Cleantech and an Analysis of the Platform Nature of Life Sciences: Further Reflections upon Platform Policies

PHILIP COOKE
Centre for Advanced Studies, Cardiff University, Cardiff, UK

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ABSTRACT Most articles about life sciences begin from healthcare. This article reaches healthcare by an unusual route. It begins by trying to map out the complex content of the “Cleantech” platform. It then cross-connects important parts of that to the Agro-food industry, only finally relating important aspects of that to Healthcare biosciences. By Cleantech is meant the complex of industry activities dealing with energy-related agriculture, air and environment, materials, manufacturing, energy generation, efficiency, storage and infrastructure, recycling and waste treatment, transportation, water and wastewater that utilize renewable resources enhanced, as appropriate by life science technologies. The agro-food industry is large and less complex than Cleantech, but is currently still in thrall to its inheritance from agro-chemicals, food technology and nutrition science that dates from the post-war rise of industrial farming under corporate tutelage. Healthcare is also large, similarly traceable to fossil-based fine chemistry (drugs) and plastics (medical devices), dominated by large corporate businesses and, like agro-food assailed by a variety of attacks from alternative production paradigms. Cleantech, in part, seeks markets to rid the world of the pollutants of agro-food and healthcare as exemplars of the hegemonic US-led mass production/mass consumption paradigm. Tackling complexity on this scale requires new policy reflection, something with which the paper engages.

Introduction

The aim of this paper is ambitious, more a prelude to a book-length treatment of its subject matter. This aim is to expose the lineaments of what many now consider to be a particularly destructive chemistry-based production paradigm, which has desertified many geographical areas of the world, polluted the oceans, air and physical environment of the
planet, and endangered the health of its populations. The paper then aims equally to explore a rising paradigm that professes to be capable of non-oil dependence, to be able to generate massively less planetary pollution and contribute to the amelioration of climate change. In most dimensions, the new paradigm stems from thinking and research that may be traced back significantly to the evolution of a global bioeconomy that intends to surpass the depredations of the predecessor chemical economy.

The medical bioscientific segment of the life sciences is remarkable for three reasons. First, in both the European Union (EU) and US it accounts for more than half of all annual patenting activity. Second, more than half of all start-ups from academia in the two leading bioeconomies, the US and UK, are in biotechnology. Finally, in terms of venture capital invested the share devoted to healthcare biotechnology has risen 2001–2006 in both the EU and US from 22% to 39% and 19% to 32%, respectively. Information and communication technology (ICT), the largest recipient, shows a declining share of venture capital investment over the same period, down from 66% to 53% in the US and 57% to 52% in the EU. Within the broad healthcare sector, by 2006 biopharmaceuticals accounted for 69% of venture capital in the US and 81% in the EU, equivalent to $5.75 billion in the former and $1.5 billion in the latter (Ernst & Young, 2007). However, contemporaneously, a new dimension of life sciences also focused partly on biotechnology promises to enlarge the market for life sciences products as it is doing with regard to investment, greatly adding to the platform-like nature of this segment of the economy.

We are here referring to “Clean Technology” often abbreviated as Cleantech. From a European perspective, it can be stated with relative confidence that the EU was late to awaken to the climate change problem and the contribution biotechnology might make to ameliorating it. Thus it was not until March 2007 that the EU agreed to a binding minimum level of 10% of all vehicle fuel being biofuel by 2020. The EU justification is that biofuels are renewable; they reduce greenhouse gases and improve Europe’s level of energy security. Each assertion here depends on moving away from corn-kernel towards cellulosic biofuel production (Schubert, 2006a, 2006b). Under these circumstances, while biofuel gives a boost to long-suffering rural economies, it has been shown to raise the price of cereals substantially as demand has rapidly outstripped supply in some countries like Germany and the US. This places an extra heavy burden on world cereal crop prices occasioning distress in developing country markets. These may be more than simple market-adjustment and learning problems. On the one hand, as many authors pointed out, until recently developing country agriculture was being rapidly undermined by, especially, the Bush administration’s dumping of surplus US cereals (notably maize) on developing countries under the guise of development “aid”. On the other hand, as currently exploited, corn is far from ideal as a source of bioethanol, mainly because of the nitrogen fertilizer, herbicide and pesticide runoff from growing it that has produced the catastrophic Mississippi Delta “dead zone”. A whole life-cycle analysis of such fossil-fuel driven bioethanol production would accordingly point to the need for more systemic innovation in the “means of production” of bioethanol involving cellulosic biomass such as wood pellets, corn waste biomass, willow and grass varieties (Herrera, 2006).

Biofuels rely on biotechnology through the production of bioethanol by the application of enzymes to biomass such as cereal crops, sugar beet or cane, trees or biowaste. Currently biodiesel is produced from sunflower and/or rapeseed oil and even from used cooking oils derived from these and other ingredients. So-called second generation
biodiesel is produced by gasification of such ingredients and chemical synthesis. Both are finally mixed with actual diesel oil to produce biodiesel but an ultimate aim for this form of bioenergy is that production of, say, bioethanol should be conducted without the use of fossil fuel, utilizing biodiesel in production plants in a self-sustaining biofuel production system. This ideal is relatively close to achievement in some Brazilian bioenergy plants, but currently some of these are open to serious criticism of exploiting unregulated labour, especially regarding sugar cane-cutting labour in remote bioenergy production locations. Once again, this is a clear case of an adjustment problem susceptible to proper regulation in a period when demand for bioethanol has risen steeply, not least from the US (CEC, 2007; IPTS, 2007).

Having made these introductory points, the paper’s first main section opens out the discussion to other elements of the coming bioeconomy, stimulated as producers and regulators have belatedly become alarmed by the unacceptable exigencies of climate change. This involves various aspects of agriculture, air and environmental bioremediation, manufacturing and other industrial processes, materials, notably nanotechnology, recycling and waste (including waste water) treatment and transportation. But by far the biggest segment of the “cleantech” economy concerns energy generation, infrastructure, storage and efficiency. Thus Cleantech overlaps rather than being confined by biotechnology. In the second main section of the paper, the implications of a cleantech perspective upon the agricultural or agro-food industry are explored before a relatively brief account of relationships in this rising new technology industry for healthcare is presented, taking account of both prevention and pharmaceutical treatment of bad health. In the process, it will become clear just how overlapping and platform-like are these three huge and hitherto mainly distinct economic activities. Thus a final main section will consider the implications of such platforms for policies, indeed platform policies, before conclusions are drawn. In this attention will be drawn to the few empirical instances available from actual policy practice and efforts made to build upon these (Harmaakorpi & Melkas, 2006; Harmaakorpi, 2005; Feldman, 2007).

