The presentation summarises some key points from a book to be published 2018. The starting point: the history of fossil fuel consumption can inform our understandings of the problem of global warming.

Note about the title of the talk: “how global fossil fuel consumption became unsustainable”. “Sustainable” has as many meanings as democracy, justice or freedom. From some points of view, fossil fuel production and consumption has been unsustainable for a very long time – for example coal production has always involved the deaths of thousands of mineworkers per year, and coal burning has always involved millions of victims of disease or death caused by air pollution. Many people saw these as reasons to stop coal production, or change the way it was done, in other words they thought it was being done unsustainably. But the people who made the decisions did not think that.

With the discovery of global warming in the 1980s, and recognition by political elites of the likely consequences in the 1990s, the idea that fossil fuel consumption is unsustainable became generalised.
The time period my research covers starts in 1950. It is in that period, and not before, that fossil fuel consumption has contributed substantially to the global warming effect. The industrial revolution was extremely important to this story, because it marked the start of widespread fossil fuel consumption via industrial systems. But those systems did not operate on a scale relevant to global warming until the late 20th century. The numbers on this graph show that the carbon emissions from fossil fuels in the entire 19th century were probably less than those from three years’ worth of use in the 21st century.

The technologies of the industrial revolution (such as coke production and the steam engine) stimulated coal consumption. Much more relevant to the story I am telling are the technologies of the second industrial revolution: electricity networks; steam turbines that soon replaced steam engines in power generation; the internal combustion engine that stimulated oil production; and chemical fertilisers, which came slightly later (a by-product of poison gas production in the first world war). These technologies of the second industrial revolution, and their derivatives and successors, account for most fossil fuel consumption today.
Some points about the early 20th century.

1. In terms of large-volume fossil fuel consumption, the USA’s dominance started with the second industrial revolution, in the last quarter of the 19th century, before the large-scale development of the oil industry. The red blocks on this slide are US coal production, which in the early 20th century was larger than Britain’s and larger than continental Europe, and soon became larger than both those put together.

2. Fossil-fuel-intensive technological, social and economic systems came together in the USA in the first half of the 20th century, and much of the story of the second half of the century is of those systems being replicated elsewhere. Specifically: urban electricity networks; road-based transport, which grew at the expense of rail and urban public transport; and automation in industry, dependent on electrification of industry, not least in motor car production.

3. To understand what happened in the 1950s – when we see a huge rise in oil production, either in the USA or controlled by US companies – we need to bear in mind the importance of the second world war, in which the massive expansion of oil-based infrastructure in the USA (roads, aviation, shipping and so on) played a huge part.
Technological contexts. Energy flows through technological systems, from primary energy sources (most of which are from fossil fuels); to final energy that is produced by some sort of processing (such as oil products or electricity); to useful energy and thence to energy services. Research on consumption is often limited to considering useful energy and energy services. I have taken the view that the picture needs to be considered as a whole.

So for example to understand the level of electricity consumption in the UK, we need to think not only about why I leave the light on when I leave a room, or why my computer uses so much electricity even when it’s in standby mode, but also why the electricity system has developed as it has, as centralised generation from fossil fuels (that is inherently wasteful of energy for reasons of the laws of physics), and why it did not happen some other way.

These technological systems are embedded in social and economic systems, and shaped by those social and economic systems.
The phrase “roads not taken” was coined by Amory Lovins, the environmentalist and energy reform advocate. … During the post-war boom, energy systems and industrial processes that were not just energy intensive but wasteful proliferated in rich countries: engineers understood this.

The first quote on this slide relates to the waste inherent in car manufacture in the 1950s in the USA, due to the annual model change and the trend towards heavier vehicles. Neither of these phenomena abated as a result of the 1970s oil price shock, and fuel efficiency improvements were pathetic in comparison with the technological possibilities.

The second quote is about the use of centralised electricity where other forms of energy would do.

The third quote is about the waste inherent in overcapacity in industry, and the fourth quote, from a quarter of a century later, about the wastefulness in energy terms of very basic industrial processes.

All these statements concern the energy-inefficient use of existing technology. The fifth quote concerns the failure to deploy energy-efficient technology, in this case networked computing, which could transform electricity distribution network.

A historian’s question is: why are technologies employed in the way that they are? The answers are mainly economic, or social – cost, including the relative costs of energy and labour; market dynamics that encourage energy profligacy; and so on.
Social contexts. Market dynamics are not the whole picture, because not all energy is supplied through markets. I argue that there are three types of provision: (1) commodified energy, (2) energy provided as a state benefit, and (3) non-commercial energy, in the first place the biofuels on which most people in rural parts of the third world rely, which are collected and burned without any commercial transaction.

