Stu's Notes #14

Stu's Notes provide selected passages from books that are of interest to Stu. They are primarily direct quotes, though some longer passages are summarized. They do not generally provide a thorough synopsis of the book. Rather, they capture individual facts or opinions of interest, which may or may not be reflective of the overall text.

Title:	**Sustainable Fossil Fuels: The Unusual Suspect in the Quest for Clean and Enduring Energy**
Author:	Mark Jaccard
Publisher:	Cambridge University Press
Published:	2005
Stu's Notes:	2007 January 23
Summary:	*If the environmental impacts can be substantially eliminated, fossil fuels should continue to be used as they are still abundant and are more economical than renewable energy resources. Specific fuel sources and processes are analyzed, and some are recommended. Includes market-based faith that, for example, hydrogen fuel cells will be commercially viable. Policy recommendations in keeping with his recommendations are proposed, in particular an Emissions Cap and Tradable Permit system.*
Highlights:	Galbraith on economic forecasting [p.32]
	1875 Congressional Record on the perils of gasoline [p.68]
	Industrial countries should reduce GHG emissions by 90% [p.89]
	At current rates, known reserves of fossil fuels will last 130 years [p.152]
	Carbon-capture technologies don't capture 100% [p.188]
	"Sustainable" shouldn't have to mean "lasts forever" [p.252 and p.321]

1: What Is Energy Sustainability?

"Although energy appears to us on the earth's surface in different guises, these are all in some way the product of only two primary sources of energy. These are gravitational forces and the conversion of mass into energy via nuclear reaction." [p.7]

"… at 174,000 terawatts (TW), solar radiation dwarfs all other natural energy sources and is 10,000 times greater than the current human use of energy." [p.7]

"To be sustainable, an energy system must meet two conditions.

- "First, the energy system must have good prospects for enduring indefinitely in terms of the type and level of energy services it provides. Moreover, given the significant energy use that will be required to improve human well-being in much of the developing world, the size of the global energy system would ideally grow substantially over this century.

- "Second, extraction, transformation, transport and consumption of energy must be benign to people and ecosystems. Flows of the energy system's material and energy byproducts must not exceed the ability of land, air and water to absorb and recycle them without significant negative disruption. In this sense, both the known, cumulative impacts of the energy system must be negligible and any extraordinary risks it poses must be extremely unlikely, and ones from which the system could recover within a reasonable period of time, perhaps aided by rehabilitation efforts" [p.11-12]

"In units of megajoules per kilogram, rough estimates for energy density are: peat – 15 MJ/kg; wood – 18 MJ/kg; coal – 20-30 MJ/kg; natural gas – 45 MJ/kg; and oil – 50 MJ/kg." [p.15]

"Finally, basic human preferences are a source of inertia. In many respects, human preferences are malleable. Fads change quickly. Beliefs evolve at a more moderate pace, but can profoundly affect our behaviour over long time periods. For an energy analyst, however, the basic human preferences with significant influence over energy use have considerable stability. Humans want comfort and convenience, which includes a sizeable living space and a comfortable indoor temperature. This factor alone has profound implications for the evolution of our energy system as populations grow and incomes rise over the next century. Humans have a strong desire to acquire things, whether for themselves or to offer as gifts. These require energy to produce and perhaps energy to use and dispose of. This acquisitiveness trait exists in traditional and modern societies and shows no sign of diminishing. Finally, humans enjoy mobility, which requires energy, and this desire for mobility increases in step with income." [p.25]

2: Is Our Current Energy Path Sustainable?

“Certainly, it is true that hindsight analysis in recent years has revealed the abysmal predictive record of most energy forecasting services. But does this mean that we should just throw up our hands and avoid forecasting?

