaxation factors for the different fuels are given, the corresponding relaxation factor for all fuels under the proposed EPC compliance criterion for Ireland is the weighting given to primary energy, i.e. 0.50 for a 50/50 weighting of EPC/CPC. This is fairly close to the current relaxation factors in England & Wales.

Basing compliance on an average of PPC and CPC, rather than a separate requirement for each (i.e. two requirements), has the advantage that better performance in one is tradable against poorer performance in the other. For example, a house heated by oil may do better on primary energy, whereas one heated by wood-pellets may do better on CO_2. As with DEAP generally, this tradability allows the most cost-effective solution in each case to be adopted. For given national reduction targets for primary energy and CO_2, it makes no difference in terms of sustainability whether these are achieved uniformly across all dwellings or whether some dwellings do better on one and other dwellings do better on the other, but they can be achieved more cost-effectively under the proposed compliance criterion.

Reference dwelling vs. equation

The England & Wales compliance criterion is determined based on a reference dwelling, whereas the Danish, German and Dutch requirements are based on a mathematical equation involving floor area, volume, and/or exposed surface-to-volume ratio. In the case of Denmark, for apartments it is the floor area of the building that is used rather than that of the apartment.

An advantage of having a reference house is that, if changes are made to the energy assessment procedure or to the data it uses, these affect both actual and reference dwellings, so the performance, measured in relation to the reference dwelling, should not be substantially affected. With a formula, a change in the assessment procedure requires a change in the equation. Examples of possible future changes to DEAP include the primary energy and CO_2 factor for electricity as more wind power comes on-line, and changes in hot water consumption, internal gains, and standardised number of occupants as functions of floor area in the light of new or updated information.

Another advantage of the reference house approach is that it is easier to set up – and to update if the assessment procedure or accompanying data changes. With an equation, careful analysis of a range of dwelling types must be carried out to determine the best-fit curve. As well as dwelling form and size, the relation between internal gains and floor area within the assessment procedure may affect the best choice of equation. The use of a reference dwelling automatically allows for such effects.

Of course, a compliance criterion in the form of a constant energy performance limit per m^2, e.g. “Calculated energy performance must not exceed 110 kWh/m^2 y” is simple to set up. However, this would favour large dwellings over small ones by virtue of their smaller exposed-surface-to-volume ratio, which could be counter-productive in terms of energy conservation objectives.

A disadvantage of the reference house as used in England & Wales, i.e. one having the same size and shape as the actual dwelling, is that it does not account for the effect of dwelling shape on fabric heat loss. An equation offers scope for taking account of this. However, a reference dwelling may also be configured to account for the effect of shape – see “Accounting for dwelling form” section over.

Coefficient vs. absolute value

A measure of compliance may be expressed as an absolute value, e.g. kWh/m^2 y, or as a dimensionless coefficient, e.g. kWh/m^2 y of actual house divided by kWh/m^2 y of reference house.

The proposed measure of performance for compliance purposes is an average of primary energy and CO_2 emissions. As these have different units, these must be normalized before they can be averaged, hence the primary energy and CO_2 coefficients are needed for this measure of performance.

Apart from the above, a coefficient has the advantage that it is essentially independent of the dwelling size. In contrast, a measure of performance based on kWh/m^2 y of primary energy tends to favour larger dwellings, due largely to their lower surface-to-volume ratio. Within the DEAP calculation procedure, any non-linearity of factors such as internal gains or hot water usage with respect to floor area is also cancelled out when the coefficient is calculated.

A coefficient also has the advantage that if the energy assessment procedure or its associated data changes, the absolute measure of performance may change, but any change to the coefficient may be negligible.

Accounting for dwelling form

Two aspects of dwelling form influencing heat loss are:

(a) Its shape. A dwelling with a regular rectangular compact shape will have less exposed area than one with irregularities such as bay and dormer windows, recessed porches, or extensions projecting from the main part of the dwelling.

(b) Its type. Other things being equal, a semi-detached house will have less exposed area than a detached house, and an apartment less still.

Rather than having the same size and shape as the actual dwelling, the proposed reference dwelling has the same floor area and volume as the actual dwelling, but its form is fixed. This incentivises efficient dwelling forms.

The exposed envelope area, At, of the reference dwelling is given by

$$At = 5.7 * V^{2/3}$$

where At = exposed envelope area

V = dwelling volume

The index “2/3” above represents the relation between exposed area and volume; it is a reasonable approximation for the range of dwelling types. The coefficient “5.7” is the average value for the representative dwelling types, weighted by floor area and percent of new dwellings represented, after allowing for an average increase in exposed area due to irregularities of 10%.

Apart from increasing the exposed envelope area of new dwellings, irregularities also increase the concentration of thermal bridging between elements, and this is not accounted for in DEAP (except in rare cases where the length and linear thermal transmittance of all such thermal bridges are evaluated for the particular dwelling). Also, in practice both in design and on site, attention to detail regarding insulation thicknesses and thermal bridging avoidance around dormer windows and other small or non-standard irregularities may be less than perfect. For these two reasons, actual savings due to the incentivisation of efficient dwelling form may be greater than that calculated using DEAP.

The effects of this incentivisation of efficient dwelling form are (a) it is easier to comply with a compact rectangular shape than with an irregular shape, and (b) it is easier for apartments to comply than detached houses. Regarding (a), the dwelling’s shape is generally under the control of the designer. Regarding (b), the dwelling type is sometimes under the control of the designer (for example, subject to planning requirements, a developer may have freedom to choose the type or mix of dwelling types on a development site), and sometimes not under his or her control (e.g. a one-off house in a rural area will be detached). A point which may offset the greater difficulty of compliance for one-off detached houses compared to apartments is that, depending on the site, the former may have more opportunity to use passive solar heating.

While a cubic shape is theoretically good for minimising heat loss, it may not always give the best energy performance in reality, since

- If low U-values are easier to achieve in roofs and floors than walls, a “flattened cube” may be better.
- When passive solar gain is accounted for, a rectangular shape with longer facades facing south and north, and with larger windows on the south façade, may be better than a square plan.

- For attached dwellings, a shape which minimises exposed area by maximising attached area is best. For example, a half-cube shape is better than a cube for a semi-detached house (this gives a cubic building shape for a pair of such houses).

It is recommended that TGD L state that, if a proposed dwelling shape contains irregularities, all of the envelope elements, even the small ones, must be accounted for in the fabric heat loss calculation, and should be itemised in the DEAP report to facilitate checking.

Note that bungalows and detached two-storey houses are not treated separately. Thus there is an incentive to design two-storey detached houses rather than bungalows, particularly where larger floor areas are required. It is assumed that this option will be open to the designer in some cases.

In a multi-dwelling building (e.g. apartment block or row of terraced houses), TGD L should state that as an alternative to each dwelling having an EPC not exceeding the MPEPC, it is sufficient that the average EPC of all dwellings in the building, weighted by floor area, does not exceed the MPEPC. There is a similar provision in the England & Wales regulations (UK ODPM, 2006a). This will allow similar specifications in different dwellings in the building, including north-facing and south-facing apartments, or top-floor and ground-floor apartments with different solar access.

