# Energy Efficiency: DEFRA Introduction and Projections Methodology

**Introduction**:
A series of six working papers has been prepared by DEFRA for the Interdepartmental Analysis Group over the period March – October 2001. Together with this introductory note, they cover the economy as four sectors (Domestic, Industry, Transport and Services), and present a general method for cost estimation. The titles are as follows:

1. (this introductory paper)
2. Energy Efficiency: DEFRA paper on Low Carbon Options for the Domestic Sector
3. Energy Efficiency: DEFRA paper on Scope for Demand Side Measures in Industry
4. Energy Efficiency: DEFRA paper on Energy Projections for the Service Sector
5. Energy Efficiency: DEFRA paper on Transport Energy Efficiency
6. Energy Efficiency: DEFRA paper on Additional Savings and Associated Costs

**Aim**: to estimate the scope for energy intensity reduction, and the corresponding costs, for five scenarios, in 2050.

**Steps**:
1. Estimate energy demand for the four reference Foresight scenarios, together with the "BAU" (current trends) case, and the contributions to energy intensity trends of energy efficiency and structural changes (different in each scenario).
2. Identify demand-side options for further reductions in energy intensity under each scenario.
3. Estimate relative costs of demand-side energy technologies, within the context of each reference scenario, and the additional energy intensity reduction options envisaged.

## Projections Methodology

### *BAU projections*

Energy demand is estimated for several different end uses or "energy services" in each of the four main sectors. Energy services are regarded as the fundamental drivers. At the most basic level, examples include a workspace or dwelling at a comfortable temperature, an adequately lit space, appropriate computing power. For some services, it is possible to quantify the level of service and calculate directly to a corresponding energy consumption figure, using assumptions on technical factors along the way, eg from an average whole-house temperature, using heat losses from the building and heating system efficiencies, to delivered energy (preferably split by fuel) for space heating. For others, particularly process use in business, in practice we may have to use something closer to the energy use, possibly even the actual use itself.

Projecting the demand for a particular energy service is probably best done by linking it to a consuming unit, eg a dwelling or household, an employee, a square metre of floor space. The level of service per unit, or service intensity, may remain constant over time (eg lighting levels in offices) or may rise with increasing income (eg average indoor temperatures in housing).

The final element in this approach is the number of “units”, eg households, employees, floor area, and how this number varies with GDP and the other socio-economic variables which define a scenario. The product of the service intensity and the number of units gives the level of total energy service.

All of this can represented by the identity:

$E = E/ES * ES/U * U$,

where E = energy, ES = energy service, and U = number of “units”. Then E/ES represents an efficiency factor while ES/U gives a measure of energy service intensity.

Future values of E relative to today’s can then be calculated by giving values to the relative change in each of the variables on the right hand side of the equation. For example, if the efficiency improves by 50%, the service intensity increases by 20% and the number of units increases by 60%, the respective factors are 0.5, 1.2 and 1.6 and the energy demand is 0.96 times today’s value.

This approach to projecting energy demand

- involves a relatively small number of factors,
- separates technical ones from socio-economic ones,
- focuses attention on a few key energy services which represent the development of the economy under different scenarios, and
- is reasonably transparent.

For each energy service, the relative importance of each factor is easily seen. Particular values can be discussed and the sensitivities readily calculated. If necessary, more detailed underlying models can be constructed to check particular values. In particular, likely limits on future growth of some service intensities, eg whole-house temperatures, time per individual spent travelling, can be built into the equations in a way which is impossible with conventional econometric modelling.

ES/U and U are socio-economic factors while E/ES is a technical one. Conventional energy efficiency improvements, i.e. via technical measures, would be represented by reductions in E/ES. However, energy demand could also be reduced via demand-side reductions represented by a fall in the energy service intensity, ES/U: for example, a drop in average whole house temperature.