“Unfortunately, avoidance is not an option.” [p.31]

“The famous economist J. K. Galbraith went so far as to say, ‘The only reason economists produce forecasts is to make astrology look respectable.’” [p.32]

“Once I was at an energy conference in which a presenter compared short-term oil price forecasts from the last several decades with actual price developments prior to and following each forecast. Most forecasts turned out to be simply a projection of the energy price trend of the previous six months.” [p.32]

“This means that the typical American household potentially commands close to half a megawatt of power if it were to use all its devices at the same time (furnace, vehicles, appliances, etc.), an amount similar to the power available to a Roman landowner with 6,000 slaves or a nineteenth-century landlord employing 3,000 workers and 400 horses.” [p.44]

“A. Reddy estimated the energy consumption that would provide a significant improvement in living conditions for poor rural inhabitants in the state of Karnataka in India. If a rural household could convert from biomass to liquid petroleum gas (butane, propane) for cooking, it would use about 2.3 GJ/year. If the household were also electrified for minimal services of lighting, fans, refrigeration, and entertainment, instead of being limited to just kerosene for lighting, it might require about 0.7 GJ/year, for a total of 3 GJ/year. For a household of four people, the demand would therefore be less then 1 GH/capita, while achieving a significant improvement over having no electricity, collecting and burning biomass for cooking (and heating) and relying on kerosene for lighting. Once energy consumption in industry, transportation, institutions and energy production itself is included, however, the energy use per capita would be substantially higher, perhaps at 10 GJ/capita – still only one thirty-fourth of the current US level.

“In another approach, J. Goldenberg and co-authors estimated the amount of energy required for everyone in the world to attain the energy services associated with the standard of living of the average European in the 1970s, if they were able to acquire the most efficient energy conversion and end-use technologies available in the 1980s. The authors calculated that this required 30 GJ/capita (1 average kilowatt of power) – one-tenth the current US level.” [p.45]

“For my rough indicator of sustainability in this case, I compute only energy-related CO_2 emissions, which are estimated to account for 60% of the climate change effect – ignoring other GHG emissions such as nitrous oxides and methane.” [p.50]

“… the CO_2 emissions from my current trends case would result in a CO_2 concentration in the earth’s atmosphere of over 650 parts per million by volume (ppmv) in 2100 compared to the pre-industrial concentration of about 280 ppmv, and this concentration would keep increasing rapidly into the following century. Climate scientists suggest that concentrations above 450 ppmv could substantially affect the earth's climate and make even stronger statements about concentrations above 550 ppmv. [p.51]

3: The Prospects for Clean Secondary Energy

"There are three general options for addressing the environmental challenges of end-use combustion of hydrocarbons. We could develop combustion technologies that emit less, or even nothing if it becomes technically and economically feasible to attach emission capture devices directly to end-use technologies – such as a carbon capture device on an automobile. We could shift from higher emission to lower emission hydrocarbons such as natural gas, and new synthetic fuels like methanol and dimethyl ether in the case of reducing emissions that affect urban air quality. We could switch completely away from hydrocarbon combustion towards zero-emission electricity and hydrogen, the latter used in fuel cells or combusted directly." [p.56-57]

"Although they were invented over 150 years ago, fuel cells only became a technology of interest with their application in the space exploration program of the 1960s." [p.65]

"The most promising fuel cell design today is the proton-exchange membrane (other types include alkaline, phosphoric acid, molten carbonate, and solid oxide)." [p.66]

"[Increased demand for auto use and increased demand for improvements in air quality] explain why some observers see hydrogen vehicles as almost inevitable. In essence, when it comes to the prospects for hydrogen, 'necessity is the mother of invention'; if hydrogen fuel-cell vehicles are the best means of achieving zero emissions in cities, society will invent the required technologies and figure out a way to commercialize them. Sceptics caution, however, that energy history is replete with mistaken visions, as necessity confronted the real-world constraints related to thermodynamic limits, physical properties, economic costs, and even the preferences and concerns of users." [p.66-67]

"In assessing early concerns about [hydrogen's] safety risks, it may be noteworthy to see the parallels with earlier concerns about gasoline, as in this quote from the US Congressional Record of 1875: 'A new source of power … called gasoline has been produced by a Boston engineer. Instead of burning the fuel under a boiler, it is exploded inside the cylinder of an engine … The dangers are obvious. Stores of gasoline in the hands of people interested primarily in profit would constitute a fire and explosive hazard of the first rank. Horseless carriages propelled by gasoline might attain speeds of 14 or even 20 miles per hour … the cost of producing [gasoline] is far beyond the financial capacity of private industry … In addition, the development of this new power may displace the use of horses, which would wreck our agriculture.'" [p.68]