Accounting for dwelling form in Draft Final Report

In the Draft Final Report submitted to DEHLG, the recommended method of incentivising efficient dwelling form included a relaxation of the effect of dwelling type. This was included in the Draft TGD L, and is therefore included here for completeness. Both approaches are considered reasonable, though on further consideration, the above (non-relaxed) method is now preferred. The issues on which this preference is based are discussed in the following paragraph. The method itself is then described.

If it is considered that dwelling type (detached, semi-detached, apartment) is not usually under the control of the designer, then incentivising efficient dwelling form will force increasingly less cost-effective measures on detached houses, while requiring less of apartments. Nationally, some relaxation would be more cost-effective. However, if it is considered that dwelling type is usually under the control of the designer, then it is considered better to incentivise it fully. One-off houses in rural areas will always be detached. However, in housing developments in towns and cities, designers may often have the option of choosing dwelling types, and of designing dwellings to maximise attached areas in order to minimise exposed areas. Even when a one-off house in a rural area is being considered, in a few cases options may include building a pair of semi-detached houses for two family members, or for a household not from the area, opting for a development in the nearest village instead. On reflection, it is considered that dwelling type is a design option in enough cases to justify no relaxation. Further slight advantages of no relaxation are that (a) it is simpler, as can be seen by comparing the proposed method above to that below, and (b) it does not require assessors to enter the ratio of exposed to total envelope area.

The details of the method are as follows. The exposed envelope area, At, of the reference dwelling is given by

$$At = 7.0 * V^{2/3} * Rref$$

where At = exposed area

V = dwelling volume

Rref = ratio of exposed to total envelope area for reference dwelling.

The index “2/3” above represents the relation between exposed area and volume; it is a reasonable approximation for the range of dwelling types.

The coefficient “7.0” was arrived at as follows. A coefficient of 6.2 is the value for a detached house of dimensions 9m * 6m * 5.1m, of rectangular shape with no irregularities. This was increased to allow for a typical amount of irregularity, and rounded to 7.0.

“Rref” is given by

Rref = (R – 0.83) * s + 0.83

where R = ratio of exposed to total envelope area for actual dwelling

s = relaxation factor.

0.83 is the pivot value of ratio R. It represents a typical value for a semi-detached house.

The ratio R of exposed to total envelope area is required from the assessor. It is noted that the exposed envelope area is available from the heat loss calculation, and the total envelope area may be available if a pressurisation test has been done; these may be helpful to the assessor in determining R. Typical values of R, and of Rref for a relaxation factor of 0.5, are given in the table below.

Dwelling type	**Sides exposed**	**Typical value of R**	**Corresponding value of Rref (s = 0.5)**
Detached house	6	1.00	0.92
Semi-detached house	5	0.83	0.83
Terraced house	4	0.67	0.75
Peripheral apartment	3	0.50	0.67
Mid-floor apartment, dual aspect	2	0.33	0.58
Mid-floor apartment, single aspect	1	0.17	0.50

A relaxation factor of 0 would give Rref = 0.83 for all dwelling types. This would require similar energy performance from detached houses and apartments, and all other things being equal, would require considerably higher insulation levels in detached houses than in apartments.

A relaxation factor of 1 would give Rref = R for all dwelling types. All other things being equal, this would require similar U-values in detached houses and apartments, and would allow poorer energy performance in detached houses due to the greater heat loss area.

The relaxation factor proposed here is 0.5.

A slight disadvantage of this method is that irregularities in either the exposed or heated envelope can affect the reference dwelling's exposed area, though the effect diminishes as the relaxation factor is reduced.

Another slight disadvantage is that irregularities in the exposed area will reduce the ratio R, offsetting slightly the full accounting of heat loss from the irregularities themselves. However, in most cases the effect will not be large. Again, this effect diminishes as the relaxation factor is reduced.

Reference dwelling specifications

These are given in Appendix D of this document. They are based on the reference dwelling specifications in Tables 37 and 38 of TGD L 2006, with typical assumptions made for aspects going beyond these specifications.

Calculation of MPEPC

All nine representative dwellings were made to just comply with the current TGD L requirements. The average EPC, weighted by floor area and percentage of new dwellings represented, was calculated, and was found to be 1.09. A 40% improvement thus requires an MPEPC of 0.65 (i.e. 1.09 * 0.6).

As the reference dwelling itself just complies with current regulations, one may ask why the average EPC is greater than 1. The reason is that the reference dwelling is heated by gas, whereas four of the nine representative dwellings are heated by oil, and one by electricity. The oil-heated ones have higher CO_2 emissions than gas, and the electrically-heated one has both CO_2 emissions and primary energy higher. If all nine dwellings had gas-fired heating systems as in the reference dwelling, the average EPC would be close to 1.00.

It should be noted that the choice of values for aspects of the reference dwelling not covered by the current regulations, together with the specifications of the representative dwellings, fix the base case against which the required 40% improvement is determined. Examples of such aspects of the reference dwelling include a boiler efficiency of 78%, secondary heating consisting of an open fire, and zero low-energy lighting. Because the current regulations do not cover all aspects addressed by DEAP, there is no "correct" base case from which to measure savings – assumptions are necessary. Also, the nine representative dwellings constitute only an approximate representation of the national new-build dwelling stock; this is an additional reason why the 40% savings prediction should not be regarded as highly precise.

A distinction is made between "regulated" energy performance and "actual" energy performance. Regulated energy performance is based on the assumption that all new dwellings, both currently and under the new regulations, will only just comply. Actual performance will probably be different, as some dwellings currently perform better than current regulations, for example, those supported under the "House of Tomorrow" programme. The 40% improvement specified here relates to "regulated" energy performance.

The performance improvement will not be uniform across all dwelling types. It will tend to be greater in detached houses than in apartments, and in dwellings heated by oil than by gas. The 40% improvement is a national average for new dwellings.

2.3.2. Getting representative dwellings to comply

The purpose of the analysis reported in this section was to see how easy or difficult it is for the different dwelling types to comply with the proposed new regulations, and to identify any potential compliance problems for particular dwelling types.

The starting point for the analysis was with the nine representative dwellings just complying with the current regulations. Aspects were then changed successively in order to achieve compliance with the revised standard.

Measures considered

The main measures considered are described below. Other means of improving performance also exist.

– Make dwelling shape more compact (by removing irregularities and adopting a regular rectangular shape).

