Energy and the New Reality 2

Carbon-Free Energy Supply

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Policy Sketch and Concluding Thoughts

The purpose of this book and of Volume 1 has been to critically assess the technical potential and (where possible) the cost of achieving deep reductions in energy use through improved efficiency, on the one hand, and of rapidly deploying C-free sources of energy, on the other hand. Our focus has been on assessing the prospects of reducing CO_2 emissions rapidly enough that the atmospheric CO_2 concentration will not exceed 450ppmv. Assuming stringent reductions in emissions of other GHGs or their precursors, a CO_2 concentration of 450ppmv gives the climatic equivalent of a CO_2 doubling (from 280ppmv to 560ppmv), which, as discussed here, already poses significant risks and will entail substantial ecological and social losses. However, if CO_2 is allowed to rise above 450ppmv, the losses – both human and ecological – will be greater still.

Our key conclusion is that it is technically feasible and affordable to limit the peak atmospheric CO_2 concentration to 450ppmv through a combination of:

- family planning and other measures sufficient to produce the 'low' population scenario considered here;
- acceptance of a declining rate of growth in world average income per person, rather than continuous exponential growth (something that will probably occur in any case due to declining availability of inexpensive energy and other resources);
- an increase in the rate of improvement in the economic energy intensity from 1.1 per cent/year (the 1965–2005 average) to 2–4 per cent/year until about 2040, and decreasing thereafter; and
- installation of 17–28TW of C-free electricity generation capacity and provision of 40–98EJ/yr of biomass energy by the end of the century (for the H_2-intensive supply scenarios), or installation of 6–11TW of C-free electricity generation capacity and provision of 178–344EJ/yr of biomass energy by mid-century (for the biomass-intensive supply scenarios).

Together, these measures would permit the elimination of fossil fuel CO_2 emissions during the latter quarter of this century. Technological measures – greatly improved energy efficiency and new, C-free energy supplies – will almost certainly not be able to reduce CO_2 emissions rapidly enough if a high population growth scenario is combined with high rates of economic growth throughout the coming century.

Declining rates of economic growth do not mean unemployment or declining human welfare, or entrapment of the poorest countries in their current poverty. The low-growth scenarios considered here assume substantial growth rates throughout the coming century for non-OECD countries, combined with a slight decrease to a slight increase in per capita GDP in OECD countries (depending on the region). Low rates of growth in OECD countries will not lead to unemployment if increasing labour productivity is channelled into increasing leisure time rather than increasing consumption of goods. As discussed in Chapter 11 of Volume 1 (section 11.2), greater leisure time combined with a gradual shift to more compact, vibrant and pedestrian- and transit-oriented cities will do much to increase the quality of life while reducing the proclivity to consume.

In the following pages, broad strategies for achieving rapid deployment of C-free energy sources are outlined, along with a brief consideration of measures to stop further deforestation. Some brief comments on geo-engineering and a final wrap-up are offered.

13.1 Promoting C-free energy

Some C-free energy sources are already economically competitive based on market costs, although in most cases, market costs of C-free energy sources are greater than the market costs of fossil fuels. However, market costs do not reflect a wide variety of social and environmental costs, of which climatic change is only one. These costs are much larger for fossil fuels than for C-free energy sources. To greatly accelerate the deployment of C-free energy sources and to belatedly begin to prepare for the imminent peaking in the supply of oil and later peaking in natural gas and coal supply, deliberate government action is needed. Three overarching policy options are:

- imposition of a gradually increasing C tax, so that some of the climate costs of fossil fuels are reflected in their price;
- removal of all subsidies for fossil fuels (and for nuclear energy); and
- increasing funding of research and development related to a wide array of C-free energy options.

Additional policy options specifically for the electricity sector are:

- developing backbone high-voltage grids (HVDC or HVAC) to permit the linking of scattered regions of high-quality solar and wind resources with the major electricity demand centres;
- promoting an increasing use of C-free energy sources through requirements for minimum fractions of renewable energy (renewable portfolio standards) or through offers by the power utility to purchase C-free electricity at favourable rates (called a fixed feed-in tariff);
- production tax credits, accelerated depreciation and support for green certificates;
- system-wide surcharges to support financial incentive payments and research and development;
- removal of procedural, institutional and regulatory barriers to renewable energy (by, for example, permitting independent power producers to sell to the electricity grid, or permitting net metering of home PV systems); and
- promotion of stakeholder participation (required for public buy-in).

