The Black Death and Energy Use in Late Medieval England

Mobilising and Using Energy, from Antiquity to the Present Time

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Fernand Braudel in his 1967 first volume of *Civilisation matérielle, économie et capitalisme: XVe-XVIIIe siècle* wanted to evaluate, '...the limits of what was possible in the pre-industrial world'.[1] He called energy sources the pivotal problem facing pre-modern Europe. After doing a tally of the total energy available he concluded: 'Lack of energy was the major handicap of *ancien rêgime* economies'. [2] Paolo Malanima has followed Braudel in pointing to the power of energy supplies to limit the economy.[3] If that were the case then the demographic disaster in mid fourteenth century should have released Europe from any constraint which energy supplies placed on that pre industrial world and opened the door to new possibilities for survivors. Measurement of energy consumption is difficult, accuracy and completeness being constant problems. England, because of the availability of sources and because of recent extensive studies of various aspects of the energy production and consumption, offers a testing ground to evaluate the results of changes in available energy per person. The test is a comparison of the energy regime before the Great Death of 1348-50 and the regime 150 years later. 1300 is the start, falling at the end of the long period of sustained economic growth and relative social stability. 1450 is the end point, in the middle of a period of stability in population, that is when demographic change was minimal and when the energy economy had made what

adjustments it would make in the face of the great population fall. If energy availability was the constraint on both economic growth and social change, then massive surplus mortality in theory eliminated the constraint and signs of dramatic adjustment should be obvious.

Late medieval England fell in the agricultural phase of energy history. The principal sources of energy were firewood, human muscles, animal muscles, water and wind power. A breakdown based on Malanima's work on Europe give an impression of the regime in pre-industrial societies.

Using different methods it was possible to produce estimates of the energy consumed by the principal carriers as well as estimates of the land area needed to supply that energyin late medieval England.

The population of the kingdom in the fourteenth and fifteenth centuries has been a source of debate since the 1940s. Here, the figure for 1300 is taken to have been 4,750,000, perhaps a little high, and for 1450 1,900,000. Contrary to expectations, recovery from the Great Death was extremely slow. The figures accepted put the cumulative population fall over the 150 years at 60 per cent or an annual compounded fall of about 0.6 per cent.

For human beings food intake per day in 1300 is taken to be 2100 kilocalories and in 1450 2200. The increase from 3.2 gigajoules per person per year to 3.4 in 1450 is attributed to the fall in grain prices after about 1380 and also to changes in diet. 80 per cent of those calories came from grain. Anything above that threatened nutrition. The remainder came from animal products. About 20 per cent of pasture is assumed to have been for grazing the beasts. Grain came from sown acreage, less five per cent of which went to feed animals.

For firewood, consumption in England was relatively low at an estimated 2.0 kilograms per day.[4] With a reasonable estimate of the amount of energy in a weight of wood that made

annual consumption in 1300 about 8.6 gigajoules per person. Production of firewood was well organized as was forest management in general in pre modern England. Assuming output averaged 3.3 cubic metres per hectare and that a cubic metre produced around 9.0 gigajoules of energy, a hectare could produce about 30 gigajoules each year. If people on average burned about 1.0 cubic metres annually in 1300, a hectare supplied the needs of 3.3 people.

The quantities of firewood consumed were high because of inefficient burning, more prevalent in England in the late Middle Ages than on the Continent. In open fires perhaps 95 per cent of the energy released was lost. Though there is evidence of the combination of fireplace and chimney being known in the early ninth century it was in the twelfth and thirteenth centuries that the expensive innovation came into use, at least for the most well-off. While over the long term stoves reduced firewood consumption per person in the rest of Europe, late medieval England apparently reaped no benefits from better burning techniques.[5]

Consumption of firewood rose per person by 1450. Domestically more food consumed would have pushed up thermal energy use and climate changed possibly too, though undoubtedly little. Outside the home industrial output expanded per person, 2.6 times. Relative to agriculture though the sector was very small. Also there was from around 1440 to 1470 a slow down in the economy.[6] One industry that enjoyed fast growth was brewing. People drank more ale, more than twice as much per person in 1450 as in 1300. Even so English consumption was still well below contemporary levels in northern European towns. Data from the extremely prosperous late medieval Dutch brewing industry give an indication of energy required to make the ale. If anything the figure errs on the high side. Thermal energy consumption did rise between 1300 or 1450. The degree is difficult to estimate and difficult to ignore. An overall increase in energy consumption from firewood per person of 49 per cent is assumed to include all factors. with ale

making a somewhat significant contributor to the change.

