Daylight Saving in GB; Is there evidence in favour of clock time on GMT?

Oct 2007 version revised Oct 2009

Brendan Cronin and Elizabeth Garnsey

Centre for Technology Management,

Department of Engineering and

Judge Business School,

University of Cambridge

ewg11@cam.ac.uk

brendan.cronin@ireland.com

This version has been abridged (Oct 2009) since the pilot report in 2007 on work-in-progress entitled "Daylight Saving in GB; Is there evidence in favour of clock time on GMT?" As in the preliminary version, an overview of issues is presented and inferences drawn from daily accident, activity and electricity demand profiles that show there is a case for a policy change. Pilot regression analysis reported in the first version of the paper is not included. This has been superceded by a much more extensive modelling exercise on clock time and electricity demand since conducted for National Grid. Current findings are reported in a new paper **Daylight Saving, Electricity Demand and Emissions; Exploratory Studies from Great Britain", October 2009, by Yu-Foong Chong, Elizabeth Garnsey, Simon Hill and Frederic Desobry** of Cambridge University Engineering Department.
available at:
http://www.ifm.eng.cam.ac.uk/people/ewg/091022_dst.pdf

Executive Summary October 2009

The impact of setting the clocks back to Greenwich Mean Time after the end of British Summer Time requires study in the light of recent evidence. This report examines mainly descriptive data relevant to assessing impact of returning to GMT in winter (1) on road accidents (2) on activity patterns over the course of the day (3) on energy use patterns (4) on electricity generation and price and (5) other issues relating to clock time policy.

Road accident statistics for GB show that in Scotland, England and Wales, earlier timing of sunset under GMT results in the onset of dark during the heaviest traffic period of the day. Traffic is heavier for longer in the early evening than in the morning. Consequently an hour of light at evening rush hour reduces risk for more drivers and pedestrians than an hour of light during the shorter morning rush hour, when there are fewer road users than at the end of the working day. Studies by the Transport Research Laboratory have shown that clock time on GMT instead of on daylight saving time results in over a hundred unnecessary deaths on the road annually in GB, and over 40 deaths and serious injuries in Scotland.

Electricity demand in GB is higher in the late afternoon and early evening than in the early morning and peaks in the late afternoon/early evening at a level above that reached at any time during the morning. It follows that shifting light from the evening to the morning will increase demand for artificial lighting at a time when demand for electricity is at peak levels, leading to recourse to expensive, inefficient and polluting sources of reserve power generation. An analysis shows that the market price of electricity rises as a result of higher demand peaks (from early onset of dark under GMT). This higher price affects consumers throughout the country, in Scotland as in England and Wales.

Sunrise and sunset were set historically too early in the standard clock time day to align with current activity patterns of the population. The recommendation drawn from the study is to move the clocks onto GMT+1 in winter and GMT+2 in summer. Local working hours and school hours could be adjusted to local seasonal conditions, as in Scandinavia.

Evidence on issues other than electricity impact of clock time is summarized in the following table.

Summary of potential impact of GMT as clock time policy in winter

	Current Evidence	**Source of Evidence**	**Groups involved**	**Effect of moving the time regime forward**
Road Accidents Associated medical costs to NHS	In GB 450 serious injuries and 104 deaths annually could be prevented by GMT+1/GMT+2 clock time. GMT- induced injuries cause £200m per year costs to NHS. Cumulative costs since GMT reintroduced in 1971: £7b	Transport Research Lab, 1998 Hillman 1993	RoSPA Royal Society for Prevention of Accidents Support/ Association of Head Teachers support	Favourable
Electricity demand and price	Inference is that lighter evenings at time of higher demand will save electricity on GMT+1 in winter Reduction of peak time electricity generation costs	Daily electricity demand profiles, GB	NG provided data on GB electricity demand	Favourable
Crime & Security	Decreased crime & increased security	Policy Studies Institute, 1993	Age Concern support	Favourable
Health, Leisure & Wellbeing	Average of 55 min daily increase in accessible daylight	Policy Studies Institute, 1993	BMA support	Favourable
Tourism, Commerce & Industry	£1 billion boost due to more opportunities for sightseeing / activities in the evening	Policy Studies Institute, 1993	Tourism Alliance support	Favourable
Trade and Finance	Improved conditions for trade with Europe	No studies found	Business support has not been sought	Favourable effects can be inferred
Early morning workers	Issue of light for early morning workers	Construction industry findings	National Farmers Union now neutral	Unfavourable but working hours could be adjusted.
Population living in north	Darker morning in winter counterbalanced by more light during early evening – which is the peak period on roads and for energy use.	Accident impact studies Higher Electricity price in all GB	Scottish MPs oppose change	Favourable evidence - has not been diffused.

