Local Cooling: Global Warming?
UK Carbon Emissions from Air-Conditioning in the Next Two Decades

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Abstract

This paper explores electricity consumption and carbon emissions associated with air-conditioning in the UK over the last 20 years and potential changes over the next 20 years. If current trends continue, energy use and the consequent carbon emissions associated with air-conditioning could quadruple by 2020. Realistic but assertive regulatory measures reduce consumption and emissions by 35% relative to the business as usual case. Technically feasible limits could reduce energy consumption below current levels but would be difficult to implement.

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1. Introduction

Energy use for air-conditioning accounts for only a small proportion of building energy use in the UK. Unlike the situation in some other countries, it does not stress the power supply system at times of peak demand. So, is it something we ought be concerned about?

This paper argues that we should. Few UK buildings are currently air-conditioned but, extrapolating current acquisition rates, electricity use for cooling could easily rise to several times its present levels (we are using the term to include all comfort cooling, irrespective of whether humidity control is provided). Energy use for most building-related end-uses is falling as average insulation levels and equipment efficiency levels improve – in terms of carbon emissions, these gains could be negated by growth in air-conditioning energy use.

Of course, the future is not necessarily a continuation of present trends: a "business as usual" scenario simply sets an easily-defined reference with which other possible futures can be compared. We consider compare a "business as usual" scenario with an alternative "technical-fix" energy efficiency scenario. We sketch in, but do not consider in detail, a scenario in which the majority of building users and their agents recognise that they can have acceptable working conditions without the energy and environmental costs of air-conditioning. We believe that there is an arguable case that mechanical cooling is avoidable in the UK in many instances. We think that it is unlikely that this will actually translate into a significant reduction of demand for air conditioning, so this scenario is of rather academic interest. There will certainly be changes to the demand for cooling beyond those we have considered: for example, in the structure and nature of employment, with more twenty-four hour and seven day commercial activities and - very likely - more home working. On the other hand, "hot-desking" and wider use of IT could increase the internal heat loads of working space and the intensity of cooling energy use.

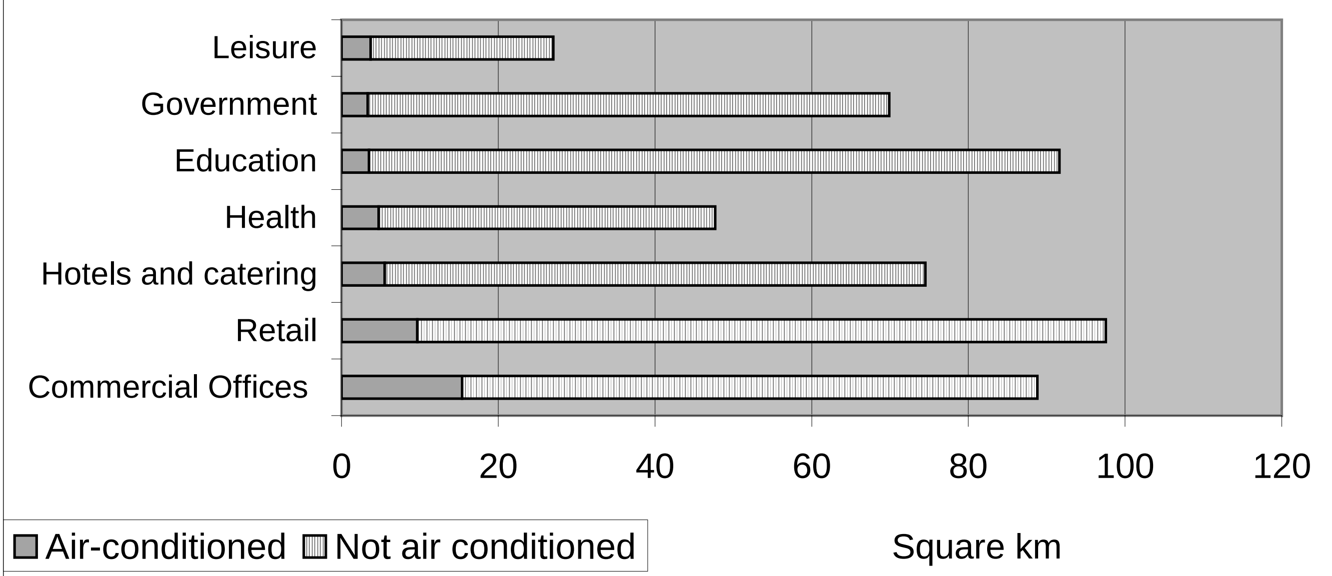
2. Current Energy Consumption and Carbon Emissions

Before we look to the future, we need to establish where we are now and have been recently.

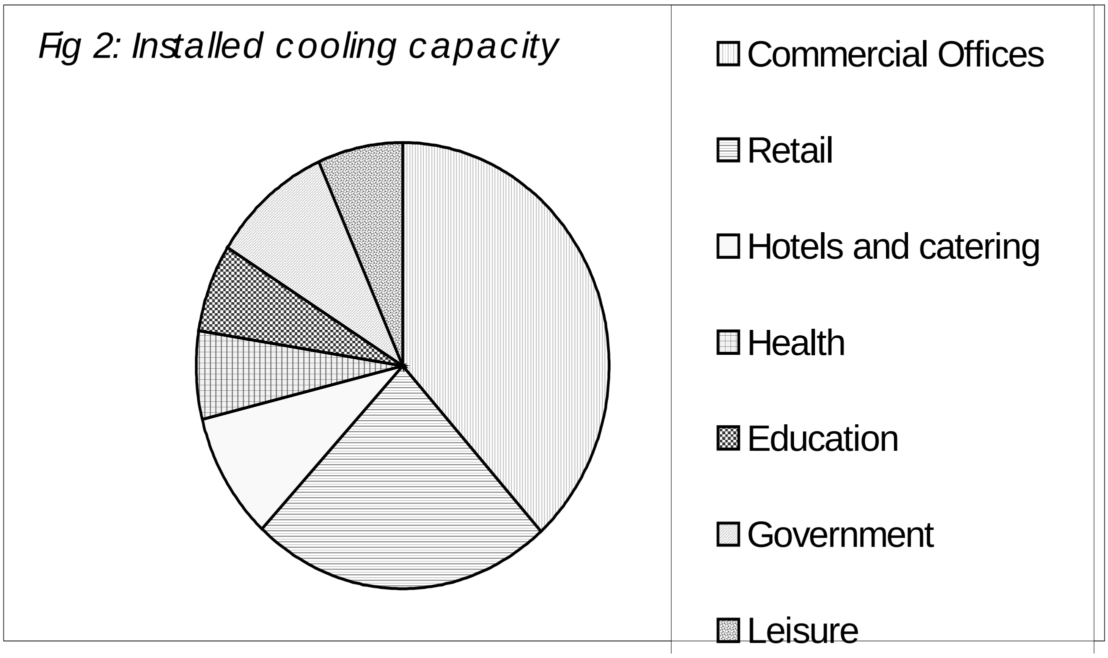
2.1 Where are we now?

