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Hydrogen: Its Future Role in the Nation's Energy Economy

Hydrogen fuel derived from water could extend nuclear power and reduce dependence on imported oil.

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In the near future, large scale economical sources of energy derived from nuclear fission or from other domestically available primary sources such as solar or geothermal energy will be needed. Because of its complex nature, and for reasons of safety, nuclear energy clearly cannot be utilized directly in small scale transportation systems such as the automobile. Thus the original promise that nuclear power will eventually supply all the nation's energy needs can only be effectively fulfilled by supplying the energy in the form of electricity or some storable, portable fuel.

Electricity is obviously a clean and convenient form of energy for the consumer and will always fulfill a unique and necessary role in the energy system; however, it is not the best and most practical, or even the most economical form of transportable energy for all domestic and industrial applications. The cost of transmission and distribution to the residential consumer is high—that is, in excess of 50 percent of the total cost at the point of end use. In places where environmental considerations require that cables be placed underground, the cost of transmission and distribution will be even higher. Economical storage of electricity by such means as pumped storage is not possible in most plant locations. Therefore, the output of a power plant must be continually adjusted so that it meets the varying demands of the consumers; this causes the average power plant load factor to be about 0.5. The convenience and flexibility of general-purpose fuels is reflected in the current fuel mix in the energy economy where approximately 80 percent of the energy resources consumed are for uses other than electric generation. Thus, the present industrial and domestic technology is geared to combustible chemical fuels. Therefore, the future supply of nuclear energy to all sectors of the energy economy depends on the development of portable and storable synthetic fuels which can be derived from nuclear energy and some abundantly available or recyclable resource.

Hydrogen has the necessary properties and can fulfill the role of a secondary source of energy that can be derived from the primary source by the decomposition of water (*1*). It can be substituted for petroleum and coal in almost all industrial processes which require a reducing agent, such as in steel manufacturing and other metallurgical operations. Further, hydrogen can easily be converted to a variety of fuel forms such as methanol, ammonia, and hydrazine. The use of hydrogen as a fuel would allow the industrial establishment to retain its present structure and would cause the least economic burden in the process of changeover from fossil to synthetic fuels, that is, in the transition from fossil fuel to nuclear energy which will come in the future.

Thus, for the future, a hydrogen fuel economy is of major interest as an alternative to a predominately electric economy; in either case the primary energy sources would be nuclear and possibly solar, supplemented by coal. In the immediate future, hydrogen can serve as a clean fuel for special purposes, such as urban transportation systems, and it offers significant benefit to the quality of the urban environment. A most important characteristic of hydrogen is its versatility in being able to serve both the electrical energy demands, by the use of either fuel cells or more conventional "total energy systems" (*2*), and other thermal energy demands. A significant amount of operating experience has been acquired with hydrogen fuel cells; such cells have already been used successfully in automotive systems (*3*). The feasibility of operating an internal combustion engine on hydrogen fuel has been demonstrated at Oklahoma State University and at other locations (*4*). The use of hydrogen in the two winning entries in the National Urban Vehicle Design Competition, August 1972 (*5*) was an impressive demonstration of the potential of hydrogen-fueled automobiles; however, the key problem in the application of hydrogen as an automotive fuel is storage. Storage as liquid hydrogen may be practical in some types of vehicles; however, a better alternative may be to store hydrogen as metal hydrides (*6*). These materials have hydrogen densities comparable to that of liquid hydrogen and release hydrogen when heated to their dissociation temperature. Hydrogen may also be used in several industrial processes including the reduction of metal ores (*7*). It is compatible with a variety of supply systems and may be produced electrolytically (*8, 9*) or by the gasification of coal or oil (*10*). The byproduct oxygen that is obtained from electrolytic production is a valuable commodity for industrial use, for sewage treatment, and for the oxidation of other urban waste (*11*).

A gaseous fuel such as hydrogen

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Table 1. Estimated total cost of equipment for five different energy systems including the LMFBR (liquid metal fast breeder reactor).