INTRODUCTION

"Evidence based policy" is the watchword today.[1] The aim of daylight saving is to align clock time with the activity patterns of the population. But no comprehensive recent evidence has been produced in support of current clock time on GMT in winter. In this paper we examine the case for returning to GMT in winter in the light of (1) road accidents (2) activity patterns and solar time (3) energy use patterns (4) generation costs and (5) other issues relating to clock time policy are examined.

1. Road Accidents under GMT

The timing of sunrise and sunset is relevant to road accidents because activity on the roads is in response to clock time rather than to the timing of sunrise and sunset; for example most people return from work between five and six p.m., whatever the timing of sunset. Reduced daylight reduces visibility and so provides less opportunity for drivers to react.

To highlight the diurnal pattern of road accidents, we carried out an analysis of the proportion of road accidents that occurred at different times of day in GB. The figures are consistent with more intense activity on the roads occurring for longer in the late afternoon than during the early morning peak. Consequently there is grater risk of accidents from early evening darkness than from early morning darkness. Moreover drivers are less tired and less prone to error in the morning. There are more pedestrians on the roads in the afternoon, including more children, who are at 75% greater risk of accident after school than before school (RoSPA 2006 & House of Commons Library 2007). The distribution of accidents by time of day reflects travel-to-work patterns, which do not show much seasonal variation.

Figure 1 shows the daily pattern of road accidents in GB and separately for Scotland, where the activity on the roads and hence of accidents by time of day is very similar to the rest of GB.

---

[1] www.defra.gov.uk/science/how/evidence.htm refers to the 1999 *Modernising Government* White Paper, which noted that Government "must produce policies that really deal with problems,that are forward-looking and shaped by evidence rather than a response to short-term pressures; that tackle causes not symptoms".

