ENERGY CONSUMPTION IN THE ROMAN WORLD

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Economic development has been supported, over the last two centuries, by a technical revolution in the use of power and energy. The introduction of modern machines, able to deliver huge quantities of work per unit of time on the one hand, and the availability of cheap fossil energy sources on the other, have enormously increased productive capacity. Both changes were the necessary although not sufficient conditions for the notable discontinuity in the economic history of the human populations and were the main determinants of a huge increase of output. The scarce availability both of mechanical power and energy set a limit to the growth potential of previous agricultural economies from the 5th millennium BC until the start of modern growth two centuries ago, and was the direct determinant of phases of decline or collapse. We cannot but agree with the view presented by E.A. Wrigley on pre-modern agricultural or ‘organic’ societies. His opinion is that ‘societies before the Industrial Revolution were dependent on the annual cycle of plant photosynthesis for both heat and mechanical energy. The quantity of energy available each year was therefore limited, and economic growth was necessarily constrained’. This was the main reason why decreasing returns to labour prevailed in past agricultural civilisations, as the English classical economists maintained.

The topic of energy consumption as a whole has been only marginally investigated in the case of the Roman world (though there has been some attention to particular energy sources such as wood). Previous attempts to quantify energy consumption do not allow one to understand the procedures followed. It is obviously impossible to present definite figures of energy consumption, since local conditions and the relations between human beings and the environment differed so much within the Roman

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1 Wrigley 2013, 1. See also Wrigley 2010 on the same topic.

2 See the Appendix.
Empire. It is possible, however, to present plausible data and plausible confidence intervals around the figures. This is a first step towards a comparison of energy consumption within past societies and between past societies and the present world.

The purpose of the present work is to focus on energy consumption in the early Roman Empire; and, in particular, to identify the energy sources (§1), to quantify their exploitation (§2–3), and their constraints to the growth potential (§4–5). The last section (§6) will be devoted to the dynamics of the ancient energy systems, that is the innovations in the technical exploitation of energy and its availability. The Appendix will present the procedure followed in the quantification of energy consumption in the Roman Empire and discuss alternative estimates.

1. The Input of Energy

Often it is not completely clear what actually were the sources of energy in past agrarian civilizations. The consequence is that any quantification becomes imprecise or, indeed, quite impossible. Although certainty is unattainable on the subject, a plausible order of magnitude is not out of reach.

There were three main inputs of energy in pre-modern agrarian civilizations from about 5000 BC until 1800 AD: food, firewood and fodder for working animals.

Food has been the primary source of energy since the beginning of the human species. A second source, firewood, began to be exploited as fuel between 1,000,000 and 500,000 years ago. From then until the Industrial Revolution it was the main provider of heat. The third source, fodder for draft animals, began to supply mechanical work in the agricultural civilizations between 5000 and 4000 BC, that is since the exploitation of animal power on a wide scale in agriculture and transportation. These were still the main

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3 Here I refer to the energy sources with a cost (often an opportunity cost). Solar light is important for our survival, but is free and then excluded from our calculations. The same holds true for the vegetation of a forest, when not exploited by the humans. Water and wind power, when exploited through mills and sails (expensive to build), is included, while it is excluded when not exploited for some productive activity. See, however, the Appendix for more information on the subject.

4 I have discussed this topic in greater depth in Malanima (forthcoming). See the following Appendix on the quantification of energy consumption in the early Roman Empire.

5 I have examined the transitions among energy systems in greater depth in Malanima 2010.