Introduction

Today, we are faced by the global imperative to reduce greenhouse gas emissions from our use of hydrocarbon energy. This is the biggest challenge the world faces – even the credit crunch pales into relative insignificance compared to the threat of global warming. I began researching what is happening in the economy to develop the elements of a new post-hydrocarbon economy. My previous work indicated that everything evolves unevenly, that some regions are more receptive to innovation challenges than others and some firms similarly. Such regions usually had business clusters in which and from which their leading firms grew. But in the past, most clusters, defined as similar sector firms competing but also co-operating in proximity to each other in a specific geographic space, were looked upon as more-or less as belonging to a particular sector with a few support activities from other sectors and some kind of cluster management function, maybe run by the firms themselves, sometimes with some subsidy from government.

Cleantech is very different from this model, I discovered. It sprawls across many if not all sectors of the economy because everywhere energy is used there lies an opportunity for decarbonising it. Also water is a target for Cleantech because in many places it is in short supply and prone to pollution, especially in the disease-carrying water courses of the less developed countries of the world. Recycling assists clean-up of course, but Cleantech has the embedded intelligence to perceive waste as a new source of energy as well as a reincarnation of previous products. It is from this kind of industrial and knowledge-based convergence of technologies that we see, in fact the rapid evolution of Cleantech in places and in clusters that are mutating from an evolutionary process that builds upon previous clusters. Moreover, these absorb wholly different industries compared to ICT or biotech. Hence entrepreneurs and managers from the oil, power generation and biochemistry industries find themselves in boardrooms with executives from telecoms, software, aerospace and biopharma. So this article examines the cluster cross-fertilization phenomenon in leading Cleantech regions of the world. In the process it discovers something hitherto relatively un-noticed about economic growth. This is, as Jane Jacobs
suggested, that over-specialisation and over-diversification of business are equally bad, but that related variety among industries in a particular place can be very good for economic growth. We start our study in California and Jutland, Denmark before reflecting on Cleantech practices in Israel.

*California’s Cleantech Cluster Ecology and Mutations*

Space doesn’t permit reporting on the surprising similarity between Danish region Jutland’s Jacobian cluster evolution and that of California. In Schumpeterian terms both took off economically in relation to ‘railroadization’ in the nineteenth century, early clusters connected to agro-food industry emerged soon after, both pioneering intensive, industrialized agricultural production rather than engaging in traditional family farming *per se* and, with intervening periods of cluster-formation in varieties of bio-medical and bio-food, and ICT, including wireless telephony at Aalborg and San Diego, both regions have taken leading positions in Europe and the US respectively with regard to the strategic niche management of green technologies. In California, the technological convergence found also in the Jutland case, where path dependence on agricultural and marine engineering continued to influence technological branching, is even more pronounced. However, while there are some regional industry organization practices that look superficially similar underpinning what in the Jutland case is often referred to as ‘collective entrepreneurship,’ the form this takes in California is distinctive.

Denmark and Jutland’s railroadization, its radical innovation trigger, after Schumpeterian reasoning, was collective in the sense of social democratic practices of communality and mutual self-help based heavily upon co-operative organizations, that of California is more ‘counter-cultural’ than social democratic in the European sense. In particular, and despite a penchant for networking among clustered entrepreneurs in places like Silicon Valley, and elsewhere – for instance, Napa Valley wine cluster hegemony was very much dependent on associative practices led by pioneers like the late Robert Mondavi and the California Wine Growers Association, with strong historic links to the University of California, Davis – California is home to major venture capital firms and collective action. This is evident nowadays as never before in the face of Climate Change imperatives and the technological convergence exigencies of green and clean technological exploration and exploitation. Venture capitalists, notably Vinod Khosla of Khosla Ventures, John Doerr, of Kleiner Perkins, and Steve Jurvetson of Draper, Fisher Jurvetson are among the leaders of
California’s Cleantech Crusade, enjoining political leaders in the field like former Vice-President Al Gore and Governor Schwarzenegger as unlikely bedfellows in a vivid example of regional strategic niche management that, to varying degrees, presages the emergence of a post-hydrocarbon technological regime, if not yet a full-blown ‘landscape’.