A more complete discussion of these and other options can be found in Aitken (2003), Holm (2005), GAC (2006), Lesser and Su (2008), Barbose et al (2008), Albadi and El-Saadany (2009) and Sovacool (2009). Barbose et al (2008) discuss the approaches used to encourage high PV system performance in 32 prominent PV incentive programmes in the US. Sovacool (2009) reviews and assesses the options for promoting renewable energy (and energy efficiency) based on interviews with 181 energy experts from 93 institutions in 13 countries. A total of 30 different policies were recommended by the interviewed experts, but four policies were repeatedly recommended: eliminating all subsidies for fossil fuels and nuclear energy, pricing electricity more accurately,[1] introduction of fixed feed-in tariffs for renewable energy, and implementation of a system benefits charge to fund public education with regard to efficient use of electricity and to fund concrete measures to use electricity more efficiently. According to Sovacool (2009), fossil fuel and nuclear subsidies in the US amount to about $28 billion/yr. The lack of a carbon tax at present is an additional subsidy to fossil fuels in that future monetizable costs are not included in the current cost of energy. As stressed by Sovacool (2009), pursuing any one of the top four policy recommendations alone will not be particularly effective. For example, removing subsidies without reforming prices still clouds the price signals seen by consumers and will make it difficult for renewable power to compete. Implementing a national feed-in tariff without promoting energy efficiency will cause over-investment in energy supply (and will make it more difficult or impossible to close the gap between demand and C-free energy supply).

The development of bioenergy systems involves complex relationships among a number of different actors. The primary barriers to more widespread use of modern bioenergy systems are primarily non-technical rather than technical. For example, the limited flexibility once energy crops are established makes farmers or landowners reluctant to pursue energy crops, production of bioenergy crops requires a change in business practice and farmers are averse to bearing all of the risk themselves. Strategies for overcoming these and other barriers are discussed by McCormick and Kåberger (2007), Mårtensson and Westerberg (2007), Gan and Yu (2008) and Carlos and Khang (2009). The Biomass Task Force (WGA, 2006) presents specific recommendations for the promotion of biomass energy in the western US. These include providing tax parity among all renewable energy sources, establishing long-term contracts pertaining to the use of biomass from government-owned land, and charging a delivery cost for biomass electricity based on the actual distance transmitted (which is invariably shorter than average) rather than based on the average distance for new power sources (as is currently done). However, as emphasized in earlier chapters, competition between land for food and land for bioenergy crops is likely to be a significant barrier unless future per capita meat consumption is low. Bioenergy should therefore be developed only in step with the freeing of current cropland and pastureland, which will be a relatively slow process. Bioenergy crash programmes must be avoided.

13.2 Research and development

Although great strides have been made in the development of C-free technologies for electricity generation, research and development (R&D) are needed in many areas in order to improve performance and bring down costs. Critical areas include:

- crystalline and thin-film PV modules;
- concentrating solar thermal electricity production;
- advanced adiabatic compressed air underground storage for use with wind and solar energy;
- further improvement in the performance of wind turbines and optimization of the design of offshore wind farms;
- high-voltage DC transmission;
- advanced gasification and cogeneration using biomass fuels;
- biofuels for transportation applications;
- enhanced (hot dry rock) geothermal systems;
- wave, tidal, tidal current and OTEC systems.