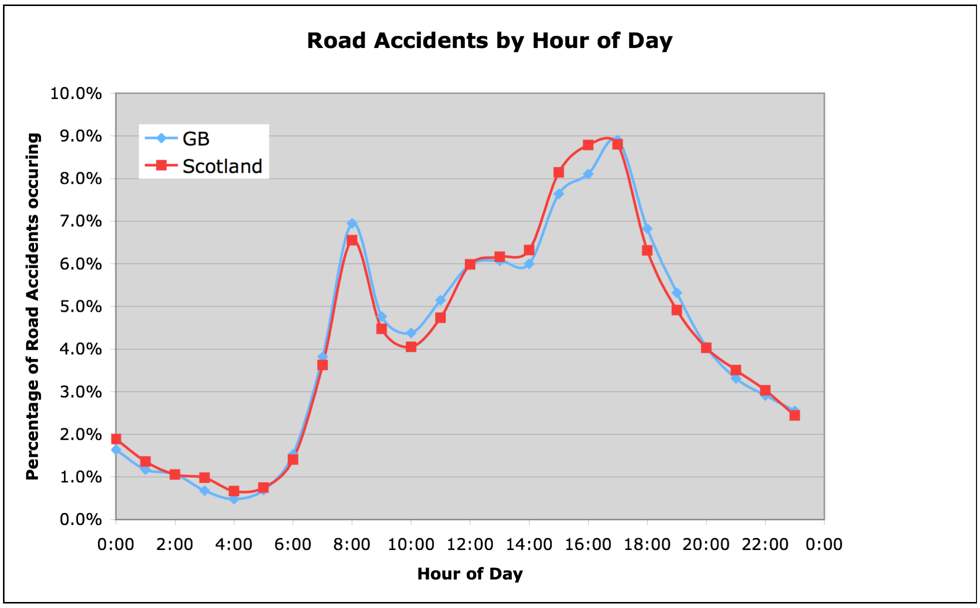

Figure 1: Percentage of Road Accidents Occurring by Hour of Day, GB and Scotland, (2001-6 averages).

There is an early morning peak in accidents from 8.00 am to 9.00 am, but a higher and longer lasting accident peak occurs from 3.00 pm to 6.00 pm. In Scotland, as in the rest of GB earlier timing of sunset under GMT results in the onset of dark during the period of the day when the traffic is heavier for longer than during the morning peak. The effect on accidents of a return to GMT in winter is therefore predictable and explains the consistent series of findings that road accidents are higher under GMT than GMT+1. Folk memory is in error in holding that there were more accidents during 1968-1971, the period when the clocks were not set back in winter. The reduction in accidents in the early evenings was over twice as great as the increase in early morning accidents over this period, with a net reduction of 8.6% of road casualties in Scotland.[2] To assess the impact of clock change, relevant data are the net total of accidents morning and evening. It is misleading to focus on the one without the other.

The effects of a GMT+1/GMT+2 regime on road accidents for the period 1991-1994 are shown in Table 2.

[2] House of Commons Hansard, 02nd Dec 1970 c.1340.

	Killed	Seriously Injured	Injured
Morning	-39	-265	-601
Evening	143	604	1717
Net reduction	104	339	1116
Reduction as % of total	**2.5%**	**0.7%**	**0.4%**

Table 2: Net annual reduction in accidents in GB for the period 1991-1994 had a GMT+1/GMT+2 clock time regime been implemented in place of GMT/GMT+1.

Net reduction in fatalities of 104 people per year and of 339 serious injuries were estimated by this analysis. A GMT+1/GMT+2 regime would cause a small decrease in accidents, but the severity of accidents overall would decrease by a much greater extent.

If a GMT+1/GMT+2 regime had been adopted during the 1990s in Scotland, there would have been an annual reduction on Scottish roads of all casualties of 57 persons per year and a reduction of killed and seriously injured persons of 41 persons per year, according to the Transport Research Laboratory's study (Broughton, 1998), the most comprehensive inquiry yet conducted (Table 3).

	Killed and Seriously Injured	All casualties
Morning	-30	-44
Evening	71	101
Net reduction	41	57
Reduction as % of total	**0.74**	**0.24**

Table 3: The Estimated Effect of a GMT+1/GMT+2 regime in Scotland in the 1990s Transport Research Laboratory (Broughton and Stone, 1998).

To the incalculable social and human costs of traffic accidents must be added costs to the National Health Service and related infrastructures. Over 35 years of accidents during darker than necessary early evenings, the National Health System may have accumulated over £7b in costs. In a comprehensive report on the impact of GMT, Hillman estimated in 1993 that the reduction in expenses to the National Health System of GMT+1/GMT+2 would be in the region of £200 million a year (Hillman, 1993).

The deaths of schoolchildren on the way to school during the darker winter mornings were well publicized by the press and attributed to the GMT+1 experiment.[3] However, the figures on the much greater reduction in afternoon deaths on GMT+1 did not make the news and have not been assimilated in the collective memory in Scotland.

2. Activity Patterns and Clock Time

From a study of activity patterns it is possible to explain both accident patterns and energy consumption patterns, and to infer the impact of clock change policy.