Cleantech: Some Burning Issues

The first aspiration in an expository effort such as this is to give a clear definition of cleantech and make the necessary effort to categorize and organize the field. Thereafter, some salient points may be made about the relative importance of the identified elements, using wherever possible available metrics, although inevitably in a new economic field such metrics may be shown to be somewhat patchy and even conflicting. Hence, a working description of cleantech is the following: “Cleantech is a venture capital buzzword, making eyes sparkle the way ‘biotech’ and ‘infotech’ once did” (Patel, 2006). This is clearly not a definition, but probably an accurate opinion of the cultural origin of this particular technology species. Problematically, it transpires that the venture capitalists are not discriminating, utilizing a definition much broader than might be imagined, so broad in fact as to allow obviously dirtytech in—essentially it is “… anything in energy, water, transportation and materials science …”. University of Virginia Darden Business School Fellow Joel Makower defined it more circumspectly as: “… a diverse range of products, services and processes that harness renewable materials and energy sources and substantially reduce the use of all resources and dramatically cut or eliminate emissions and waste …” (cited in Pernick & Wilde, 2006). This has the advantage of capturing
the product and process aspects of the ideal clean technology, which is that it contributes to
material sustainability utilizing sustainable processes. Thus a solar panel producer that
used non-polluting production methods fuelled by renewable energy might epitomize
“cleantech” (Pernick & Wilder, 2006). Even this, though, Patel (2006) vexes about as
too broad, encompassing “... spectrometer devices, solar cells, water filtration systems,
software that manages a building’s air conditioning, biofuels and ozone-water systems
for disinfecting fruit ...”.

Burtis et al. (2004) note that they too, for the purposes of their report, chose to use the
term “cleantech” the way private equity investors do. Accordingly, they define cleantech
as products and services that use technology to compete favourably on price and perform-
ance while reducing pollution, waste, and use of natural resources. They go on to avow
that cleantech encompasses a broad range of industries, from renewable energy generation
to wastewater treatment to environmentally sensitive consumer products (Table 1). Some

Table 1. Cleantech industry categories and examples

<table>
<thead>
<tr>
<th>Industry Category</th>
<th>Examples</th>
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</thead>
<tbody>
<tr>
<td>Advanced Materials and Nanotechnology</td>
<td>- Non-platinum catalysts for catalytic converters</td>
</tr>
<tr>
<td></td>
<td>- Nano-materials for more efficient and fungible solar photovoltaic panels</td>
</tr>
<tr>
<td>Agriculture and Nutrition</td>
<td>- Innovative plant technologies and modified crops designed to reduce reliance on pesticides or fungicides</td>
</tr>
<tr>
<td>Air Quality</td>
<td>- Stationary and mobile emission scrubbers</td>
</tr>
<tr>
<td></td>
<td>- Testing and compliance services</td>
</tr>
<tr>
<td>Consumer Products</td>
<td>- Biodegradable plastic ware</td>
</tr>
<tr>
<td></td>
<td>- Non-toxic household cleaners</td>
</tr>
<tr>
<td>Enabling Technologies and Services</td>
<td>- Advanced materials research services</td>
</tr>
<tr>
<td></td>
<td>- High throughput screening research equipment</td>
</tr>
<tr>
<td>Energy Generation, Storage, and Infrastruc</td>
<td>- Solar photovoltaic technology</td>
</tr>
<tr>
<td></td>
<td>- Wind power</td>
</tr>
<tr>
<td></td>
<td>- Hydrogen generation</td>
</tr>
<tr>
<td></td>
<td>- Batteries and power management technology</td>
</tr>
<tr>
<td>Environmental Information Technology</td>
<td>- Regulatory and policy compliance software</td>
</tr>
<tr>
<td></td>
<td>- Geographic Information Services (GIS)</td>
</tr>
<tr>
<td>Manufacturing/Industrial Technologies</td>
<td>- Hardware and software to increase manufacturing productivity and efficiency</td>
</tr>
<tr>
<td>Materials Recovering and Recycling</td>
<td>- Chemicals recovery and reprocessing in industrial manufacturing</td>
</tr>
<tr>
<td></td>
<td>- Remanufacturing</td>
</tr>
<tr>
<td>Transportation and Logistics</td>
<td>- Fuel cells for cars</td>
</tr>
<tr>
<td></td>
<td>- Diesel retrofit equipment</td>
</tr>
<tr>
<td></td>
<td>- Hybrid electric systems for cars, buses, and trucks</td>
</tr>
<tr>
<td>Waste and Water Purification and Manage</td>
<td>- Biological and chemical processes for water and waste purification</td>
</tr>
<tr>
<td></td>
<td>- Fluid flow metering technology</td>
</tr>
</tbody>
</table>

Source: Burtis et al. (2004).
industries such as wind power, solar power, and air pollution control equipment, have long pedigrees and numerous successful companies. Other technologies and industries are newer. For example, environmentally focused nanotechnology and solid oxide fuel cells remain just promising fields without widespread commercial acceptance. Interestingly, one of the few UK studies also ties its categorization of cleantech to that of the venture capital industry but gives a better, more restrictive definition of it as:

... diverse products, technologies and processes which, through improvements in the clean energy supply chain from energy source through to point of consumption, result in reduction in carbon dioxide emission. (Library House, 2007)

A weakness here, which we would propose superseding, is that this otherwise clear definition refers only to carbon dioxide (CO₂) whereas global warming is related to greenhouse gas production which includes nitrogen dioxide (NO₂), sulphur dioxide (SO₂) and methane (CH₄) inter alia. Hence we prefer to replace “carbon dioxide” with “greenhouse gas” in the Library House definition. It is worth clarifying here that cleantech has in mind the achievement of this but not all cleantech is life sciences-derived, although an increasing portion seems to be.