It is clear from our discussion of PV power (Chapter 2, section 2.2), concentrating solar thermal power (Chapter 2, section 2.3), wind energy (Chapter 3, sections 3.11 and 3.13) and efficient cogeneration of electricity and heat from biomass (Chapter 4, section 4.4), that these four renewable energy sources are close to the point where they can begin to take over from fossil fuels in the generation of the world's electricity. Wind energy systems are well developed technically and are already highly competitive; concentrating solar thermal electricity is the least expensive of the solar electricity options and, with thermal energy storage, provides electricity 24 hours per day; and PV power, while currently still expensive, is likely to see a factor of two or more reduction in cost during the next decade and to become competitive with peaking fossil fuel-derived electricity. PV electricity is most attractive when PV panels are integrated into the façade or roof of new buildings, as it is then subject to embodied-energy and cost credits from the displacement of conventional building materials, and can provide significant societal-scale benefits through reduced transmission and distribution costs, losses and bottlenecks. By linking dispersed wind farms, concentrating solar thermal arrays and other renewable energy options, and combining these with various storage techniques and dispatchable end-use loads, renewable energy can completely displace fossil fuels for the generation of electricity.

Given the important role that wind energy will play in a C-free electricity system, IEA (2009) recommends substantially increasing the level of R&D funding for wind energy. During the past three decades, OECD funding for wind power has fluctuated between only 1 per cent and 2 per cent of all energy R&D funding. IEA (2009) sees the potential for significant improvements in the capacity factor of wind turbines (by up to 35% of current capacity factors); the development of stronger and lighter materials that would enable larger rotors, lighter nacelles and use of less steel in towers; the development of superconductor technology for lighter and more efficient generators; and significant improvements in all areas related to offshore wind farms. Private wind turbine companies have tended to focus on short-term R&D efforts, where returns on investment are more likely, but according to IEA (2009), long-term fundamental research supported by the public sector is required. The same is surely true of other renewable energy technologies as well.

Given that renewable energy can completely displace fossil fuels for the generation of electricity, the development of 'clean' coal technologies and carbon capture and storage for coal is not recommended. Instead, the overarching policy goal should be to phase out the use of coal altogether as rapidly as possible. As discussed in Volume 1 (Chapter 2, subsection 2.5.2), the mineable coal resource is likely to be much smaller than widely believed, and coal mining itself entails significant negative environmental impacts. CCS technologies are, however, potentially useful in niche applications (such as at cement and fertilizer plants) and for application to biomass CO_2 (so as to create negative emissions). As nuclear energy is not a viable long-term C-free energy source, and it cannot be ramped up fast enough to address the need for early and large reductions in CO_2 emissions, research and development related to nuclear energy should be terminated, with the possible exception of research related to the use of nuclear powerplants to consume discarded plutonium and highly enriched uranium from nuclear weapons as the world moves (hopefully) toward much lower levels of nuclear armaments (if not eventually to complete nuclear disarmament).

In a world of limited funds and limited human scientific resources, choices need to be made while still supporting a diverse portfolio of technologies. Advocates of both nuclear energy and CCS argue that there are no supply-side alternatives to these technologies for reducing CO_2 emissions. The analysis presented in this book shows that this is decidedly not the case.

The technology dynamics literature identifies the possibility of two different future technology paths: the first, a carbon-intensive path, in which gaseous and liquid fuels are made from coal and replace conventional gaseous and liquid fuels as they are depleted (this assumes that the available coal resource is large, an assumption that is questioned in Volume 1, Chapter 2, subsection 2.5.2); and the second, a low-carbon path, in which biomass, solar, wind and other renewable energy sources gradually replace fossil fuels as conventional fuels are depleted. Because initial developments along either path will lead to cost reductions through learning-by-doing, it will be very difficult to switch from one path to another once we have started down one path. This phenomenon is referred to as 'carbon lock-in' and already characterizes the present energy system (Unruh, 2000, 2002).

Thus, if we do not want a carbon-intensive future, or if we do not want to begin travelling a path that will have to be aborted, at great cost, then governments should *not* support research and development of various processes for making gaseous and liquid fuels from coal. If the mineable coal resource is as small as suggested in Volume 1, this path will have to be aborted in any case, so the investment will largely be wasted, additional CO_2 will have been emitted (even if CCS of large point sources can be widely deployed), and the development of a sustainable energy system unnecessarily delayed.

