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Energy and the New Reality 1

Energy Efficiency and the Demand for Energy Services

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Chapter Highlights

Chapter 1 Prospective climatic change, impacts and constraints

Four independent lines of evidence (simulations with three-dimensional coupled atmosphere–ocean models, observations of temperature changes during the past century, inferences concerning temperature changes and driving factors during the geological past, and inferences concerning natural variations in atmospheric CO_2 concentration during the geological past) indicate that the long-term, global average temperature response to a sustained doubling of the atmospheric CO_2 concentration is very likely to be a warming of 1.5 Celsius degrees (°C) to 4.5°C. Under typical BAU emission scenarios, the concentration of greenhouse gases (GHGs) will rise to the equivalent of three to four times the pre-industrial CO_2 concentration by the end of this century and the climate will have warmed by 3–9°C on average. Likely impacts include an eventual sea level rise of at least 10 metres, reductions in food production in key food-producing regions, reductions in the availability of water in regions already subject to water stress, eventual extinction of the majority (up to 90 per cent) of species of life on this planet, and acidification of the oceans (with potentially catastrophic consequences for marine life). To stabilize the atmospheric CO_2 concentration at 450ppmv (which is the rough equivalent of a CO_2 doubling when the heating effect of other GHGs is taken into account) requires the near elimination of human emissions before the end of this century. Even at 450ppmv, significant ecosystems losses and negative impacts on humans cannot be avoided.

Future CO_2 emissions depend on the future human population, average gross domestic product (GDP) per person, the average energy intensity of the global economy (primary energy required per dollar of GDP) and the average carbon intensity of the global economy (kg of C emitted per gigajoule of primary energy use). The carbon intensity in turn depends on how rapidly C-free energy sources grow compared to the growth in total energy consumption. For middle population and GDP/person scenarios, stabilization of atmospheric CO_2 at a concentration of 450ppmv requires either that the rate of decrease in the global mean energy intensity increase from 1.1 per cent/year (the average over the period 1965–2005) to 3 per cent/year until 2050 with no increase in C-free power, or that annual average C-free power supply increase from 3.3TW in 2005 to 21TW in 2050 (almost 1.5 times total world primary power supply in 2005) with no increase in the rate of reduction in energy intensity, or some less stringent combination of the two.

Chapter 2 Energy basics, usage patterns and trends, and related greenhouse gas and pollutant emissions

A peaking in the global supply of oil by 2020 or sooner is a near certainty. Rates of discovery of new oil have been steadily declining over the last few decades, while the rate of decline in the supply of oil from individual utilized oilfields has occurred at progressively faster rates for oilfields peaking progressively later in time. Data for gas supply are much more uncertain than for oil, but it is likely that gas supply will peak soon after oil supply peaks. Until recently, supplies of coal were thought to be sufficient to last several hundred years. However, recent re-evaluations indicate that the supply of mineable coal is much less than previously thought, and it is possible that the global availability of coal could peak as early as 2050.

Chapter 3 Generation of electricity from fossil fuels

Technologies exist to dramatically improve the efficiency with which electricity is generated from fossil fuels. The global average efficiency in generating electricity from coal powerplants is about 34 per cent, that of new state-of-the-art plants is about 45 per cent, and both advanced pulverized coal powerplants and integrated gasification combined cycle (IGCC) powerplants are expected to achieve efficiencies of 48–52 per cent. State-of-the-art natural gas combined cycle powerplants have an efficiency of 60 per cent. With cogeneration (the co-production of electricity and useful heat), the effective efficiency of electricity generation can exceed 100 per cent. The key to high effective electrical efficiency in cogeneration is to make use of almost all of the waste heat that is produced.

Chapter 4 Energy use in buildings

Technologies already exist to reduce the energy use in new buildings by a factor of two to four compared to conventional practice for new buildings. This is true for buildings of all types and in all climate zones of the world. The keys to achieving such large reductions in energy use are: (1) to focus on a high-performance thermal envelope, (2) to maximize the use of passive solar energy for heating, ventilation and daylighting, (3) to install energy-efficient equipment and especially energy-efficient systems, (4) to ensure that all equipment and systems are properly commissioned and that building operators and occupants understand how they are to be used, and (5) to engender enlightened occupant behaviour. In order to design buildings with factors of two to four lower energy use, an integrated design process is required, in which the architects and various engineering specialists and contractors work together simultaneously in an iterative fashion before key design decisions are finalized. Attention to building form, orientation, thermal mass and glazing fraction is also critical. With regard to renovations of existing buildings, factors of two to four reductions for overall energy use, and up to a factor of ten reduction in heating energy use, have frequently been achieved. In many parts of the world, the cost of reductions in energy use of this magnitude is already justified at today's energy prices.