Energy system	Cost* (dollars per kilowatt of capacity)	Reference
LMFBR electric generating station	385	
Coal fired electric generating station	280	
Electrolytic hydrogen plant	56	(8)
Fuel cell electric generator	100	(20)
Reformer to convert methane to hydrogen	50	

* The cost in dollars per 10^6 Btu is given by dollars/10^6 Btu = (\$/kw) (0.1) $(3.413)^{-1}$ $(8.760)^{-1}$ $(\text{l.f.})^{-1}$ where l.f. is the load factor and (0.1) is the capital recovery factor for 30 years at 9.3 percent interest. There are 8760 hours per year and 3413 Btu per kilowatt hour.

can be transported and distributed to individual consumers by pipeline at a lower cost than electricity, and hydrogen has the added advantage in that it can be stored. Recent estimates suggest that the transmission cost for hydrogen would be in the range of \$0.02 to \$0.04 per 10^6 British thermal units per 100 miles (*12*), as compared to the cost of natural gas which is \$0.01 per 10^6 Btu per 100 miles (*13*). It is estimated that future underground electric transmission costs will be in excess of \$0.20 per 10^6 Btu of electrical energy per 100 miles. As the problem of finding sites for generating facilities that are centrally situated near urban load centers becomes more severe, transmission costs of electricity from more remote sites may dictate the energy form that is to be delivered. A nationwide pipeline grid transporting a clean fuel such as hydrogen may provide a more flexible and economical system than an eletctrical delivery system of similar scope. Such a hydrogen grid could act as a load leveling device for the projected nuclear systems. Thus, these generating stations could be base-loaded (that is, running at maximum capacity) and supply either electricity directly or hydrogen for storage in the pipeline system, or both.

In this article we present the results of a preliminary evaluation of the economics and environmental benefits of hydrogen energy delivery systems in the residential and transportation sectors. We examine the future cost of energy delivered to residential consumers by several different delivery systems, and we assume that the technology required, which is theoretically feasible, can be developed and implemented.

It is evident that the systems we describe could only be implemented with a vigorous engineering research and development program; however, since the nation is now entering a period when massive amounts of capital—some \$374 billion—will be spent over the next 15 years to upgrade and improve the quantity and quality of the energy delivery system (*14*) it is important at this time that alternatives such as the hydrogen fuel economy be thoroughly evaluated and discussed.

Table 2. Estimated long-distance transportation costs per 100 miles to a local substation, including capital, operating, and maintenance costs (*21*).

Transportation	Cost (dollars per 10^6 Btu)
Methane by pipeline	0.030
Hydrogen by pipeline	0.033
Electricity by high voltage transmission	0.21
Gasoline by tanker	0.10

Table 3. Distribution costs from the local substation to a residential household including capital, operating, and maintenance costs. These costs are based on a multiple of the U.S. national average distribution costs estimated from (*22*). The multiple factor of 3 that holds for gas is assumed to hold for electricity as well.

Distribution	Cost (dollars per 10^6 Btu)
Methane by pipeline	0.60
Hydrogen by pipeline	0.66
Electricity by overhead wire	2.55
Gasoline by truck	0.70

Table 4. Estimated total costs of fuels.

Fuel	Cost (dollars per 10^6 Btu)
Coal at the mine mouth	0.15
Nuclear fuel	0.05
Gasoline at the filling station	0.80

Table 5. Estimated costs of operation and maintenance of energy supply, not including the cost of fuel.

Energy supplies	Cost (dollars per 10^6 Btu)
Liquid metal fast breeder reactor	0.15
Coal fired electric system	0.15
Fuel cell electric generator	0.15
Electrolytic hydrogen plant	0.06

Reference Systems and Options

A preliminary evaluation has been made of the use of hydrogen fuel to satisfy the annual energy requirements of a typical household including the automotive fuel requirements. Comparisons are made with all-electric supply systems and systems that are based on coal gasification. Industrial and commercial demands were not considered in this preliminary evaluation because they involve complex interactions between supply, demand, and the substitutability of electricity and fuels in these sectors.