13.3 Preserving forests and enhancing carbon sinks

Deforestation and loss of soil carbon contributed an emission of 1.6±1.1GtC/yr during the 1990s (more recent estimates are not available), compared to a fossil fuel emission of 7.2±0.3GtC/yr during 2000–2005 (Denman et al, 2007). During the 2000–2005 period, the atmospheric CO_2 increase averaged 4.1±0.1GtC/yr. As discussed in Chapter 4 (subsection 4.8.1), it is thought that 0.5–1.5GtC/yr could realistically be absorbed from the atmosphere through reforestation of degraded land or of land in need of erosion protection and flood control, through improved land management and through buildup of soil carbon. The difference between an emission source of about 2GtC/yr and a sink of up to 1.5GtC/yr is almost equal to the current rate of accumulation of CO_2 in the atmosphere. *Thus, with current rates of fossil fuel CO_2 emission, a rapid transition from net deforestation to the estimated maximum achievable rate of biomass accumulation could dramatically slow the increase in atmospheric CO_2 concentration.* Of course, once atmospheric concentration is stabilized the natural sinks (absorption of CO_2 by the oceans and terrestrial biosphere) would themselves weaken, but near-stabilization of atmospheric CO_2 concentration would provide the time for absolute reductions in fossil fuel CO_2 emissions.

As discussed in Nabuurs et al (2007), measures to reduce deforestation and the associated CO_2 emissions can be designed to be compatible with promoting sustainable development. These measures include improving institutional capacity, providing investment capital for investments in sustainable ecotourism and sustainable extractive activities, and implementing appropriate government policies and incentives along with international cooperation. Creating an additional carbon sink of 0.5–1.5GtC/yr requires funds to support reforestation in areas subject to erosion or in need of flood control and to support improvements in land management, as discussed in Chapter 4 (subsection 4.8.1). Kindermann et al (2008) estimate that reducing the global deforestation rate by 50 per cent by 2030 would require funding of $17 billion to $28 billion per year.

13.4 Geo-engineering?

As noted in Chapter 12, it is likely, even with stringent efforts to reduce CO_2 emissions, that the CO_2 concentration will shoot beyond safe and acceptable levels. Even with large negative emissions (1–2GtC/yr), it would take two centuries or more before the CO_2 concentration is brought back down to levels that are likely to be tolerable. In the meantime, the irreversible collapse of the Greenland and/or West Antarctic ice sheets might be triggered or significant release of methane from thawing permafrost soils might begin. In that case, some sort of temporary geo-engineering option – the deliberate manipulation of the earth's radiative balance to offset the effect of higher GHG gas concentrations – might buy us the needed time.

Among the options that have been considered are:

- to place sunshades into earth's orbit in order to block an amount of sunlight sufficient to offset the heating effect of the GHG buildup (which, however, changes over time);
- to spray mist into the atmosphere above the oceans so as to induce the formation of more reflective clouds; and
- to disperse sulphur into the northern polar stratosphere, mimicking the effect of occasional volcanic eruptions, thereby arresting the retreat of Arctic sea ice, the melting of the Greenland ice sheet and the thawing of permafrost.

There are significant uncertainties concerning the effectiveness and side-effects of these and other geo-engineering options, as reviewed by Vaughan and Lenton (forthcoming). Geo-engineering is defensible (if at all) *only* in the context of global efforts to rapidly reduce emissions. There are three primary reasons for this:

1. In the absence of emission reductions leading to at least stabilization of concentrations, the required geo-engineering increases indefinitely, which means that (a) unwanted side-effects increase, and (b) there is a risk of a catastrophically fast warming if the measures should ever stop (for those measures that require continuous application).
2. Geo-engineering does not deal with the problem of ocean acidification.
3. Geo-engineering reduces the incentive to deal directly with the source of the problem (an energy system that requires large use of fossil fuels).