There is an argument which says that this last change represents a move to a different scenario, on the basis that a scenario could effectively be defined by the values of a full set of energy services. DTI have chosen to use a more basic definition of a scenario, i.e. using only the Foresight variables - GDP, population, number of households, Industry/Services balance, traffic growth. DETR has followed the latter approach for the present to try to link DTI’s projections as closely as possible to our projections for each scenario. This then allows us to include further demand-side reductions from changes in the levels of energy service intensities, and other structural factors. We can envisage the final results as being new, low-carbon paths for the UK economy within the international backdrop defined by each of the Foresight scenarios.

This approach forms the basis for the four DEFRA Sector papers listed above.

**Additional demand-side reductions and corresponding costs**

An underlying aim in this section is to treat demand- and supply-side measures in the same way, as far as possible. That should ensure that comparisons are fair, that the same cost definitions are used – and it may have the added bonus that apparently intractable problems on one side are illuminated, and possibly solved, by using "standard" techniques from the other.

For example, we have unit costs and potential for energy efficiency measures for the present, but not for the more distant future: and this is in the form of carbon-saving supply curves, showing how the potential varies with rising unit cost. For Renewables, we classify them as short-, medium- and long-term according to the time when their unit cost for a sizeable amount of potential drops to within an acceptable range of the conventional alternative (usually CCGT-generated electricity around 2-3 p/kWh); the difference, usually about 5p, is taken as the relevant unit cost.

In fact, we could construct an analogous Renewables supply curve for the present, with the three broad categories at their current unit costs; this would show the current best, i.e. onshore wind, around 3p/kWh or £40/tC, and photovoltaic cells (PV) somewhere around 40p/kWh, or over £3000/tC. However, the same curve 40-50 years hence could well show PV down at the low end, alongside residual high-cost wind with other, perhaps as–yet-uninvented, technologies occupying the high-cost end: fusion might or might not be on the horizon.

This illustrates several points:

- installation costs can fall over time – but only if someone carries on with the development;
- this development has a cost; does this appear anywhere in our calculations?
- as markets develop, new technologies are likely to be developed, initially at very high costs – even if we cannot identify them today.

These points will apply equally to energy efficiency measures. So we might expect a similar supply curve to today's in the future, with (some of) today's high cost energy efficiency measures then at low cost.

However, there will be a "normal" or "natural" rate for today's high cost measures to move to the low cost end of the supply curve, corresponding to the BAU rate of energy efficiency improvement (or rate at which particular renewables become less costly). [It may be interesting to explore – in a future paper – possible links between these rates and so-called "learning curves" for different technologies: PIU now has a substantial body of information on these.] So our interest is in how this normal rate can be increased, and at what cost, since this would correspond to the extra energy efficiency savings which we are looking for. It is clear from these arguments that there is no single figure for either the amount or the cost: rather there is a sliding scale, with successive tranches becoming available at ever higher costs – as for Renewables.

One of the reasons for this "generalised", rather abstract, approach to extra energy efficiency savings is that we do not always have specific technologies in mind, particularly for the myriad business process uses in the future. But we are confident that such technologies will become available in time, and will gradually drop in cost, as a result both of the usual continuing improvements in existing technologies (the learning curve effect) and of more formal R&D programmes. Heating, lighting and cooling in buildings is a partial exception to this rule, and may be able to offer clues to solving the more general problem.

This generalised approach is developed in some detail in the sixth DEFRA paper ‘Energy Efficiency - Additional Savings and Associated Costs’.

There are other general issues which we have not yet had time to analyse fully. These include:

- other demand-side savings, eg from socio-economic measures;
- the nature of the costs for extra savings (renewables, sequestration, energy efficiency etc) – capital, total implementation, programme, welfare;
- how much the availability of low-carbon electricity under some scenarios might influence the balance of energy sources in each sector (e.g. switch from gas central heating to electric heat pumps).

**Summary of Projections**

The table which follows below presents a summary of the energy demand and carbon emissions estimates for each of the five scenarios, based on the results described in the four DEFRA Sector papers on energy efficiency. All of these projections are broadly compatible with the DTI’s baseline carbon intensity projections, but have been constructed separately in a bottom-up fashion, in terms of demand for fossil fuels and electricity. Energy efficiency improvements are included explicitly. No attempt has been made to take into account the likely changes in electricity generation under each of the scenarios, nor have possible system effects (e.g. switch to electric heating if cheap low-carbon electricity is available) yet been investigated. However, estimates for CHP generation are included since they already have a significant effect on the emissions from the Industry (and to a lesser extent the Services) sector.