At the end of 1994 about 10% of the floor area of commercial buildings was air-conditioned, but practically no housing. In absolute terms, the largest areas of cooled space were in commercial offices and retail premises. Penetration was also highest in commercial offices, at over 20% of floor area cooled, followed by leisure (16%), retail and health (both around 11%).[1]

Fig 1: Air-conditioned space



The total installed cooling load for air-conditioning is estimated to have been about 8GW. [2] (This excludes cold storage and industrial refrigeration but includes close-control plant used to condition such spaces as computer and communications rooms in buildings). The distribution of installed capacity broadly follows that of cooled floor area, with commercial offices accounting for nearly 40% and retail premises nearly 25% of the total.



Virtually all the air-conditioning uses electricity as its energy source. The electrical load is, of course less than the cooling load. If we assume an average coefficient of performance of 2.5, the equivalent electrical load would be just over 3 GW. (Total connected load would be higher because of the usual practice in central systems of installing multiple chillers whose total capacity exceeds the peak design load. A survey of a small number of installations found that at the median, the installed capacity was 2.4 times the maximum observed load[3]). This represents around 10% of the summer peak electricity generating demand. Nevertheless, it is sufficient to cause the summer afternoon electricity demand to be increasingly temperature sensitive[4].

These figures includes both central systems which distribute cooling through a building from a central plant, and packaged systems. Overall, slightly more than half the installed capacity is estimated to be in central systems, though this varies between sectors, being significantly above 50% in the education, government, leisure and health sectors, and significantly lower in hotels and catering. Because central systems are much larger, central system chillers account for less than 5% of chillers by number.

Around 60% of sales (expressed as cooling capacity) are of packaged systems, and around two-thirds of these go into existing buildings as retrofit installations - though the use of packaged systems in new buildings seems to be increasing [5,6]. Conversely, most central systems are installed in new buildings.

In 1994, air-conditioning consumed some 48 PJ (13.3 TWh) of electricity causing emissions of over 2M tonnes of carbon to the atmosphere. This represents about 7% of all electricity used in non-domestic buildings and 14% of electricity use in such buildings for building services purposes (including lighting).[7] Perhaps half of the "cooling" energy is actually consumed by chillers, with a similar used by fans and other ancillary equipment – especially in central systems.

To put this into context, this cooling energy use is less than the equivalent figures for France, Spain or Italy, and two orders of magnitude less than the USA or Japan. Even on a per capita basis, air-conditioning consumption in the USA is around 30 times than of the UK: Japan's is over 50 times higher.

2.2 How did we get here?

Historical statistics on UK air-conditioning are rather spasmodic and inconsistent. By combining sales data with survey information and other sources [7] [8], we can build up a broad picture of the last twenty years.

Expressed in terms of installed cooling power, it seems clear that average market growth in the 1970s and early 1980s was only around 100 to 150 MW per year. During the late 1980s and 1990s this accelerated to around 1000 MW per year.

The immediate market driver has been the belief of developers, owners and tenants that air-conditioned spaces result in more satisfied and more productive employees - and higher rental values.
"… businesses can currently see no justification for any compromise which may expose expensive human resources to any discomfort ….. Without air-conditioning, even the best-designed offices will fail in this primary requirement." [9]

As exposure to cooled spaces in cars, offices and shops has grown, positive feedback has been created, reinforcing expectations of summer comfort. Of course, these beliefs are not entirely disconnected from reality or from an increasing physical risk of overheating: highly-glazed buildings, increased lighting and IT loads (and fears of even higher levels), worsening outdoor air pollution and traffic noise have all contributed to an increasing likelihood of over-heating at some part of the year. Surveys showing that occupants prefer naturally ventilated buildings apparently do not carry much weight with developers.

A striking trend is that sales of packaged equipment have been growing more rapidly than of central plant (expressed in capacity terms). 1997 sales of packaged plant were around two-thirds higher than in 1991, while the equivalent increase for central plant was less than one third. Statistics on the relative numbers going into new and existing buildings are sparse, but in 1994 about two-thirds of packaged equipment and one half of central systems (by capacity) was reported to be installed in existing buildings[1].

We estimate that electricity consumption for air-conditioning increased more than ten-fold between 1971 and 1996. Because of the changing fuel mix of the electricity generation system the associated increase in carbon emissions was about a five-fold increase.

3. Possible Futures

The number of possible futures that could be considered is large. We will confine ourselves to a few, easily definable, reference scenarios. These illustrate the range of possibilities and can act as benchmarks against which to compare the consequences of alternative sets of assumptions.

These are:

- business as usual (continuation of historical trends)
- minimal air conditioning (avoiding air conditioning wherever possible)
- energy-efficiency regulation (introduction of assertive regulation)

In our illustrative scenarios, we ignore any impact of global warming – other than observing that concern over its possibility may strengthen beliefs that comfort cooling is desirable. In particular, relatively small increases in maximum outdoor temperatures [10] – and in the frequency of spells of hot weather – could tip the balance between naturally-ventilated and mechanically cooled design strategies.