Chapter 5 Transportation energy use

Urban form (in particular, residential and employment density, and the intermixing of different land uses) and the kind of transportation infrastructure provided are the most important factors affecting future urban transportation energy use. Today there is almost a factor of 10 difference in per capita transportation energy use between major cities with the lowest and largest transportation energy use per capita.

Existing or foreseeable technologies could reduce the fuel requirements of gasoline automobiles and light trucks (sport utility vehicles (SUVs), vans, pickup trucks) by 50–60 per cent with no reduction in vehicle size or acceleration. With a modest reduction in vehicle size and acceleration (to that of the 1980s), a factor of three reduction in fuel consumption could be achieved. Due to the inherent high efficiency of electric drivetrains compared to gasoline or diesel drivetrains, plug-in hybrid electric vehicles (PHEVs) would reduce the onsite energy requirements per kilometre driven by about a factor of three to four when compared to otherwise comparable gasoline vehicles. The economic viability of PHEVs depends on significant reductions in the cost of batteries and verification that they will maintain adequate long-term performance, but the prospects look good. Use of hydrogen in fuel cells could reduce onsite energy requirements by up to a factor of two compared to advanced gasoline–electric hybrid vehicles (depending on the performance of the latter) and by a factor of four compared to current gasoline vehicles, but significant problems remain concerning the cost of fuel cells and onboard storage of hydrogen. The global supply of platinum (Pt) would probably be a significant constraint on the development of a global fleet of hydrogen fuel cell automobiles.

The foreseeable feasible reductions in the energy intensity (energy use per passenger kilometre or tonne kilometre) of other modes of transportation are as follows: transport of freight by trucks, 50 per cent; transport of freight by ship, 45 per cent; diesel freight trains with conversion to trains using hydrogen in fuel cells, 60 per cent; air travel, 25–30 per cent; urban buses, 25–50 per cent (through use of diesel–electric hybrids); interurban buses, 50 per cent.

Chapter 6 Industrial energy use

Compared to the current world average energy intensity, improved technology could reduce the primary energy requirements per unit of output by almost a factor of three for iron and steel, by almost a factor of two for aluminium and cement, by 25 per cent for zinc, and by 20 per cent for stainless steel. Technical improvements in the production of refined copper should roughly balance the tendency for increasing energy requirements as poorer grades of copper ore are exploited. However, much larger reductions in primary energy requirements for metals are possible through recycling combined with projected technical advances: a reduction in primary energy requirements by a factor of 7 for aluminium, a factor of 4.5 for regular steel, a factor of 2.5 for zinc, and a factor of 2 for copper and stainless steel (these savings pertain to uncontaminated materials and assume that the recycled fraction reaches 90 per cent for steel, aluminium and copper, and 80 per cent for zinc and stainless steel). Yet larger reductions in primary energy requirements would occur in combination with ongoing improvements in the efficiency with which electricity is generated. Increasing the recycled fraction of new glass from 25 per cent to 60 per cent reduces on-site energy requirements by about 10–15 per cent compared to production of glass from virgin materials. If the world population and material stock stabilizes by the end of this century, then the production of metals would be used almost exclusively for replacement of existing materials and so could be largely based on recycling, with attendant energy savings. The pulp and paper industry can become energy self-sufficient or a net energy exporter through the efficient utilization of all biomass residues. The potential energy savings in the plastics industry is unclear, but is probably at least 25 per cent through improved processes and at least 50 per cent through recycling of plastics. Potential energy reductions in the chemical industries appear to be very large but cannot be specifically identified at present. Better integration of process heat flows through pinch analysis and better organization of motor systems can save large amounts of energy in a wide variety of different industries.

Chapter 7 Agricultural and food system energy use

Energy in the food system is used for the production of food, for transportation, processing, packaging, refrigerated storage and cooking. Energy use for the production of food consists of direct on-farm energy use and the energy used to produce fertilizers, pesticides and machinery used in farm operations. Fertilizers and pesticides are energy-intensive products. Fertilizer energy use can be reduced through substitution of organic fertilizers for chemical fertilizers, more efficient use of chemical fertilizers (30–50 per cent savings potential in the case of nitrogen (N) fertilizer), and more efficient production of chemical fertilizers (40 per cent savings potential in the case of N fertilizer). Pesticides are particularly energy intensive, but many jurisdictions have targets of reducing pesticide use in agriculture by 50 per cent or so through integrated pest management techniques. Organic farming systems reduce energy use per unit of farm output by 15 per cent to 70 per cent, but can also reduce yields by up to 20 per cent. However, rebreeding of crop varieties to maximize growth under organic farming systems could result in no yield reduction compared to current varieties with conventional methods. The biggest potential for energy savings in the food system is with a shift toward diets with lower meat content. Low-meat diets (and especially vegetarian and vegan diets) reduce direct and indirect fossil fuel energy inputs, and free up land that can be used to produce bioenergy crops.

