Drivers of global fossil fuel consumption since 1950

Simon Pirani, December 2014

The purpose of these notes is to outline an agenda for this research project. Please read them together with the accompanying slides. I welcome contact with researchers working on similar issues to simon.pirani@oxfordenergy.org.

Introduction/purpose of the project

Global fossil fuel consumption in 2000-2009 was running at more than four times the level of 1950-1959. Since fossil fuel consumption, and production, are key causes of global warming, it is generally accepted that reduction of both would be a good thing.

But policies aimed at reducing consumption, at both national and international level, have failed – a striking fact of modern history. And the explanations heard in the public domain for fossil fuel consumption being high and rising are often superficial.

Reference is made to increasing world population; expansion of economic activity; the growth of both population and economic activity in so-called middle-income countries, notably China and India; and excessive individual consumption in rich countries. Individual consumption is a particular favourite of a significant group of historians, who write about it as a social phenomenon, without much reference to the process by which objects of consumption are produced and traded. Integrated explanations, and interrogation of underlying assumptions, are less often heard.

The aim of the project is to try to work out some integrated explanations.

This presentation outlines the research agenda. It covers (i) the historical background (in brief), (ii) issues about ways of counting fossil fuel consumption and statistics, and (iii) some broader research questions.

Part One. The historical background

■ Energy history to 1950 (SLIDE no. 2)

The "industrial revolution" (a very broad term) included the substitution of human and animal power by water power and wood burning, and then by coal; the steam engine (paved the way for widespread use of fossil fuel for transport); expansion of metalworking (which was important for agriculture); etc. Historians of labour see fossil fuels as a source of energy that can produce physical power on a scale that dwarfs that of human and animal muscle power, and do so plentifully and flexibly. There is a huge body of published research on this.[1]

[1] Books and articles I have found useful include: Alfred Crosby, *Children of the sun: A history of humanity's unappeasable appetite for energy* (W.W. Norton, New York, 2006); Matthew T. Huber, "Energizing historical materialism: Fossil fuels, space and the capitalist mode of production", *Geoforum* 40 (2008), pp. 105–115; Bruce Podobnik, *Global energy shifts: Fostering sustainability in a turbulent age* (Temple University Press, Philadelphia, 2006); Joachim Radkau, *Nature and Power: a Global History of the Environment* (German Historical Institute/ Cambridge University Press, 2008); Vaclav Smil, *Energy in World History* (Westview Press, 1994) and *Energy in Nature and Society* (MIT Press, 2008)

A group of technological developments in the late nineteenth and early twentieth centuries, separate and distinct from the earlier changes that are categorised as the "industrial revolution", were important in laying the basis for the expansion of fossil fuel consumption in the twentieth century: electricity and electricity networks (which completely transformed the way in which energy could be consumed); the internal combustion engine and the gas turbine (that provided for the expansion of fossil-fuelled transport); the Haber-Bosch process (that is used to turn fossil fuels, mainly natural gas, into fertiliser). These developments were key drivers of the more-than-ten-fold rise in the rate of fossil fuel consumption in the twentieth century. In the period I am dealing with, from 1950, the continuing rise of fossil fuel consumption is, I think, driven more by expansion and development of these technologies, than by new technologies.

■ **<u>Global fossil fuel production</u>** <u>(SLIDE no. 3)</u>

Slide no. 3 shows the rate of expansion of fossil fuel production during the twentieth century. (On this scale, i.e. measured by decades, global production and global consumption are sufficiently close that the production statistics can stand as a reflection of the levels of consumption. There are no consistent series of consumption statistics that I have found going back beyond the second world war.)

Note that, as economic activity expanded and technology changed, fossil fuel production and consumption grew far more rapidly than world population. Population was 1.65 billion in 1900, 2.52 billion in 1950 (less than double), and 6.07 billion in 2000 (three-and-two-thirds times greater), while fossil fuel production rose from 5961 millions of tonnes of oil equivalent (mtoe) in the 1900s to 21298 mtoe in the 1950s (three and a half times greater) and 93467 in the 2000s (15 and a half times greater).