- Improve fabric insulation levels.
- Improve glazing. Both the window U-value and glazing transmittance are considered. Depending on the window types being considered, some of the benefits of an improved U-value may be offset by reduced transmittance.
- Reduced thermal bridging at element junctions. This is achieved by implementing the UK's "approved construction details" at all element junctions throughout the dwelling fabric.
- Improve air tightness of envelope. If a non-standard value of air permeability is to be used in the DEAP calculation, a pressurisation test is required for verification.
- Improve boiler efficiency. Measured efficiencies of particular boiler types are given at www.boilers.org.uk.
- Improve secondary heating efficiency. Improved performance may be achieved by replacing an open fire with a closed solid-fuel stove, a balanced-flue gas fire, or by having no secondary heating at all. Apart from improved efficiency, reduced ventilation heat loss via chimney or flue is also achieved.
- Increase proportion of low-energy lighting.
- Install a solar water heating system. The specifications of the solar water heating system used in this study unless otherwise stated are as follows:

  Collector type: flat-plate

  Collector aperture area = N [m2] where N = standardised number of occupants

  Orientation: SE/SW, inclined at 30 degrees

  Optical efficiency and heat loss coefficient: 0.8 [-] and 5 W/m2 K respectively. These are slightly better than the DEAP default values, based on assumption that certified manufacturers values will be used.

  Twin-coil cylinder of volume 65*N [litres], with 75mm insulation
- Install a wood pellet stove or boiler.

Measures for compliance

First the specifications of all nine representative dwellings were improved as follows.

Remove dwelling shape irregularities to give rectangular shape.

Replace open fire with balanced flue gas fire of efficiency 70% (run on LPG in the case of oil-fired dwellings). This allows chimney to be removed.

Improve U-value of walls to 0.25 W/m^2 K, and floor to 0.22. Leave roof at 0.16.

Improve U-value of windows (low-E double glazed) to 1.8 W/m^2 K.

Improve U-value of door to 1.8 W/m^2 K also.

Adopt approved construction details at element junctions (parameter 0.08 W/m^2 K).

Increase hot water cylinder insulation to 50 mm, and insulate primary pipework.

Include 50% low-energy lighting.
Change electric heating in small apartment to gas heating.
Improve boiler efficiency to 90% for gas, and 93% for oil.

After these are implemented, the apartments and terraced house comply with a margin to spare, and two of the semi-detached houses just comply. All of these are gas-fired. None of the oil-fired houses, detached and semi-detached, comply.

For these four dwellings, the following were implemented
Low-energy lighting percentage increased to 100%
Air permeability reduced to 0.4 ac/h
Secondary heating gas fire efficiency increased to 75%
Wall and floor U-values reduced to 0.20.

The oil-fired semi-detached house now complies, but none of the detached houses do. For these, the following were implemented
Glazing orientation changed from E/W to N/S, with 60% facing south and 40% north, without changing total glazed area.
Roof U-value improved to 0.11 (this would require about 400 mm of insulation)

The two-storey detached houses now comply, but the bungalow doesn't. A solar water heating system was installed on the latter, and it then complied with a margin to spare.

The above represents just one way of achieving compliance for each dwelling. Other combinations of the above measures are also possible. Other areas of potential improvement not included in any of the above options are triple glazing, wood pellet stove/boiler, or changing dwelling type, e.g. bungalow to two-storey house. Further possible options that could be considered include installing whole-house mechanical extract ventilation (MEV) or mechanical ventilation with heat recovery (MVHR), installing a heat pump, improving heating system controls to category 3 where appropriate, changing thermal mass or living area fraction, or installing a photovoltaic system.

It is concluded that it is feasible for all of the representative dwelling types to comply without undue difficulty.

2.3.3. Limits on flexibility

An important advantage of basing compliance on DEAP is that it affords designers the flexibility to choose the most cost-effective set of measures to achieve compliance. However, some limits on flexibility may be justified. For example, a mid-floor apartment, a dwelling heated by wood pellets or by group heating with CHP, or a dwelling having a large PV array, may achieve compliance easily, while being relatively inefficient in other aspects of the design. Limits on flexibility regarding aspects that may be implemented without excessive cost, and that are difficult to upgrade subsequently, may be justified in some cases. Also, a limit on flexibility may help to standardise a particular aspect of design, which may lead to reduced costs through widespread adoption.

U-values

As fabric insulation may have a long life-span, and as achieving a good U-value is easier and more cost effective during construction than subsequently, the following limits on flexibility are proposed.

	Upper limit on average for element type [W/m² K]	**Upper limit for individual elements [W/m² K]**
Roofs	0.22	0.3
Walls	0.27	0.6
Ground and exposed floors	0.25	0.6
Ground and exposed floors with underfloor heating	0.22	0.6
Openings (windows, rooflights, doors)	2.2	3.3

Notes:

1. The upper limit for individual elements might apply, for example, to that part of a wall behind a recess for a meter-box. The rest of the walls would then need to compensate for this by achieving a more demanding U-value than the upper limit for this element type.
2. The upper limits on averages correspond to elemental values in the current TGD L, except for the underfloor heating one.
3. The upper limit for individual walls/floors of 0.6 corresponds to the thermal resistance of a 58 mm thickness of insulation of conductivity 0.035 W/m K.

Heating systems

Limits on the flexibility of DEAP regarding heating systems are not considered necessary, as heating systems can generally subsequently be replaced with more efficient ones. However, the

UK's Domestic Heating Compliance Guide (UK ODPM, 2006b) Guide provides a lot of useful information and guidance on aspects not addressed by DEAP. For this reason, and because the limits it gives would generally be compatible with cost-effective DEAP compliance anyway, it is considered that a corresponding Irish document would be worth producing.

This may also help to prevent dumping on the Irish market of less efficient heaters no longer acceptable in the UK. For related reasons, it is suggested that a rating scheme for the efficiencies of solid-fuel heaters similar to that of HETAS in the UK be provided in Ireland, for use both in DEAP calculations and in building regulations compliance.

2.3.4. Other recommendations for TGD L

Pressurisation testing

It is widely acknowledged that in many cases, the fabric energy performance of new dwellings in reality does not achieve design performance levels. Quality checking of as-built new dwellings, where cost-effective, can help to ensure acceptable quality for house-buyers. With this in mind, it is recommended that pressurisation testing be made mandatory in Ireland in a manner similar to that in England & Wales. Together with the incentivisation of a suitable level of airtightness as specified below, this should both improve and verify efficiency regarding air-tightness.

In the England & Wales regulations, the limiting value of design air permeability is given as 10 m^3/m^2 h at 50 Pa, where the "m^2" refers to dwelling envelope area. For the Irish regulations, an upper limit in terms of air changes per hour (ac/h) rather than envelope area is recommended, as this is consistent with the proposal to incentivise efficient dwelling form. "m^3/m^2 h" can be converted to "ac/h" once the dwelling's envelope area and volume are known. An upper limit of 10 ac/h at 50 Pa, corresponding roughly to the England & Wales value, is considered appropriate.

Mechanical ventilation systems

As an inefficient or badly-installed MVHR (mechanical ventilation with heat recovery) system has the potential to waste energy, it is recommended that similar requirements to those in England & Wales be included in the Irish regulations, and similar guidance either provided or referenced. Specifying limiting values of specific fan power and heat exchanger efficiency requires the specification of a testing procedure, and unless an alternative one is to be adopted, it is recommended that the UK testing procedure for MVHR systems be referenced; this is described in the SAP Appendix Q website, and is based on two European Standards.

Mechanical cooling systems

In the Irish climate, mechanical cooling should not be necessary in properly-designed dwellings. In the Irish regulations, it is recommended that mechanical cooling systems be discouraged in new dwellings, for example, via a statement in TGD L to this effect. An additional way of discouraging such systems might be to account for them in DEAP; this is outside the scope of the current study.