In addition to the five scenarios, there is an additional column labelled ‘extra energy efficiency’. This presents demand and emissions estimates corresponding to what we currently regard as the most rapid, credible implementation of demand-side efficiency measures, taking into account all of the results presented in the five other DEFRA papers. These figures relate specifically to the BAU growth rates, and would scale accordingly for other growth scenarios.

**Projections for Energy Consumption and Carbon Emissions in the Domestic, Industry and Service Sectors**
for a Business As Usual baseline scenario, and for extra energy efficiency

| | | | Business As Usual | | | Extra EE | **WM** | **PE** | **GS** | **LS** |
|---|---|---|---|---|---|---|---|---|---|---|
| Energy consumption (excluding transport) | | ***2000*** | ***2010*** | ***2020*** | ***2050*** | ***2050*** | ***2050*** | ***2050*** | ***2050*** | ***2050*** |
| Mtoe | Domestic Elec | 10 | 10 | 11 | 11 | 9 | 14 | 10 | 9 | 7 |
| | Domestic FF | 37 | 36 | 34 | 31 | 19 | 40 | 30 | 28 | 20 |
| | Industry Elec | 10 | 11 | 12 | 13 | 10 | 13 | 14 | 12 | 11 |
| | Industry FF | 26 | 24 | 23 | 16 | 12 | 15 | 17 | 12 | 15 |
| | Services Elec | 8 | 9 | 10 | 11 | 7 | 12 | 10 | 9 | 8 |
| | Services FF | 14 | 13 | 13 | 14 | 10 | 17 | 15 | 12 | 12 |
| | Total Elec | 28 | 30 | 32 | 35 | 27 | 40 | 33 | 30 | 25 |
| | Total FF | 77 | 73 | 70 | 62 | 41 | 72 | 61 | 53 | 47 |
| | Grand Total | 105 | 103 | 102 | **97** | **68** | **112** | **94** | **83** | **72** |

| Carbon emissions (excluding transport) | | ***2000*** | ***2010*** | ***2020*** | ***2050*** | ***2050*** | ***2050*** | ***2050*** | ***2050*** | ***2050*** |
|---|---|---|---|---|---|---|---|---|---|---|
| MtC | Domestic Elec | 14 | 14 | 14 | 15 | 12 | 19 | 13 | 12 | 9 |
| | Domestic FF | 28 | 25 | 23 | 21 | 13 | 27 | 20 | 19 | 14 |
| | Industry Elec | 14 | 14 | 14 | 16 | 12 | 17 | 17 | 14 | 13 |
| | Industry FF | 20 | 17 | 15 | 11 | 8 | 10 | 11 | 8 | 10 |
| | Services Elec | 12 | 12 | 13 | 14 | 9 | 16 | 13 | 11 | 10 |
| | Services FF | 10 | 9 | 9 | 10 | 7 | 12 | 10 | 8 | 8 |
| | Total Elec | 40 | 39 | 41 | 45 | 33 | 52 | 43 | 37 | 32 |
| | Total FF | 58 | 50 | 47 | 41 | 28 | 48 | 41 | 35 | 31 |
| | Process emissions | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| | Grand Total | 103 | 93 | 91 | **89** | **63** | **104** | **87** | **76** | **66** |

| | | | kgC/GJ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Assumptions: | Electricity emission factors | ESI | 35.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 |
| | | CHP | 35.0 | 25.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| | CHP fraction of generation | Industry | 18% | 26% | 30% | 23% | 47% | 19% | 15% | 33% | 33% |
| | | Services | 6% | 8% | 10% | 11% | 23% | 6% | 6% | 15% | 15% |
| | Fossil fuel emission factor | Weighted | 18.0 | 16.5 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 |