"I often insist that we refer to a private automobile not as a vehicle, but as a PMD – a personal mobility device. Many people love their personal mobility devices, and even in cities with excellent public transportation systems in Europe, North America and Japan, they stick to this device to the point of mind-numbing congestion. Indeed, from our recent detailed research into people's mobility preferences when comparing public transit and automobiles, we have considered again changing the name we use for a personal vehicle in order to more fully convey its perceived value, this time to PSED – personal status enhancing device." [p.73]

"In my own projection, I assume that by 2100 hydrogen will attain a 30-40% share of the secondary energy market – with expansion occurring especially during the second half of the century – while hydrocarbon fuels fall to 30-40%." [p.75]

4: The Usual Suspects: Efficiency, Nuclear and Renewables

"In response to the oil supply crisis of the 1970s, energy efficient analysts emphasized that the same level of energy service could require significantly different amounts of secondary and primary energy. If energy service demands grew by 20% over a twenty-year period while energy production, conversion and end-use technologies improved their efficiency by an average of 20%, primary energy requirements would not increase." [p.79-80]

"This distinction between the first and second law is illustrated by A. Lovins' memorable example of cutting butter with a chainsaw. First law efficiency is the ratio of the motive force of the spinning chain to the gasoline consumption of the chainsaw. The energy actually required to do the task is immaterial as this approach focuses only on the inputs and outputs of the device itself. Second law efficiency is the minimum theoretical amount of energy necessary to cut the butter (the energy required to separate its molecules at a given temperature), divided by the gasoline consumption of the chainsaw. In this case, the choice of device to perform the task is a critical determinant of efficiency." [p.80]

"The first and second law efficiency of our global energy system can only be crudely estimated. … yields a first law efficiency of 37.5%. … an efficiency level of less than 15% as we shift from first law toward second law analysis." [p.81]

"Some analysts suggest that designing for energy efficiency should extend beyond energy using equipment and buildings to include integrated development of urban and industrial activity that captures the synergies between, for example, the thermal waste from some activities and the low-temperature heat requirements of others. *Community energy management* and *industrial ecology* are two overlapping concepts that exemplify this approach. [p.83]

"If we could redesign our cities, transportation networks, energy grids, industrial processes, and all the technologies that operate within these in accordance with the second law of thermodynamics, we can conceive of a world in which we receive the same level of energy services (lighting, heating, mobility, consumer products) while using only 10% of our primary energy demand." [p.86]

"Using GHG emissions as a critical indicator, Schmidt-Bleek argues that if global GHG emissions must be cut in half, and if developing countries need to increase their material and energy flows five-fold in order to attain a decent standard of living, then the emissions from industrialized countries must fall by 90%. In this sense, the 90% reduction is more of a precautionary target based on ecological and social necessities than the outcome of a detailed analysis of technologies and thermodynamic potentials. [p.86] Footnote: F. Schmidt-Bleek; "MIPS and Factor 10 for a Sustainable and Profitable Economy"; Wuppertal Institute; 1997.

“By the 1960s and 70s in industrialized countries, you didn’t need to be a physicist or engineer specializing in thermodynamics to feel that we sometimes use energy wastefully … This observation of wasteful use seemed especially pertinent in the US and Canada where relatively inexpensive energy resources had allowed these countries to develop energy-intensive industries and lifestyles compared to Europe and Japan.” [p.89]

Discussion of energy efficiency, and why it may not have the potential that some people claim. Example of compact fluorescent light fixtures, and why adoption has been slower and more limited than some had predicted. [p.89-100]

Global reserves of uranium are 47 years (at today’s consumption rates), and global resources are 180 years. “If uranium estimates do not increase significantly, reserve depletion would presumably drive up uranium prices until fast breeder reactors became economic, effectively extending the life of the uranium resource for thousands of years – even before including the uranium potential from seawater and the world’s thorium resources.” [p.103-104]