In the twenty years after 1990, i.e. after the science on global warming became clear and was accepted by governments, the rate of fossil fuel consumption very nearly doubled on that of the previous four decades.

■ **<u>Global warming makes the past look different</u>** <u>(SLIDE no. 4)</u>

The discovery of global warming was itself a process. Climatologists and other earth scientists reached a consensus during the 1980s, and through the international process that led to the formation of the Intergovernmental Panel on Climate Change had convinced some within the political establishment of the scale of the problem by the late 1980s or early 1990s.[2]

Slide no. 4 highlights the (perhaps obvious) point that, while we can view the past with the benefit both of hindsight and of scientific understanding that is now available, we can not judge past actors by standards based on that hindsight and that understanding. Specifically, large-scale fossil fuel consumption looks different, once you know about global warming. Calls for fossil fuel consumption to be reduced were of course made long before the discovery of global warming (e.g. in the 1970s, on one hand as a result of governments of rich oil-importing countries becoming acutely aware of their vulnerability to rising prices,

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[2] Bert Bolin, *A History of the Science and Politics of Climate Change: the role of the IPCC* (Cambridge University Press, 2007); WMO/UNEP, *Climate Change 2007: the physical science basis. Working Group I contribution to the Fourth Assessment Repport of the IPCC*, chapter 1, pages 93-127; Spencer Weart, *The Discovery of Global Warming* (Harvard University Press, 2003)

and on the other due to the emergence of environmentalism). But the fact that large-scale fossil fuel consumption might cause not only e.g. air pollution, poor labour conditions or excessive corporate power, but also climate change, only became clear in the 1990s. This produced quite a different motivation for reducing global fossil fuel consumption.

The slide shows the amount of carbon emitted by the world economy, and two estimates (one by the IPCC, and a more conservative one by a group of climatologists led by James Hansen of Columbia University) of the total carbon "budget" available in order to have a reasonably good chance of keeping global warming to less than two degrees centigrade over pre-industrial levels.[3]

The slide shows that fossil fuel consumption could have continued at its early twentieth century level for a long time (probably, hundreds of years) before it presented an unsustainable global warming threat, in the terms set out by the researchers mentioned. On the other hand, at its early 21st century level, fossil fuel consumption can only continue for a very short time – in any case less than a human lifetime – before it presents such a threat. In other words, the period of the greatest expansion of fossil fuel consumption (since the 1990s) coincides with the period when the scientific understanding of global warming had developed to the point of being able to say confidently that consumption needs to be sharply reduced.

Part Two. Ways of counting consumption are contested

One of the first problems encountered when researching the history of global fossil fuel consumption is in finding sets of statistics that reflect most accurately the key historical problems.

To start right at the beginning: why the focus on consumption? Should not the production of fossil fuels, and the corporations that engage in it, be the starting point? One researcher, Richard Heede has counted greenhouse gas emissions from fossil fuel production and cement production, and compiled statistics that attribute these emissions to the companies that produced the fuels, or the cement. His conclusion is that most of the emissions over the last 300 years originate from fossil fuels produced by just a few dozen companies.[4] On one hand this approach is valuable, because it shows the dominant role of these few companies in fossil fuel production; on the other, it is problematic because it downplays the obvious point that oil and coal companies supply a market, in which there is demand from other companies and organisations. The fossil fuel producers have obviously done their best to stimulate demand, but – equally obviously – that is not the main reason that demand exists.