Before exploring key elements of this variant of strategic niche management, it is important to observe just how Jacobian California’s main clusters are both in terms of spatial location and path-dependent branching (Fig. 1). Examples of the latter range include farming’s reaction against the perceived depredations of intensive agribusiness in deploying hydrocarbons in agro-food production in the form of chemical fertilizers, fungicides,

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Fig. 1. California’s Jacobian Clusters
Source: Centre for Advanced Studies, Cardiff University, UK
pesticides and herbicides, a localized food network springing up by actors mainly associated with University of California, Berkeley (e.g. Alice Waters, founder of Chez Panisse, the first organic restaurant) and University of California, Santa Cruz (e.g. as epitomised in the history of Earthbound Farm, established in 1970 in the Carmel Valley by the Goodmans). Other connected clusters would nowadays include the Hollywood film cluster evolving popular scientific films railing against the human causes of Obesity (Super Size Me, Morgan Spurlock), Climate Change (An Inconvenient Truth, Al Gore), and Environmental Degradation (The Eleventh Hour, Leonardo Di Caprio). The mutations from Silicon Valley’s and San Diego’s ICT into biotechnology, especially in relation to software applications, bioinformatics and bio-chips of various kinds, is well-documented.

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1 Waiting to go to graduate school, they rented farmland for an organic salad and fruit farm, from which 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 pre-washed salad (Guthman, 2004).
### 25 Who Mutated from ICT to Cleantech

- **Shai Agassi** (SAP), Founder, CEO Project Better Place, Palo Alto, SV
- **Vinod Khosla**, Founder Khosla Ventures.
- **Bob Metcalfe** Partner, Polaris Venture Partners, CEO GreenFuel (Camb.MA)
- **John Doerr**, Partner KPCB
- **Sunil Paul**, Seed investor, early stage cleantech, Nanosolar, Oorja.
- **Elon Musk**, Chairman, Tesla, Chairman, CEO SolarCity
- **Steve Jurvetson**, Partner, Draper Fisher Jurvetson.
- **Bill Gross**, Founder Idealab
- **Ray Lane**, Partner, KPCB
- **Steve Westly**, Founder The Westly Group.
- **Dan Whaley**, Founder, CEO Climos.
- **David Cope**, CEO of PurFresh.
- **Al Gore**, founder, Generation Investment, Partner KPCB
- **Martin Eberhard**, Founder, former CEO Tesla.
- **Martin Roscheisen**, Founder, CEO Nanosolar.
- **Martin Tobias**, Former CEO Imperium Renewables.
- **Manny Hernandez**, CFO SunPower.
- **Jonathan Gay**, CEO of GreenBox
- **Jeff Skoll**, Founder Skoll Foundation, investor in Tesla, Nanosolar.
- **Mitch Mandich**, CEO Range Fuels.
- **Bill Joy**, Partner, KPCB
- **Larry Gross**, CEO of Edeniq.
- **Bruce Sohn**, President First Solar.
- **David Kaplan**, Founder V2Green.
- **Raj Aturu**, Partner, Draper, Fisher, Jurvetson

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**Fig. 2. Recent Entrepreneurial Cluster Mutation Carriers, California**

Source: earth2tech

However, now the convergence ecology and the entrepreneurial mutations among clusters are remarkably evident as a consequence of various leadership moves made principally by venture capitalists consciously to become active players in green and clean technologies in the San Francisco city-region in particular. The clearest evidence of this move is given by reference to Fig. 2, which lists the most prominent ICT entrepreneurs and venture capitalists who have decided to forsake their previous incarnation as ICT entrepreneurs, or prioritise investment in green technologies as investors, or entrepreneurs retaining some interest in their previous technological vocation.
Notes on the Israeli Contribution