Calculations show that a 1 deg C increase in average temperature – a figure that has been mentioned as a possibility over the next two decades - would increase the number of cooling degree-days by 50% to 60% in different regions of the UK. ***Table 1*** shows that the result would be that regions had a cooling climate comparable to that today in the South East and Thames Valley – where the greatest concentration of air-conditioning is found. (However, current regional differences in the proportion of floor space that is cooled can be explained by variations in the age and size of buildings without introducing rather climatic influences.)

Regional cooling degree-days	**Currently**	**With 1 dec C temperature rise**
Over 150	None	Severn Valley
100 to 150	Severn Valley	Thames Valley, South West
50 to 100	Thames Valley, South West, South East, East Anglia, West Pennines, Southern	South East, East Anglia, West Pennines, Southern, East Pennines, Midlands, Wales, North East, North West, Northern Ireland., West Scotland.
below 50	East Pennines, Midlands, Wales, North East, North West, Borders, East Scotland, North East Scotland, Northern Ireland, West Scotland, North West Scotland,	North East Scotland, North West Scotland

Table 1. Regional cooling degree-days:

In our scenarios, we assume for simplicity that cooling loads per unit floor area remain at current levels – demand is driven by increases in cooled floor area. Clearly there are factors that may change cooling loads (apart from global warming) - either upwards or downwards. While the energy-efficiency of IT equipment continues to improve, there are still many business sectors where its use is increasing. Flat-screen technology allows greater density of occupation, and new working practices such as hot-desking are allowing facilities managers to increase average occupancy densities. Lighting loads in existing buildings ought to decline as they are replaced by more efficient installations, and there is certainly scope to design and refurbish buildings to have reduced solar heat gains.

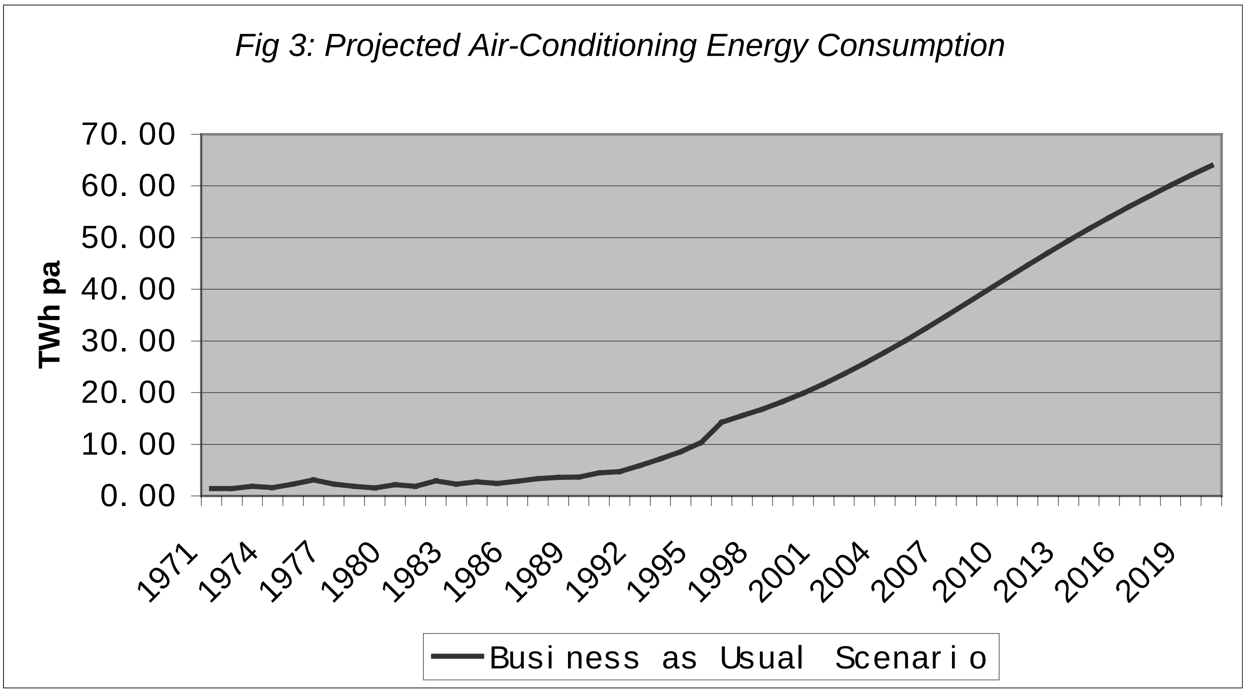
We have not considered scenarios based on fiscal measures such as carbon taxes. While abrupt and seemingly permanent price increases may have a psychological impact on energy users, for the majority of users of (potentially) air-conditioned space energy costs are a very small part of their total business costs. In economists' terms energy demand is price-inelastic. This means that only very high rates of taxation would be likely to have a significant impact on purchase decisions. We think that such high rates would be more difficult to implement than the regulatory measures that we have considered.

3.1 Business as Usual Scenario

Conceptually, the simplest future to describe is "more of the same". We assume that the market drivers stay much as they are, that the technology used does not alter significantly, and that the area of cooled space develops along a classic S-curve, with first-time sales eventually declining as a level of market saturation is reached. In time, a replacement market builds, and is assumed to consist of like-for-like replacement. Specifically, we model this by fitting a logistic curve to the historical data, and projecting this into the future. The results have been subjected to a number of informal "reality checks" and their sensitivity to the parameter values have been checked: for any reasonable fit to the historical data, the market diffusion curve does not digress substantially from the scenario shown. The "best-fit" value of the characteristic time constant of the curve – the time to go from 10% to 90% market penetration – has been compared to the values that have been found to be typical of comparable markets.[11] [12] The inferred value of around 35 years is lower, for example, than the 23 years observed for car air-conditioning (implying slower take-up). The level of penetration that constitutes market saturation is difficult to estimate, but sensitivity studies show that changing it has little effect on the projections over the next twenty years unless it is much lower than we have assumed. We have assumed, rather arbitrarily, that the maximum possible market share is around 60%. If saturation is actually much below 50%, the market curve will start to flatten out towards the end of the scenario duration.