The effort required for some geo-engineering options underlines the importance of addressing the root cause of the problem. For example, as reviewed by Vaughan and Lenton (forthcoming), a sunshade of 4.7million km^2 *in earth's orbit* would be required to offset a mere CO_2 doubling. However, an area of only 84,300km^2 *on the world's land surface* (in desert regions) would need to be covered with 10 per cent efficient PV panels in order to generate an amount of electricity equal to the total world electricity production of about 18,500TWh in 2005. Other options (such as injecting sulphur aerosols into the stratosphere) would require substantially less effort but, like all geo-engineering options, have uncertain side-effects.

In summary, research into some geo-engineering options is certainly justified, but it is too early to say whether or not geo-engineering would be a good idea. Geo-engineering is justifiable, if at all, only as a measure to temporarily mask the slowly decaying CO_2 heating effect as emissions are reduced, and most of its supporters see it only in these terms. It can in no way be justified as a substitute for stringent emissions reduction.

13.5 Concluding thoughts

The approach taken here has been to assume aggressive improvements in energy use over the coming century, to postulate a sufficiently rapid deployment of C-free energy sources that CO_2 emissions are eliminated before the end of this century (fast case) or early in the next century (slow case), and then to estimate the required material and energy flows and the required rates of construction of new PV or wind turbine factories and rates of establishment of new bioenergy plantations. The conclusion is that the required rates of deployment of C-free energy are achievable for the scenario of low growth in world GDP. The required area of new bioenergy plantations under the biomass-intensive scenario would be available for a diet with moderate rather than high (North American) average meat consumption. The high GDP scenario requires about twice the C-free energy as in the low GDP scenario, and almost 2.5 times the land area under the biomass-intensive variant. The hydrogen-intensive scenario requires much less land than the biomass-intensive scenario, and assumes the use of fuel cells in automobiles and trucks. However, material constraints are likely to severely constrain the size of a fuel cell automobile fleet. A truly sustainable future will almost certainly entail very low levels of car ownership in the global average.

Can we afford it? A more relevant question is, do we have sufficient human and physical resources to bring about the required deployment of C-free energy while retrofitting 2.5 per cent of the existing building stock per year to achieve deep savings in energy use? At present, levels of unemployment and under-employment in much of the OECD are hovering around 20 per cent, perhaps more. Similarly, 20–30 per cent of current industrial capacity is idle. We need simply redirect currently unused or underutilized human and industrial capacity to the activities needed to bring about massive reductions in energy requirements and rapid deployment of C-free energy supplies. The limiting factor could very well be the speed with which we can train a workforce skilled in these tasks.

Governments need to set the agenda, at least by setting the overall framework and rules. Careful planning of the logistical requirements associated with the transformation envisaged here is required, especially since the transition must occur quickly (three decades to largely eliminate fossil fuels from the electricity supply in most regions). The situation is analogous to the mobilization that was required of the Allied Forces at the beginning of World War II, and several useful lessons can probably be derived from the study of this mobilization (see, for example, Gilbert and Perl, 2007, concerning the transformation of the US automobile industry to the production of materials needed for the war effort). The big difference between the situation now and at the beginning of World War II is that, in the latter case, there was a clear external and immediate threat. The threat from global warming is not as immediate, nor is it as clear to the general public. To remedy this, climate scientists need to do a better job in communicating their concerns to the public and in countering the well-orchestrated campaign (in the US in particular) to discredit science in general and global warming science in particular (see Mooney, 2005, Monbiot, 2006, Michaels, 2008, Hoggan and Littlemore, 2009, and Schneider, 2010).

The analysis presented here indicates that not only is there a large renewable energy potential, sufficient to power a much more prosperous world than today's, but the transition to renewable energy can be made very rapidly if there is sufficient political will backed up with public support. The obstacles are not technical or financial in nature. The difficult task will be repairing (to the extent that this is possible) the damage done to nature and to the oceans. Elsewhere (Harvey, 2008), I have demonstrated the near-futility of trying to reverse the acidification of the oceans by adding crushed limestone in ocean regions where water that is unsaturated with respect to calcium carbonate is close to the surface. Ultimately, we will need to repair the soil in order to repair the oceans: building up soil carbon is the most effective single mechanism for reducing ocean acidification because it leads to a direct withdrawal of CO_2 from the oceans, whereas the neutralization of ocean acidification caused by inducing the dissolution of limestone in ocean water is partly counteracted by an induced flow of atmospheric CO_2 back into the ocean.