Burtis et al. (2004) list several cleantech industries admitting many have applications that extend far beyond the environmental field. In their study, they are concerned only with those applications that reduce the environmental impact of human activities. In their update report of 2006 they differentiate cleantech from established environmental technologies such as air pollution control, remediation and hazardous waste management, which tend to be “end of pipe” solutions to existing problems and the need to meet environmental regulations. Cleantech, by contrast, is seen as being designed in such ways that these problems do not arise in the first place—they are thus intended or claimed as systemically “clean” (Burtis et al., 2006). Furthermore, unlike predecessor “renewables” in, for example, the energy industry, cleantech products and services are designed to be competitive with conventional technologies by being innovations, which means commercialized new (cleantech) knowledge with an economic rationale first and the environmental one second. This is evidently a somewhat controversial claim, especially as it is also stated in the update report that being market-oriented as a priority means that environmental regulations are not as much of an innovation driver as they were in the past, but rather merely one among many. The debate here would rest upon the issue of spillovers of the economic kind. With respect to, for example, renewable energies of various kinds, full-cost accounting indicates that none is currently cheaper than fossil fuel (Kunstler, 2005).

This classification matches up moderately well with that routinely utilized in the venture capital community discussed earlier, which seeks to classify and benchmark the scale of investment in the distinctive cleantech industry categories at given points in time. In Table 2 a comparison of magnitudes and distributions in North America 1999–2006 and EU 2003–2006 are provided. The obviously noteworthy point is that (as shown in italic typeface in Table 2) the overwhelming majority of venture capital outlays in cleantech are devoted even more in Europe than North America to energy-related investments, and of that it is energy generation that takes the lion’s share. The main recipient industries include solar photovoltaics, wind power and hydrogen. Of course, none of these comes under the life sciences rubric, an official definition of
which includes only the following: any of the branches of natural science dealing with the structure and behaviour of living organisms (OECD, 2006). Thus only the agriculture and nutrition, consumer products and waste and wastewater categories are unambiguously covered from Table 1. But a rapidly growing field such as biofuels makes no appearance in any of the risk investment statistics or categories, a possibly curious, or alternatively telling, omission. Either way, biofuels for one do not appear, as it were, on the venture capital “radar”. Most general investment here is done by large corporations, sometimes in partnership with smaller “specialists” in, say, biofuels production as in the case of BP and D1 Fuels.

This returns us, albeit briefly, to Kunstler’s analysis of the currently-perceived commercial non-viability not only of biofuels but even many of those in which the investment community does appear to be interested. His analysis could be said to be apocalyptic and somewhat fundamentalist, being based, first, on methodologies for forecasting “peak oil” after which the availability of oil globally declines because no new sources are economically accessible, and, second, on a pure price model of the true (unsubsidized) cost of alternative energies. King Hubbert was head of research at Shell until his death in 1989 and he invented the Hubbert Curve of oil depletion rates and dates. This was further refined by his successor as chief of research at Shell, Colin J. Campbell and others in academia. All put the peak at between 2000 and 2010, Campbell opted for 2007, Kenneth Deffeyes of Princeton University for 2005. If US experience is anything to go by, its peak in 1970, accurately predicted by Hubbert, was not confirmed until a year after it had occurred, once lower production levels were recorded and markets fluctuated accordingly. Current market fluctuations and the plateauing of estimated reserves, and for some firms massive downward revision of reserve estimates, gives reason to believe “peak oil” denotes the contemporary state of affairs. From mid-2007, Hubbert models predict that, even excluding variables like explosive global population growth and the rapid growth in demand for oil from India and China, the world has only 35 years of oil consumption left if every last drop can be delivered. Presently, most oilfields deliver 30% and in Saudi Arabia, where innovation in raising the extraction rate has progressed furthest using desalination plant water to hose it out horizontally, 40% of the known content of a given oilfield.

<table>
<thead>
<tr>
<th>Industry</th>
<th>North America (venture capital share) (%)</th>
<th>EU (venture capital share) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy generation</td>
<td>35</td>
<td>58</td>
</tr>
<tr>
<td>Energy storage</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Energy infrastructure</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Energy efficiency</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Energy-related</td>
<td>62</td>
<td>72</td>
</tr>
<tr>
<td>Materials</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Recycling &amp; waste</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Air &amp; environment</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Manufacturing &amp; industrial</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Waste &amp; Wastewater</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Agriculture</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Transportation</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Cleantech Venture Network; Haemmig (2007).
Hence, while more expensive and innovative methods of fuller extraction will be forthcoming, fossil oil-fuel is likely to become a luxury item in more like 20 than 35 years time.

Accordingly, and belatedly, governments world-wide have, as with the EU, only very recently begun to awaken to the strategic implications of these estimates and their likely economic, political and military consequences. Hence, the revival of interest by many governments in nuclear energy, large scale and long-term investments and contracts for natural gas supply, including lengthy new marine pipelines and liquefied natural gas (LNG) harbour terminals. But also, of course, the “bolt for biofuels” and other “cleantech” energies that are also addressing the more important issue of climate change, greenhouse gases and the contribution of fossil fuel burning to that even greater danger. If there is a consensus about global warming, it seems to be that it is at least occurring since CO₂ has never been a greater element than now of the measurable gas content of the earth’s air supply. Measurement is from now back over the previous 600,000 years of the content of the successive annual snowfalls composing the Greenland ice-cap to its base (Johnsen et al., 2001). The dissensus is about the cause, but even the sceptics of the argument that it is not simply cosmic, for example solar radiation cycles, accept that human economic activity is a significant contributor, as demonstrated, for example, in the Stern Review report (Stern, 2007). This advocates measured policy action to help control harmful CO₂ emissions from burning fossil fuels (75% of global energy production) and related practices.

Although, as we have seen, the major area of practical economic activity, measured by risk-investment in two of the world’s main industrialized areas, North America and the EU, concerns cleantech in the form of alternative energy generation, implying a focus on urbanized CO₂ production (76% of total greenhouse gases), it is a modern irony that much of overall greenhouse gases is rural in origin. Domesticated animals, along with wetlands, organic decay, termites, natural gas and oil extraction, biomass burning, rice cultivation, and refuse landfills account for a one and a half-fold increase in methane (13% of total greenhouse gases) during the past 250 years, while the destruction of forests, especially rainforests along with organic decay, forest fires, volcanoes, and land-use change contributes 24% share of annual emissions of CO₂. However, within the earlier-mentioned 76% burning fossil fuels for transportation, industrial processes and power stations contributes 52% of greenhouse gas emissions (Held & Soden, 2006).