The model deals separately with penetration of cooling into floorspace already existing in 1994, and penetration into newly constructed floorspace.

The business as usual projection implicitly assumes that the market drivers do not change significantly, and neither do cooling loads or the energy efficiency of cooling systems. For reasons described, it is difficult to see expectations for cooled space declining unless there were to be, for example, a major health scare. It has been said in the context of US offices, that once 20% of the office space in a city is air-conditioned, this sets the rental value and uncooled space can only be let at a discount. With concern about - and perhaps evidence of - global warming, uncooled space may well look like an increasingly risky commercial option.



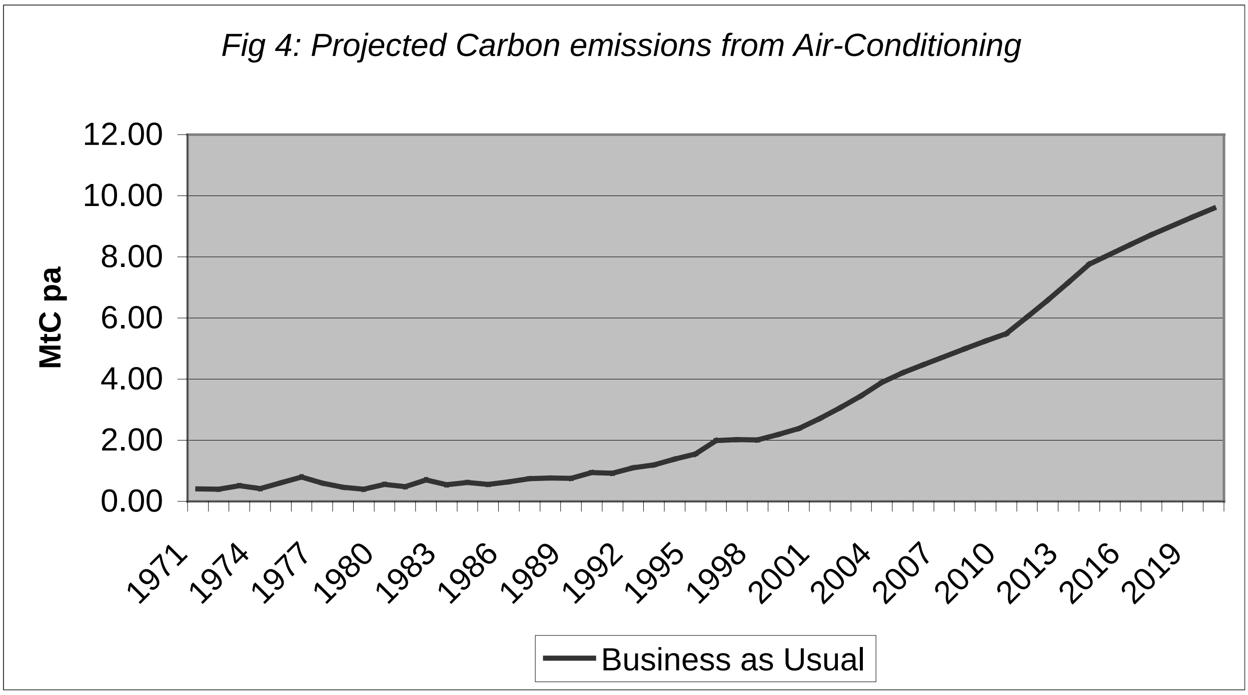
The projected trend in cooling electricity use is shown in ***figure 1.***

The model predicts that sales accelerate gradually from current levels, reaching a peak of over 2000 MW per year around 2010. Sales levels (of first-time installations) remain at or above current levels throughout the twenty-year period. This is broadly in line with – perhaps slightly more bullish than – industry short-term views of the market [13] – and does not, of course, attempt to reflect short-term influences such as fluctuations in the economy. By 2020 about 40% of commercial floorspace is air-conditioned. The average compound growth rate of sales over the period is 6.5% pa, compared to around 16% pa for the period 1991 to 1996. (But 7% by value in 1997[13] though some analysts put it lower [14]). Beyond 2010 annual sales of first-time installations decline (although there is a growing replacement market, not shown here). In these projections, we are ignoring sales into housing. Generally, we agree with BSRIA's view [15] that such sales could increase rapidly - but from such a low base level that we feel that ignoring such sales is acceptable, given the many other uncertainties in our projections.

Annual electricity consumption by 2020 increases four-fold to nearly 64 TWh. These figures are higher than the increases (themselves significant) implicit in Energy Paper 65 [16] [17] which are based on econometric modelling rather than explicit market penetration estimates. A SAVE project[18] looking only at room air-conditioners has projected similar growth rates, but lower energy consumption. This appears to be based on lower assumed hours of use and smaller installed loads than we have assumed. We are currently associated with a study to add confidence to the values of these important, but somewhat uncertain figures. On a per capita basis, the projected figures are only around 15% of the current level for the US and around 7% of that for Japan. The implied growth of peak electrical demand by 2005 is around 9 GW – similar to the projected growth in winter peak demand [19]. On a business as usual scenario, individual system efficiencies do not improve. However, the average efficiency of all systems does change slightly because of the changing mix of central and packaged systems.

The growth in carbon emissions associated with this expansion of electricity consumption depends on assumptions about the future fuel mix of the electricity generation system. We have used figures from Energy Paper 65 [16], interpolated where necessary. These assume that the carbon intensity of power generation stays close to current levels for the next few years, before rising slightly as Magnox nuclear stations are phased out and replaced by fossil fuelled generation. From about 2005 to 2020 there are relatively small fluctuations in carbon intensity around the values typical of the mid 1990s – but tending to rise towards the end of the period.

Because the assumed carbon intensity is higher in 2020 than now, the increase in carbon emissions is even higher than for electricity consumption, rising to over 9 MtC pa. Of course, this result is dependent on how the generation mix actually changes – for example, whether a significant proportion of renewable generation is added. The effect of *changes* in electricity demand – whether due to air-conditioning or other mechanisms - on carbon emissions also depends on which types of power station are required to operate more frequently. At the limit, if all additional generation were from coal-fired plant, the change in carbon emissions could be very much higher than that shown in the figure. We are investigating this interaction between electricity use in buildings and the generation system, but this is outside the scope of the present paper: suffice it to say that – for the estimated increase in electricity demand - the projected changes in carbon emissions may be under-stated.