■ Total primary energy consumption (SLIDE no. 5)

Slide no. 5 is compiled from one of the most widely-used sets of statistics, the BP Statistical Review. These have many advantages: they are well researched, published each year on line, and can be used easily to compare the quantities of oil, gas and coal consumed at national level. The way I have set them out here shows the respective levels of consumption by rich countries (i.e. the OECD countries) and the rest (non-OECD). Two disadvantages are that (i)

[3] Hansen J, Kharecha P., Sato M., Masson-Delmotte V., Ackerman F,. et al. "Assessing 'Dangerous Climate Change': Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature", *PLoS ONE* 8(12) (2013): e81648; IPCC, *Fifth Assessment Synthesis Report* (November 2014)

[4] Richard Heede, "Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010", *Climatic Change* (2014) 122: 229–241

they cover only commercially traded fuels – so for example nearly half of African's fuel consumption (mostly wood and other biomass fetched and consumed by some of the poorest people in the world, and not commercially traded) is not included; and (ii) there is no sectoral breakdown, i.e. no information about what fossil fuels are used for within separate national economies.

Such a sectoral breakdown is given in statistics published by the International Energy Agency, and for that reason these are among the most potentially useful statistics. See below (see "China's consumption 2011", Slide no. 13). Before looking at those, I make three more points, (a) about the statistical relationship between population and fuel consumption, (b) about consumption levels of rich and poor and (c) about energy consumption via technological systems.

<u>(a) Population and fuel consumption</u>. The most widely used methods for counting greenhouse gas emissions (the most significant environmental impact of fossil fuel consumption) derive originally from the IPAT equation. This approach has dominated discussions for most of the last forty years about the pressure put on natural resources by human society and economy.

■ **<u>IPAT and its variants</u>** <u>(SLIDE no. 6)</u>

IPAT (impact = population x affluence x technology) was first proposed in 1972 by Paul Ehrlich, the father of neo-Malthusianism, and his colleague John Holdren, in the course of a polemical exchange with Barry Commoner, a left-leaning environmentalist, about the correct way to understand the pressure exerted by the economy on natural resources about pressure on resources.[5]

Commoner argued that population and affluence made little difference to natural resource use in comparison to factors grouped under the heading "technology". Commoner notably illustrated his argument with reference to statistics on beer consumption, showing that the introduction of throwaway beer cans increased the environmental impact, via aluminium production, regardless of the size or affluence of the population of beer drinkers. This was a metaphor for Commoner's key argument, that Ehrlich and Holdren were exaggerating the connection between population growth and the pressure placed by the economy on natural resources. (For Ehrlich, IPAT was one of the ways of arguing for his view that population reduction, and if necessary population control, was a priority for human development.)

The Ehrlich-Holdren approach has ever since the 1970s figured prominently in discussions of the environmental impact of resource use, including fossil fuel consumption. The IPAT equation, and variants of it developed by statisticians, have been used by researchers, including those who have worked on the IPCC reports. Specifically, the Kaya identity (emissions = population x (GDP/population) x (energy/GDP) x (emissions/energy), proposed by Yoichi Kaya and his colleagues to look at the drivers of greenhouse gas emissions.

In my view, the Kaya identity can be useful e.g. in comparing some parameters of national consumption in different countries. But it appears to me that – because it assumes *a priori* a key role for population numbers and for the level of GDP – it inevitably downplays other factors such as the level of industrial output, and obscures such factors as differences between

[5] Paul Ehrlich, John Holdren and Barry Commoner, "A Bulletin dialogue on The Closing Circle", *Bulletin of the Atomic Scientists* 1972, vol. 28, no. 5; Barry Commoner, *Making Peace With the Planet* (The New Press, New York, 1990); Marian R. Chertow, "The IPAT equation and its variants", *Journal of Industrial Ecology* 4:4 (2001).

types of consumption, and the roles of particular industrial sectors and social processes. In short, people consume energy by way of economic, social and technological systems – and these are too feebly reflected in IPAT-based approaches.