Thus, as we have seen, the bulk of the cleantech effort focuses upon alternative energy generation. But why? When, according to Kunstler, one of the main fossil fuels may have disappeared from consumer markets within 20 years. Clearly, there is a hidden expectation that technological innovation will increase the practicality of further extraction from known reserves, lengthening the life of oil in particular to perhaps more like 100 years. It is at this point that Kunstler’s (2005) second methodology raises some apparently alarming conclusions, as follows:

Based on everything we know right now, no combination of so-called alternative fuels or energy procedures will allow us to maintain daily life in the United States the way we have been accustomed to running it under the regime of oil. No combination of alternative fuels will even permit us to operate a substantial fraction of the systems we currently run—in everything from food production and manufacturing to electric power generation, to skyscraper cities, to the ordinary business of running a household.
by making multiple car trips per day, to the operation of giant centralised schools with their fleets of yellow buses. We are in trouble. (Kunstler, 2005, p. 100)

Essentially, the approach taken encapsulates the classic problem of energy economics namely, energy returned over energy invested (ERoEI). If the result of that calculation results in an unfavourable ratio, the investment is non-feasible. Thus early oil-era Texas crude had a favourable ERoEI ratio of twenty to one due to its easy conditions of extraction. That has subsequently declined, but even North Sea oil-extraction retains a favourable ERoEI result, otherwise it would have ceased being recovered. Except that, once again, innovation can moderate the EI part of the equation.

Part of Kunstler’s reasoning goes missing on this dimension, as it does when he extends discussion to natural gas, particularly its LNG variant. He views the capital costs of LNG high enough only to be viable for 20-year contracts. Given the main source of LNG is the “unstable” Middle East the likelihood of the necessary investment being forthcoming is remote. Yet precisely such a project is near completion in the UK in mid-2007. The Qatar Liquefied Gas Company (Qatar Gas), a joint venture company set up by Qatar Petroleum and ExxonMobil Corporation, has expanded its facilities at the Ras Laffan industrial city natural gas liquefaction plant in Qatar. The contract for the construction of the facilities at the South Hook receiving terminal in Milford Haven, Wales (UK), was awarded in 2004 to the Chicago Bridge and Iron Company (Woodlands, Texas) as a lump sum turnkey contract for an estimated $700 million to construct the LNG import terminal. The facility will be operated in a 70/30 split by South Hook LNG Terminal Company Ltd, a British company owned by Qatar Terminal Company and ExxonMobil Qatar Gas II Terminal Company. Overall project investment has been estimated at $12.8 billion. Against ExxonMobil’s wishes, Qatar Petroleum subsequently also negotiated with the French oil and gas company Total and a $3.5 billion deal was signed in 2005, under which Total paid $1 billion for a 16.7% stake in a liquefaction plant and to buy up to 5.2 million tonnes per year of LNG from Qatar Gas for 25 years. So Kunstler’s analysis is accurate but his fears are misplaced.

Another way in which this simplistic ERoEI model has to be modified is to take account of reductions in EI occasioned by state subsidies. In the field of alternative energy in order to stimulate production such mechanisms are common. The Bush administration has a subsidy programme budgeted at $1.7 billion for hydrogen fuel innovation and more like $10 billion for biofuels (Schubert, 2006b). The French case also is instructive on this with regard to biofuels. France is the second largest EU producer of biodiesel after Germany, and the second largest EU producer of bioethanol after Spain. However, due to an increasing number of diesel cars and trucks in France, biodiesel programmes are more promising than bioethanol programmes. In early 2003, the European Commission adopted a new biofuels promotion Directive, prior to the further Directive on the biofuel tax regime of 2007. The French government had displayed great interest in biofuels since 1993 as demonstrated by significant reductions in national excise tax. France mainly produces biodiesel from rapeseed and bioethanol from sugar beet and wheat. France’s largest oil company Total is a strong opponent of direct blending of ethanol in gasoline. Their main argument is that the increased volatility of ethanol would make the blend exceed EU fuel volatility norms. Bioethanol is thus not used directly in petrol but is blended with isobutylene, a petroleum product to produce EBTE (ethyl tertio-butyl ester) which is then added to petrol. Industrial crop production
is produced on EU-subsidized set-aside land. Rapeseed dominates French industrial crop production.

To be allowed to produce biofuels that benefit from a tax reduction programme for fuels when sold on the French market, a plant needs to have a governmental agreement for a maximum volume of biofuel. There is an annual total of 317,500 million tons production of vegetable oil methyl ester (VOME) suitable for biodiesel approved by the French government and benefiting from the French tax cut. Petrol and diesel biofuels are not being developed at the same rate in France, where diesel fuel is the leader. With lower taxes and French car building know-how focused on diesel engines, particularly at Peugeot-Citroen, currently 63% of private vehicles in France use diesel while only 37% use petrol. This situation creates a large problem for French oil refiners: refining crude oil produces a certain amount of diesel oil as well as a large amount of petrol. Thus, in France, refiners face a surplus of petrol and a deficit in diesel oil: petrol is exported at low prices, mainly to the US, while diesel oil has to be imported, sometimes at much higher prices. It is thus easy to understand why oil companies in France are against blending ETBE or ethanol in their petrol, as it increases their surpluses, but they are strongly in favour of incorporating VOME in diesel as it reduces their need for imports (USDA, 2003). Thus to return to the more doom-laden prognoses of Kunstler (2005) in particular, it is clear that a crude market cost ERoEI model simply does not work given distinctive varieties of capitalism, institutional structures and regulatory regimes. Interestingly, not least because of its market scale, EU standards on such issues are being more widely adopted world-wide than those of the US, including California, something which is less than enthusiastically received by the federal government (Buck, 2007).

Hence, in all too brief a space we have tried to articulate in as clear a way as possible, some of the burning issues surrounding the rationale and motivation for the rise of cleantech. This is a key dimension of the contribution of modern life science to possibly overcoming the greatest danger faced by the world—climate change—taking into account efforts to map the field, discuss the analysis and critique some of the underlying assumptions that fuel a “nothing can be done” mentality coming either from the “cosmicists” on the one hand or the ERoEI “apocalyptics” on the other hand. We make the interim conclusion that bioscience will have a major role to play in eventually moderating and perhaps limiting the rise in greenhouse gases, particularly CO₂ that so threaten the habitability of large areas of the planet. In the remainder of the paper an effort will be made to trace the life sciences “platform” that might construct an alternative base to future sustainable economic growth, displacing the somewhat ruinous chemical-fossil fuel nexus that dominated economic development for so much of the past 150 years of industrialization. Before that, a last word on Kunstler (2005) and a positive point to reflect upon is that he is neither merely a “peak oil” scaremonger nor a climate change doomsayer.