The residential and automotive energy demands specified for these comparisons are estimates of future national averages for a single household (*15*). A central air-conditioning system is assumed in specifying that energy demand, and it is assumed that gaseous fuels and electricity have the same efficiency for water heating and cooking. The efficiencies of utilizing energy for the other demands are indicated on the energy flow diagrams (Figs. 1 to 7).

When electrical heating is used, a heat pump with a coefficient of performance of 3 is specified and is sized for the air-conditioning load. The balance of the space heating is provided by electrical resistance heating. When hydrogen or methane gas is delivered to the consumer, it is burned directly for space heating and operates an absorption cycle system for air conditioning.

The estimated total costs for fuel, transportation, distribution, and maintenance and operations are summarized in Tables 1 to 5. It is assumed that the facilities have the same useful life and their capital costs are amortized over a 30-year period at a 9 percent interest rate and at load factors listed in the figures.

It is assumed that it will be more expensive to transmit and distribute hydrogen than natural gas because of the higher relative pumping energy required to deliver 10^6 Btu of hydrogen compared with natural gas and the higher degree of leak tightness that is required for hydrogen. The costs for transmission of hydrogen and local distribution are assumed to be \$0.042 per 10^6 Btu per 100 miles and \$0.66 per 10^6 Btu, respectively. The cost indicated for hydrogen produced by electrolysis does not include any credit for by-product oxygen since the exact market for this material is uncertain.