Nuclear issues: high cost & investor risk; perception of increased risk of nuclear weapons proliferation; concern of vulnerability of plants to nuclear attack; concern re radioactive waste. Considerable discussion of each of these issues. [p.104-111]

“Solar power plants covering just 1% of the earth’s deserts would meet total current electricity demand. … Renewables do not, however, perfectly match human needs in that these sources of energy are often intermittent, of relatively low energy density, and inconveniently located.” [p.112]

Challenges of biomass: competing uses for land and water; degradation of soil and water that can occur from converting indigenous forests and grasslands to biomass energy production; air and water impacts from the processes that convert biomass into various forms of secondary energy, and then the use of that secondary energy. [p.121-123]

“Energy storage is the other alternative for renewables.” (i.e., to overcome the intermittency problem) Examples: pumping water up to a reservoir, compressed air (75% efficiency), spinning a flywheel (90-95%), batteries (70-80%), and producing hydrogen (40-50%). [p.127]

“The earth intercepts an enormous amount of solar radiation. After subtracting the solar energy reflected back to space by the atmosphere, about 3,900,000 EJ are potentially available on the earth’s surface, which is almost 10,000 times greater than the 429 EJ of the global energy system in 2000. … The World Energy Assessment incorporates these factors along with crude estimates of land availability to generate regional estimates for solar energy potential. Their estimate ranges widely, from 1,500 EJ to 50,000 EJ, but even the low estimate suggests that available solar radiation alone exceeds my current trends projection for 2100 for the entire human energy system of 1,390 EJ.” [p.128]

“One estimate is that an area 750 kilometers by 750 kilometers would be covered with PV cells to meet current global electricity needs.” [p.129]

"… because the geothermal gradient of the earth's crust averages 30^{o}C increase per kilometre of depth, humans can tap into the earth to capture lower quality geothermal energy at just about any location." [p.131]

"The potential of biomass, wind, solar and geothermal far exceed in their annual output the system in 2000 and the expanded system of my current trends projection for 2100. Even hydropower has this capacity if I include the potential energy from all surface flow of water on earth, and likewise ocean energy if I include the vast potential to produce mechanical energy from ocean temperature differentials." [p.134]

"Depending on how they are affected by their tree main challenges – intermittency, low energy density and inconvenient location – many renewables must overcome substantial environmental impacts and will incur significant costs in providing dependable energy." [p.134-135]

5: The Unusual Suspect: How Long Can Fossil Fuels Last – And Does It Matter?

"Since the 1830s, the accelerating application of the coal-fired, high-pressure steam engine … triggered a revolution in industrial production techniques and railway transport, increasing the productivity of labor and capital and driving rapid industrialization in Western Europe and North America. … Around 1900, three key innovations strengthened the bond between fossil fuels and industrial societies and set the pattern for developments throughout the twentieth century. The introduction of the steam turbine … the electric motor … the internal combustion engine …" [p.145]

"Ultimately, the future evolution of fossil fuel use depends on the relative supply cost of each fuel for the different energy-using techniques and end-use services in conjunction with its performance for achieving environmental and social objectives. A key consideration when the issue is endurance is the magnitude and distribution of each resource." [p.147]

"Resource is the estimated natural occurrence of a particular form of energy or matter, while reserve is the subset of the resource that is 'available' for current exploitation. Its magnitude depends on our state of knowledge of the resource's location and our technological capability to extract and process it at reasonable cost." [p.147]

"If coal consumption continued at its current rate of 100 EJ per year, reserves might last 210 years and the estimated resource 2,000 years." [p.148]

"Together, the estimated conventional and unconventional oil resources are 11,000 GJ for reserves within a total resource base of 32,000 EJ. If global oil consumption continued at its current annual rate of 163 GJ, currently estimated reserves would last sixty-seven years and the estimated resource 200 years." [p.150]

"Combining conventional and unconventional gas yields total gas reserves of 15,000 EJ and a total gas resource of 49,500 EJ. If global natural gas consumption continued at its current annual rte of 95 EJ, reserves would last 160 years and the resource 520." [p.151]

"As an aggregate, fossil fuel reserves would last 130 years at current rates and the resource almost 800 years." [p.152]