He trained as an architect-planner and shares many of the anti-scalar misgivings of the early planning pioneers who successfully fought suburban sprawl. He also rails against its modern correlate of the gas-guzzling sports utility vehicles (SUVs) that ferry suburbia to the distant edges of the metropolis for schooling and shopping, mindlessly pumping out CO₂ and other greenhouse gases on a daily basis. He sees such emblems of neo-liberal consumption norms as storing up a vast depletion of wealth, through vertiginous suburban house-price declines (that may have already begun with the sub-prime mortgage crisis) as consumers choose different, more sustainable ways in which to live urban and rural life. In this, a return to smaller scale, community-based city planning is perceived by Kunstler to
be not simply desirable but inevitable. The exemplar is Mayor Will Wynn of Austin, Texas, progenitor of the first US green building programme at city-level as well as the Austin Climate Protection Plan. This aims to have zero net energy-using single-family homes by 2017 and for the city to be carbon-neutral by 2020. The plan requires, amongst other things, better materials science for buildings utilizing, for example, sustainable natural materials, nanotechnology, innovating the next generation of solar energy technology, smart metering and other energy-selection biosensor devices, even stimulating University of Texas research teams to innovate them. Bioscience will play a big part in enabling such clean technologies and cities to evolve.

The Agro-chemical Dilemma

So how and in what major, structural ways did Western consumption’s mode of production of its environments and reproduction of its people themselves evolve to produce such a dysfunctional outcome as that against which Mayor Wynn is fighting in its very heartland of Texas? Science and technology are at the epicentre of this ecological syndrome, complicit of course with government subsidies and large corporate interests. A useful introduction to how this operated is to be found in Morgan and Murdoch (2001) who trace the rise of “conventional” farming, food production and distribution emanating from regions like California’s “Cadillac Desert” in the Central Valley where industrial vegetable farming began (Reisner, 1986), the American mid-west centred upon the “corn-and-hogs” culture of Minnesota and neighbouring states, including Wisconsin for dairying, and Texas itself, stretching also to Oklahoma and Kansas where intensive, especially corn-fed beef-production was pioneered on dry grasslands that could only support very few cattle per acre.

The key points made by these authors, writing from a UK perspective about the adoption in the 1940s of “productivist” agriculture include the following three dimensions:

- a strategic economic rationale occasioned by post-war food shortages and a perceived need to evolve a cheap food strategy which also reduced Britain’s unsustainable food imports bill
- political and administrative authority left over from wartime to drive farmers into increasing output by providing a regime of sustained subsidies, guaranteed prices and markets and credit for investment in new equipment, buildings and agro-chemicals
- technological innovation aimed at increasing output and productivity, rooted in agro-chemical discoveries, some dating to the previous century, Liebig in 1843 having identified the three key growth nutrients of nitrogen, potassium and phosphates which now form synthetic agro-chemical fertilizers. Subsequently pesticides, herbicides and fungicides were innovated chemically. Other innovations were, of course, in agricultural equipment like tractors, harvesters and milking machinery.

In return for these vast subsidy expenditures farmers were expected massively to increase output and productivity by investing in new equipment, agro-chemical fertilizer, pesticides, etc. and abandon what we would now call, ironically, their traditional organic farming practices. Induced by this “witches brew” or proto-triple helix between science, industry and government, chemicals companies like Bayer, ICI, Dupont and Dow were to profit enormously and rapidly from their investments in agro-chemical research
while similarly scaled profits were made by companies like International Harvester, McCormick, Ford, John Deere and Alfa Laval when they specialized in the production of agricultural equipment. A new and hegemonic regime descended upon agriculture whereby huge subsidies gave economic security, but only to modernizing farmers whose productivity increases forced latecomers to follow—the whole process driving some 600,000 UK agricultural labourers off the land between 1950 and 1980. It is curious that in the modern categorizations of technological intensity of industries, promulgated by the likes of the Organization for Economic Cooperation and Development (OECD) and EU benchmarked against some often arbitrarily designated category like “high-tech” or “knowledge economy”, agriculture and the food industry are perceived uncritically as “low-tech” when in truth it is scarcely possible to find—in its intensive manifestation to be sure—a more science and technology saturated sector on earth, as Keith Smith (2002) once memorably showed.

This alliance around agro-chemicals became a truly pervasive platform spreading its relationships across sectors as different from each other as agriculture, automotives, fuels, chemicals, and supermarkets, all predicated on the existence of the motherlode which was cheaply extractable, transportable and refinable oil. For, of course, the conventional food industry (Manniche, 2007) would not exist as such without the presence of this fossil fuel and its natural gas relative, from which agro-chemicals also derive. In its early evolution the platform was the handmaiden of modernity and the consumer society—a Fordist idyll which fitted the suburbanization and privatized motoring symbolism that drove post-war capitalist recovery in Europe, modelled with national and regional variations on an unquestionably American paradigm. Once the European Common Market opened for business in 1957, the model was extended ever more deeply into a sometimes reluctant, still semi-peasant culture of artisan farmers, vintners and retailers with the aid of subsidies the levels of which resulted in some categories of farmer, notoriously the UK’s “barley barons” who sold to the large corporate bakery and brewing concerns, becoming virtually as rich as Croesus. Even in 2005 85% of the EU Common Agricultural Policy (CAP) direct payments of €32.5 billion were absorbed by just 18% of the EU’s farmers and some 720 German and 90 UK farms received over €500,000 annually (Morgan et al., 2006).

But now, that revolution and that platform are under tension because, as we have seen the oil is running out, the climate change that modern farming and modern energy generation and use contributed to, and the bad health of the consumers of “conventional” food habitually now suffer dictates it. Health scares span a spectrum ranging from 50% of some populations being obese or seriously overweight, to finding that foods in some cases, such as processed meat Red 2G (E128), and red meat (which research shows contains carcncenic N-glycolylneuraminic acid and N-nitrosocompounds) have high association with various cancers. This is not to mention the emergence of BSE (mad cow disease), Escherichia coli, Avian Flu and Salmonella in “conventional” food scares initiated from large scale catering companies or supermarkets. This has put the “conventional” food industry on the back foot and opened up new consumer demands which are being satisfied, albeit from an incredibly low base but at a growth rate of up to 20% per year in some countries by two kinds of alternative food, biotechnologically derived “functional foods” and “organic food”. Both sell themselves and are sold as “healthy foods”, the former in a relatively trouble free way in conventional supermarkets, not least because it comes from science in the form of lactobacters like Finland’s Benecol and France’s
Actimel or oats-derived drinks like Sweden’s ProViva and Oatly that are claimed to have anti-cholesterol properties (Cooke, 2007). The tension between these “alliances of science” and supermarkets are revealed by omission in a book on Sweden’s Scanian food region, which received substantial innovation funding from the state innovation agency VINNOVA to develop its food cluster (Lagnevik et al., 2003). However, this was done with the total exclusion of any organic food farms or companies, despite the existence of numerous of both, on grounds that they were anti-science, and in apparent ignorance of the existence on that region’s doorstep of two huge markets for organic canteen food in Malmö and neighbouring Copenhagen. As their contribution to the Kyoto climate change protocols both cities had committed to introducing organic food in all schools (Malmö) and all public institutions (including schools, hospitals, care homes, administrations, etc.; Copenhagen’s Dogme project) by 2008–2009.