The slide shows estimates, mostly by the World Bank, of the scale of non-commercial energy use. The green blocks are people who do not have access to electricity: they live outside the markets for fossil fuels and in some cases outside the markets for any fuels. The orange blocks are people who have some electricity, but still use biomass to cook. In the 2000s, while the number of people without access to electricity has fallen, to about one billion, this group – much of which lives on the edge of markets for commodified energy – is growing. A large part of this group comprises people in slums in big cities in developing countries.

As for energy supplied by a state benefit, this means, mainly, electricity and some fuels, provided for free or at negligible cost, to industry and individual consumers. This has been a substantial factor in the history of energy provision, especially in developing countries in the late 20th century.
This slide shows how the worlds of commercial and non-commercial energy collide. In the groups of bars, the first two are Nigeria’s primary energy consumption and final use of energy. Throughout the period covered Nigerian consumers are overwhelmingly supplied by biofuels, with a minute quantity of electricity that can only be clearly seen in the bars representing 2011. At the same time, Nigeria exports a volume of crude oil that, measured in energy terms, has been greater than – or, by 2011, a fraction less than – its own total primary energy consumption.
Social contexts. Technological systems that consume energy are embedded in social and economic systems. These have expanded in particular ways in the period since the second world war, and these paths of expansion have been fundamental drivers of the increase in fossil fuel consumption.

- Industrialisation has, in particular, expanded beyond the rich countries in the period covered.
- Changes in the labour process and the introduction of new technologies have driven fossil fuel consumption. Above all the proliferation of the manufacture of industrial materials (steel, aluminium, cement, plastics, etc).
- Electrification.
- Urbanisation. Cities, with the type of buildings and infrastructure that modern cities have, use far more energy per capita than the countryside.
- Motorisation.
- Household material consumption and the growth of consumerism. Until the late 19th century, large-scale personal material consumption was unknown except among social elites. It remained unknown to much of the rich-world population, and most of the population outside the rich world, until the late 20th century. It has expanded rapidly since the mid 20th century.
Although individuals are sometimes the final consumers of fossil fuels, and often of products made with fossil fuels, the flow of energy through systems means that there is no direct relationship between population growth and fossil fuel consumption growth.

Russia provides a particularly dramatic example of this. Its population has been declining since the 1970s. Nevertheless, fossil fuel consumption grew in Soviet times (not shown on this slide because of the difficulty of getting a relevant statistical series), fell in the early 1990s due to economic collapse, and then grew again quite rapidly as population continued to decline.

The world’s two largest consumers of energy. China: energy use has long grown faster than population, but in the early 2000s it accelerated, not because of an increase in population but because of an increase in industrial consumption.

The USA: energy use increased more rapidly than population over long periods, but fell due to the oil price shock in the 1980s and due to financial crisis in the late 2000s.

The argument is not that population growth is irrelevant to the growth of fossil fuel consumption, but that the relationship between them is indirect and mediated between systems. Changes in these systems are of overwhelming importance.
Inequality is a very central feature of all the social systems we are talking about, and per-head consumption statistics give an idea of the scale of the problem. Look at the striking contrast between the USA to Bangladesh. But there are things that these statistics do not tell us: for example, let’s compare Russia to Germany. Russian households have far fewer energy-intensive products in them than German households; Russia has fewer cars, and fewer car-kilometres driven, per head of population, than Germany does. But Russia’s per-head consumption was higher than Germany’s, even during the slump of the 1990s. The reasons include: Russian industry is much less energy-efficient than Germany’s; its infrastructure is older; and it is bigger and colder than Germany. Such differences in social, economic and technological systems are not reflected in these statistics.

The next part of the presentation looks at numbers in more detail.
The most important analytical tool for understanding the time-scales available for transition away from fossil fuels is the carbon budget (i.e. the total amount of carbon that can be pumped into the atmosphere, principally via CO2 emissions from fossil fuel use, while avoiding dangerous levels of global warming). There are different views of where to set the budget, reflected in the IPCC’s central scenario, and a scenario offered by James Hansen and colleagues. Depending on whose assumptions you use, the budget will be completely used up within 13-79 years if consumption continued at its 2001-2010 level. The consensus is that the focus must be on the lower end of that range. Don’t forget that (1) consumption is higher now than it was in 2001-2010; (2) these figures assume that global temperatures can rise to 2 degrees higher than the pre-industrial level, whereas the consensus, even among governments, is that 1.5 degrees is preferable; and that (3) for some people whose voices are scarcely reflected in international climate negotiations – e.g. fishing communities in Bangladesh – all these timescales are too long.
In my research I have focused on the sectoral breakdown of consumption. Three points, focused on the issue of technological and social systems, to note about this breakdown.