Chapter 8 Municipal services

Energy is used in the supply of municipal water through pumping and water treatment. Per household, this energy use is comparable to that of major individual household appliances. It can be reduced through measures to use water more efficiently (up to 50 per cent savings potential), through the reduction of leakage in water distribution systems (up to 30 per cent of input water is lost), and through optimization of distribution system pressures and flow rates (10–20 per cent savings potential). The biggest opportunity to reduce net energy requirements at sewage treatment plants is through the recovery and use of methane from anaerobic digestion of sludge. Installation of systems (toilet, plumbing, storage tanks) to separately collect minimally diluted urine in new housing developments would facilitate energy-efficient recycling of nutrients from human wastes, something that will eventually be necessary. With regard to solid wastes, recycling of metals, plastics, paper and paper products is preferred to other management options. Dedicated anaerobic digestion with recovery and use of methane is the preferred option for organic wastes. Incineration with energy recovery is not particularly efficient but is preferred to landfilling for wastes that cannot be recycled further.

The energy requirements of new recreation facilities such as indoor skating arenas, swimming pools and gymnasia can generally be reduced by at least 50 per cent compared to current typical practice for new facilities.

Chapter 9 Community-integrated energy systems

Community-integrated energy systems involve district heating and/or district cooling systems consisting of underground networks of pipes to distribute hot or cold water, respectively, from centralized sources. Waste heat from electricity production can be provided to district heating networks as part of cogeneration, or heat can be captured from low-temperature heat sources (such as sewage water) and upgraded to a higher temperature with heat pumps. Cogeneration at the community scale can displace more centrally generated electricity and yield greater overall energy savings than cogeneration at the building scale (25–45 per cent instead of 10–25 savings, depending on the efficiency of central electricity generation). Centralized production of chilled water with electric chillers can save 30 per cent compared to cooling with separate chillers in each building. Due to economies of scale and reduced backup requirements, the investment cost of district cooling systems can be no greater than having separate chillers in each building. Use of cogeneration greatly reduces the impact of higher natural gas prices on the cost of electricity. Trigeneration (the production of cold water using steam from power generation to drive an absorption chiller) does not save energy compared to operating a powerplant to maximize electricity production and using the extra electricity so produced in highly efficient electric chillers.

Chapter 10 Energy demand scenarios

Scenarios of energy use as fuels and as electricity to the year 2100 are constructed for ten different world regions, taking into account differences in per capita income, floor area and travel today, and are then summed to give a scenario of global demand for fuels and electricity. A low population scenario (global population peaking at 7.6 billion around 2035) combined with modest growth in GDP per capita is considered along with a high population scenario (global population reaching 10.3 billion by 2100) and high growth in GDP per capita. Slow (by 2050) and fast (by 2020) implementation of stricter standards for new and renovated buildings are considered along with the assumption that all existing buildings are either replaced or undergo a major renovation between 2005 and 2050 and that all buildings existing in 2050 undergo a major renovation between 2050 and 2095. Relatively slow and fast rates of improvement in automobile and industrial efficiencies to the potentials identified here are considered, but replacement of existing fossil fuel powerplants with the current state-of-the-art is not assumed to be completed before 2050.

For the low population and GDP scenario, global fuel demand peaks at 20 per cent and 35 per cent above the 2005 demand for fast and slow implementation of energy efficiency measures, respectively, before dropping to about half the 2005 demand by 2100, while global electricity demand rises to and stabilizes at about 70 per cent above the 2005 demand. For the high population and GDP scenario, global fuel demand peaks at 30 per cent and 60 per cent above the 2005 demand for fast and slow rates of efficiency improvement, respectively, then returns to about the 2005 level, while global electricity demand rises to 2.6 times the 2005 demand. When additional structural shifts in the economy (50 per cent of baseline value-added for industry and freight transport shifted to commercial services by 2100), the resulting annual average compounded rate of decrease in the primary energy intensity of the global economy is 2.7 per cent a year between 2005 and 2050 and 1.8 per cent a year between 2005 and 2100.

Chapter 11 Policies to reduce the demand for energy

This chapter outlines strategies for non-coercively promoting lower fertility rates, and gives examples of recent rapid reductions in fertility rates in several countries. Strategies for promoting slower economic growth while simultaneously improving human well-being are discussed. Foremost among these are the channelling of increasing labour productivity into shorter working weeks and greater investment in public transportation systems, affordable housing and other public services. Policies for promoting much greater energy efficiency in all sectors of the economy and for promoting diets low in meat and with less embodied energy are outlined. Important areas where additional research and development are needed are identified. Strategies for reducing or reversing the rebound effect (the tendency for the energy cost savings due to more efficient use of energy in specific applications to result in greater energy use in other areas) are also outlined. Some final reflections on the present overarching policy goal of promoting economic growth and of the urgent need to figure out how to build stable economies that don't depend on continuous growth are offered.