There are some very convincing critiques of the IPAT model, e.g. that made in the early 1990s by Thomas Dietz and the late Eugene Rosa (sociology and environmental science scholars), who wrote that while IPAT has "appealing features", it also has "serious limitations", including: "In its current form it does not provide an adequate framework for disentangling the various driving forces of anthropogenic environmental change."[6]

Dietz and Rosa proposed that the formula be considered a stochastic model, i.e. it could be used in conjunction with probability theory to test hypotheses, and they developed it with that in mind. This was essentially the foundation of structural human ecology, a sub-discipline that has tried to quantify environmental impacts. But in 2012 Dietz and Rosa again published a critique, arguing that researchers in various disciplines were not talking to each other and that their use of these formulae was "blinkered" as a result.[7]

A more wide-ranging critique of methodologies based on IPAT is needed, because most of them completely fail to account for the role of economic, social and technological systems in consumption. So individual consumption is stripped from its real context. (I would have thought that Marxists would have a field day developing a critique of this fundamentally neo-Malthusian approach, but quite surprisingly one sometimes reads approving references to IPAT methodology in discussions of global warming by Marxists.)

Slides nos. 7 and 8 show some of the perils of starting out from the assumption that population growth is a key driver, or even the key driver, of fossil fuel consumption.

■ Rising population and energy use (SLIDE no. 7)

If population growth and energy use are not very well correlated, then that would lend weight to my argument that, since people consume energy via economic, social and technological systems, population growth can not be considered a key driver. Slide no. 7, which shows population and energy consumption in Russia since 1990, makes this point. In Russia population has been falling consistently; energy use fell sharply in the early 1990s, and has grown, much more rapidly than population, since then. There is a much closer correlation between the level of economic activity and energy use than between population and energy use: in the slump of the 1990s energy use fell, during the oil-driven boom of the 2000s it rose.

■ Rising population and energy use (China and USA) (SLIDE no. 8)

The lack of correlation between population and energy use is also evident in China and the USA.

In China, up to 2003, energy use rose slightly more rapidly than population (as you would expect in any country whose economy is expanding). After 2003, there is an acceleration of the rate of growth of energy use. It is very unlikely that this reflected any change in people's

[6] Thomas Dietz and Eugene Rosa, "Rethinking the environmental impacts of population, affluence and technology", *Human Ecology Review*, summer/autumn 1, 1994, pp. 277-300.

[7] Eugene Rosa and Thomas Dietz, "Human drivers of national greenhouse-gas emissions", *Nature Climate Change* vol. 2, August 2012, pp. 581-586.

living standards, and very likely that it can almost all be attributed to the massive expansion of manufacturing industry, particularly export-oriented manufacturing industry, in China at that time.[8]

While on one hand it is the expansion of industrial production that is likely to have driven much greater energy use in China, on the other, there is plenty of research to show that improvements in energy access for hundreds of millions of poor people, in the first instance as a result of electrification, is one of the *least* substantial factors in rising fossil fuel consumption. A recent paper on electrification in India[9] showed that, over the last 30 years, an increase in household electricity access from around 20% to around 70%, which gave 650 million people access to electricity, accounted for 3-4% of India's emissions growth, and that the total direct and indirect use of electricity by those 650 million people accounted for 11-25% of emissions growth. The vast majority of emissions growth was due mainly to urban populations and industry. (The quality of electricity access for poor households in rural India should not be overstated. Often, it is excruciatingly bad. Nevertheless, the negligible role that it plays in total energy consumption growth is striking.)

In the USA, energy consumption growth is again very weakly correlated with population growth. It has risen more rapidly than population except for periods in the early 1980s, and in the last five years, when efficiency improvements have been a key cause of falling consumption.

(b) Energy consumption levels of the rich and the poor. A key issue in understanding the drivers of fossil fuel consumption growth is the gigantic gap between the level of consumption of the haves and the have-nots.