The time at which urban people wake in the morning is influenced to a greater extent by clock time than by the timing of sunrise. Figure 3 shows weekday sleep patterns in the UK. Overlaid on the diagrams are the hours of sunlight during the winter and summer months under various time regimes. Currently under GMT, around 35% of the population are asleep when the sun rises in winter. Shifting to GMT+1 in winter would time sunset to occur when under 20% of people are asleep.

[3] It is now easier to set street lights to come on again in the morning than it was in the period 1968-1971 before switching was fully computerized. Hence children are at greater risk from accidents after school (RoSPA).

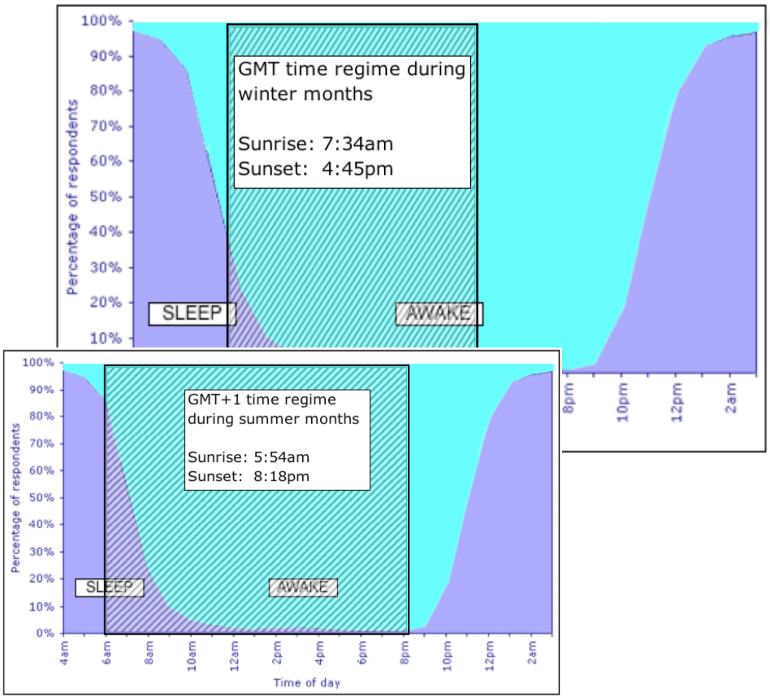

Figure 2: Daily Activity Patterns and hours of sunlight during winter and summer months showing hours of daylight (shaded) on GMT and on GMT+1 (For Birmingham; adapted from National Office of Statistics).

From the figure showing the period of sunlight in summer under GMT+1 it can be seen that under GMT+1 on average over 80% of the population are asleep at sunrise, while several hours of energy-consuming activity follow sunset. The activity patterns of the population indicate as a matter of logic that excess energy is being consumed as a result of the timing of sunrise and sunset under current clock time.

3. Demand for Electricity and the Impact of GMT

In this section we examine evidence on daily patterns of energy use to see how they are likely to be affected by advancing official clock time, with particular reference to the timing of peaks in demand

Electricity Analysis: Peak Demand Trends

To enable us to isolate the effect of GMT on the peaks in demand, the data for the week after the clock change were normalized by assuming that demand at midday on both days was independent of any clock change effect. The demand for the week after was scaled, so that the demand at 12.00 matched the week before. This method (proposed by Chris Rogers of National Grid Co.) does not claim to represent absolute values, but is useful for comparing the shape of the demand profile from one week to the next. It shows how peaks increase when the clock shifts to GMT in autumn and lessen with the return to GMT+1 for the spring clock change.