Artificial lighting

The DEAP documentation currently doesn't specify what is meant by "low-energy lighting". As such lighting can help in complying with TGD L, it is recommended that this be added to the DEAP documentation. A specification similar to that in the UK's ADLIA would be acceptable.

Including a separate requirement for a proportion of low-energy lighting in TGD L is not considered necessary, as this is covered by DEAP. However, as this measure is considered to be compatible with cost-effective DEAP compliance, such a requirement would not be unreasonable – it could be viewed as a step towards the wider use of energy-efficient lighting, and perhaps eventually the exclusion of inefficient lighting.

As a step towards the wider use of energy-efficient lighting, and perhaps eventually exclusion of inefficient lighting, it is recommended that the specification and requirements for energy-efficient lighting in the England & Wales regulations be adopted in TGD L.

On a related matter, it is recommended that the DEAP manual be updated to be compatible with such a regulation, by specifying what is meant by a low-energy light fitting.

Incentivisation of renewables

In the context of limiting national primary energy consumption and greenhouse gas emissions, it makes no difference whether these are achieved by energy-saving measures or by renewable energy technologies. The proposed DEAP compliance criterion incentivises both, while giving builders the flexibility to choose the most cost-effective set of measures to achieve compliance. Under this compliance criterion, the extent to which renewables are used will depend to a large extent on their cost-effectiveness relative to energy-saving measures. It is considered that further incentivisation of renewables within the building regulations would not be desirable if it were to occur at the expense of more cost-effective energy-saving measures.

Lowering the MPEPC will make it increasingly difficult to comply without renewables. Under the specified 40% improvement on current requirements, it is expected that many new dwellings, particularly detached houses away from the gas grid, will incorporate solar water heating and/or other renewable technologies in order to comply.

The scope and timescale of this study have not permitted any investigation into the future of energy efficiency standards beyond the 40% reduction of current standards proposed for amendment in 2007.

2.3.4. Recommendation for future regulation

In the pursuit of improving the performance of our built environment it may be judicious to set ambitious long term targets for buildings and provide a national framework to achieve realistic improvements in the short and medium term. It may also be necessary to move to the provision of broader environmental standards for new developments to encourage more holistic environmental approaches, taking account of construction materials and urban design matters, for instance.

Delivery mechanisms for achieving higher performance standards for the future may require a review of the relationship between planning, building regulation and building control in the implementation, monitoring and enforcement of building energy performance regulation. As a minimum, a more fundamental review of TGD Part L to coincide with the 2010 target is recommended.

As standards become more demanding the need for clarity of purpose, practical application and means of implementation is increased. There is a critical need to develop awareness in the construction industry of the impact which design and construction practices have on the delivery of energy efficient buildings and to provide guidance and training in ensuring that a more rigorous construction process with requirements for verifiable performance is achieved.

2.4. Analysis of Options

2.4.1. Evaluation of individual energy saving measures

A range of energy saving measures were determined and evaluated individually for their contribution to the achievement of a target 40% improvement on current standards and incentivising the use of renewables. These included innovative materials, energy efficient components and technologies, and renewable supply systems.

An assessment of energy savings and cost benefit analysis was undertaken of each of the individual measures. The basis of the analysis was the assessment of the energy saving measures relative to a selected reference dwelling. The two-storey semi-detached dwelling of masonry construction, similar in layout form to that used to illustrate compliance in TGD Part L 2005 has been adopted as the reference dwelling and from which elemental quantities have been derived. The base premis of the reference dwelling specification was that it complied with current Building Regulations and in line with adopted reference publications such as Homebond's House Building manual. For each of the proposed energy saving saving measures a construction detail and specification has been assumed to form the basis of the cost assessment and comparison with the corresponding detail and specification in the reference dwelling.

The cost benefit analysis assessed the direct capital cost as well as associated indirect capital costs. The direct capital costs include the contractor / subcontractor's prime costs, associated attendances, overheads and profit and preliminaries costs.

The indirect capital costs include an assessment for professional fees and applicable VAT rates on fees and construction costs.

The pricing of the proposed energy saving measures were based on initial consultation with the market place as well as analysis of relevant tender prices and on market rates applicable as at August 2007.

It should be noted that the costs of energy saving measures are reflective of a typical of a two-storey semi-detached dwelling and will vary for other dwelling types such as detached dwellings and apartments etc. The key factors that are cost sensitive are wall to floor ratios; quantity of glazed areas; dwelling orientation; number of units in development and sizes of units in development.

Whilst with any innovative measures cost premiums are to be expected initially in the short term as the market adjusts to new specifications and manufacturing processes etc. However, it is likely that in the medium to longer term once the market adjustments have taken place and with increasing adoption of energy saving measures as standard, costs of those measures are likely to fall.

The assessment of energy savings and cost analysis undertaken of each of the individual measures is included below.

2.4.1.1. Assessment of energy-saving measures individually

The base case used in this section is a house just complying with the TGD L requirements in so far as they go, and assumed values for parameters not covered by TGD L. These assumed values include:

Proportion of low-energy lighting: 0.3
Gas boiler efficiency 78%
Secondary heating: Open fire

Exposed wall and floor U-values – smaller improvement

Walls 0.27 to 0.25, ground and exposed floors 0.25 to 0.22

Exposed wall and floor U-values – larger improvement

Walls 0.27 to 0.22, ground and exposed floors 0.25 to 0.20

Thermal bridging

Apply English “Accredited construction details” to all junctions.
Thermal bridging parameter improved from 0.11 to 0.08 W/m2 K.

Windows and doors – smaller improvement

U-value of windows from 2.2 to 2.0, opaque door from 3.0 to 2.0
This is achieved by selecting values for *Double glazed, argon filled (low-E, en = 0.15, hard coat)”, 12 mm gap, wood frames.* from the DEAP tables 6a and 6b. (U-value 2.0, solar transmittance 0.72).

Windows and doors – larger improvement

U-value of windows from 2.2 to 1.5, opaque door from 3.0 to 1.5
This is achieved by selecting values for *Triple glazed, argon filled (low-E, en = 0.15, hard coat)”, 12 mm gap, wood frames.* from the DEAP tables 6a and 6b. (U-value 1.5, solar transmittance 0.64).

Notes

DEAP Table 6a gives default U-values for windows, and Table 6b default solar energy transmittances. It should be borne in mind that

(a) If certified values for particular products are used instead of these default values, they should be used for BOTH U-value and solar energy transmittance.
(b) Changing from double to triple glazing will improve the U-value, but will reduce the solar and light transmittance.
(c) With low-emissivity double glazing or triple in the DEAP tables, "soft coat" has better U-values, but "hard coat" has better transmittances.

It is noted that if the "soft coat" option corresponding to the above double-glazed option ("double glazed, argon filled (low-E, en = 0.05, soft coat)" is selected, giving a better U-value of 1.8 but a worse solar transmittance of 0.63, this gives only a slightly better performance despite the significantly better U-value. With the corresponding triple glazing hard and soft coat options, hard coat performs better.