■ National consumption-per-person statistics (SLIDE no. 9)

National consumption-per-person statistics are a reminder of the vast scale of inequality, but they do not capture all of it. They can not reflect: inequalities within nations; the role of energy systems and consumers' relationship to them (i.e. the fact that most people, particularly poor people, have little or no choice in determining how their energy is produced); and the role of industry in consumption (because these statistics will count energy used at work by people e.g. in South Africa who work in energy-intensive industries, and at home have no electricity and minimal personal energy consumption).

■ Diesel and gasoline consumption (USA and China) (SLIDE no. 10)

It is important to find ways around the limitations of statistics. In the case of road transport, for example, most sets of statistics give only one figure for energy used in road transport. But fortunately the International Road Federation divide them up into diesel (which I assume is overwhelmingly consumed by commercial transport), and gasoline (which is mostly but not entirely personal transport).

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[8] See for example Andreas Malm, "China as Chimney of the World: the Fossil Capital Hypothesis", *Organisation and environment* 25:2 (2012), pp. 146-177; Steven J. Davis and Ken Caldeira, "Consumption-based accounting of CO2 emissions", *Proceedings of the National Academy of Sciences*, vol. 107 no. 12, 5687-5692

[9] Shonali Pachauri, "Household electricity access a trivial contributor to CO2 emissions growth in India", *Nature Climate Change*, October 2014 (advance on-line publication)

This slide, based on IRF statistics, reflects the unnecessarily high consumption of fossil fuels for personal transport in the USA. It shows that, not surprisingly, the US population consumes six times as much gasoline as the Chinese population, which is more than four times as big. It also shows that, while Chinese gasoline use is growing, Chinese diesel use is growing much faster, surely as a consequence of the manufacturing boom.

■ Diesel and gasoline consumption (other countries) (SLIDE no. 11)

The diesel/gasoline breakdown for other countries also highlights significant trends, e.g. energy saving in personal transport in Germany. The comparatively high level of gasoline use compared to diesel use in Nigeria is not what I have expected and it will be interesting to look at that further.

(c) Energy consumption in technological systems. My starting point, as mentioned above, is that people consume energy through economic, social and technological systems. A challenge for the research is to explain why those systems work as they do.

■ Energy provided and losses: a Sankey diagram (SLIDE no. 12)

With regard to technological systems, slide no. 12 draws attention to issues that are very poorly reflected in the available statistics, about both the consumption, and the losses, of energy in those systems.

This diagram (a Sankey diagram, i.e. one that illustrates flows of something, in this case different types of energy, through a system) emphasises losses of energy by: technologies that burn fossil fuels to produce electricity and heat ("fuel loss" and "generation loss"); by systems that distribute electricity ("distribution loss"); and by technologies that act as final consumers of energy in whatever form, e.g. cars, buildings that need heating, industries that use (and lose) energy in the production process ("passive systems"). This has been put together by engineers, not historians, and I am using it only to illustrate a problem the history of which needs to be considered.

The diagram is taken from a paper, one of many by a group of engineers at Cambridge who research potential reductions in global fossil fuel consumption by means of energy efficiency. Their conclusion is that "we have engineering options to reduce current energy demand by 73%".[10] This means that essentially the same results in terms of the end uses could be achieved, with currently available technology, using a quarter of the energy inputs now used. Incidentally, this places a gigantic question mark against assertions that reducing greenhouse gas emissions means asceticism and suffering.

But to a historian it poses a different question: why have the technological systems been developed with such massive inefficiencies? Obviously part of the reason is that technology has developed between the time that systems have been built and the time that the research on the article was done. But this is certainly not the only reason – probably not even the main reason.

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[10] Jonathan Cullen, Julian Allwood and Edward Borgstein, "Reducing Energy Demand: what are the practical limits?", *Environmental Science and Technology* 2011 (45), pp. 1711-1718.