"Another group of researchers … offer an alternative view [to those that follow Hubbert]. They argue that the depiction of Hubbert and his followers of ultimate oil reserves overlooks the role of price and technological change in determining the magnitude of these reserves at any given time." [p.155]

"The oil price increases [of the 1970s] triggered demand and supply responses." [p.156]

"Humans slow and eventually halt their search for conventional oil when the returns from this activity are likely to be lower than the returns from pursuing conventional oil's substitutes. When this happens, the reserves of conventional oil are exhausted in the economic sense that none of the remaining resource can be profitably exploited." [p.159]

6: Can We Use Fossil Fuels Cleanly – And What Might It Cost?

Extreme event risks vs. ongoing impacts and risks. [p.169]

"Although these options are generally categorized as zero-emission, this is not entirely accurate. Virtually every emission prevention technique designed thus far allows at least some escape of CO_2 into the atmosphere. A more precise term, therefore, would be near-zero-emission processes." [p.188]

"… academic and industry researchers … have tackled [carbon capture] no differently than their predecessors solved earlier problems in reducing SO_2, particulates, NO_x and other emissions." [p.189]

"… most CO_2 capture technologies currently under serious consideration prevent 85-90% of the carbon in the fuel from reaching the atmosphere." [p.190]

"This 'CO2 scrubbing' technique can be integrated into new coal-fired power plants, and even retrofitted on to some existing plants. The energy required to run the capture process, however, would decrease the efficiency of a typical plant by 8-9%." [p.190]

"Thermal power stations and some types of large industrial plants are stationary sources of CO2 emissions for which this post-combustion capture approach would be relatively easy to implement. When it comes to smaller-scale fossil fuel combustion, however, the technological challenge is daunting. Carbon capture implies that equipment like home furnaces and personal vehicles would be fitted with miniature versions of the elaborate processes involved in CO_2 extraction, concentration and disposal in a coal power plant. This seems unlikely, although technological surprises can never be completely discounted."

"[A] possibility for surface storage is for humans to extract elemental carbon from oil and natural gas directly and store it as solid carbon bonded with other elements to produce carbonate rocks. This may ultimately turn out to be the solution, but considerable R&D is required before we know if this can be achieved at a reasonable cost on a large enough scale." [p.198]

"Ocean storage was initially seen as the most promising means of storing carbon. The oceans are already a major carbon sink, but their capacity to hold carbon can be augmented by pumping CO2 into ocean depths from where it would not resurface because of its physical properties relative to seawater. At ocean depths below 800 meters, CO_2 changes from gas to liquid and below 3,000 meters it would have negative buoyancy relative to seawater, meaning that it would sink to the ocean floor. … However, the option raises environmental concerns about how acidity changes caused by increased CO2 might affect deep ocean lifeforms." [p.198]

"Geological storage has garnered the most attention in recent years. For several decades, the fossil fuel industry has had experience transporting CO_2 and injecting it in underground geological structures. In more than seventy sites worldwide, CO_2 is injected into oil reservoirs to increase pressure as part of enhanced oil recovery (about 20-30 million tonnes annually)." [p.198]

"However, current and future depleted reservoirs have a combined carbon storage capacity of only 300-600 GtC, not nearly enough to contain all carbon from fossil fuels if these were to continue to dominate the global energy system through this century and beyond. Other research has widened the search for suitable geological storage sites to include the much more plentiful deep saline aquifers which underlie sedimentary basins at depths greater than 800 meters – far deeper than typical freshwater aquifers, which are found at 300 meters and less." [p.199]

"Carbon capture and storage cost estimates are constructed from individual estimates for the three separate components: capture, transport and storage. Capture represents about 90% of the costs in most estimates." [p.203]

7: Sustainable Energy Choices: Comparing the Options

A multi-criteria analysis based on:

- Cost (free of subsidies, and with minimal ongoing impacts and risks to land, air and water) [p.216-225]
- Extreme event risk to the environment and humans [p.225-226]
- Geopolitical risk [p.226-230]
- Path dependence (momentum) [p.230-233]

All brought together on p.234.