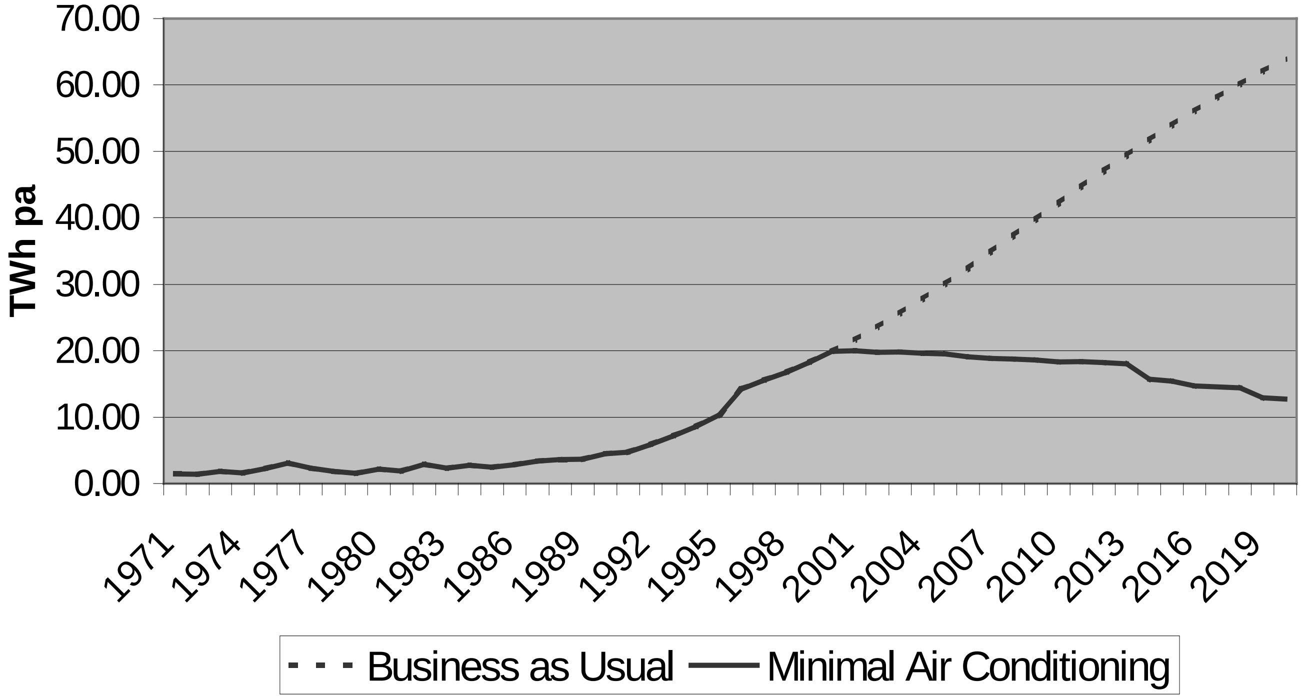


3.2 Minimal Air Conditioning Scenario

We sketch in a scenario based on the "minimum feasible use of cooling energy", as an indication of what is arguably the fundamental reference level - the absolute minimum level of cooled building space to provide acceptable comfort. We do not see this as a likely future, at least in the short to medium term: we believe that the market drivers are such that it would be impractical to limit the use of cooling to this minimal level. Although "acceptable comfort" may be definable technically in terms of internal temperature frequencies, we take the (perhaps pessimistic) view that the majority of the market – at least for the foreseeable future – will be driven by less rational expectations. It his, however, not impossible – Switzerland, for example, has very demanding restrictions on the installation of air-conditioning. This is not to say that we should not be promoting the idea that cooling is often avoidable: we return to this later.

Theoretical analysis of typical offices suggests that it would be possible, technically and economically, to provide acceptable summer conditions in 77% of office space without using air-conditioning [20 21]. The remaining spaces are mainly deep-plan spaces for which technical solutions exist but are uneconomical. The existing penetration of air-conditioning into offices already exceeds this level.

Fig 5: Projected Air-Conditioning Energy Consumption



In this scenario, we assume:

- progressive removal of air-conditioning from a proportion of existing buildings on refurbishment, until only 23% of offices are air-conditioned
- pro-rata reductions in other sectors
- no further increase in the proportion of new buildings that are air-conditioned
- increased energy efficiency for all new and replacement systems. Scope for efficiency improvement is discussed in the following section, in the context of the “energy-efficiency regulation” scenario. In the present scenario, we assume that the most demanding requirements of that scenario are introduced from 2001.

As would be expected, in this scenario energy use for air conditioning declines with time. Initially the decline is slow, as the life of existing central systems is assumed to be 20 years, and that of packaged systems 10 years. By 2020, energy use is about 65% of the current level, and 20% of the “business as usual” scenario.

3.3 Energy-Efficiency Regulation Scenario

From a technical point of view, there is no doubt that there is considerable scope to improve the efficiency of both packaged and central systems beyond the levels that are typical today. There are numerous examples of energy-efficient air-conditioning already, both in the UK and overseas.

The challenge is to bring these technical solutions into widespread use in a market that currently places great store on low first cost, and in which energy costs are a very small part of business costs. Fiscal measures, such as carbon taxes, seem unlikely to make a major or rapid impact – neither do information and exhortation unsupported by more tangible incentives. The most reliable enforcement mechanism seems to be regulation, and we have produced an "energy-efficiency regulation scenario" that assumes assertive energy-efficiency regulation without - we believe - demanding measures that are technically or administratively infeasible in the assumed timescales.

In this scenario, we assume that the demand for cooled space is unchanged from the business as usual scenario and that regulatory energy-efficiency measures are introduced over a period of time. We emphasise that this is an illustrative scenario, but one that we believe to be feasible. We believe that the crucial barrier to more energy –efficient cooling is market pressure that puts first cost ahead of energy efficiency: if all players in the market have to comply with (reasonable) requirements, there are no significant technical obstacles.

