would be ~ 2 arc sec across, which is ruled out by the data. However, it may be possible to concoct a source structure that, when imaged, resembles the radio map in both angular structure and intensity distribution. Consider a compact object nearly on the midpoint of the line joining A and B, and an extended object located ~ 1 arc sec southeast of C-D. The compact object would be imaged as A and B. One image of the extended object would be C-D, and the other would be located ~ 2 arc sec northeast of B and contain ~ 3 percent of the flux of C-D. This second image would be at the limit of the present map and could not be ruled out. A full-synthesis VLA map should be able to determine the viability of this model.

It is clear that the existence of the extended radio structure in 0957+561 severely strains the gravitational image hypothesis. Consider instead the possibility that A and B are separate quasars, quite possibly gravitationally bound, with A undergoing an active phase, sending out bursts or beams of relativistic particles. The difference in the radial velocities of the emission-line systems should be measured more carefully. A difference of 270 km/sec (the maximum allowed by the optical observations) implies somewhat high masses if the system is bound—at the emission redshift of 1.414, the projected separation is 52 kpc, and the masses would be of the order of 10^{12} $M_{\odot}$ each. Given the uncertainty in the radial velocity difference and our poor understanding of quasars, such masses do not rule out this interpretation. It is also suggestive that the line of sources C-D-A-E is slightly bent in the sense that would arise from the gravitational attraction of B.

When the A-C-D-E complex is compared to a known quasar-jet source such as 3C273, there are interesting parallels. The total 6-cm radio luminosity densities 3C273 (*7*) and 0957+561 are nearly equal for any reasonable q_0, even though the flux of the jet is a larger fraction of the total flux in the case of 0957+561. The total linear extent of 3C273 is about 110 kpc, compared to the A-C separation of 52 kpc.

In the above discussion, we have assumed that the brightness does not vary with time. Most quasars are time-variable, and it is not unreasonable to expect that 0957+561 also varies. If the gravitational lens hypothesis can be maintained, the time variation in the single object would be manifest in similar light curves of the double image, with a time lag corresponding to the difference in light travel times for the two images. If the light travel time to the refracting object is t_R and the ratio of the distances to the refracting mass and to the object is f, the time lag will be of order $(\alpha_A + \alpha_B)(\alpha_A - \alpha_B)t_R/(1-f)$. This characteristic time depends sensitively on the alignment of object, refracting mass, and observer, and on the distance to the refracting mass: it ranges from months if the bender is close to the observer to decades if it is at the absorption-line redshift. One could imagine that the difference in brightness of the two objects is actually greater, and that an unlucky coincidence in the time lag of a brightness variation accidentally makes the fluxes nearly equal at the moment. [Note that the optical flux ratio S_A/S_B appears to have been unchanged between the epoch of the Palomar sky survey (around 1950) and the present (*1*).] However, the range of intrinsic luminosity variations in quasars is limited, so the refracting mass is still constrained to be near the midpoint of the line joining A and B. More complicated geometry of the refracting mass is another possibility, but would seem to be artificial.

In summary, the 6-cm map of the double quasar 0957+561 derived from the VLA observations shows unresolved sources coincident with the optical images, and a complex of related extended emission. The suggestion that the double optical sources are actually a single quasar refracted into two images by the gravitational field of an intervening massive object is severely constrained, but not ruled out, by the complex of other related sources. The observations are consistent with the source being a true double object, with the north component actively ejecting relativistic plasma. The near identity of the radio and optical spectra of the compact objects is still remarkable. We suggest that the two objects had a common origin, are similar in their basic physical parameters, and are evolving in similar fashions. The average radio and optical properties of the compact objects are thus characteristic of this stage in their evolution. The outburst phenomenon, so common in quasars, is then seen as a sporadic phenomenon, with only one of the objects being active at the present time.