1. Look at the large amount of primary energy consumed by electricity production (i.e. the line “electricity” plus the larger amount in the line “energy used in producing electricity”). Overall, since 1950, the proportion of fossil fuels used to produce electricity has risen from one tenth to one third. On one hand, this reflects electrification, which has changed hundreds of millions of people’s lives for the better – even though it in most countries it starts with industry and urban residents and only later spreads to the countryside. On the other, it reflects the downsides of centralised generation, and the roads not taken to developing other types of systems.

2. The lines “blast furnaces” and “coke ovens” on the transformation side, which have to be added to the numbers for “iron and steel” on the final consumption side. All these three columns added together more than doubled between 1971 and 2011: despite the considerable efficiency gains in steelmaking due to the invention of the electric arc furnaces, much production was moved to countries with older equipment.

3. Look at “other energy industry own use and losses”. It nearly trebled between 1971 and 2011. At all times it was three times larger than the total energy use of domestic and international aviation. These are (i) losses in the electricity transmission and distribution networks; and (ii) other losses that energy companies either don’t understand themselves or don’t want to report in detail to national statistical authorities. This is the sort of thing the IEA refers to in its frequent complaints in its reports on energy efficiency issues about the lack of accurate information. Obviously without such information, no serious effort can be made to improve efficiency. This reflects a lack of corporate will to do anything about energy efficiency on a truly global scale.

The next part of the presentation follows the chronology of global fossil fuel consumption.
There were two overarching trends in the 1950s and 1960s. The first was the rise of oil. This did not mean the decline of coal; it meant that oil use, particularly for transport, rose even more rapidly than coal use. The second trend was the consolidation in the USA of the fossil fuel-consuming systems established before the war, and their consolidation, or expansion, or introduction, in other rich countries. I have already said a bit about industry and electricity, so let me highlight two other areas of consumption: households, and road-based private transport.

In households, the appliances that most US households acquired before the war – gas cookers, electric irons, sewing machines, radios, vacuum cleaners and washing machines – became widespread in other rich countries. The introduction of such appliances is one of the most profound ways in which people’s lives have been changed by the diffusion of fossil-fuel based energy systems. There has been a huge amount of research on these changes by social historians, which deserves some reflection.

In particular, these appliances enabled energy to substitute for labour. Washing machines and vacuum cleaners, for example, eased some of the most back-breaking household tasks. But as with all technologies, the changes they bring are never unilateral or straightforward. While the physical nature of domestic work in rich countries has been eased, the length of time it takes has not, and there is a body of research showing that the hours that women spend on domestic labour have hardly fallen. This is because the new technologies not only eased old tasks, but also made new ones possible.

The same is true of fossil-fuel based technologies in industry, of course, the introduction of which have apparently never led to a reduction of working hours.
On roads and cars. 1. Note the state support given to the development of a car-based transport system in the USA. In the 1950s, the interstate highway system (direct state expenditure) cost more than four times as much as the Marshall Plan (to support economic recovery in Europe after the war), and more than seventy times as much as investment in rail transit in the same period. The highway infrastructure went together with suburbanisation and the undermining of public transport systems. 2. Note the strong relationship between government and car makers, who were the epitome of corporate lobbyists, weakening all types of regulation, and also the pioneers of planned obsolescence in marketing. One noticeable feature of the political history of fossil fuel consumption is the bitter battle in the USA over fuel efficiency, in which the car manufacturers have been almost completely successful.
Three trends to note in the 1970s.

1. The fall in OECD countries’ oil consumption came only after the 1979 oil shock. Non-OECD oil consumption, and all coal consumption, rose consistently in 1972-85.

2. The most significant economic effect of the price shocks was the accumulation of debt by non-OECD importers. This fed into the debt crisis of the 1980s.

3. More broadly, the 1970s marked the end of the long post-war boom and the consistently high rates of economic growth in the rich countries that it had brought.

In the 1980s, the OECD countries continued to account for most consumption (62% in 1980, falling to 58% in 2000).

There were some substantial efficiency gains, but overall the picture is mixed. Changes in industry practices helped, e.g. the use of electric arc furnaces for steelmaking. But there was a countervailing tendency, i.e. the export of steel production to poorer countries with inferior equipment. During the 1990s, European industry raised its output by 2%/year without raising energy consumption. But new sources of consumption appeared, e.g. computer technologies.

There were conservation gains in the early 1980s, but many of these were reversed when oil prices fell.

The discovery of global warming in the mid 1980s, and consolidation of a consensus about it among climate scientists by the late 1980s, marked a turning point.
In the book I have looked at trends in electrification in the USSR, China, India, Nigeria and South Africa.