For comparison, the above window improvement measures were repeated with all glazing south-facing. In this case, "hard coat" performed better in both improvement options, despite its poorer U-value. Conversely with north-facing glazing, the U-value would be more important relative to the transmittance.

Increase hot water cylinder insulation

From 35 to 50 mm

Insulate primary pipe-work between boiler and hot water cylinder

Increase proportion of low-energy lighting

From 0.3 to 0.7

Increase boiler efficiency

From 78 to 90%

Replace open fireplace with closed solid-fuel room heater

Efficiency improved from 30 to 60%.
Chimney replaced with flue.

Remove open fire and chimney

i.e. no secondary heating

Add solar water heating system

Flat-plate collector, aperture area 2.8 m²

Zero-loss collector efficiency 80%, collector heat loss coefficient 5.0

Collector orientation: southeast, 30 deg.

Twin-coil cylinder, 180 litre, with 75 mm insulation

Pump is mains-powered.

Replace gas boiler with wood-pellet boiler

Efficiency 85%

Electricity consumption of pellet autofeed considered equal to that of oil pump.

Electricity consumption of flue fan considered equal to that in gas boiler.

Heat pump

Ground-source;

Underfloor heating, hence seasonal performance factor (SPF) for space heating 320%;

Underfloor heating element over insulation and under wooden floor, hence responsiveness category of 1.

Heat pump meets all of hot water demand, hence factor of 0.7 applied to SPF for water heating.

Note: Since underfloor heating is used, ground floor U-value should be improved. This is not considered here.

Improve air-tightness, verified with pressurisation test

Air permeability of 0.35 air changes per hour.

Note: With natural ventilation, there should be a certain minimum level of air permeability. The level needs to be decided for TGD F.

Whole-house mechanical extract ventilation (MEV)

Air permeability of 0.15 ac/h, verified with pressurisation test

DEAP default used for specific fan power (proprietary systems tested by BRE may achieve better values). Intermittent fans removed.

Whole-house mechanical ventilation with heat recovery (MVHR)

Air permeability of 0.15 ac/h, verified with pressurisation test

DEAP defaults used for specific fan power and heat exchanger efficiency (proprietary systems tested by BRE may achieve better values).

Intermittent fans removed.

Notes

If the chimney were removed also, the system would perform better. The chimney is not removed here.

Characteristics of an efficient system include the following. Not all of these are currently addressed in DEAP, but may be addressed in the next version.

High degree of air-tightness, from pressurisation test.

Low specific fan power and high heat exchanger efficiency, as measured by BRE or equivalent.

Rigid rather than flexible ductwork.

Insulated ductwork.

Fan speed set to give required air-change rate taking account of infiltration, in view of pressurisation test results.

As the proportion of renewables in Ireland's electricity mix increases, the primary energy consumed by the fans will reduce.

Other measures

Not all of these are currently credited by DEAP.

- Glazing orientation: Smaller windows on north side, larger ones on south side.
- Group heating with CHP
- Group heating with renewables
- Photovoltaic array
- Ventilation options
  - Air-tight envelope, and pressure-sensitive vents.
  - Air-tight envelope, and whole-house mechanical extract ventilation with heat recovery via heat pump, supplementing space and/or water heating.
- Hot water options
  - Low-flow taps and shower-heads
  - Short pipe-work runs
- Wood pellet boiler/stove in combination with solar water heating with space heating support

Results

Measure	Primary energy	CO_2	Saving		Capital Cost of Enhancement	Indirect Capital Cost of Enhancement	Total Additional Capital Cost of Enhancement	Cost Notes
	[kWh/m² y]	[kg/m² y]	Prim E	CO_2	€	€	€	
Base case	**157.5**	**33.35**			**160,000.00 capital cost**	**42,896.00 indirect capital cost**	**202,896.00 total cost**	**Based on Developer Specification Dwelling**
Wall and ground floor insulation levels - smaller improvement	155.1	32.83	1.5%	1.6%				
Wall and ground floor insulation levels - larger improvement	152.5	32.26	3.2%	3.3%	4,065.12	1,089.86	5,154.98	U-Value of 0.22
Reduce thermal bridging throughout external fabric	152.7	32.32	3.0%	3.1%	631.00	169.00	800.00	.
Window and door U-values 2.00 - smaller improvement	153.0	32.37	2.8%	2.9%	480.00	128.69	608.69	U-value of 2.00
Window and door U-values 0.80 - larger improvement	146.9	31.05	6.7%	6.9%	757.04	202.96	960.00	Extra over for solar reflective glazing
Insulate primary circuit pipe-work	155.7	33.06	1.2%	0.9%	0.00	0.00	0.00	Included in the figure below
Increase insulation on hot water cylinder	156.8	33.24	0.5%	0.3%	250.00	67.03	317.03	
Increase proportion of low-energy lighting	154.2	32.54	2.1%	2.4%	41.58	11.15	52.73	
Improve boiler efficiency	142.5	30.58	9.5%	8.3%	0.00	0.00	0.00	
Replace fireplace with closed solid fuel stove	145.2	29.58	7.8%	11.3%	3075.47	824.53	3,900.00	Including Grant of €4,200, not including removal of fireplace
Remove open fire and chimney	140.8	27.34	10.6%	18.0%	(1,794.00)	(480.79)	(2,274.97)	
Solar water heating	143.1	30.88	9.1%	7.4%	3,903.00	1,046.39	4,949.39	Solar water heating system with flat plate, twin coil cylinder 180

								litre with 75mm insulation, pump main powered (Including €1,500 Grant)
Wood pellet boiler	150.4	15.57	4.5%	53.3%	7,800.00	2,091.18	9,891.18	Includes grant of €4,200 and storage
Ground-source heat pump	123.6	31.32	21.5%	6.1%	8,070.00	2,163.57	10,233.57	Includes grant of €6,500.
Improve air-tightness	152.4	32.26	3.2%	3.3%	2,549.00	683.39	3,232.39	0.35 air changes per hour – masonry option
Whole-house MVHR	156.3	33.43	0.7%	-0.2%	1,900.00	509.39	2,409.39	0.15 changes per hour

2.4.2. Evaluation of two alternative combinations of energy saving measures

2.4.2.1. Analysis of two combinations of measures which achieve 40% reduction in energy and CO_2 emissions

Following the evaluation of individual measures two alternative combinations of measures, which achieve the proposed 40% reduction target and one of which will include renewable energy technology, were selected for overall review.

The savings associated with each measure are given relative to a base case as outlined above, except with an irregular shape that is assumed to increase exposed area by 10%, e.g. a kitchen extension and a recessed porch. The measures are not costed cumulatively – each is costed relative to the base case independently.

Two sets of measures that will each achieve compliance with the proposed new regulations are as follows.