In my view, issues that need researching here are: Why do some technologies develop at the expense of others (e.g. petrol cars as opposed to electric cars at the beginning of the 20th century)? Why do some technologies develop unevenly (e.g. combined heat and power in the mid 20th century, ubiquitous in the former Soviet Union and Scandinavia, pretty well non-existent elsewhere)? Obviously technological systems develop in a social context, and we need to ask: why did 20th century rich-country urbanisation produce such energy-intensive cities and energy-inefficient buildings? In some aspects of fossil fuel consumption – such as the incredible expansion of inefficient individual motor transport in the US – we see the hand of corporate sales techniques and corporate championing of infrastructure. But all too often such issues are explained by corporate conspiracy, when a stronger analysis is needed.

■ **China's consumption 2011** (SLIDE no. 13)

The most rapid development of fossil-fuel-intensive technology in the early 21st century has been in China, as it has become the "workshop of the world". This table, based on IEA statistics for 2011, gives a breakdown of where it goes. Note:

-- The proportion of energy used in the course of electricity production and the large amount categorised as "energy industry own use";

-- The significant proportions of energy used in steel production and by the chemicals industry; and

-- The relatively limited role of Chinese household consumption.

■ **Ways of counting consumption: research issues** (SLIDE no. 14)

To sum up on ways of counting consumption, questions to research are: do IPAT and its variants set a flawed context, by making individual consumption an absolute and downplaying the role of social, economic and technological systems? Which data better reflect the role of those systems? The IEA sectoral breakdown is one important source.

Part Three. Broader historical issues

The remaining slides set out different aspects of the history of fossil fuel consumption. The aim of my research project is to find ways of integrating these.

■ **Rich countries' economic history** (SLIDE no. 15)

Throughout the period since 1950, cheap energy has stimulated energy-intensive industry and agriculture, and disfavoured other technology.[11]

1950s and 60s: the post-war boom; growth of industrial and agricultural production, and of urban infrastructure, in developed countries; parts of Europe reached higher, USA-style living standards. Oil and gas grew faster than coal.

1970s. Recession, and high oil prices, dampened energy demand.

[11] A basic text for the period 1950-1990 is John G. Clark, *The Political Economy of World Energy: a twentieth-century perspective* (Hemel Hempstead: Harvester Wheatsheaf, 1990)

1980s. Conservation policies, adopted in the wake of the 1970s oil shocks, were soon eclipsed by renewed demand growth.

From the 1980s, energy systems in developing countries expanded substantially, and the internationalisation of finance capital ("globalisation") was a key part of the background to this.

1990s and 2000s. A new leap in fossil fuel use, driven by: economic expansion; higher rich-country consumption; coal-fuelled industrialisation of China and other Asian countries; and other factors.

■ A history of inequality (SLIDE no. 16)

Inequalities were integral to the expansion of energy use.

Pre-1980s, rich countries mostly had commercial, fossil-fuel-based energy systems and electricity grids, and poor countries did not. My initial reading suggests that electrical and energy systems were exported to developing countries to serve the international economy, not people's needs (that is, power systems were installed in the first place to serve industrial development; provision to communities, especially rural communities, came a poor second).

Big systems (technological, economic and corporate) were copied wholesale from developed to developing countries. These systems excluded the poorest, who continue to rely on traditional biofuels, or go without. (Note that in 2010, 1.4 billion people had no electricity, and 2.4 billion people were cooking with traditional biomass.)

The "export" of power systems from the rich countries to developing countries has been examined closely by many researchers, especially with regard to the ideological accent placed on private ownership at the time.[12] Less has been said about the copying of technological models completely unsuited to those countries' needs, that I think is also a big issue.

The gap between consumption levels of richest and poorest is hard to measure, but seems to have widened.[13]

■ Consumption by people and technological systems (SLIDE no. 17)

Cultural historians have mapped changing consumption habits, of energy and of stuff produced by energy.[14] However, some historians' emphasis on consumers' agency neglects the restrictions imposed by systems (e.g. millions of Americans who can not reach the local school, shop or workplace except by car).