For draught animals calorific intake depended on size and level of activity. England had a relatively high number of animals. They would have consumed on average 29 gigajoules per year per animal, or 3.3 times as much as a human being in 1300. At a maximum permanent, grassland could have been 50 per cent greater than the sown area. Animals also grazed on fallow. The estimate for grasslands is by far and away an exaggerated upper limit since pasture was used to feed the considerably larger population of non-working animals as well. Also about two per cent of arable went to growing fodder to feed draught animals.

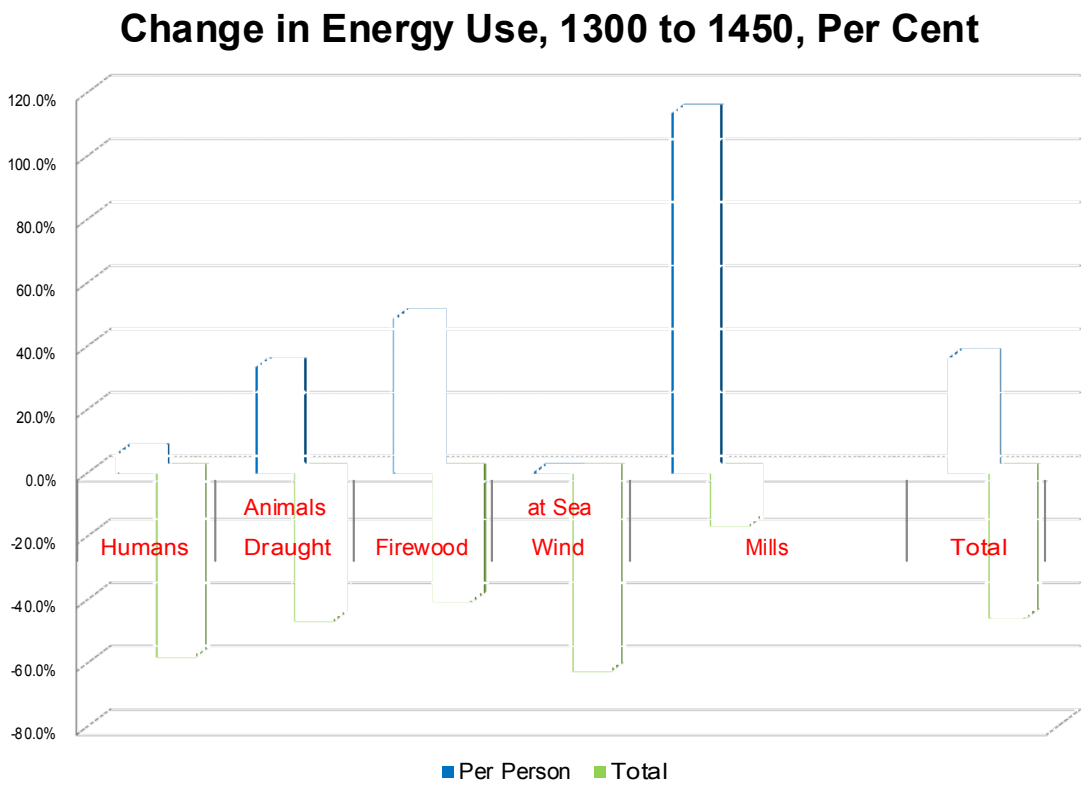
For mills, both water and wind, there were technical improvements over time which increased their energy output. Watermills produced about 100 megajoules per day operating for eight hours, windmills 22 per cent less with wind speed being the major determinant. Mills declined in number but not as fast as population which meant a dramatic percentage increase in energy from mills but with still a very low contribution to total energy consumed.

With ships on the water, to estimate the energy consumed it is necessary to know the energy needed to move a specific tonnage and the total tonnage of the English fleet, an unknown figure, and the number of days ships spent at sea, also difficult to estimate. Considering the size of the object moved the amount of energy was extremely small. With different forces working to raise and to lower the level of wind energy consumed by ships at sea the figure per person probably did not change much from 1300 to 1450. In any case the total was so small it had no significant impact on the totals. With ships, considerable technical improvements in design and not only of the largest but also of small craft, made vessels more effective. An addition to the numbers of machines, be those watermills or ships, per person would have made life easier for workers. Whatever differences existed they were nothing like the scale in the changes in

population or total output.