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Market Penetration Characteristics for Energy Production and Atmospheric Carbon Dioxide Growth

Abstract. *Estimates are given for the maximum rate at which fossil fuel consumption can be reduced by the introduction of noncarbon-based energy sources, according to the market penetration time concept. These estimates indicate an immediate need to implement a revised energy policy if major climatic changes induced by increased amounts of carbon dioxide are to be avoided in the next century. However, application of market penetration ideas to energy consumption is new and may not be valid for the prediction of future trends.*

The long-acknowledged potential for large climatic change arising from atmospheric release of increasing amounts of fossil fuel–generated CO_2 has only recently been recognized as posing an immediate environmental control problem. The reasoning behind the altered attitude is as follows. It is claimed that serious climatic consequences will result from the "greenhouse warming" associated with increasing atmospheric CO_2 concentration when the concentration doubles, some 50 or 60 years from now (*1*), although with large probable error. Even though the uncertainty in this doubling date is large, it was believed to be sufficiently distant for the problem to be one of academic concern only, but introduction of the market penetration time concept (*2*) radically altered this viewpoint. This idea is that a period of at least 50 years is required to replace one dominant form of energy production by another. The coincidence of the market penetration time (actually defined as the time taken by the new energy source to increase its share of total energy production from 1 to 50 percent) with the date projected for hazardous CO_2-induced climatic change introduces a critical aspect into the situation that was absent before, as was first pointed out by Marchetti (*2*) and Hafele and Sassin (*3*). Thus, if a demand is made that the projected buildup of large concentrations of atmospheric CO_2 be avoided by switching from the present-day predominant use of coal and oil as primary energy sources to a noncarbon-based fuel, a market penetration time of 50 years suggests that such a step be taken now, rather than in the more distant future, once we accept the best currently available estimates for atmospheric CO_2 growth.

Such a description of the problem in broad qualitative terms can be made more convincing by quantitative application of the market penetration idea, a step which, in spite of its simplicity, has not been taken thus far. I report here on the results of such an analysis and confirm quite vividly the validity of concern with the issue.

Let us assume that at an initial time, t_0 (which we measure relative to a 1975 base date), a new source of "clean" fuel that does not release CO_2 produces 1 percent of total world energy, just starting to replace the 99 percent of the primary energy source, which we assume to be fossil fuel. The market penetration time of the new energy source is defined as t_p, and only these two forms of energy production are taken to be competing for the energy market. The growth in time, t, in the output of the replacement energy source is governed by the market penetration logistic curve

$$\frac{f}{1-f} = \frac{1}{99} \exp \left(\ln 99 \frac{t - t_0}{t_p} \right) \quad (1)$$

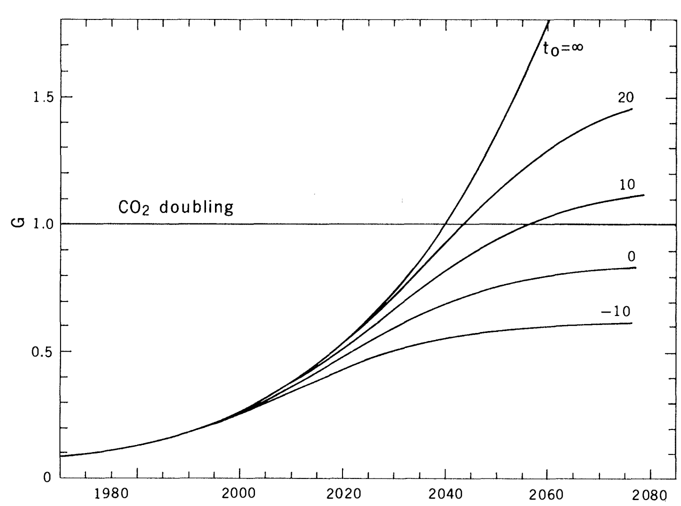
where f equals the fractional share for the new source. This simple formula for a two-component system can be extended to multienergy source systems, as described by Marchetti (*2*) and Peterka (*4*). Since my purpose here is not to accurately portray actual future energy growth but rather to illustrate the nature of the CO_2-fossil fuel problem, such a refinement is hardly appropriate.

In order to use Eq. 1 to compute the growth in the atmospheric CO_2 burden, we need estimates for projected global energy use and for the fraction of emitted CO_2 that is retained in the atmosphere. As I have demonstrated (*5*), for forecasts extending up to the middle of the next century, it appears quite adequate to assume a constant fractional atmospheric retention of CO_2. In the computations, I shall thus take a fixed value of 56 percent for the retained fraction, a figure based upon empirical data on CO_2 growth taken over the last 20 years (*6*). Such an approximation will certainly suffice for atmospheric CO_2 concentrations up to twice the preindustrial (1860) value, and I shall take doubling to indicate a serious environmental threat. The growth in the atmospheric CO_2 can then be calculated by integration of Eq. 1 coupled with a total energy growth curve.

