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# Economic development and the demand for energy: A historical perspective on the next 20 years

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HIGHLIGHTS

▸ Analyses the evolution of energy intensity over two centuries of industrialisation.
▸ Increased specialisation of the fuel mix and convergence of economies continues to improve energy efficiency.
▸ Growth in per capita income over the next 20 years need not be constrained by resource availability.

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ABSTRACT

This paper draws on evidence from the last two centuries of industrialisation, analysing the evolution of energy intensity over the long- and short-run. We argue that the increased specialisation of the fuel mix, coupled with accelerating convergence of both the sectoral and technological composition of economies, will continue to improve energy intensity of economic output and to reduce the reliance on any single energy resource. This analysis suggests that even high growth in per capita income over the next 20 years need not be constrained by resource availability.



## 1. Introduction

When the future of global energy markets is discussed, two main concerns feature regularly. One is climate change and carbon output, an issue beyond the scope of this paper. The other is the question whether growth in energy demand will exceed the resources available to fuel continued economic growth and industrialisation, especially in the non-OECD economies. The paper contributes to this second question, with a particular focus on energy intensity and demand.

It is an attempt to draw lessons from past experiences with periods of industrialisation and structural change, and the impact they had on energy demand. The reason for this attempt originates with the need to assess future energy demand for the next 20 years in BP's *Energy Outlook 2030* (BP, 2012).

The *Energy Outlook 2030* forecasts future fuel trends for the period 2011–2030. It builds upon BP's longstanding work on the Statistical Review of World Energy, which documents trends in the production and use of energy. The results of the *2030 Outlook* are largely derived "top down": global energy demand trends are assessed and national (or regional) demand is derived using assumptions on population growth, GDP growth and changes in end-user demand. In a similar fashion, regional supply availability is assessed fuel by fuel, capacity and other constraints are taken into account, and substitutability evaluated; then, in an iterative process, demand and supply schedules and prices are determined.

The *2030 Outlook* therefore is not a "Business as Usual" exercise (i.e., it does not rely on trend extrapolation) and not constrained by any given policy scenario—rather, it is a genuine "to the best of our knowledge" forecast, warts and all.[1] The precise numbers, as with any forecasting exercise, carry a significant range of uncertainty and should always be treated with caution. The ambition is not to get the future right to the last decimal point but to delineate fault lines in today's complex global energy system, trend lines and where they may collide, points at which today's commercial and political decisions matter, or will have discernible impact on the future: in short, it is a document which should get the major trends right. The resulting projections lie broadly within the range of other publicly-available forecasts, such as the IEA World Energy Outlook (International Energy Agency, 2011) and the EIA International Energy Outlook (International Energy Agency, 2011). A more

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[1] In this respect it is different from, for example, International Energy Agency (2011) or Shell (2011).

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detailed description of the assumptions, methods and findings can be found in the 2011 and 2012 Outlooks (BP, 2011a; BP, 2012).

It was in this context that the question arose of how to have a fresh look at an old, but increasingly important issue: What constraints will the need for energy put on global growth prospects? In particular, how will the need to fuel economic growth impact the prospects of the rapidly industrializing so-called developing economies outside the OECD? This obviously is an important question, but also one where discussion is much dominated by opinion and assertion. We all have heard claims like "for the Chinese to become as rich as us, we will need four new planets" from one side of the spectrum, just as often as the "what, me worry?" from the other.

To us, this seemed to be precisely the kind of question where one can learn by having a look at the past. It is of course not the first time in history that we observe periods of rapid economic growth and structural change, coupled with pressure on the known resource base. And so the question became what, if any, lessons history may hold for economic development in regions where energy poverty is still the norm, and where high energy prices may prove an impediment to growth.

The following reports the findings of that closer look at the historical experience.

## 2. The data

### 2.1. Energy intensity

Energy intensity – defined as energy consumption per unit of GDP, and perhaps the most general measure of energy efficiency there is – lies at the heart of the following analysis. More precisely, we focus on the interplay between energy intensity and structural change—as economies develop from being dominated by agricultural production to being dominated by the industrial sector and then by services. These are periods in which both the available primary energy carriers and the composition of economic output undergo great changes.