Nuclear power has lost its momentum. "Overall, nuclear scores equally or negatively against zero-emission fossil fuels, efficiency and renewables on all four criteria." Could become competitive if it offered a significant cost savings. [p.236]

There are limits to what efficiency can do, as presented in Chapter 4. [p.236-239]

"Renewables and zero-emission fossil fuels will compete for the dominant position in meeting the needs of a sustainable energy system over the coming century.

Renewables may appear to many people to be more attractive in terms of both cleanliness and endurance, but zero-emission fossil fuels have a cost advantage and a substantial path dependence advantage." [p.239]

"… on a ten-to-fifty year timeframe, carbon capture and storage technologies will pass from the demonstration stage to commercial dissemination, provided there are policies to motivate the installation of these higher cost technologies and processes. Most of the components of this option are already commercially proven. Once this overall process is demonstrated as a total package for zero-emission fossil fuels, it will become much easier for governments in the middle decades of the century to enact more forceful policies that lead to universal compliance with carbon capture and storage requirements at coal-fired and natural gas-fired electricity generators. With these policies raising the cost of electricity from fossil fuels, renewables will find opportunities to compete." [p.240]

Options for transportation are:

- Super-efficient internal combustion engines fuelled by gasoline, synthetic fuels, natural gas or biofuels (will not satisfy requirements for greenhouse gas emissions and local air pollution)
- Hydrogen
- Plug-in hybrid cars, charged by clean electricity [p.241-242]

Sustainable fossil fuel future summarized in Figure 7.2 [p.246] and discussed on the following pages [p.246-255]

"Ignoring a low cost option just because it will not last forever is strange to me. It seems to result from people using a definition of sustainability requiring that every component of the energy system must be guaranteed to last forever. … The sustainable fossil fuel future is both likely and desirable in my view. But it is far from certain. Various surprises could change the outcome. Geological storage of CO_2 could prove technically unviable for some reason, or there could be a strong public reaction against it." [p.252]

8: Sustainable Energy Policy: How Do We Get There?

"Increasingly, I see politicians as the nexus of our own contradictions. We want the world to be better. We want a cleaner energy system that endures and is not expensive. We do not want trade-offs. Because of this, we put politicians in the impossible position where they must support all the things we desire, yet dare not tell us about trade-offs we do not want to see and the costs we do not want to bear." [p.261-262]

"Our objective is not a specific penetration of renewable energy or efficiency or nuclear power. These are only means to an end. … We measure the sustainability of that system not by the contribution of one of these means … but rather by that system's ability to satisfy the components of our sustainability objective. Those components are endurance and cleanliness." [p.262]

"It is difficult to explain that, like democracy, the market system is horribly flawed, but just happens to be better than the alternatives." [p.263]

“Reducing greenhouse gas emissions is in a special category in terms of the policy challenge. For one thing, the link between our actions as consumers and the resulting GHG emissions is not readily apparent to most people. For another, the degree to which GHG emissions place ecosystems and people at risk is highly uncertain, and likely to remain so. Policy makers wanting to reduce GHG emissions find themselves in the unenviable position of possibly imposing significant near-term costs on consumers and businesses for hazy and poorly understood benefits in the future, benefits mostly realized by future generations on the other side of the planet. Politicians who prefer minimal effort can use this uncertainty to their advantage. The rejection of the Kyoto Protocol in 2001 by US president George W. Bush was explained by former advisor Paul O’Neil as, ‘The base [President Bush’s Republican political base] likes this and who the hell knows anyway.’” [p.266]

Potential policies will be evaluated on the basis of:

- Environmental effectiveness
- Administrative feasibility
- Economic efficiency
- Political feasibility [p.271]

Types of policy options are:

- Command-and-control (prescriptive) regulations
- Financial disincentives (taxes)
- Financial incentives (subsidies)
- Voluntarism and information
- Market-oriented regulations – emissions cap and tradable permits
- Market-oriented regulations – artificial niche market regulation [p.271-290]

Comparison of the above options against the above criteria is on p.290.