Combination 1 - Optimised conventional measures

Improve dwelling shape: remove extension to give rectangular shape of same total floor area.
Improve U-values as follows:

Roof: 0.16 to 0.15 W/m² K
Walls: 0.27 to 0.23 W/m² K
Floor: 0.25 to 0.20 W/m² K

One opaque door: U-value: improve from 3.0 to 1.8 W/m² K
Glazing: Low-emissivity double glazing, change U-value from 2.2 to 1.8 W/m² K, no change in low-emissivity coating type (e.g. “hard coat”).
Change glazing orientation from all east/west-facing to 55% south-facing, 45% north-facing
Reduce thermal bridging at element junctions: factor 0.11 to 0.08 W/m² K
Achieve a structural infiltration rate of 0.4 ac/h (roughly equivalent to 8 m3/m² h at 50 Pa), verify with pressurisation test.
Improve boiler efficiency from 78% to 90%
Increase insulation of hot water cylinder from 35 to 50 mm
Insulate primary pipework between boiler and hot water cylinder
Replace open fire with gas fire (balanced flue) of efficiency 75%.
Proportion of fixed lighting outlets that are low-energy: increase from 0% to 50%

Combination 2 - Measures incorporating renewables

Install solar water heater.

Change south/north facing glazing proportions to 65%/35% without changing total glazed area.

The following relaxation of other measures is then possible. All other measures are as in improved set of measures above.

Revert to current U-values as follows:

Roof: 0.16 W/m² K

Walls: 0.27 W/m² K

Floor: 0.25 W/m² K

Thermal bridging at element junctions: go back to current requirement (0.11 W/m² K)

Use less efficient boiler – 83% efficiency rather than 90%.

Savings in primary energy and CO_2

Conventional measures

	Primary energy [kWh/m² y]	**Carbon dioxide [kg/m² y]**	**EPC**
Initial	167	35.5	0.99
Final	104	20.4	0.59
Saving [%]	38%	43%	40%

Measures incorporating renewables

	Primary energy [kWh/m² y]	**Carbon dioxide [kg/m² y]**	**EPC**
Initial	167	35.5	0.99
Final	104	20.5	0.59
Saving [%]	38%	42%	40%

2.4.2.2. Cost analysis of two combinations of measures which achieve 40% reduction in energy and CO_2 emissions

The cost analysis of the two combinations of measures found that capital costs, when compared to the same dwelling built to current standards, of the first combination which applied optimised conventional measures would cost approx €4,452 more and the second combination which integrated a renewable energy technology would cost approx €8,544 more. A breakdown of costs are given in the tables below.

CONVENTIONAL MEASURES Summary	Measure	Quantity	Total Additional Capital Cost of Enhancement		
			€	%	%
Building Envelope:-					
Cavity Wall Insulation	139mm Thick (conductivity 0.035) (U value 0.23)	87m2	441.30		
Thermal Bridging	Apply English "Accredited construction details" to all junctions. Thermal bridging parameter improved from 0.11 to 0.08W/m2K	87m2	650.00		
Windows / Glazing	Double glazed, argon filed, low E, hard coat, 12mm gap wood frames: with revised orientation mix on south facade (U value 1.8)	24m2	608.69		
Roof Insulation	250mm (conductivity 0.037) between rafters and ceiling joists	104m2	No extra cost		
Floor:-					
Floor Insulation	106mm (conductivity 0.030) (U value 0.20)	48m2	207.56		
Ventilation:-	Improved air tightness, air permeability of 0.40 air changes per hour	87m2	3,232.39		
Pipework Insulation	Hot water cylinder insulation 50mm thick together with insulating primary pipework between boiler and cylinder	1 No.	317.03		
Boiler / heat source	Efficiency increased to 90%	1 No.	No Extra Cost		
	Replace open fireplace with gass room heater including cost of fireplace & BWIC	1 No.	-1,057.21		
Energy	Low energy light fittings	14 No.	52.73		
	Total		**4,452.47**		

CONVENTIONAL MEASURES WITH SOLAR WATER HEATING

Summary	Measure	Quantity	Total Additional Capital Cost of Enhancement €	%	%
Building Envelope:-					
Cavity Wall Insulation	139mm Thick (conductivity 0.035) (U value 0.23)	87m2	441.30		
Thermal Bridging	Apply English "Accredited construction details" to all junctions. Thermal bridging parameter improved from 0.11 to 0.08W/m2K	87m2	650.00		
Windows / Glazing	Double glazed, argon filed, low E, hard coat, 12mm gap wood frames: with revised orientation mix on south facade (U value 1.8)	24m2	608.69		
Roof Insulation	250mm (conductivity 0.037) between rafters and ceiling joists	104m2	No extra cost		
Floor:-					
Floor Insulation	106mm (conductivity 0.030) (U value 0.20)	48m2	0.00		
Ventilation:-					
	Improved air tightness, air permeability of 0.40 air changes per hour	87m2	3,232.39		
Pipework Insulation	Hot water cylinder insulation 50mm thick together with insulating primary pipework between boiler and cylinder	1 No.	317.03		
Boiler / heat source	Efficiency increased to 90%	1 No.	No Extra Cost		
	Replace open fireplace with gass room heater including cost of fireplace & BWIC	1 No.	-1,057.21		
Water Heating	Low energy light fittings	14 No.	52.73		

Energy				
	Total			
				3,594.91
EXTRA OVER FOR RENEWABLE SOURCES				
	Solar water heating system with flat plate, twin coil cylinder 180 litre with 75 mm insulation, pump main powered **(including €1,500 Grant)**	1 No.		4,949.39
			8,544.31	

The cost analysis of the two combinations of measures found that capital costs, when compared to the same dwelling built to current standards, of the first combination which applied optimised conventional measures would cost approx €4,452 more and the second combination which integrated a renewable energy technology would cost approx €8,544 more.

2.5. Regulatory Impact Analysis (RIA)

An RIA Screening was applied to the recommendation for regulation within this study. Many of the requirements of the RIA Screening are integral to the study tasks and their inclusion is embedded as shown *in italics* indicated below.

Introduction

Background *(policy context)*

Aim and scope of study *(objectives being pursued, and policy options under consideration)*

Study Methodology and Recommendation

Proposal for TGD Part L *(enforcement and compliance achievement)*

Analysis of Options (*costs, benefits of any options considered*)

Consultation

Groups and individual consultation *(summary of views of stakeholders consulted)*

The DEHLG undertake periodic reviews of the content of Building Regulations and associated guidance including evaluation of the extent to which they are achieving the objectives and intended benefits of the regulation. The next review of this Part is planned for 2010 *(mechanisms for periodic review).*

3.0. Consultation

3.1. Consultation with industry stakeholders

Consultation was undertaken through a variety of mechanisms with industry stakeholders:

Group presentations by study team

DEHLG Industry Information Session	10 July 2007
Building Regulation Advisory Board (BRAB)	17 July 2007 and 11 September

Meetings with study team

Sustainable Energy Ireland - Kevin O'Rourke, Ivan Sproule, Joe Durkan and Deirdre Flood	19 July 2007
Homebond - Eugene Farrell and Michael O'Grady	1 August 2007
Housing Inspectorate - Noel Carroll	1 August 2007
Delap & Waller EcoCo - Jay Stuart	30 September 2007

Telephone contact by study team August 2007

CIF Sustainability Task Group – Aidan Burke

Planning Inspectorate - John Martin

Irish Timber Frame Manufacturers Association (ITFMA) - Phillip O'Mahony

Irish Concrete Federation (ICF) - Brian O'Murchu

Written submissions to DEHLG

Irish Homebuilders Association (IHBA)	24 July 2007
Royal Institute of Architects of Ireland (RIAI)	20 July 2007 and 23 August 2007
Pat Kyne, Energy Consultant	13 July 2007
Irish Concrete Federation	6 September 2007

Telephone contact to DEHLG

John Devitt, Consulting Engineer	28 August 2007

3.2. Views of industry stakeholders

Industry stakeholders were supportive of the objectives of the proposed amendment to the building regulation, however, a number of recurring issues arose in individual consultations and written submissions which are outlined below. Many of the issues raised are outside of the scope of this study. The written submissions are included in Appendix E.