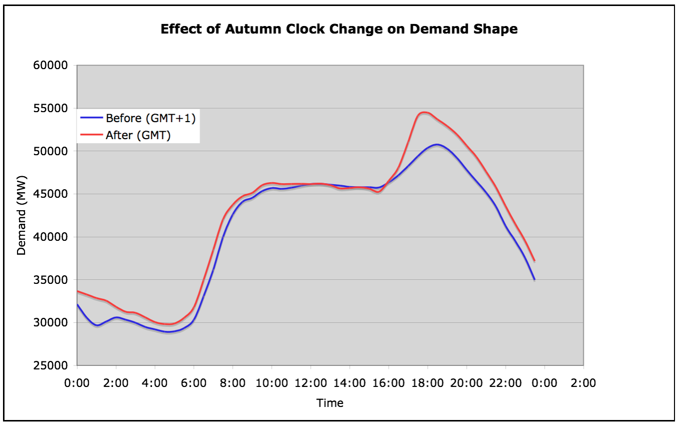

Figure 3: Effect of autumn clock change on the demand profile, 2006.

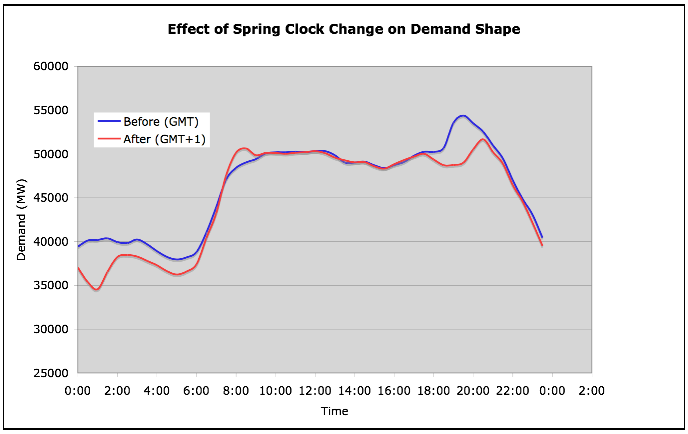

Figure 4: Effect of spring clock change on the demand profile, 2006.

The effects of autumn and spring clock changes (Figures 3 and 4) are not symmetrical because of lower temperature and more light in March. The spring change takes place three months after the shortest day while the autumn clock change takes place just two months before the shortest day when demand is greater and the scope for separating return from work and onset of darkness peaks is less.

In general, severe winter peaking occurs when the period of intensive electricity usage and the onset of demand for lighting coincide because of early darkness. For how long a period of time does severe winter peaking continue as a result of the imposition of GMT? We found from calendar analysis that there are 34 days during which sunset in London is timed when clock time is on GMT to coincide with the daily period of maximum energy demand (which extends from around 16.00 hours to around 18.30 hours). For all of these 34 days, GMT+1 would delay sunset until after the period of peak energy demand, so reducing demand peaks.

Indirect Evidence on Generation Costs under the GMT Regime

The aim of the analysis that follows was to examine how additional demand for electricity caused by sunset an hour earlier by clock time in winter translates into higher electricity prices on the spot market for electricity, given the uneven profile of daily demand. It can be inferred from the use of reserve power to cover peak demand that high peaks in demand will map onto still higher peaks in generation costs. Price to end users is difficult to calculate because of forward contracts between utility companies and suppliers so this evidence is mainly useful as proxy evidence on daily demand profiles and peaks at the time of the clock change weeks. These are affected by generation costs of meeting elevated levels of demand.

Factors affecting market electricity prices

Market price data under the current auction system fluctuates continually by hour and by day, depending as it does not only on seasonal and factors but on the interaction between traders. By averaging over five years, we found a smoother trend underlying the fluctuations in pricing from hour to hour and day to day. Electricity prices as experienced by end users are not the same as these market prices because of forward contracts between utility companies and suppliers of electricity. The market price trends are interesting as proxy evidence of generation costs caused by severe peaks in demand. Generation costs of peaks are proportionately much greater than the absolute increase in demand under GMT (as opposed to daylight saving time).

Electricity price data for the period immediately before and after the clock change date were prepared for the last 3 years for both spring and autumn clock changes. For each daily 30 minute time window (00:00-00:30, 00:30-01:00 … etc), the average for each of the 7 days, for each of the 3 years was calculated. Thus each point on the graph is an average of 21 points, allowing for market fluctuations to be smoothed and providing a clearer picture of the underlying trend in the electricity prices before and after the clock change.