The role of social hierarchies. For example, in India, there are contrasts in the way that electrification proceeded in Maharashtra (where a lobby of well-off farmers secured electricity for water pumps); Odisha (which electrified almost exclusively urban areas and then became a target for international investment during privatisation); Andhra Pradesh (where farmers were less politically powerful; where only after a big protest movement did farmers get subsidised electricity; and where this movement also then resisted privatisation).
The 1990s. Policy in the foreground. The Rio earth summit: the priority for USA was to avoid any binding emissions reduction targets, and this was achieved. In the 1997 Kyoto treaty, this was translated to a set of voluntary targets, to be achieved through market mechanisms. These targets made no noticeable impact on global level of emissions. Where they were achieved, it was due largely to reductions that would have happened anyway, due to economic crisis, and massaging the figures (sale of permits etc).

The best measure of the effectiveness of policies is the level of subsidies to fossil fuel producers and consumers (which were accurately studied from the 1980s). The World Bank’s estimate in 1992 (using the price gap method) was that fossil fuel subsidies were running at $230 billion/year. The level of subsidies increased steadily during the 1990s, and very sharply in the mid 2000s when oil prices rose.

Why was the Rio agreement so ineffective? For one thing, the 1990s were the heyday of neo-liberalism … governments and international agencies had other priorities, e.g. electricity liberalisation. More effort was put into implementing that than was put into dealing with excessive fuel consumption.

In my view the global elites’ opposition to regulation, obsession with “market” solutions, and refusal to question the dogma that economic growth is paramount, was the most significant reason why the Rio agreement became a dead letter. Climate science denial played a secondary, but significant, role. By the late 1990s, oil companies had to a large extent dropped overt support for denial. But it became possible for them to achieve their aims, of protecting their business from state regulation, without this. In July 1997, the US Senate reiterated its opposition to binding commitments on global warming by 95 to zero – in other words, supported by the Democratic party that advocated action on global warming, together with the Republican party that is strongly influenced by climate science denial. As we now know, denial was quite persistent in society and in political elites, even after without the direct funding it had had previously.
The acceleration of consumption growth in the 2000s was principally driven by the Chinese industrial boom, but not only by it. In the global north there were fairly chunky increases in household consumption, particularly of electricity. In the developing world, and not just in China, there was a real boom of coal use. Coal became the fastest-growing fuel, which of course had an additional impact in terms of emissions.

China became the “workshop of the world”. Note the predominant role of the manufacture of goods for export in Chinese coal and electricity use. Note the big energy cost of urbanisation, which was a precondition for the rapid expansion of industry.
Finally, some conclusions. …
Conclusions 1

- Fossil fuel consumption since 1950 expanded much more rapidly than before, and in a qualitatively different way – part of a “great acceleration”
- Fossil fuels are consumed by and through technological, economic and social systems. Interpretive frameworks that isolate consumption from these systems, and/or isolate consumption from production, are misleading
- Individuals consume in the context of these systems. Discretionary and non-discretionary consumption need to be distinguished from each other
- Economic expansion has driven consumption, through specific trends: industrialisation, changes in the labour process, urbanisation, motorisation, electrification and growth of mass material consumption and consumerism
- Highly-intensive forms of production and consumption were embedded in the economy from the late 19th c. and expanded rapidly in the post-war boom
- Fossil fuels and electricity are exchanged as commodities – or (particularly electricity) provided as a state benefit. A large chunk of humanity remains outside, or on the edges of, the commodified energy system. Energy systems reflect inequalities, in this way and other ways

Conclusions 2

- The discovery of global warming (1980s) provided an imperative for transition away from fossil-fuel based energy systems. Carbon budgets imply short timescales
- Transition is not a technological issue. Energy-intensive technologies have been privileged over less energy-intensive ones, and fossil fuels over renewables, for social, political and economic reasons.
- Technologies, including non-fossil energy technologies, have to be diffused. This takes time. Investment in e.g. renewables or electric cars is good; ideologised claims that a “breakthrough” is therefore imminent are bad
- Technological potentials for reducing consumption have long been known. The obstructions are social, political and economic
- The UNFCCC process has since Rio (1992) made no progress in reducing fossil fuel consumption. Governments’ indifference in practice to UNFCCC aims can be measured e.g. by the high and rising level of subsidies for fossil fuels since then
- Proposals (e.g. at Kyoto) to use market mechanisms as an impetus for change have failed. The limited progress made on efficiency and non-fossil technologies has mostly been due to government regulation and state-directed investment
- There are no easy formulae for hastening transition. The best prospects lie outside the Rio process. Radical technological change should be considered together with radical social and economic change
Are fossil fuels history? In one sense, yes. In another sense, not yet – not by a long way.

Thank you

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