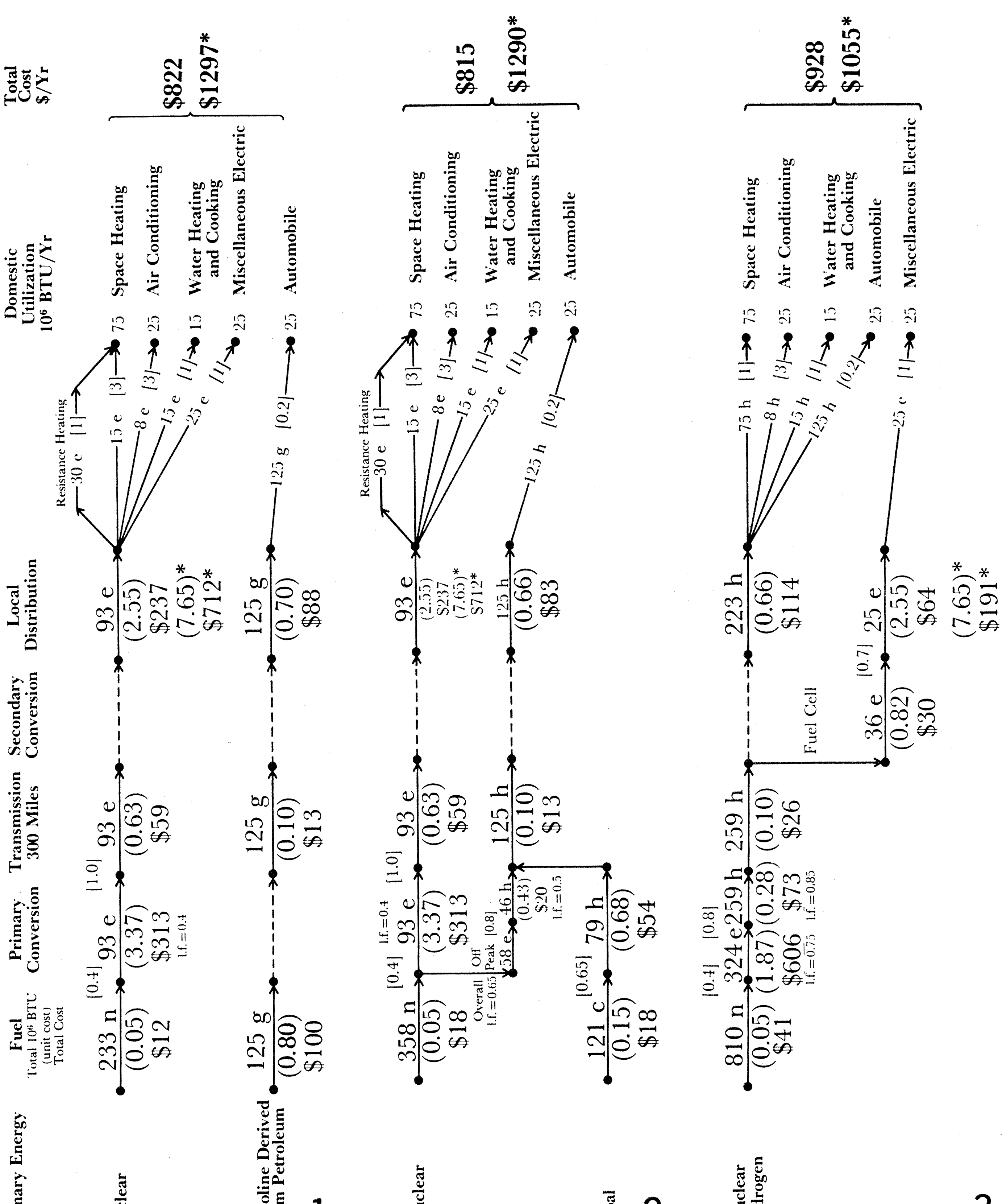

Fig. 1. Energy flow diagram of a reference system, system 1, in which the primary sources of energy are nuclear power and gasoline derived from petroleum. The number above each arrow is the total amount of energy used annually, expressed as 10^6 Btu, the cost per 10^6 Btu is shown in parentheses below each arrow. The total annual cost of each operation in the energy system is shown below the unit cost and is expressed as dollars per year. Numbers in square brackets are efficiency factors; costs marked with an asterisk are for underground distribution. Abbreviations: n, nuclear; e, electrical; g, gasoline; c, coal; m, methane; l.f., load factor. Fig. 2. System 2, in which hydrogen derived from nuclear energy and coal is used only for automotive propulsion. For further details see Fig. 1. Fig. 3. System 3, in which hydrogen derived from nuclear energy is used to supply all domestic energy needs except the electricity required for small appliances. For details see Fig. 1.

Energy Delivery Systems

We now compare the cost and environmental impact of hydrogen energy systems with some reference systems in which conventional energy sources and delivery systems are used. To simplify the problem we consider only the total annual energy needs of the average domestic residence. The energy needs of industrial and commercial sectors should be factored in a more detailed study of this type to determine the impact of those demands on total installed electrical capacity, load factors, and the availability of off-peak power. The study we describe serves primarily as an example of the application of hydrogen to a given sector, the analysis required, and the cost and benefits to be realized. The residential energy needs considered here are for space heating, air conditioning, water heating and cooking, electricity required for small electrical appliances, and the automobile. The total cost per unit of energy including amortization is made up of the following elements. (i) The cost of the primary energy source or fuel; (ii) primary conversion of the fuel to whatever form of energy is transported; (iii) the cost of long distance transportation of the energy form to the local area; (iv) the cost of secondary conversion in the local area to an alternative energy form, for example, the conversion of hydrogen to electricity in a fuel cell; and (v) the cost of local distribution to the domestic consumer.

The cost of the utilizing device or system in the household has not been included. We could not consider all possible combinations of energy sources and delivery systems, but selected seven basic systems in which a cost comparison could be made between hydrogen energy delivery systems and some alternatives. The seven systems are described below.