Figure 1 shows some results from such integrations. The ordinate, G, is the fractional increase of atmospheric CO_2 above its preindustrial concentration, so that CO_2 concentration doubling corresponds to $G = 1$. I have used a market penetration time of 50 years and an exponential growth γ of world energy of 3 percent per year. The 3 percent figure appears to be the best estimate for calculating cumulative CO_2 release well into the 21st century (*5*), although major departures may well occur. In fact, recent U.S. Department of Energy projections (*7*) also give a world growth rate close to 3 percent per year up to the year 1990.

Figure 1 depicts the dilemma created by the large value of the market penetration time. If we choose to set as an objective maintenance of atmospheric CO_2 below the doubling level ($G = 1$), the results show that it may well be too late to introduce a new fuel (other than nuclear) that does not release CO_2, without exceeding the critical level. In fact, nuclear plant development to date happens to match quite well with the $t_0 = -10$ curve plotted in Fig. 1, although most long-term projections show a much slower penetration for the future, with more reliance being placed on coal utilization (*7*).

I have carried out a number of other energy growth scenario calculations for evaluating increasing CO_2 concentrations; both t_p and γ have been varied. The most important characteristic of these calculations is the sensitivity they show to the values assumed for these parameters, as well as to the initiation date, t_0. For example, increasing market penetration time to 75 years eliminates the possibility of keeping G below unity, un-



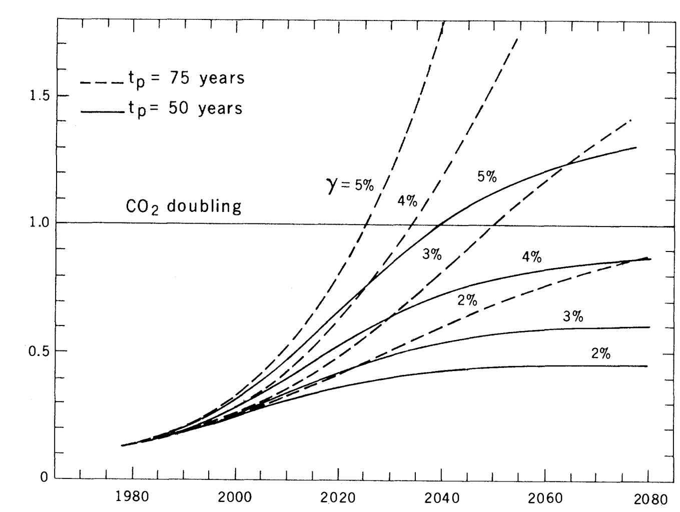


Fig. 1 (left). Fractional growth of the atmospheric CO_2 concentration (G) above the preindustrial value for various initiation dates (t_0) relative to 1975 of the noncarbon-based fuel, a world energy growth rate of 3 percent per year, and a market penetration time of 50 years (*10*). Fig. 2 (right). Fractional growth of the atmospheric CO_2 concentration for various annual world energy growth rates (γ) and two market penetration times (t_p). The 1 percent market share of the noncarbon-based fuel is taken to have occurred in 1965 ($t_0 = -10$ years).

less γ is dropped to under 2 percent per annum. At $\gamma = 2$ percent, there appears to be little difficulty in keeping CO_2 concentrations down. Figure 2 shows some examples of the effects of varying these parameters.

The best estimates of climatic change resulting from increasing concentrations of atmospheric CO_2 indicate the occurrence of critical conditions some 50 years ahead, coincident with market penetration times for new energy sources. The large uncertainties in magnitude of the climate change predictions make the situation potentially even more critical, and the market penetration time results presented here suggest the need for immediate action if the change is to be averted. However, before undertaking the pursuit of such a radical step, we would be well advised to question further the validity of the market penetration time concept as it might apply to energy source replacement.