Regulation implementation

It is strongly advised that a reasonable transitional period be provided to ensure the capacity of designers, suppliers and contractors to deliver the requirements of the regulation.

Technical achievement

Measures to achieve the proposed 40% reduction were suggested and these were reviewed by the study team. These included passive design strategies, upgrading the building envelope and in particular minimising infiltration and thermal bridging, integrating innovative components and heat recovery ventilation, efficient space and water heating systems and light fittings. Renewable energy and group supply sources were also encouraged.

Testing and inspection of construction and the commissioning of systems were indicated as essential to ensure compliance with the regulation requirements. Building Control site inspection, post construction testing (eg. blower door and thermography), post occupancy commissioning and provision of user manuals were highlighted as being favourable.

Information, skills and training requirement

The necessity for adequate provision of training and technical material for designers and contractors was highlighted. It was suggested that training in energy efficient design and construction and its evaluation should be provided for designers, suppliers and contractors. Robust construction details and installation manuals of innovative components and technologies were necessary for designers and contractors.

Construction research and market studies

The move towards energy efficiency combined with a lack of knowledge of the performance of Irish dwellings requires robust research to be undertaken, in particular on the relationship between ventilation rates and indoor air quality in dwellings.

It was suggested that market studies may also be necessary to evaluate the supply of alternative technologies and fuels and independent research to evaluate, in a holistic manner, the performance of materials.

4.0. Conclusions

Most European countries have been raising the standards set for energy efficiency in new buildings in recent years and are likely to continue so in the future to meet EU and national commitments to greenhouse gas emission reduction.

The study highlighted the difficulty in making comparisons of regulations of European countries because of the complexity of the requirements set and the differing calculation methods and expression of measurement units. The comparative analysis undertaken of energy use and CO_2 emissions in representative dwellings in Irish and five European countries' energy efficiency requirements found that England & Wales was approximately 22% and Denmark 31% more strict than current Irish energy regulation. The results obtained from Germany and The Netherlands were tentative but they suggest that the energy performance of dwellings just complying with the regulations in Germany and The Netherlands are each in the region of 20 % better than that in Ireland, and that in north-eastern France (the region with the coldest winters) about 5% better, with an uncertainty of plus or minus 10%.

The study team sought to provide a flexible basis for designers to achieve the proposed 40% energy and CO_2 reduction through improved building design and construction. The proposal provides for the use of a weighted average of primary energy and carbon emissions as the basis of compliance. Calculations, using the DEAP methodology with enhanced reference values, showed that a combination of compact form, passive solar strategies, robust building fabric construction with minimal thermal bridging and air infiltration, efficient space and water heating systems and integrated energy efficient lighting will achieve the proposed reduction in the majority of the study dwelling types. The inclusion of renewable energy technologies can provide a relaxation of the building envelope requirements and further carbon savings. It is concluded that it is feasible for all the representative dwelling types to achieve both a 40% reduction in energy and CO_2 emissions.

A range of measures were determined and evaluated for their contribution to the achievement of the 40% reduction on current standards and incentivising the use of renewables. These included innovative materials, energy efficient components and technologies, and renewable supply systems. Two combinations of measures were selected to demonstrate compliance in a typical semi-detached dwelling. The first combination complied through applying optimised conventional measures and the second option complied through optimising passive solar strategies, integrating a solar water heating system and conventional measures. It should be understood that the combination of measures were selected for compliance demonstration only, and many other combinations of measures are possible and may well be more appropriate and cost effective in particular situations.

A cost benefit analysis of the two combinations of measures found that capital costs, when compared to the same dwelling built to current standards, of the first combination which applied optimised conventional measures would cost approx €4,400 more and the second combination which integrated a renewable energy technology would cost approx €8,500 more.

The scope and timescale of this study have not permitted any investigation into the future of energy efficiency standards beyond the 40% reduction of current standards proposed for amendment in 2007.

In the pursuit of improving the performance of our built environment it may be judicious to set ambitious long term targets for buildings and provide a national framework to achieve realistic improvements in the short and medium term. It may also be necessary to move to the provision of broader environmental standards for new developments to encourage more holistic environmental approaches, taking account of construction materials and urban design matters, for instance.

Delivery mechanisms for achieving higher performance standards for the future may require a review of the relationship between planning, building regulation and building control in the implementation, monitoring and enforcement of building energy performance regulation.

As standards become more demanding the need for clarity of purpose, practical application and means of implementation is increased. There is a critical need to develop awareness in the construction industry of the impact which design and construction practices have on the delivery of energy efficient buildings and to provide guidance and training in ensuring that a more rigorous construction process with requirements for verifiable performance is achieved

The implementation of measures to reduce energy and associated emissions included in the National Climate Change Strategy 2007-2012 and An Agreed Programme for Government 2007 and in particular the amendment to energy standards to achieve better performance in new build dwellings, will also benefit occupants by providing better comfort at lesser cost.

5.0. Addendum

Following the submission of our Draft Final Report to the DEHLG, a number of meetings took place to explore our approach, our conclusions and core recommendations, and in particular, the use of a weighted average of PPC and CPC to calculate the EPC.

At the conclusion of our discussions, the DEHLG indicated that, while there was considerable merit in this recommendation, the DEHLG favoured a system whereby performance levels were expressed separately for energy efficiency and CO_2 emissions, with targets being set to ensure 40% improvement for each. The DEHLG considers that this approach provides the maximum transparency and is likely to achieve the maximum acceptance of the measures by all stakeholders in the housing market – designers, builders and consumers.

On foot of this decision by the DEHLG, we undertook additional work with the aim of identifying the relevant target values (maximum annual primary energy use and maximum annual CO_2 emissions); specifying an appropriate methodology for assessment of compliance with these targets; and analysing the implications of their adoption. The material set out in this Addendum represents the outcome of this exercise.

The DEHLG request was for a 40% improvement in performance for each of primary energy and CO_2 relative to current regulations, i.e. two requirements. Due to the incentivisation of lower-carbon fuels and efficient dwelling forms, greater improvements will be required in oil-fired detached houses than in gas-fired apartments relative to current requirements, and it was agreed that the 40% improvements were to be national averages rather than requirements for each new dwelling.