The spike in electricity price illustrated by the October clock change in 2006 (Figure 5)) shows that although the change in demand peaks (in the weeks before and after the clock change) are usually much smaller in the autumn than those in March, there can be a significant increase in the costs of electricity after the October clock change.

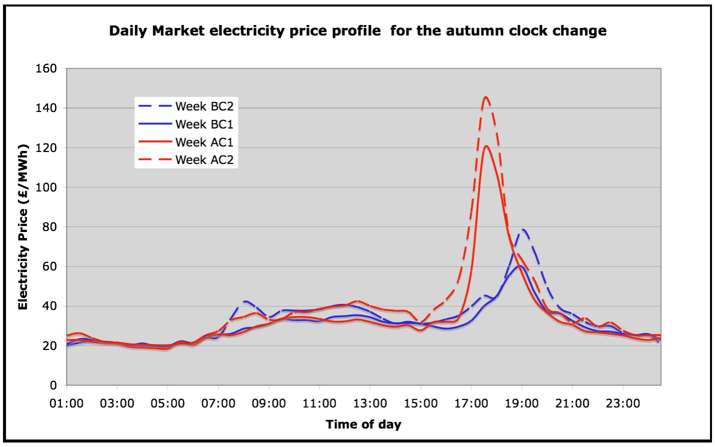

Figure 5: Average daily electricity price profile during the autumn clock change, 2004-2006 average. **(BC: before the clock change AC: after the clock change).**

We turn now to explore how price increases in electricity reflect the important underlying phenomenon of higher peaks in demand under GMT.

Generation costs and reserve power requirements

The reason why sharp peaks in demand create massive knock-on effects for generation costs is that they require recourse to the nation's reserve power. In order to meet the higher and more prolonged evening peak associated with GMT, less efficient plant (such as oil powered generation and pumped storage) have to be called on to generate electricity to meet the peak. Even when the extra generation capacity is only required for a short period, capital costs must be paid and equipment must be maintained, heated up and cooled down. A relatively minor increase in electricity demand at a time of peak consumption will give rise to a much more substantial generation cost. This explains why there is a marked price profile change at the time of the autumn clock change even though the change in evening peaking is lower than in spring.

Additional generating capacity needs to be bought online to deal with peaks and taken offline to deal with demand reductions. This must be dynamically balanced for all times of day by the electricity grid system operator (the National Grid Company). A steady demand profile is more manageable and requires less start-up and shutdown of generating capacity. Power plants cannot simply be switched on and off to deal with peaks in demand. It may be necessary to call into operation more costly and less efficient reserve power.

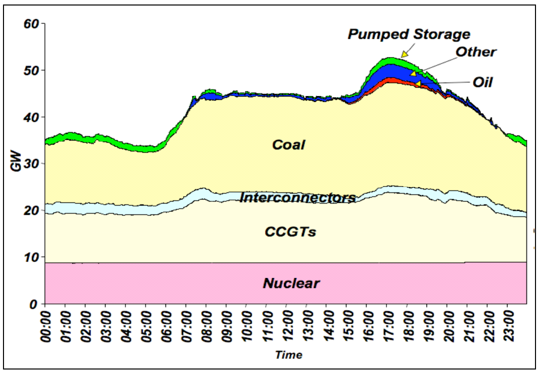

Figure 6: Generation source for a typical daily demand profile. ***Courtesy of NGC 2007* (CCGT: Combined Cycle Gas Turbines).**

When later timing of sunset concentrates most of the increase in average daily consumption at the time of afternoon/evening demand peaks, this requires that expensive reserve power be ramped up over the course of the day, resulting in a much greater increase in generation costs. As the price of electricity is the same over the whole of GB, if the price rises as a result of GMT related demand peaks, this feeds through to consumers in Scotland no less than to those in England and Wales.[4]

Other Issues

Factors addressed in other studies were reviewed in the initial summary table. Here we take up a few of these issues.