National

Proposed policies at the national level:

- Prescriptive: safety standards, mineral rights, land uses, water use / quality
- Low GHG tax
- Key item is Emissions Cap and Tradable Permit (ECTP), initially just on large emitters, and with a (rising) price ceiling to prevent excessive costs: allocate most permits by historical reference (grandfathering) and the rest by auction

- Some niche market regulations: vehicle emission standard, renewable portfolio standard (minimum requirement for renewable sources of electricity), and carbon capture and storage requirement for the fossil fuel industry [p.291-294]

"Before the complete transition from an industry-focused ECTP to an economy-wide ECTP, zero-emission technologies and processes need to be developed to the point where consumers and businesses perceive these as legitimate options. Thus, the ECTP would be applied in concert with the application of a few key niche market regulations that strategically target areas where profound technological change has great potential but faces high transitional costs. These regulations would focus on vehicles, electricity generation and the fossil fuel chain." [p.295]

"If the ECTP were relatively aggressive from the start (low cap and high permit price ceiling) and if it applied to all GHG emissions (instead of just industrial emissions) the CCSS would not be needed; an economy-wide ECTP would motivate carbon capture and storage investments just as the carbon tax in Norway motivated the Sleipner project. However, economy-wide application of the ECTP is unlikely to be politically and administratively feasible in the initial phases, and a high ECTP permit price ceiling would also not be politically feasible. The role of the CCCS, therefore, is to provide a parallel impetus for innovation and technology diffusion in the fossil fuel chain that the [Renewable Portfolio Standard] provides for renewable electricity generation. As the ECTP permit price ceiling rises, the need for the CCSS and the RPS diminishes. [p.298]

"This long-run policy design includes the eventual phase-out of all three niche market regulations as the permit price ceiling of the ECTP rises (and its cap falls) and as the ECTP is extended to the rest of the economy or matched by a parallel carbon tax for final consumers." [p.298]

International

"In an ideal world, the international community would reach an agreement on greenhouse gases that improved on the Kyoto Protocol with the following elements. It would include all major emitters. It would have a firm timetable for emission reduction consistent with the rate of innovation and capital stock turnover. It would establish a global ECTP with a permit ceiling price (or a global carbon tax) set to drive technological innovation without causing short-run economic hardship. It would create an independent and trusted agency to supervise compliance, resolve disputes and administer the international permit trading mechanism of the ECTP. And it would allocate initial permits in a manner that all countries – industrialized and developing, large emitters and small – agreed to.

"Unfortunately, this prescriptive vision needs to be balanced with predictive realism. There are enormous difficulties in negotiating most global accords, and the climate change challenge is fraught with uncertainty about the magnitude and location of costs and benefits, entailing potentially huge equity impacts between countries." [p.306]

Subsequently proposes international policies that are essentially an extension of the national policies, above.

"While comprehensive international agreement on a planetary GHG abatement target with a consistent portfolio of international policies for achieving it is a laudable ideal, reality is likely to be more complicated. Acceptance of this should increase the prospects for early progress that can later be improved upon." [p.310]

9: Broadening the Definition: Is Sustainable Energy Sustainable?

"My analysis points to a conclusion that few people believe today – that we can achieve a dramatically lower impact and lower risk energy system while fossil fuels retain their dominant role through this century and beyond. Even more disturbing perhaps, I further conclude that such an energy system be called sustainable in that it would provide a substantially expanded level of energy services indefinitely, with little increase in energy service costs, and eventually with a smooth transition – as smooth as can be expected in a commodity market with its share of spikes and crashes over the decades – to other forms of energy and greater efficiency as the depletion of fossil fuels increases the costs of developing the remaining resources." [p.319-320]

On sustainability:

"One thrust focuses on biogeophysical sustainability, what is sometimes called the natural carrying capacity of the earth. Essentially, this says that human activity is unsustainable if it exceeds or otherwise disrupts the natural cycles of energy and materials in the biogeosphere." [p.320]

"Some analysts have attempted to develop a single, comprehensive indicator. The ecological footprint compares the resource use of a particular region (or the entire planet) with the natural rate of bioproductivity from photosynthesis, and the region's material and energy wastes with the assimilative and recycling ability of the region's (or the planet's) natural system. This position is especially associated with concerns that humans are destroying natural capital (the earth's existing biogeophysical system) that will be highly valued by future generations. For some, it even suggests that any loss of natural capital is unsustainable, even if compensated by human-produced capital in the form of infrastructure, buildings, equipment and technological know-how. According to H. Daly, natural capital and human-produced capital are essentially complements with only slight substitution capability over time – an approach that has been referred to as *strong sustainability*."