Although we are at or near the peak in the supply of oil, and the availability of natural gas is likely to peak within the next 20–30 years and that of coal by mid-century, this does not come close to implying a future Malthusian disaster of hunger, unemployment, deprivation and the collapse of civilization. Renewable energy, and solar energy in particular, is capable of providing all of the services that are presently provided by fossil fuels. However, it will be possible to meet our needs for energy only if we are highly efficient in the use of energy, particularly with regard to transportation uses – the sector where it will be most difficult to replace fossil fuels. The technologies needed to dramatically reduce our energy use already exist, and most of the technologies needed on the supply side have reached the point where rapid deployment to the needed levels can begin.

However, rapid improvements in energy efficiency and in the deployment of C-free energy supply will not be enough to provide a high probability of avoiding a climate catastrophe. Restraints in economic growth will almost certainly be needed, as only the scenario that combines slow economic growth, rapid improvement in energy efficiency and rapid deployment of C-free energy has a better than 50 per cent chance of averting positive climate–carbon cycle feedbacks that would largely take the global warming issue out of human control, with globally catastrophic consequences. However, the present world leadership is determined that measures to reduce greenhouse gas emissions should not in any way slow down economic growth. As discussed in Volume 1 (Chapter 11, section 11.8), economic growth is at present the policy objective against which all other proposals are judged. What is needed is to move climatic change and reduction of GHG emissions to the place now held by economic growth. All other policies must now be evaluated, at least in part, in terms of how they contribute to the overarching goal of reducing GHG emissions. A price needs to be set on carbon that is initially high enough, and increases at a sufficiently rapid rate, that climate-related targets – such as limiting atmospheric CO_2 concentration to no more than 450ppmv and then drawing down the concentration to 350ppmv or less – are met. How high this price needs to be depends in part on how effective governments are in facilitating the transition to much greater levels of energy efficiency (as discussed in Volume 1) and in facilitating the transition to C-free energy sources (as discussed in this volume). The economy will then adapt, with the economic impact of a high carbon tax strongly dependent on how the revenues are recycled. With economic growth no longer emphasized in government policy, and with both consumers and governments living within their financial means (and moving in the direction of living within the planet's ecological and biophysical means), economic growth will slow. The fundamental problem, as discussed by Jackson (2009, p77), is that there is very little understanding of how to manage an economy that is not growing, or that grows only slowly. Thus, a whole new body of economic analysis and theory is urgently needed.

In summary, then, we need three large transformations: a transformation to vastly greater levels of energy efficiency than at present in all end-use sectors, a rapid deployment of C-free energy sources (primarily wind and solar energy), and a whole new way of thinking that places stabilization of greenhouse gas concentrations at levels below the equivalent of a CO_2 doubling ahead of promotion of economic growth. In the rich countries, that means courageous political leadership to inform the public that we do indeed have to give up something in return for limiting global warming to a level that will still leave much that is beautiful in the world and that provides the basis for a good life for our children and grandchildren. This means reducing our consumption, use and ultimate disposal of material goods; redirecting much of our productive capacity toward public investments in high-quality public transportation and in retrofitting residential and commercial buildings to dramatically reduce their energy consumption; and paying more for energy as we shift to C-free energy sources. In developing countries, economic growth is still needed and is justified, but such growth may indeed have to be slower than in the recent past, so that it is truly sustainable and with far fewer immediate adverse impacts through pollution of air and water. If we do not do this, then we will provoke globally catastrophic consequences (such as several metres sea level rise) that will eventually negate the fruits of the economic growth that we so assiduously promote, and there is a high risk that global warming will slip beyond human control as a result of positive climate–carbon cycle feedbacks that lead to additional GHG emissions that exceed any conceivable counter-acting negative emissions that humans could create after belatedly eliminating fossil fuel emissions.

Note

1 More accurate pricing would involve either elimination of price caps and declining block structures (whereby unit costs decrease with increasing consumption), or introduction of time-of-use rates.