Harmonization with Europe

Since 1971 there has been little activity by business or financial interest groups in favour of full harmonization of clock time with European Union countries. Groups opposed to such harmonization have been more vocal. The EU is the major trading partner of the UK; hence

[4] BETTA introduced a single wholesale electricity market for the whole of GB on 1st April 2005: http://www.dti.gov.uk/energy/markets/electricity-markets/betta/page30130.html

there are strong arguments for a move directly GMT+1 in winter and GMT+2, the clock time of most other EU countries.

Incomplete evidence was used to draw invalid conclusions from the Portuguese experimental The Portuguese case was presented as evidence of the undesirability of an experiment in the UK and was quoted extensively during the second reading of the "*Lighter Evenings (Experiment)*" Bill of 2006. [5] Portugal already enjoys an hour more light in the evenings on GMT than does the UK, through being located so much further south. Thus it does not require a clock change for Portugal to achieve the benefits that GMT +1 in winter would offer the UK.

The Scottish Dimension and Electoral considerations

The key issue on which recent private member's bills have foundered in attempting to effect a change in clock time regime is the Scottish issue. Scottish MPs have not been provided with comprehensive and clearly explained evidence. The reduction in road accidents from changing to GMT+1 all year would be no less in Scotland than the UK as a whole. This was known at the time of the 1968-71 debate as the 1970 Hansard record confirms.[6] *"We have the statistics of the causalities. In England and Wales there was a betterment of 3 per cent. In Scotland ... there was a betterment of 8.6%."* At the time of the debate these statistics were questioned, but a series of research studies since 1995 on more current Scottish accident data have confirmed the unfavourable impact of GMT, which have been shown to result in around 40 unnecessary deaths and serious injuries on Scottish roads annually.

Our preliminary estimates suggested that the impact of a move to GMT+1 in winter would be neutral for Scotland. The gains are less where there are so few hours of daylight in winter that dark falls before the daily peak in consumption even on GMT+1, but since Scotland has under 10% of the population of GB, the adverse impact of GMT on energy use in the rest of the country is the predominant effect. Moreover the price of electricity is the same over the whole of GB.[7] When the price of electricity rises elsewhere in GB as a result of higher

---

[5] House of Lords Hansard, 24th Mar 2006 c.479.

[6] House of Commons Hansard, 02nd Dec 1970 c.1340.

[7] http://www.statistics.gov.uk/downloads/theme_population/PopulationTrends128.pdf (accessed on 1st August 2007).

demand peaks from early onset of dark under GMT, this higher price affects end users in Scotland no less than those in England and Wales.[8]

Cumulative Effects and Climate Change

The cost in accidents of earlier onset of dark under GMT is well established, but the figures should be considered cumulatively. Without counting the thousands seriously injured since 1971, when GMT was reintroduced in winter, at least 100 people have died unnecessarily on the roads every year as a result of GMT. Thus at least 3600 lives could have been saved by a change in clock time policy (the number of people killed in NY on 9/11/2001).

Climate Change Issues

The issue of clock time has not been investigated in the UK in connection with the campaign to reduce carbon emissions.[9] Although the exact value of electricity savings cannot be calculated in the absence of actual current data on GMT+1 in winter, that there would be savings can be inferred directly from electricity demand profiles and activity patterns.

Because demand for electricity is higher in the evening than the morning, light is at a premium in the evening and setting the clocks back will result not only in higher demand for electricity for artificial lighting, but additional carbon emissions resulting from the additional power produced to meet this demand, more especially when more polluting reserve power is called upon to meet higher peaks in demand.

We are increasingly enjoined to alter our way of life to reduce harmful effects of rising electricity consumption. The government has maintained that an institutional innovation of this kind requires a change in public opinion. This however requires that the relevant evidence be brought home to the public.