So, what about Israel, which is a known centre for Cleantech and not only due to the innovative activities of Shai Agassi? The process of cluster ‘mutation’ identified in other dynamic growth locations seems also to work in Israel. Comparable instances of cluster mutation appear as shown in Fig. 3 in for Israel. Agro-food had long been a predominating industry there. Until the 1990s it had supplied the largest share of Israeli exports. But immigration from post-Soviet Russia brought numerous highly qualified scientists and engineers for whom the Israeli government designed an innovation system programme involving construction of some 200 incubators where small start-up businesses could locate and a public-private venture capital system to finance the best prospects. Some 2-3,000 such new firms, many in software and other ICT activities, medical technology, biotechnology and, most recently, Cleantech have been founded. Importantly, as Fig. 4 shows, some of Israel’s Cleantech entrepreneurs are also moving from one sector or other of technology industries like software and aerospace as in California. The question remains is it an ethical move or a hard-

![Fig. 3 Israel’s Jacobian Clusters](image-url)
headed opportunity for better profitability? Until we receive some further accounts from the entrepreneurs and venture capitalists involved, the jury remains out on this one. For once, however, some entrepreneurs may legitimately say they are driven at least as much, if not more, by concern for the planet. As John Doerr, in his TED lecture (TED.com) says he was doing fine investing for Kleiner Perkins in ICT and biotech until his teenage daughter shamed him into doing some investing aimed at cleaning up the planetary mess made by those investments. For instance, it is estimated that some 10% of US greenhouse gas emissions are associated with the Internet. As Doerr, who created a joint GreenTech fund with Al Gore notes in the video of his lecture – if we

Evolution by Mutation

- **Pythagoras Solar** was founded in 2006 by Gonen Fink, previously at Check Point Software. The company has an R&D centre in Hakfar Hayarok, Israel and a US office in San Mateo, California.
- **Ben-Gurion University of the Negev**, a leader in research and development of technologies in the fields of water, energy and the environment, will invest in Israel Cleantech Ventures, Israel’s first cleantech focused venture capital fund.
- **Israel Cleantech Ventures** was established in 2006 to invest growth capital in Israel’s energy, water and environmental leaders. To date, the Fund has invested in 6 companies.
- **Israel Cleantech Invests in Pythagoras Solar**
  Pythagoras is a solar energy company developing innovative photovoltaic technology to revolutionize the cost of solar electricity.
- **Israel Cleantech Invests in AqWise**
  AqWise develops and implements innovative solutions for biological wastewater treatment and rapid filtration using movable plastic biomass carriers.
- **Israel Cleantech Invests in Emefcy Bioenergy Systems**
  Emefcy is designing an innovative wastewater treatment system which will harness the energy inherent in organic components in wastewater.
- **XJet Solar Energy** Entrepreneur from Semiconductors
- **Orion Solar Energy** Entrepreneur from Aerospace

**Fig. 4. Some Israeli Entrepreneurs ‘Mutating’ into Cleantech**

Source; Centre for Advanced studies, Cardiff University, UK

continue to pollute the planet’s atmosphere to the point that it cannot any longer be breathed, we go the way of the dinosaurs, because we only have one atmosphere. So even if mutating entrepreneurs are motivated mainly by profitability concerns, seeing greater returns from Cleantech than biotech, for example, does that matter in the long-run? Here for once, provided they make products and services that minimise the dinosaur option, they and we are all engaged in a fundamentally Moral Crusade to - in
effect – usher in a post-hydrocarbon economic, social, political and technological landscape.

**Conclusions**

Three things are striking from this account. First, the market moves in sometimes mysterious ways. That is, there is no great profitability in many of these technologies – wind and solar possibly excepted – but entrepreneurs and investors perceive potentially profitable and ethical futures, which act as a driving force of some considerable power. Second, rather like socialism, it is difficult to be green in just one country. Thus the world needs to march together to adopt Cleantech and oust hydrocarbons out of the reckoning. Subsidies can assist this process in constructive ways. Finally, we find economic growth works well where embedded communities of innovators and entrepreneurs co-exist. Cleantech’s convergence qualities underline this insight into the economic growth process, which is evolutionary, devoted to learning, and in this sphere if not many others, somewhat of a moral imperative with beneficient intentions.