Our analysis looks at commercially traded fuels only—primarily fossil fuels (oil, natural gas, coal) and nuclear, hydro, and modern renewables.[2] This is how energy intensity is traditionally defined, and our use of this definition is not simply for reasons of data availability: Commercially traded energy is mediated by markets, with prices playing an allocative role. Fundamentally, these fuels lie at the heart of the process of economic development we are interested in—the industrial experience.

Casting the net wider would require a different definition of energy. The International Energy Agency publishes global energy consumption estimates which include traditional and largely non-traded biomass such as firewood, peat or animal dung (it puts the share of such fuels today at about 10% of global energy consumption). Historians assemble measures using a still wider definition of energy capture, including food for human consumption and fodder for animals.

Morris (2010a, 2010b) surveys the evidence on pre-industrial energy capture starting with Cook's (1971) pioneering paper. Cook estimated energy capture using this broadest of definitions of energy use for a range of stylised pre-industrial and industrial societies. His estimate for "advanced agriculturalists" was energy capture of 26,000 kcal per person per day (Cook, 1971 p. 136), or about 0.95 t of oil equivalent (TOE) per person per year. Morris finds that Cook's original estimates have held up surprisingly well. Morris' own estimates are that human energy at 1 AD – the time of classical antiquity in the advanced agricultural economies of Eurasia – was about 1.1 TOE per person per year in the West (the Roman Empire) and 1.0 TOE per person per year in the East (China). A millennium and a half later, these were still advanced agricultural economies, and with levels of energy capture that had hardly changed: Morris estimates energy capture in 1500 AD was about 1.0 TOE per person per year in the West, and about 1.1 TOE per person per year in the East. On the eve of the industrial revolution, in 1800, energy capture was still about 1.3–1.4 TOE per person in both regions. These are, of course, rough estimates that average across a wide range of energy capture influenced by local technology, climate and resources (Gruebler, 2004), but the general picture of long-run stagnation in energy capture per capita still holds.

The industrial revolution changed all that. Energy consumption in England (Humphrey and Stanislaw, 1979; Fouquet and Pearson, 1998; Wrigley, 2010), and then in other industrialising economies, grew hugely. Using the historians' broad definition of energy capture, total energy use per person in the OECD today is on the order of 8 TOE per person per year, i.e., about 6 times more than in Western Europe in 1800. Essentially all of this growth is accounted for by commercial fuels, which were hardly present before industrialisation.

In the same vein, estimates of GDP per capita for individual countries and the world during the pre-industrial period suggest living standards that showed relatively little change over time. Maddison (2007, 2010), for example, estimates GDP per capita in Western Europe in 1 AD at about $576 in 1990 international dollars in 1 AD, rising to $771 in 1500 AD; his corresponding figures for the world as a whole are $467 and $566.

Maddison's estimates, though widely used, are not uncontroversial. Clark (2009), for example, points out that Maddison's estimates rely crucially on an assumed basic subsistence income ($400 per person), and suggests that direct evidence on wages in different eras and locations should be preferred. A separate problem, raised by Nordhaus (1997), is whether such estimates properly account for improvements in the quality of goods, or for entirely new goods.

But none of this changes the general picture of broadly stagnant living standards in the pre-industrial era—certainly compared to what followed. Allen (2009), for example, using evidence from Diocletian's Price Edict of 301 AD, finds that the wage of the typical Roman worker was comparable to that of most workers in Europe or Asia in the 18th century, though these wages were somewhat low compared to those that prevailed in 15th century Western Europe. And the problem of improvement in quality and range of goods is far greater for the modern era than for the period 1-1500 AD. Nordhaus (1997) used technological advances in lighting to illustrate the measurement problem, but in his original 1996 study he notes that lighting technology was essential static in the pre-industrial era.[3]

Starting with the Industrial Revolution, GDP per capita in the developed West grows hugely. Using Maddison's estimates, it grows by almost 20-fold, from about $1200 per person in 1800 to $22,000 per person in 2000 in 1990 dollars. And this is likely a significant understatement of the growth of living standards, for the reasons given by Nordhaus. Prices of modern goods in 1800, if such goods existed, would have been extremely high, and so the

[2] Modern renewables include wind, solar, geothermal and biomass in electricity production, and biofuels (ethanol and biodiesel) in transport.

[3] "Virtually all historical accounts of illumination remark on the feeble progress made in lighting technology in the millennia before the Industrial Revolution." Nordhaus (1996), p. 33.