---

[8] BETTA introduced a single wholesale electricity market for the whole of GB on 1st April 2005: http://www.dti.gov.uk/energy/markets/electricity-markets/betta/page30130.html

[9] The draft Climate Change Bill of 13th March 2007 commits the UK to a 60% cut in the UK's carbon emissions by 2050, with an intermediate target of 26-32% by 2020.[9] These emissions cuts will be legally binding on parliament to achieve. An independent Committee on Climate Change will be set up to advise on policies required to meet this target.

References

1. Hillman, M. 1993, *Time for Change, Setting the Clocks Forward By One Hour throughout the Year, a New Review of the Evidence*. London: Policy Studies Institute.
2. Royal Society for the Prevention of Accidents (RoSPA), 2005, *Single/Double Summer Time Position Paper.*
3. Broughton, J & Stone, M, 1998, *A new assessment of the likely effects on road accidents of adopting a GMT+1/GMT+2 regime*, Transport Research Laboratory.
4. Sood, N & Ghosh, A 2007, 'The Short and Long Run Effects of Daylight Saving Time on Fatal Automobile Crashes', *Journal of Economic Analysis & Policy*, Vol. 7, Issue 1, Article 11.
5. Transport Statistics Branch, 1996, '*The Effect of Single/Double Summer Time on Road Safety in Scotland*', Scottish Office Development Department.
6. Smith, J. 2003, Home Office Research Study 254: *The nature of personal robbery*, Home Office Research, Development and Statistics Directorate.
7. Broughton, J and Stone, M 1998, Report 368: *A new assessment of the likely effects on road accidents of adopting a GMT+1/GMT+2 regime*, Transport Research Laboratory, Crowthorne.
8. Economist Intelligence Unit 2007, *Country Profile: UK*.
9. Tversky, A and Kahneman, D 1974, *Judgment under Uncertainty: Heuristics and Biases*, Science: New Series, Vol. 185, No. 4157, pp. 1124-1131.
10. Kahneman, D 2002, Nobel Prize Lecture, Stockholm.

Bibliography

Downing M. 2005, *The Annual Madness of Daylight Saving Time*, Shoemaker & Hoard.

Financial Times, 8th May 2007, *Help us sell less power, National Grid tells regulators*.

Hopkin, M. 2007, Saving Time, *Nature*, Vol. 445, No. 25, pp. 344-345.

Kandel, A & Metz, D. et al., 2001, *Effects of Daylight Saving Time on California Electricity Use*, California Energy Commission Staff Report, May 2001.

Mayer Hillman, 1988, *Making the Most of Daylight Hours*, Policy Studies Institute.

Office of National Statistics, UK, *The UK 2000 Time Survey,* Survey of 9000 households http://www.statistics.gov.uk/TimeUse/default.asp (June 1st, 2007)

McCarthy Dennis D 1991, Astronomical Time *Proc. IEEE*, Vol. 79, No. 7, July 1991, pp. 915-920

Prereau, D. 2005, Seize *the Daylight*, New York, Thunder's Mouth Press.

Ryan Kellogg and Hendrik Wolff, January 2007, *Does Extending Daylight Saving Time Save Energy?*, Centre for Study of Energy Markets.

Comment:

Comment:

APPENDIX Data Sources and Terminology

Electricity Data

National demand data at 30 minute intervals for the period 2001-2006 was provided by the National Grid Company (NGC) for this study. Data for recent years is available on the NGC website. [10] The power of electricity flowing through the transmission network of the National Grid Company is balanced in response to demand for power, and hence is termed "demand' by the NGC; since this is a measure of power, units are in MW. Energy usage over a specified time period is called "consumption" and is measured in MW hours.

The standard unit of analysis for electricity demand is the Kilowatt-hour (or at high levels, the Megawatt-hour (MWh) or Gigawatt hour (thousands of MWhs)). On a domestic bill, one unit of electricity relates to one kilowatt-hour. This is equivalent to one kilowatt of power being drawn continuously for an hour by the consumer.

.

[10] www.nationalgrid.com/uk/electricity/data/demand+data (accessed on 2nd August 2007).