Two regulatory mechanisms are assumed: mandatory energy efficiency performance levels for packaged equipment, and mandatory building-level requirements imposed through building regulations.

Mandatory minimum equipment efficiency standards are already in place in Canada, the USA, Mexico, the Philippines, Taipei and South Korea and are being considered in Australia, China, the EU, New Zealand and Thailand. Japan has voluntary standards [22]. Studies for the CEC have shown that many products on the European market would fail to meet these minimum standards [23].

Our scenario assumes a phased introduction of energy efficiency standards for packaged equipment. From 2001, new systems (including replacements) are15% more efficient than the average current system; from 2005 they are 25% more efficient and from 2010 they are 33% more efficient (in all cases relative to current systems). We assume a system life of ten years. A number of studies -and evidence from the US market - show that these levels of efficiency improvement are feasible [24, 25]. One recent UK paper suggested that 50% reductions could be realised by optimising system design [26]. A SAVE study [18] concluded that 50% reductions are technically possible, but the economic optimum would be a 25% improvement.

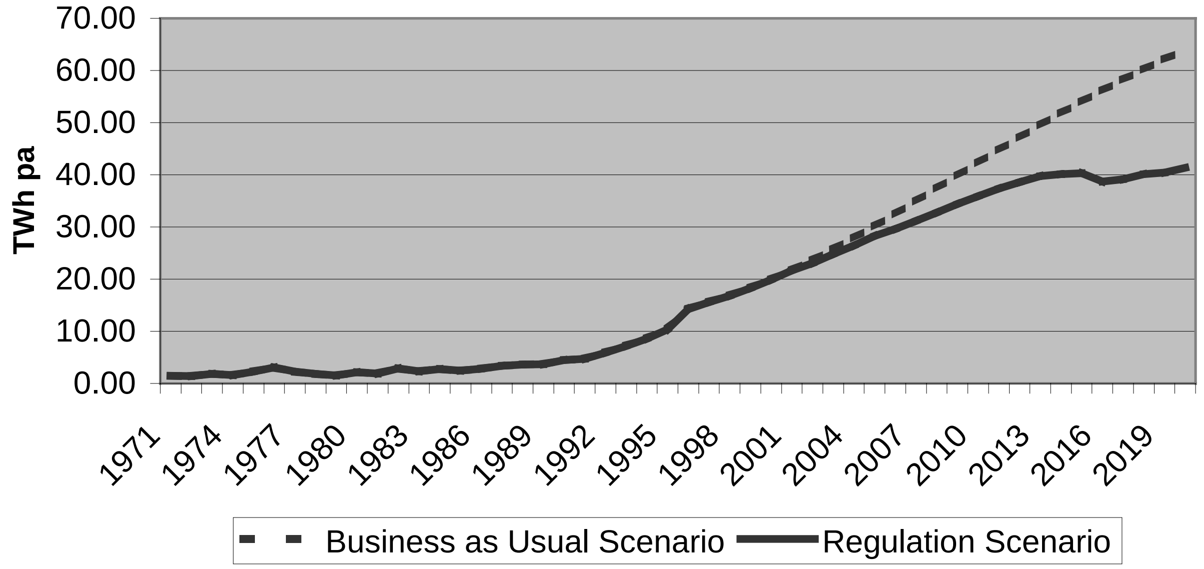
Although UK Building Regulations include efficiency requirements for domestic heating through the Standard Assessment Procedure, and for lighting in commercial premises, until now there has been no such requirement for air-conditioning. Proposals for revising the Regulations are currently being considered by the Government and we are in no way trying to pre-empt the results. However, it is clear that it should be technically possible to devise a form of regulation, probably based on the EPIM framework of analysis, that would require air-conditioning systems (and other building services) to meet minimum standards of energy-efficiency. We do not postulate any specific form for such regulations - we merely assert that they can be framed and implemented.

Technically, there is certainly scope to improve the energy efficiency of central system air-conditioning. Mandatory efficiency standards for chillers in central systems would have a similar impact to standards for packaged systems. More significantly, in UK conditions the main energy-consuming component of all-air systems is the fan. Analysis has shown that, typically, 70% energy savings savings can be achieved with a five-year payback by the use of lower (but not low) design air velocities [27]. There are obviously space implications for larger ductwork, but we believe that these are not insuperable.

Our scenario assumes a phased introduction of such regulations. Specifically, we assume that from 2001 all new installations reach the "typical" performance of the EEBPp Energy Consumption guide ECON 19 [28]. We assume that, by eliminating "worse than typical" new installations, energy savings of 25% accrue. From 2005, more stringent requirements enforcing performance at ECON 19 "good practice" levels are introduced, resulting in savings of 33% from current levels. Since fan energy use is largely determined by duct sizing and duct replacement is only likely in the context of major refurbishment, we assume a replacement period of twenty years. In consequence, the impact of these regulations in the next twenty years is almost all through new installations.