To comply, the actual dwelling and a reference dwelling are assessed using DEAP. The primary energy performance coefficient (EPC) is determined by dividing the primary energy requirement of the actual dwelling by that of the reference, and likewise the carbon dioxide performance coefficient (CPC) is determined by dividing the CO_2 emissions of the actual dwelling by that of the reference. To comply, the EPC must not exceed a Maximum Permitted EPC (MPEPC), and the CPC must not exceed a Maximum Permitted CPC (MPCPC).

Details of the reference dwelling are given below. This is based on a gas-fired dwelling just satisfying the MPCDER requirement in the current TGD L.

Element or system	Value
Total floor area, dwelling vol	Same as actual dwelling
Opening areas (windows and doors)	25% of total floor area The above includes one opaque door of area 1.85 m², any other doors are fully glazed
Walls, roof and floor	U = 0.24 W/m²K Area A = see note (1) below
Opaque door	U = 3.0 W/m²K
Windows and glazed doors	U = 2.2 W/m²K Double glazed, low-E hard coat Frame factor 0.7 Solar energy transmittance 0.72 Light transmittance 0.80
Living area fraction	= 0.15 + 15/TFA, subject to a maximum of 1
Shading and orientation	All glazing oriented E/W; average overshading
Number of sheltered sides	2
Allowance for thermal bridging	0.11 x total exposed surface area (W/K)
Internal heat capacity category	Medium
Ventilation system	Natural ventilation with intermittent extract fans
Air permeability	Infiltration due to structure = 0.5 ac/h
Chimneys	One
Open flues	None
Extract fans	3 for dwellings with floor area greater than 100 m^2, 2 for smaller dwellings
Draught lobby	None
Primary heating fuel (space and water)	Mains gas
Heating system	Boiler and radiators water pump in heated space
Boiler	Seasonal efficiency 78% room-sealed fanned flue
Heating system controls	Programmer + room thermostat + TRVs boiler interlock
Hot water system	Stored hot water, heated by boiler separate time control for space and water heating
Hot water cylinder	120 litre cylinder insulated with 35 mm of factory applied foam
Primary water heating losses	Primary pipework uninsulated cylinder temperature controlled by thermostat
Secondary space heating	Open fire
Low energy light fittings	None

Note (1)

The total area, A, of exposed walls, roof and floor of the reference dwelling is given by

$$A = (7.0 * V^{2/3}) * R_{ref} – A_{ope}$$

where V = dwelling volume;

A_{ope} = area of openings as specified above;

R_{ref} =ratio of exposed to total envelope area for reference dwelling.

$$R_{ref} = (R – 0.83) * 0.5 + 0.83$$

where R = ratio of exposed to total envelope area for actual dwelling.

As described in the main report, the nine representative dwellings were run through DEAP, and the values of MPEPC and MPCPC required to give a national average of 40% improvement in each of the EPC and CPC were determined. The results were as follows.

MPEPC	0.61
MPCPC	0.69

The nine representative dwellings were then made to comply with each of these requirements, and in addition, a solar water heater was added to each. It was found that the average solar input to the hot water cylinder was about 10 kWh/m^2 y.

The energy calculations DEAP spreadsheets are included in Appendix F.

Addendum Conclusion

In conclusion the study team have been extremely pleased to have played a core role in the elaboration of the final measures which will be decided by the Minister, after the conclusion of the public consultation process on his proposals.

References

European Parliament and the Council of the European Union (EU), 2002. *Directive 2002/91/EC on the Energy Performance of Buildings.* [Internet] EU. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002L0091:EN:NOT

European Commission (EC), 2005. *Green Paper on Energy Efficiency.* [Internet] EC. Available at: http://ec.europa.eu/energy/efficiency/index_en.html

Government of Ireland, Department of the Environment, Heritage and Local Government (DEHLG), 2000. *National Climate Change Strategy 2000.* [Internet] EC. Available at: http://ec.europa.eu/energy/green-paper-energy-supply/doc/contributions/11/2001-11-30-iec-sum.pdf

Government of Ireland, Department of the Environment, Heritage and Local Government (DEHLG), 2007. *Ireland – National Climate Change Strategy 2007-2012.* [Internet] DEHLG. Available at: http://environ.ie/en/PublicationsDocuments/FileDownLoad,1861,en.pdf

Government of Ireland, Department of Communications, Marine and Natural Resources (DCMNR), 2007a. Government White Paper *Delivering a Sustainable Energy Future for Ireland*. [Internet] DCMRN. Available at: http://www.dcmnr.gov.ie/Energy/Energy+Planning+Division/Energy+White+Paper.html

Government of Ireland, Department of Communications, Marine and Natural Resources (DCMNR), 2007b. Report of the Ministerial Task Force on Bioenergy, *Bioenergy Action Plan for Ireland.* [Internet] DCMRN. Available at: http://www.dcmnr.gov.ie/NR/rdonlyres/6D4AF07E-874D-4DB5-A2C5-63E10F9753EB/27345/BioenergyActionPlan.pdf

Government of Ireland, Department of the Taoiseach (DT), 2007. *An Agreed Programme for Government*. [Internet] DT. Available at: http://www.taoiseach.gov.ie/index.asp?locID=566&docID=3493

O'Leary, F., Howley, M. and O'Gallachoir, B., 2005. *Energy Consumption and CO_2 Emissions in the Residential Sector 1990-2004.* Dublin: Sustainable Energy Ireland.

UK Office of Deputy Prime Minister (ODPM), 2006a. *Approved Document L1A: Conservation of fuel and power in new dwellings.* DCLG. [Internet]. Available at: http://www.communities.gov.uk/corporate/html

UK Office of Deputy Prime Minister (ODPM), 2006b. *Domestic Heating Compliance Guide.* DCLG.[Internet]. Available at: http://www.communities.gov.uk/corporate/html

UK Department for Communities and Local Government (DCLG), 2007. *Building Regulations – Energy efficiency requirements for new dwellings – A forward look at what standards may be in 2010 and 2013.* [Internet] DCLG. Available at: http://www.communities.gov.uk/publications/planningandbuilding/energyefficiencynewdwellings/html

United Nations Framework Convention on Climate Change (UNFCCC), 1997. *The Kyoto Protocol.* [Internet] UNFCCC. Available at: http://unfcc.int/resource/docs/convkp/kpeng.html

Appendices

Appendix A: Representative sample of new-build Irish dwellings
Appendix B: Ireland, Eng & Wales energy calculation DEAP spreadsheets
Appendix C: EU Member States energy regulation format spreadsheets
Appendix D: Reference dwelling values for calculation of MPEPC
Appendix E: Industry written submissions to DEHLG
Appendix F: 40% improvement energy calculation DEAP spreadsheets

Appendix A: Representative sample of new-build Irish dwellings

Appendix B: Ireland and England & Wales energy calculations DEAP spreadsheets

Appendix C: EU Member States energy regulation format spreadsheet

Appendix D: Reference dwelling values for calculation of MPEPC

Appendix E: Industry written submissions to DEHLG

Appendix F: 40% improvement energy calculation DEAP spreadsheets