"This contrasts with an approach, commonly associated with J. Hartwick and R. Solow, which posits that ongoing substitution between natural and human-produced capital can be consistent with sustainability – what has been referred to as *weak sustainability*. From this perspective, a concept like sustainable development cannot provide us with detailed guidance about what we can and cannot do in order to protect the interests of future generations. Instead the concept simply expresses a moral obligation under extreme uncertainty to act in accordance with our best guess at what future generations would have preferred us to do. This would mean, for example, that our use of exhaustible resources like fossil fuels would be acceptable if we reinvest the net benefits from resource exploitation into human-produced capital that might better the lives of people in ways that lead to wealthier and healthier future generations (clean water supply and sewage infrastructure in developing countries, advances in medical knowledge)." [p.320-321]

“This latter perspective especially finds illogical the argument that we should abstain from the use of non-renewable resources like fossil fuels in case future generations might value them more highly than ourselves. How can any past or future generation escape this same argument? No generation can know if the resource would be more valuable to future generations. But if all generations assume this, humanity forgoes in perpetuity the high quality energy from fossil fuels even if their use could better the lives of needy people today and improve the human condition for generations to come.” [p.321]

“Human history includes periods of steady progress in bettering our conditions, but also evidence of catastrophic collapse of fairly sophisticated societies.” [p.322]

“If the precautionary principle suggests reducing fossil fuel use in rural parts of India, will this accelerate deforestation in areas where biodiversity is threatened? Should we not simultaneously apply the precautionary principle to deforestation when we apply it to fossil fuel use reduction?” [p.323]

“When deciding to preserve conventional oil and natural gas for future generations, we need to understand the slowing of economic growth in developing countries that might be implied by this decision. This can have real repercussions for the well-being of the poorer people on this planet today and for those yet to be born during this century.” [p.324]

“Like most economists, I have sympathy for the argument that our ability to develop substitutes to meet our needs is greater than most people suspect – and far greater than foretold by today’s prophets of doom. I believe that a static view of resources can lead to the wrong decisions if we are seeking a balance between improving the lives of poorer people today and preserving options for future generations. On the other hand, I also worry about the risks of ardent techno-optimism. Because of this concern, the technological options I focus on for achieving zero-emission fossil fuels are already used in industry today, which provides greater confidence in their capabilities and costs.” [p.324]

“Finally, what ultimately might happen if I am right? What if we can and do achieve a relatively clean and inexpensive energy system over this century? Does this mean that we will also satisfy the broader definition of sustainability?

“Unfortunately, it does not. The impacts and risks to the earth from human activity are so much more than just those directly associated with our energy system. Indeed, a cornucopia of cheap and clean energy unshackles humanity to continue, if it wants, the appropriation of more and more of the earth’s surface. We can already see what cheap energy means where wealthy people in wealthy countries can realize their dreams for luxurious, spacious and mobile lifestyles without feeling constrained by energy costs. Rich people use a great deal more energy per capita than poor people, in spite of having more energy efficient devices. They also use more of the earth’s surface – land and water – for living space, recreation, and the production and disposal of materials.” [p.325]

“Human economies will need to evolve toward closed-loop principles that are currently identified with concepts such as *industrial ecology*, *biomimicry* and *environmental life-cycle management*. All of these imply that the inputs and outputs of human activity are designed and controlled to ensure that these flows are non-disruptive to the earth's biogeophysical system, including the maintenance of biodiversity. [p.325]

"Viewed according to their attributes, as we currently know them, fossil fuels are an undesired input that calls for rapid banishment. Viewed according to their quality and quantity, and the technological potential to use them differently than we currently do, fossil fuels can play a key role over this century and beyond as we pursue an enduring, benign and affordable energy system." [p.326]