The estimates for per person and total energy consumption for all carriers suggest a heavy reliance on firewood for thermal energy and on muscle power, much of it human, to do work. Wind and water power offered convenient and helpful supplements on land but were of little importance within the total energy budget. The data from 1300 suggest that there was still potential for expansion in population and output. Investment in water and wind power, changes in cropping, more efficient use of firewood among other options offered possibilities to deploy more energy more effectively.

Land used to produce energy per person rose considerably from 1300 to 1450 while the total fell with the fall in population. People and draught animals took advantage of the extra land to supply them with more energy. Perhaps most informative are the percentage changes in per person and total energy consumption and changes in land required to produce the energy. Population fell by 60 per cent and no category declined that much. Firewood consumption rose little relative to other categories. The great beneficiaries were draught animals. The graph shows the changes in energy use per person and in total. Though total energy consumption fell dramatically from 1300 to 1450 energy at the disposal of each individual rose on average 36 per cent - a gift to survivors of the Great Death and a reward for those who kept population low for so long. The percentage changes in land sources for the energy carriers shows that production became considerably more land intensive. There was a sharp increase in hectares used per person.



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the land area in England used to produce energy on the one hand decreased pressure on land use, with regional and local exceptions, and on the other hand left considerable areas to develop distinctive environments with minimal interference from humans. Land use calculations suggest a serious constraint on growth in 1300. The 86.2 per cent share is so high as to suggest overestimation. Still, if there was potential for increasing production and population it probably had to come from better technology and more efficient use of resources. Raising output would rely on more intensive than more extensive production. Land needed to satisfy demand for firewood was around 10.0 per cent of the total, a figure that suggests that there was some pressure on wood sources. Protection of woodlands, finding alternative sources of wood such as from the pollarding of trees that were not part of woods, finding alternative sources of thermal energy such as peat and coal must have been part of life in 1300. With so much land in grass it

should be no surprise that there were cases in the first half of the fourteenth century of the conversion of grassland to arable.[7] In energy terms it was more efficient to grow fodder crops than to let animals loose to forage on their own. Any problems of pressure on land disappeared after the Great Death and the question was how best to use the greater acreage per person.

There is an upward bias in the estimate of pasture. There is an upward bias in the estimates for energy from mills since the number of hours per year chosen for their working is optimistic. Since windmills, like ships at sea, made such a small contribution to the total any overestimate makes little impression on the final results. Rounding can introduce misrepresentation though that would be insignificant in dealing with such large quantities.

The mid fifteenth century level of energy consumption was one not seen again until the 1670s.[8] The rise came mostly from better nutrition for people and the increase in the number of draught animals. There was some undoubted improvement for people working though, given the massive excess mortality, the energy gain was not on a scale with population change, even if much welcomed by survivors. Those people made good use of the new supply of energy. From 1300 to the 1450 real gross domestic product per person went up by as much as 45 per cent, that is about 25 per cent more than the increase in energy consumption per person.[9] The very positive change in incomes indicates that overall energy efficiency improved considerably in the wake of the Great Death, that despite a shift to lower extraction rates from grains, caused byk making more ale, and some loss in scale economies in energy use. The efficiency improvement is remarkable since with more energy available per person and costs of energy falling the logical choice would have been using more energy and even wasting it.

In England from 1300 to 1450 the amount of land per person producing energy rose 59 per cent, the land producing food rose 54 per cent. If calorific intake rose by only some five per

cent then farmers were being much more lavish in their use of land and in the processing of the products of the land for food consumption. Pasture, like arable, did not contract per person. The area devoted to supporting draught animals almost doubled per person. Animals were apparently better off after the Great Death. Having painfully cleared land for arable from the tenth century through the thirteenth English farmers and estate managers were apparently reluctant let the land go back to forest and waste when population dropped. Instead they converted the land to pasture and turned animals loose on it. The rising prices for animal products made such a choice even more logical.[10]

There was a decrease in the total energy used, a considerable fall of some 46 per cent. The decrease was less than the 60 per cent decrease in population but not by a big margin. Gross domestic product fell by about 41 percent so well short of the rates of decline in population and energy consumption.[11] The scale of the economy in 1300 was high relative to earlier and later periods. The evidence from total energy consumption confirms that, as it confirms the slow recovery from the Great Death in the size of the economy. It was to be the mid seventeenth century before total energy consumption, by which time about a third came from burning coal, was at the same level as in 1300.[12]

Similarly the expectation would be an increase in woodland. Trees could be allowed to fill in gaps left by deserted arable and, properly managed, could provide more home heating and thermal energy for industry. The ability of the population of all of Europe to double between 1500 to 1800 without running into serious shortages of wood[13] and the restoration of populations more or less like those of 1300 in the eighteenth century suggests that apparently from 1350 to 1500 supplies of wood rose, creating a stock for later exploitation.