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[12] Key articles include J.H. Williams and R. Ghanadan, "Electricity reform in developing and transition countries: a reappraisal", *Energy* 31 (2006), pp. 815-844, and K. N. Gratwick and A. Eberhard, "Demise of the standard model for power sector reform and the emergence of hybrid power markets", *Energy Policy* 36 (2008), pp. 3948-3960

[13] See IEA World Energy Outlooks since 2002 and, e.g. *Energy Poverty – How to make modern energy access universal? Special early excerpt of WEO 2010* (IEA, 2010)

[14] An overview of the large quantity of literature is F. Trentmann (ed.), *The Oxford Handbook of the History of Consumption* (Oxford, Oxford University Press, 2012). On energy consumption in the USA, the work of David Nye (e.g. *Consuming Power: a social history of American energies* (Cambridge, Mass., MIT Press, 1998)) is a starting point

Most energy is consumed by technological systems operating within particular economic and social relationships. A research question is: why do these big systems persist, and constrain alternative technologies, both large (US mass transit, combined heat and power) and small (solar panels, heat pumps)? What role is played by corporations that control technology and investment? What role is played by the commodification of energy?

In some cases there are obvious explanations, e.g. mass transit in the USA was essentially choked by the car manufacturers and those at various levels of government who believed in a car culture. But this is an extreme case. It can not account for the way that urban infrastructure and urban energy consumption has developed more generally. Theories of "technological momentum" (also called "path dependency" and "infrastructure lock-in") provide some insights. The key historical work is by Thomas Hughes[15] and those who have sought to develop his methods of research.

■ How and why energy policy failed (SLIDE no. 18)

After the 1970s "oil shocks", environmentalism and demand management began to be taken seriously in US politics. But from the mid-1980s it was rejected by government Government and corporations eschewed new technologies and favoured investment in fossil fuels and nuclear.

Scientific consensus on climate change (late 1980s) and the UN framework agreement (1992) was followed by a gigantic acceleration of global fossil fuel consumption. In the 2000s (particularly as oil prices rose), state subsidies to fossil fuel consumers and producers expanded rapidly, providing a key indicator of government priorities in a large number of countries.

The Copenhagen summit of 2009 in practice marked the failure of efforts to achieve international agreement on emissions reduction.

I consider it significant that in the USA, at the centre of the world economy and world politics, there was a very serious discussion in the late 1970s about alternative technologies including solar power, heat pumps and other decentralised sources of energy that it is now widely accepted will play a big part in future non-fossil-fuel energy systems. A study of the reasons why this discussion failed to produce changes may produce insights into why fossil fuel consumption expanded so rapidly in subsequent decades. The history of those more recent times is much harder to grasp. The failure of the international talks on greenhouse gas emissions is such a historic disaster, that it is difficult to conceptualise. It shows very profoundly that the state – or here, more accurately, the joint efforts of all the major states – could not come up with even vaguely adequate answers to the potentially enormous destructive power for human beings of global warming. A thoroughgoing critique of the relationship between state, capital and society, and the way in which fossil fuel consumption fits in to this, is surely a precondition for explaining this remarkable historical failure.

[15] Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (London, Johns Hopkins University Press, 1983).

■ **<u>Research questions</u>** <u>(SLIDE no. 19)</u>

How can the history of the global economy, technological systems, social consumption trends and politics be integrated?

How to assess the centrality of fossil fuel consumption to capitalist economy without normalising it (e.g. with concepts such as “fossil fuel civilisation”).

How can the repeated and persistent rejection of non-fossil-fuel technologies, particularly after 1990, be explained?

What interpretive framework can explain the catastrophic failure of international climate change policy, culminating at Copenhagen? (Or: why did they fail with greenhouse gases where they succeeded with ozone?)

Should we try to anticipate the questions that will be asked by future historians, who might perceive our time as one of collective madness?

The notes are based on presentations given in November 2014 at a seminar in the History Department at Sheffield Hallam University, and at the Historical Materialism conference in London.

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