Of further interest here is that the health claims of “functional foods” have never been ratified as such by food and drug administrations world-wide, hence a new and meaningless category of “health claim approved” has been invented by the adjudicators of such claims, which products may carry even though the standard simply acknowledges that the producer has filed a claim that the product is healthy. Nevertheless the market for healthy food is growing exponentially in countries like the US, UK, Germany, the Netherlands and Nordic Countries as worried parents try to mitigate the obesity of their offspring and that and other fears for themselves too. Hence organic food is now routinely on sale in “conventional” food outlets, particularly large supermarket chains or in some cases like Denmark, Germany and UK actual organic supermarket chains. British consumers have been assailed by numerous large food retailers like Tesco, Asda and, particularly Marks & Spencer (M&S) “going green”, in the last case with a green covenant and 100-point plan meaning that by 2012 M&S will become carbon neutral, send no waste to landfill, extend sustainable sourcing and set new standards in ethical trading. Additionally, M&S will help customers eat more healthily.

Biotechnology is, ironically, compatible with and utilized in organic food analysis and production. Blind prejudice from many quarters associates biotechnology only with genetic engineering or genetically modified organisms (GMOs) but biotechnology is utilized in numerous ways to facilitate and speed up traditional breeding of plants and animals (e.g. DNA markers). Another irony in the field is that the deprivations wrought upon animals by intensive farming now require the techniques of bioinformatics and biobanks to assist breeding of, for example, cross-bred cattle that can in one notorious case at least, assist the Holstein super-cows of America to recover their ability to give birth normally. The intensive breeding of animals to maximize the Holstein’s already gargantuan milk-yields had resulted in pathologies that prevented their normal physiological functions. Cross-breeding with carefully selected Norwegian Red Cattle conducted by Norway’s BioInn biobank research facility has aimed at righting the problem. But whether it can produce equivalent results for consumers of intensively-bred pork or non-organically farmed fish is open to question. These intensively farmed animals and fish require such large intakes of antibiotics that consumers develop immunity against them and may suffer longer bouts of Asian influenza accordingly due to their acquired immunity to antibiotics like penicillin routinely injected into the pigs and salmon.

Yet a further irony is that the organic movement which, to repeat, is far from anti-scientific, was born on the doorstep of California’s Cadillac Desert at the University of California Santa Cruz and University of California Berkeley campuses in the counter-cultural 1960s and
1970s. This variant of bioregionalism is nowadays frequently associated with Alice Waters who pioneered at her Chez Panisse restaurant in Berkeley, California, the philosophy that the intensively farmed vegetables of the Central Valley she could smell being chemically fertilized and see being sprayed with what later were often found to be poisons that affected humans as well as insects, fungi and weeds were fundamentally unhealthy. Moreover, the trucking of them all over North America, accounting for 40% of all US trucking (some 10% of US CO₂), was and remains wasteful in energy terms and substantially reduced both the nutritional value and flavour of the no longer fresh vegetables on their ultimate arrival on the consumers table. In its place she argued in favour of what has become the mantra of modern chefs everywhere that meals should only be prepared with local, fresh, seasonal, preferably organically-grown ingredients. This she has extended to the Berkeley school meals system, promoting the “Edible Schoolyard” in a pioneering local school.

But others see even greater innovation having come from Santa Cruz, or at least Santa Cruz and Berkeley together, and epitomized in the history of Earthbound Farm, established in the Carmel Valley by the Goodmans, waiting to go to graduate school. A rented space was turned into an organic salad and fruit farm, the produce was washed, bagged and sold to a Carmel chef. He moved on and they persuaded local retailers to take their “spring mix” of bagged mixed salad leaves—the origin of prewashed salad (Guthman, 2004). This was preceded, however, by Cascadian Farm, founded in 1971 by university dropout Gene Kahn near Seattle. Nowadays Cascadian Farm has been acquired by General Mills as its organic produce line—what fundamentalist organic farmers consider the new “organic empire” compared to those that remain true to the counter-cultural principles of always going against “the man” whether it was RCA which the founders of Silicon Valley’s microelectronics cluster railed against, or food corporates of the likes of ConAgra, Cargill or Archer Daniels Midland (ADM) (Manning, 2004).

These accounts show just how dynamic the contemporary food industry is, and how interconnected it has become with ideas of healthcare through healthy eating rather than perceiving food as (human) fuel. But ironically, as farmers struggle to build a foothold in markets in which super-corporates like WalMart (now also sporting ‘green’ credentials) insistently drive supplier prices down until firms go bankrupt and vacate markets, new market opportunities have opened up with alacrity (Fishman, 2007). As we have seen, one of these is in biofuels, one of the major, rapidly growing cleantech industries with sizeable investment into it, more from large energy companies and the like than venture investors interested in small firm growth. Thus BP and D1 Oils, a UK-based global producer of biodiesel, announced in June 2007 that they were forming a 50:50 joint venture, to be called D1-BP Fuel Crops Limited, to accelerate the planting of *Jatropha curcas*—a drought resistant, inedible oilseed bearing tree which does not compete with food crops for good agricultural land or adversely impact the rainforest—in order to make more sustainable biodiesel feedstock available on a larger scale. Under the terms of the agreement, BP and D1 Oils intend to invest around $160 million over the next 5 years. D1 Oils contribute into the joint venture their 172,000 hectares of existing plantations in India, Southern Africa and South-east Asia and the joint venture has exclusive access to the elite *jatropha* seedlings produced through D1 Oils’ plant science programme. Beyond that, BP, Associated British Foods and DuPont announced their intention to invest around $400 million for the construction of a world scale bioethanol plant alongside a high technology demonstration plant to advance development work on the next generation of biofuels in June 2007.
Healthcare: A Brief Account