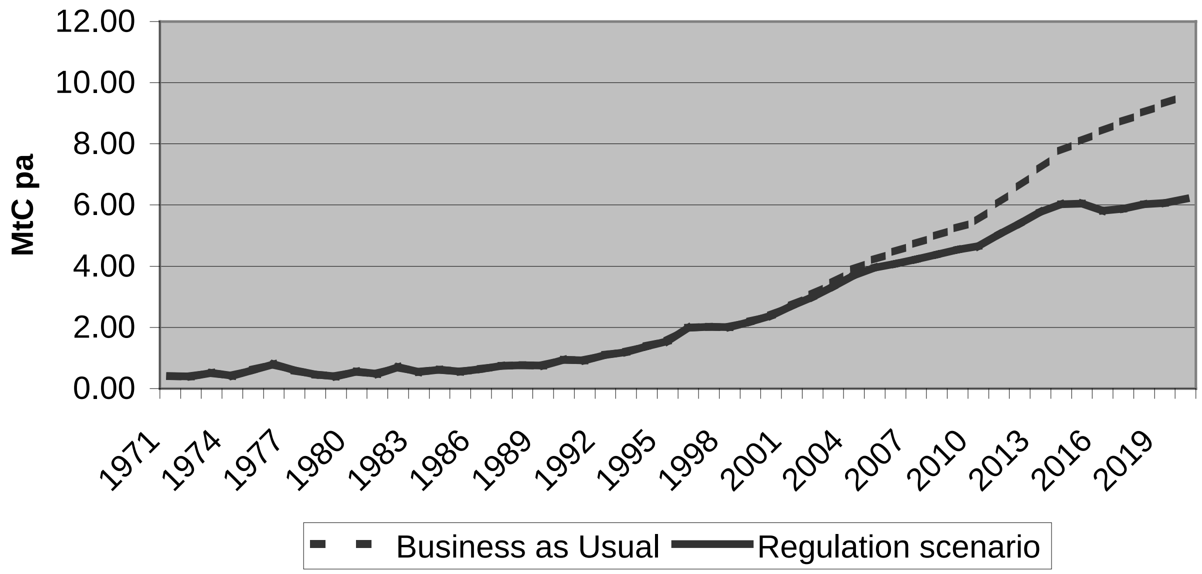
Under this scenario, energy consumption by air-conditioning in 2020 is 35% lower than in the “business as usual” scenario – but is still more than two and a half times that in 1997. In the earlier years of the scenario, most savings come from improvements to packaged plant (because of the more rapid stock turnover assumed), but by 2020, 70% of the savings are associated with central plant.

Fig 6: Projected Air-Conditioning Energy Consumption



The reduction in carbon emissions is also around 35% - equivalent to just over 3 MtC pa. The absolute values are subject to the same caveats that we have already discussed under the "business as usual" scenario.

Fig 7: Projected Carbon emissions from Air-Conditioning



3.3 Feet on the Ground: where next?

The energy-efficiency regulation scenario maps out a view of what might be possible given assertive regulation. Although we believe it to be achievable, the assumed timetable might be thought to be optimistic. What signs of movement can we see, and what could we be doing in the meantime?

We know that the European Commission is looking to extend energy labelling to a wider range of products and has recently issued a draft Directive on “Household Air Conditioners” [29]. This would require such equipment to carry an energy efficiency label of the sort becoming familiar on household white goods. Mandates exist for CEN to develop the relevant standards to include part-load efficiency tests. There do not seem to be any visible signs of mandatory minimum performance requirements, but energy labelling obviously puts into place an important part of the infrastructure that would be necessary for such a development. Publication of “league tables” of performance has the potential to influence the market – but only if buyers and specifiers rate energy efficiency as an important criterion. Efficiency figures will be included in the next editions of the Eurovent [30] equipment directories, and the DETR’s Market Transformation Programme is developing web-based equipment lists.

A SAVE study [19] has recommended that a minimum efficiency standard for room air conditioners should be introduced before 2003, set at the current European average performance, to be progressively tightened towards the economic optimum level of a 25% improvement on this figure. This should be accompanied by energy labelling. Voluntary agreements with manufacturers’ associations could be an alternative path.

The impact of voluntary standards on the marketplace would be stronger if they were linked to incentives of some form. The Enhanced Capital Allowance scheme linked to the Climate Change Levy could be extended to efficient air conditioning equipment, but might be more effective if linked to whole-building performance standards akin to those proposed for the Building Regulations.

Proposals for revisions to the Building Regulations [31] include limits on the installed capacity of air conditioning and mechanical ventilation equipment. For offices, one method of compliance is a Carbon Performance Index, the pass rate of which is equivalent to the median performance of observed consumptions – that is, below-average (strictly below-median) performance is not allowed in new buildings. A slightly less onerous requirement applies to retrofit installations, and there are also requirements on replacement equipment and for system performance to be improved as part of building alterations. This is broadly in line with our assumption for the first phase of regulation in our Regulation Scenario. In this scenario we have assumed further tightening up of regulations. These are neither ruled in or out by the consultation document, but do not appear explicitly in the section describing future amendments.

In the meantime, there is scope for progressive clients and designers to lead the way by demonstrating that better environmental performance is possible at reasonable cost. In some market sectors, the risk of being seen as “not-green” is important and voluntary but independent assessment and labelling, such as the BREEAM scheme are having an impact.

Designers and clients need to be confident that benefits will be achieved – and will not compromise other aspects of building performance. Successes – and shortcomings – need to be disseminated honestly and impartially. Professional institutions and governments both have roles to play here. CIBSE already provides tools through its Guides and Application Manuals. The governments’ Energy Efficiency Best Practice programme is a source of case study information, general guidance and – through its Design Advice activity – of subsidised strategic design advice.

4. Discussion

The rate at which air-conditioning continues to penetrate the building market, and its ultimate market saturation level, are inevitably questions for speculation rather than precise prediction. It is clear that, even with assumptions that are more cautious than we have made, electricity use and carbon emissions due to building cooling are likely to rise several-fold in the next two decades.

We do not believe that demand for summer comfort will disappear; nor that comfort cooling will cease to play a major part in achieving it. We do believe that the environmental consequences that will follow if we simply allow the market to grow in a "business as usual" manner can be very markedly ameliorated by relatively straightforward measures - and that there is much that we can do now to start this process.

We have argued that technical solutions to ameliorate the carbon emissions from increasing market penetration exist - and that the most effective way of ensuring that they are used would be through regulation of different kinds. Although we see signs of movement in this direction, we cannot perhaps realistically expect progress to be as rapid as we have postulated. Regulatory requirements have often been seen as a constraint of trade, when they are actually supporting a fair and open market.. They place all equipment suppliers on an even footing, and remove the often-expressed concern that "of course we could make our equipment more efficient, but then we would be undercut by less scrupulous competitors".