Marchetti's derivation of market penetration times (*2*) was based entirely on empirical evidence on transitions between the predominant use of various primary energy sources, such as from wood to coal and from coal to oil. His empirical fits to logistic curves are indeed impressive, as are those derived earlier by Fisher and Pry (*8*) for technology transfer rates. Although recommending a penetration time of 50 to 100 years for projecting future energy scenarios, Marchetti had no causal explanation for his results, and it is difficult to accept its global applicability and the irreducible value of market penetration time. Peterka (*4*) has provided a theoretical basis for the logistic curve (Eq. 1), but his analysis suggests that penetration times might not be bound to the 50-year time frame. Thus, put briefly, Peterka's model assumes that the two energy production systems are in economic competition and that, after a short initial period of venture capital use, the growth of production is limited by the amount of capital that can be generated solely from their own profits. This feature serves to limit the rate of growth of even a much less costly energy production system. However, if in fact the two energy sources are cost-competitive but are owned by the same controlling group (be it a government or a large corporation), Peterka's assumption would appear to break down, since profits from the old production system can be transferred to provide capital for the new.

Since immediate policy questions are strongly affected by the coupling of the CO_2 effect with market penetration time concepts, the applicability of the large market penetration time figure to the CO_2 question must be carefully scrutinized. As yet and perhaps because the market penetration idea in application to global energy systems is relatively new (*9*), it has not attracted the attention of economic theorists to whom we might appeal in order to establish or refute its predictive veracity.

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9. Historical time trends for energy sources have been discussed much before Marchetti's quantitative analysis, as, for example, in P. C. Putnam, *Energy in the Future* (Van Nostrand, New York, 1953). I am indebted to a reviewer for pointing out this fact.
10. The 50-year figure is taken by Marchetti (*2*) to be a minimum value for market penetration time.
11. The results presented here are part of a continuing study being conducted for the Electric Power Research Institute, Palo Alto, Calif.; a partial description of this work, amplifying on the material alluded to here in (*5*), is to be published in an article entitled "Climate change from fossil fuel generated carbon dioxide and energy policy" in *Environment International*.

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Dehydration of Ethanol: New Approach Gives Positive Energy Balance

Abstract. *Water was removed from aqueous ethanol by using cellulosic materials, starch, corn, and other agents. The combustion energy of the ethanol product can exceed the energy needed to carry out the dehydration by a factor of 10.*

We have found a way to dehydrate ethanol in which the combustion energy of the ethanol product exceeds the energy needed to carry out the dehydration by a factor of 10. Drying of aqueous ethanol by materials such as cellulose, cornstarch, shelled corn, corn (cellulosic) residue, (mineral) oxide, hydroxide, or sulfate results in a product that is up to 99.8 percent water-free.

Alcohols are made from either grains or biomass by first converting these materials to fermentable sugars (*4*). The sugars are then fermented, typically with yeast, to give a broth containing 6 to 12 percent ethanol along with small amounts of aldehydes, ketones, amyl alcohols (fusel oils), and methanol (*5*). The final step, distillation to water-free alcohol, consumes 50 to 80 percent of the energy used in a typical fermentation ethanol manufacturing process (*1*, *2*). The energy intensity of traditional distillation techniques is frequently cited in criticizing the potential of biomass-derived ethanol as a liquid fuel (*1–3*).

Recovery of ethanol from the fermentation broth is at least a three-step process: (i) distillation of dilute aqueous alcohol to its azeotrope (95.57 percent ethanol by weight) (*5*), (ii) distillation using a third component—either an organic solvent (*7*) or a strong salt solution (*8*)—to break up the azeotrope and remove the remaining water, and (iii) distillation to separate water from the third component so that it can be recycled. Trace constituents, including pentanol (fusel oil) and methanol, can be removed by additional distillation, but this is not necessary for ethanol to be blended with gasoline (*2*).

Analysis of the ethanol-water distillation, using the McCabe-Thiele method for analysis of fractionation columns (*9*), indicated the energy-sensitive regimes. Energy consumption greatly increases with decreasing ethanol concentration in the feed below 4 percent alcohol, since a disproportionately larger quantity of feed must be vaporized to obtain the same amount of product. Current fermentation technology results in a product containing 5 to 12 percent ethanol (*11*), so this energy problem is avoided. Most of the energy consumption occurs in distilling above 85 percent ethanol, as shown by the equilibrium diagram in Fig. 1a. With increasing alcohol product concentration (92.2 percent by weight in Fig.