The final and far greater element of this burgeoning life sciences platform is healthcare, ranging from biomedical devices to biotechnologically-derived drug cures for hitherto intractable diseases. The direct bridge from agro-food to healthcare bioscience comes in two dimensions—one is the discovery of novel agricultural products of the kind researched at the York University (UK) research centre of that name, which as well as researching new plant sources for industrial oils and rubber has made progress in developing a treatment for malaria from *Artemisia*, a plant with the requisite inhibitor features to the disease. This is much needed, given resistance has grown among mosquito populations to traditional quinine-based treatments; accordingly 51 countries where malaria is endemic have signed up to receive the artemisia-based treatment when it is through trials and costs have been reduced. Of course, drugs from plants is an ancient transition epitomized by the long utilized properties of willow-bark to form aspirin and birch-bark for toothache and other anti-inflammatory requirements. But it continues, even to the point where developing countries seek international regulation to protect their biodiversity from exploitation by advanced country pharmacologists and bioscientists and some reward for hosting such advantageous flora.

The more controversial bridge from agro-food into healthcare concerns so-called “Pharming” where monoclonal antibodies are grown in plants. With the demise of smoking tobacco in advanced economies, hope has arisen that tobacco can in future be utilized as a carrier of biotechnological elements. Many are in any case grown in the blood of animals, such as sheep in which the serum antibodies for snakebites is grown by Welsh serum firm Protherics in farms both in west Wales and Australia.

As argued by Ray (2005) tobacco is a well-researched and utilized plant that is not in competition with food production and environmentally relatively safe.

Tobacco is an ideal plant to use for the production of biologics because its genetic makeup is well known and tobacco is not a food crop. In fact, some scientists have referred to tobacco as the white mouse of the plant world. In addition, tobacco can be harvested before the plants reach maturity, reducing the risk of the genetically modified genes escaping into the environment. Another advantage of tobacco is that it yields a large amount of plant matter, or biomass, per acre with the biologic being contained in the biomass rather than in the seeds. (Ray, 2005, p. 1)

Plantibodies was the first broad patent “pharming” granted to agricultural “farming” of DNA antibody sequences for healthcare application, patented by San Diego firm Epicyte through its patented Plantibodies product. Although objections have been raised by researchers about the scope of such a “broad patent” for restricting academic research freedom, it does not take extra-sensory insight to see that such technologies can be the saving of some agricultural areas assailed by global competition provided they become more “knowledge-intensive” in this and other ways (Cooke, 2007).

The earliest successful products of genetic engineering were protein-based drugs like insulin, used to treat diabetes, and growth hormone. These proteins are nowadays produced at scale by genetically engineered bacteria or yeast in industrial-scale bioreactors. There are human proteins used as drugs that require biological modifications that only the cells of mammals, such as cows, goats and sheep, can provide. Using farm animals for
drug production has many advantages because they are reproducible, have flexible production and are easily maintained. There is a significant challenge in having the new transgene expressed only in the relevant animal’s milk. This requires connecting the gene for the protein drug with a DNA signal or promoter only active in the mammary gland. Drugs currently available are those designed to treat blood clots, anaemia, haemophilia, emphysema and cystic fibrosis. More companies will engage in “pharming” for treatments against, inter alia arthritis, herpes, cancer and infectious diseases which all need viral proteins, including antibodies and—especially—enzymes and other living biological material. This material is thereafter synthesized in industrial fermentation vats, the aforementioned bioreactors.

Two limits to the extension of this approach to the production of biopharmaceuticals are cost and capacity. Processing with animal cell cultures is expensive and possibly unaffordable by healthcare systems or individual patients. The other limitation is that there are insufficient bioreactors available to meet even current demand, although China and India are coming on-stream to meet some of the shortfall (Cooke, 2004). On the cost side, evidence from practice is emerging that growing transgenic proteins in plants such as corn may be many times cheaper than in animals. The US firm Centocor a specialist in this kind of healthcare biotechnology has given evidence that while it costs $80 million to produce 300 kilogrammes of antibodies in mammalian cells, in GMO corn it might cost only $10 million. But, of course, we turn full circle at this point since in many countries outside the Americas GMO crops are not produced owing to public unease—about eating their products, on the one hand, and fears for environmental contamination, on the other hand. Since anyone who has visited the US in the past 15 years has most likely eaten GMO corn, tomatoes and other plant products directly or indirectly (for example, through feed in beef cattle) the former objection tends to weaken, while the latter tends to strengthen as evidence of cross-pollination mounts. This arises from evidence that industrial canola or rapeseed oil, poisonous to humans, cross-pollinates with the cooking oil variety. Where GMO canola or rapeseed oil is grown, cross-pollination occurs in public spaces like roadside verges, and poor locals collect it for home pressing. It is known to have caused illness and may have caused deaths (Myers, 2005). Of course, most biopharmaceuticals production is not conducted through “pharming” proteins. But the expectation of growth in future is high, putting even more pressure upon corn production (Fernandez et al., 2003).

Strikingly, therefore, this account of the platform nature of life sciences tends to return us to the question of maize as the super-plant, from which so much is expected in the future, whether for biofuels, food and feedstocks, or “pharming” healthcare products. Corn was also central to the rise of agro-chemicals as fertilizers, alluded to by Michael Pollan as follows:

The great turning point in the history of corn . . . can be dated with some precision to the day in 1947 when the huge munitions plant at Muscle Shoals, Alabama switched over to making chemical fertilizer. After the war the government had found itself with a tremendous surplus of ammonium nitrate, the principal ingredient in the making of explosives. Ammonium nitrate also happens to be an excellent source of nitrogen for plants . . . agronomists [said] to spread the ammonium nitrate on farmland . . . The chemical fertilizer industry is the product of the government’s effort to convert its war machine to peacetime purposes. (Pollan, 2006, p. 41)
Thus government policy introduced the agro-chemicals industry to the traditional farming industry, rather as government policy is introducing corn and other sources of biofuels to the energy, equipment and automotive industry, amongst others.