A rather different approach to reducing the carbon emissions impact of air-conditioning is to source electricity from a low (or zero) carbon emission source. Some of the "green tariffs" now available promise to offset electricity purchased by users by providing an equivalent quantity of renewable energy to the supply system (though not necessarily at the times that the end-user is consuming). Leaving aside the slightly difficult carbon-accounting questions posed by the timing mismatch, these obviously have the potential to reduce carbon emissions – as too do the use of waste heat or air-conditioning linked to CHP. The availability of low-carbon electricity is likely to remain limited for the foreseeable future and so should be seen as complementing energy-efficiency measures rather than as a substitute for them. The first priority should still be to reduce demand for grid-connected electricity, whether or not that electricity is provided by traditional or renewable sources.

In the meantime, there is much that building service engineers can do to encourage good practice, and to build a climate in which regulation can be introduced in an orderly manner.

As professionals, our advice on design strategy should be:

- can I design this building to stay comfortable without mechanical cooling? (eg is night cooling appropriate?)

    if not:

- can I limit or contain the heat gains to a level such that only local cooling, or one of the less familiar low-energy cooling systems can be used? (eg is ground-water cooling feasible?)

    if not:

- select a system and its design parameters with energy use in mind. (eg if an all-air system is used, keep the velocities down)

Strategic design support tools and technical information to support such approaches are daily becoming more accessible. We have argued that a regulatory framework is desirable to ensure widespread impact. We need not wait for this though – the greater the number of exemplary buildings, the easier it is for regulators to develop workable rules.

There is some evidence that, although energy costs are not a major issue with developers "future-proofing" – including sustainability is becoming an issue [32]. Designs that allow for the possibility of satisfactory future removal of air-conditioning are inherently more robust against uncertain futures.

Voluntary "green labels" are already establishing precedents that show how better environmental performance can be achieved without compromising overall building performance - and commanding premium rental too. Strategic design aid tools exist to guide clients and designers towards appropriate solutions and away from inappropriate ones. Feedback about performance is already available through PROBE studies and government EEBPp. Conferences like this are the forums where we need to honestly admit that very few buildings are perfect, and that admitting - and correcting - a few minor faults enhances our professional standing much more than hiding problems from sight.

5 Conclusions

If current trends continue, energy use and the consequent carbon emissions associated with air-conditioning will increase substantially by 2020 – on our estimates a “business as usual” scenario would quadruple current levels.

Regulatory measures could substantially reduce this growth - our energy-efficiency regulation scenario reduces consumption and emissions by 35% in 2020. It can be argued that more extreme limits on the use of air conditioning could reduce energy consumption below current levels, but we believe that while these may be technically feasible, market demand for air-conditioning would make them very difficult to implement.

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References

[1] Derived from surveys carried out for BRE

[2] Derived from BSRIA and other surveys

[3] Enhancing the Performance of Oversized Plant, Application guide AG 1/2000, BSRIA, 2000

[4] Private communication, National Grid Company Ltd.

[5] Packaged Air Conditioning, BSRIA Report 12880/1 1997

[6] Central Plant Air conditioning BSRIA Report 12658/1 1997

[7] Pout C H et al, Non-domestic Building Energy Fact File, BRE, 1999

[8] BSRIA Market Surveys, BRE internal reports and private communications

[9] Thompson P, Employers, Employees, Property Developers – Why Air Conditioning Matters. Air Conditioning 2000 plus, Mid Career College Press, 2000

[10] Levermore G, New CIBSE Guidance on Outside Design Criteria, Air Conditioning 2000 plus, Mid Career College Press, 2000

[11] Guebler A et al, Dynamics of Energy Technologies and Global Change, Energy Policy (27) pp 247-280, 1999

[12] Knapp K E, Exploring Energy Technology Substitution for reducing Atmospheric Carbon Emissions, The Energy Journal, (20) 2 pp 121-143, 1999

[13] see, for example, Giles A, Winners and losers line up, Refrigeration and Air Conditioning, March 1998 pp19-20, 1998

[14] UK ac market expands… ACR Today May 2000

[15] Future Market Potential for small Scale Air Conditioning in the UK, BSRIA Report 79570/1, 1998

[16] Energy Projections for the UK , Energy Use and Energy-Related emissions of Carbon Dioxide in the UK 1995 – 2020, Energy Paper 65, HMSO 1995

[17] A Realistic Strategy to reduce CO2 Emissions from Energy End-use, Association for the Conservation of Energy, 1998

[18] Adnot J et al, Energy Efficiency of Room Air-Conditioners, Final Report, Ecole de Mines de Paris May 1999,

[19] 1999 Seven Year Statement, National Grid Company Ltd. 1999

[20] Robinson P and Perera E, Retrofitting Natural Ventilation systems in UK Office Buildings, Building Services Journal, August 1998 pp37-38.

[21] Natural and Low Energy Ventilation Strategies – retrofitting UK offices, New Practice Case Study 118, BRECSU, 2000

[22] Heat Pump Energy Efficiency Regulations and Standards, Report HPC-AR4, IEA Heat Pump Centre, 1996.

[23] Energy-Efficiency of Room Air Conditioners – interim report. J. Adnot et al, Ecole de Mines, Paris 1998

[24] M. Pearson and J Clark, Market Assessment and Economics in North America for Voluntary Programs for Energy Efficiency ….., 5th IEA Conference on Heat Pumping Technologies, Toronto, 1996.

[25] High-Efficiency Commercial Air Conditioning Equipment project reported in Ira Krepchin and Ned Nisson, "Energy-Efficient HVAC Systems", Cutter Information Corp. Arlington MA. 1996

[26] C. Hawthorne, Design Issues for a/c Split Systems, Building Services Journal March 1999

[27] Energy-efficient Mechanical Ventilation Systems, Good Practice Guide 257 , BRECSU, 1998

[28] Energy Use in Offices, Energy Consumption Guide 19, BRECSU, 1998

[29] Draft Directive implementing Council Directive 92/75/EEC with regard to energy labelling of Household Air Conditioners, 1999

[30] Directory of Certified Products: Air Conditioners, Eurovent Certification Company, Paris 1999

[31] The Building Act 1984. Building Regulations. Proposals for Amending the Energy Efficiency Provisions. DETR June 2000

[32] Design Advice tackles 'future proofing', Energy and Environmental Management, 1999

[33] More details of the programme and the issues described in this paper can be found on www.mtprog.com

[34] www.energy-efficiency.gov.uk