Braudel argued that energy supplies were the break on economic growth, the source of

limits on population increase. The evidence from energy consumption in late medieval England raises questions about the existence of an energy ceiling in pre-modern Europe. The durability of practices from 1300 to 1450 along with the apparent potential for increasing productivity suggest that there were options open to deal with potential constraints. People changed habits in the wake of the Great Death. Still the technology and the organization of energy use of 1450 would have been easily recognized by a late thirteenth century European. The impression is that any changes were more adjustments than radically new departures. Given the scale of population loss the expectation would be a great transformation but, as with so many aspects of the Great Death, the results of searches for change prove disappointing. Measuring in averages of course obscures some significant shifts which were localized or disseminated slowly. The muted character of adjustments in English energy consumption after the Great Death was, in part, because the absolute level of energy consumption was considerably lower than in the industrial era. In 1450 at 24 gigajoules per year, people in England had much more energy employed than in 1300 and very possibly more than throughout the high Middle Ages. The figure is dwarfed by levels in the modern fossil-fuel based economy. The average in Europe in 1800 was less than in 1450, about 23 gigajoules per year. By 2000 average energy consumption per capita per year had stabilized at about 155 gigajoules, about six and a half times the level in fifteenth century England.[14] The lower absolute level compared to the twentieth century helps to explain the limited impact of the rise in late medieval per person energy use.

People in England in 1300 had options to expand energy supplies in 1300. The large loss of life starting in the mid fourteenth century made it unnecessary to explore any of those options. People could continue in earlier patterns and even become waste energy supplies though, surprisingly, they did not. It looks like they became more efficient. They used more land per

person, shifting to less energy-intense production. Energy consumption per unit of output fell. Gross output rose considerably faster than energy use.

In 1450 people compared to their predecessors 150 years before saw more trees and saw more lands devoted to pasture. For energy they used 55.3 per cent of the land in the kingdom, leaving more open space, less subject to regular human intervention. In 1450 travel was easier and the variety of goods known to them was greater than in 1300. Data on energy consumption suggest the weight of tradition and institutions dulled shifts in energy metabolism as did the moderate pace of change in technology. The fourteenth- and fifteenth-century sustained fall in population was not like what is anticipated for the twenty-first. The latter will presumably be slower but, if the late medieval pattern is any guide, the response in the economy will see a limited adjustment in the mix of inputs rather than dramatic transformations.

1.Braudel, *Civilization and capitalism*, p. 25
2.Ibid., p. 371.
3.Malanima, 'The energy basis for early modern growth'.
4.Malanima, 'The energy basis for early modern growth', p. 53; Warde, *Energy Consumption in England & Wales*, 34-9, 115; Warde, 'Fear of Wood Shortage', p. 38.
5.Dresbeck, 'Techne, Labor et Natura', pp. 86-90, 109-10; Dam, 'Het onderaardse bos', pp. 197-200; Gaimster, *German stoneware 1200-1900*, pp. 191, 208; Pardailhé-Galabrun, *The Birth of Intimacy*, p. 120.
6.Broadberry et al., *British economic growth,* pp. 137-9, 150-6, 179-81; Hatcher, 'The great slump of the mid-fifteenth century', pp. 240-7.
7.Postan, 'Medieval Agrarian Society', 559 e. g. For a nuanced view of the use of land of lower quality Bailey, 'The concept of the margin', pp. 10-14. The conversion was the long-run and successful strategy in English agriculture. Broadberry et al., *British economic growth,* pp. 73-9.
8.Warde, *Energy Consumption in England & Wales*, p. 132.
9.Broadberry et al., *British economic growth,* pp. 205, 228, 232.

10.Campbell, ‘Matching supply to demand’, pp. 830-2.
11.Ibid. 228, 232.
12.Warde, *Energy Consumption in England & Wales*, p. 115-6.
13.Paul Warde, ‘Fear of Wood Shortage’, pp. 38-9.
14.Malanima, *Energy in History*, p. 12.

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