**Concluding Policy Reflections**

There are clearly positives and negatives in the account just given. Two big positives are the widespread recognition that climate change related to global warming is happening and that to some, possibly significant extent, it is an unintended consequence of human action, particularly in the burning of fossil fuels. The second big positive is a growing recognition that “peak oil” is probably with us. The combined consequence of these two megatrends is the sudden rediscovery of certain truths, first acted upon in the 1970s, that alternative energy sources must be sought and sustainable development must underpin human activity, particularly economic activity. In its modern version, the collective response in the economic dimension has been innovation in the relatively newly-minted sphere of cleantech, technologies that, as we saw earlier, are being seriously invested in by venture capitalists and corporate oil and chemicals businesses at a growing rate and with as much if not more enthusiasm as the former’s appetite for investment in biopharmaceuticals businesses or ICT. The policy dimension of this is straightforward and to a great extent gradually being pursued. Tax relief on renewable energy investment, adoption of platform-wide strategy to encourage carbon neutrality, sustainability and reduction of environmental footprints as represented, for example, by food miles, and especially municipal as well as country-wide or supranational policy requires at minimum sustaining and preferably increasing. It was noted earlier that one of the most heartening such municipal strategies has been the highly successful Copenhagen Dogma organic food project. This set a target of 75% organic food in all municipal canteens, ranging from schools to elderly care homes. By 2007 this had been 85% achieved within the pre-existing €25 million annual budget, reviving demand for local (organic) farm products in the process. It reduced food miles, raised the nutrition and flavour quality of institutional food and diminished the use of harmful agro-chemicals in the environment in one fell swoop. This is an excellent example of a “platform policy” which in focusing on one key factor—in this case, diet—produces a number of radiating improvements beyond the original focus.

This complements the recent research into platform policies that have as their object the combining of complementary economic activities around a “related variety” platform either as a corporate insurance against cyclicality in the business environment, or as a means of assisting restructuring in economic settings where globalization has undermined a dominant industry and efforts are required to utilize existing skills and capabilities in combinations that suit new industry. Feldman (2007) discusses the platform nature of the evolution of a Swedish science park towards life sciences from aerospace because of Saab’s need for counter-cyclical diversification, but also how an association of interested actors and institutions assumed responsibility for the healthcare ventures when Saab’s strategy changed and the biomedical businesses they had established were subsequently divested. Harmaakorpi and Melkas (2006) and Harmaakorpi (2005) show how the disappearance of furniture manufacturing from a Finnish industrial district to Eastern Europe led to a process of new platform-building utilizing established knowledge to construct advantage in a combination of food, healthcare and cleantech activities.
Expert panels were established as policy advisory teams and where necessary, special expertise such as nanotechnology was mobilized from national centres of research excellence to advise on technological solutions to problems of, for example, water filtration in low energy pumps.

What of the negatives entailed in the analysis of moves in the economic sociology and geography of cleantech and the problems its rise aims to address? The two biggest of these are, first, the adjustment problems entailed by the “bolt for biofuels”. As noted, this has impinged upon poorer countries most, as the price of cereals has risen significantly and will do so even more, given the implications of “pharming” albeit these are less significant than those of cleantech. The lesson here is that business and government perceive the need to act, believing action to be superior to reflection or even research. An example is the already noted green conversion of the UK’s retailer M&S. Buying into global warming, greenhouse gas effects and climate change in a pervasive way in early 2007, one immediate action was to require fruit and vegetable suppliers to source locally and cut contracts or production overseas on food miles grounds. This immediately caused supply chain sourcing and capacity problems among UK vendors to M&S but also to suppliers from elsewhere in Europe and developing countries. Shortly after the decision was taken research was published that showed the CO₂ generated by flying products from Kenya was six times less than equivalents grown in nearby Dutch or UK hothouses (Williams, 2007). The second large negative has been the sudden rise in utilization of the “berries” of cereals for the production of bioethanol and the substantial subsidies being paid by governments, notably the Bush administration in the US, when research shows it to be uneconomic compared with the use of lesser plant material such as biomass or specific high calorie plants like elephant grass. In other words governance policy from public and private sources needs to be far less “knee-jerk” in reaction and more roundly informed of lateral “platform effects” than presumed vertical or narrow sectoral effects. Space does not allow for fuller reflection on the implications for policy of the rise of a concept of lateral absorptive capacity to accompany the more traditional vertical or sectoral one. But the appearance of multifaceted life science platforms with numerous applications means that attention will need to be devoted to this in some detail if platform policy-making is to be successfully achieved to mirror the large-scale and pervasive technology platforms visible now and evolving in the future.

The issues raised in this review are clearly complex for policy-making. It might be asked if regions are competent to policy plan platform interactions that facilitate “related variety” interactions, knowledge spillovers, and recombinant innovations that involve inter-sectoral “platform technology” knowledge adaptations. Clearly, having stated the objection, the prospect of national innovation system actors and institutions being more able to decree opportunity of this sort is limited in the extreme. But judicious state intervention may assist key national technology opportunities in two platform ways, both long-implemented in Scandinavian countries. The first is by “infant industry” protection such as the Danish government practised from the early 1970s until 2000 with its subsidy to the Danish wind-turbine industry. This assisted the evolution of competition, standards and technology. Then in 2000, pursuing a neo-liberal agenda the government removed subsidy causing a freeze-up in the domestic market, which persists, but a significant growth in export markets, notably the US such that most of the leading wind-turbine producers remain in Denmark. The other “platform” approach is to do as Sweden has done and implement a national strategy to be fossil-fuel free by 2020 which has tremendous
energy and other economic implications resulting in a growth in markets for many items from wood-chip boilers to high demand for organic produce of many kinds. This is despite the question as to whether organic food is necessarily less energy intensive than conventional but rather because it is customer preference for the more fresh, flavourful and nutritious product. However, the national sustainable development strategy finds room for regional development recommendations at the level of assisting the construction of, for example, “green supply chains” such as the Farmers Own localized and cooperative food chain connecting farms in Uppsala, Västerås and Södertälje food clusters to markets and retailers in Stockholm, an approach also subsequently emulated by Malmö. Hence the regional level is crucial for implementation of national and supranational goals as the Swedish strategy makes clear (Ministry for the Environment, 2002).

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Notes

1. I am grateful to Emma Frow, ESRC Genomics and Policy Research Forum, Edinburgh University, for drawing my attention to the probable major institutional and sustainability as compared to short-term market adjustments involved in transforming global energy policy. Moving away from corn bioethanol, currently heavily subsidized in the US, seems a pre-requisite.

2. I am grateful to Phil Shapira for this comment on my original draft.

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