In making the cost comparisons we assume that in each example the entire system is newly installed. This implies that the comparison applies to either a new city or to a long-range evaluation where the existing system is completely replaced. The air pollutants, waste heat, and other waste products produced in each system are summarized in Table 6. Wastes and emissions produced in centralized operations are stated separately from those produced at or near the place of consumption.

System 1. This is a reference system in which we assume that the primary sources of energy are nuclear power and gasoline derived from petroleum (see Fig. 1). Nuclear electricity is assumed to supply all the domestic energy needs and gasoline is used for transportation. The average long distance transmission of the energy is taken to be 300 miles. Local distribution of electricity can be done either by conventional overhead transmission or by underground electrical cables and the costs for each are shown in Fig. 1. Conservative estimates (*16*) indicate that underground transmission will cost three times that of conventional overhead systems used presently for local distribution of electricity.

System 2. In this system the primary source of energy is nuclear power and coal (see Fig. 2). Nuclear power is used to generate electricity which is transported by conventional means to satisfy all the domestic energy needs except the automobile. Off-peak electrical power at the central station is used to produce hydrogen to supply 37 percent of the hydrogen required for automotive propulsion (*17*). The remaining hydrogen requirements are supplied by converting coal to hydrogen by means of conventional technology.

System 3. Nuclear energy is used to generate hydrogen by electrolysis of water (see Fig. 3) by means of an improved technology that has been shown to be feasible. All of the electricity is converted to hydrogen which is transported by pipeline to the local area. A major fraction, 86 percent, of the hydrogen is used to supply all the domestic energy needs including the automobile, but excluding electricity required for small appliances. The remaining fraction, 14 percent, of the hydrogen is used in a fuel cell operating at a load factor of 0.5 to generate the electricity required for small appliances. We have assumed that the fuel cell is located at a local electrical substation; however, the fuel cell could be located in the domestic residence with a lower load factor. Although this might increase its cost, the cost of distributing the electricity in the local region would be reduced. The cost of transporting gas by pipeline is significantly less expensive than transporting an equivalent amount of electrical energy by wire.

System 4. This is similar to system 3 except that the primary source of

Table 6. Summary of emissions and waste production; T, tritium; Kr, krypton; CO_2, carbon dioxide; CO, carbon monoxide; SO_2, sulfur dioxide; NO_x, oxides of nitrogen; Part., particulates; HC, hydrocarbons.

Concentrated waste production in centralized plants, per household, per year										Distributed waste production at fuel cell sites and points of end use, per household						
Wastes (curies)			CO_2 (10^3 lb)	Wastes (lb)					Heat (10^6 Btu)	CO_2 (10^3 lb)	Wastes (lb)					Heat (10^6 Btu)
T	^{85}Kr	Solids*		CO	SO_2	NO_x	Part.	HC			CO	SO_2	NO_x	Part.	HC	
System 1. Nuclear-electric energy and gasoline																
0.084	0.31	0.34							140	18.6	113	8.8	12.5	8.8	11.3	218
System 2. Hydrogen derived from nuclear energy and from coal																
0.13	0.48	0.53	27.1						261				12.5			218
System 3. Nuclear energy conversion to hydrogen																
0.29	1.08	1.19							551				17.5			259
System 4. Coal conversion to hydrogen																
			89.1						139				17.5			259
System 5. Coal conversion to methane																
			42.5						146	27.2	115		17.5	4.3	12.0	271
System 6. Nuclear-electric energy only																
0.12	0.45	0.49							203							135
System 7. Coal conversion to electricity and gasoline																
			52.2	4.7	280	163	47	1.9	140	18.6	113	8.8	12.5	8.8	11.3	218

* Solid high-level radioactive wastes.

energy is coal and the electricity is generated at the mine mouth (see Fig. 4). The cost of gasifying coal to hydrogen is assumed to be 10 percent less expensive than the production of methane (*18*).

System 5. This is similar to system 4 except that the coal is used to generate methane rather than hydrogen (*18*) (see Fig. 5). The fuel cell is located at the substation and requires a reformer to convert the methane to hy-

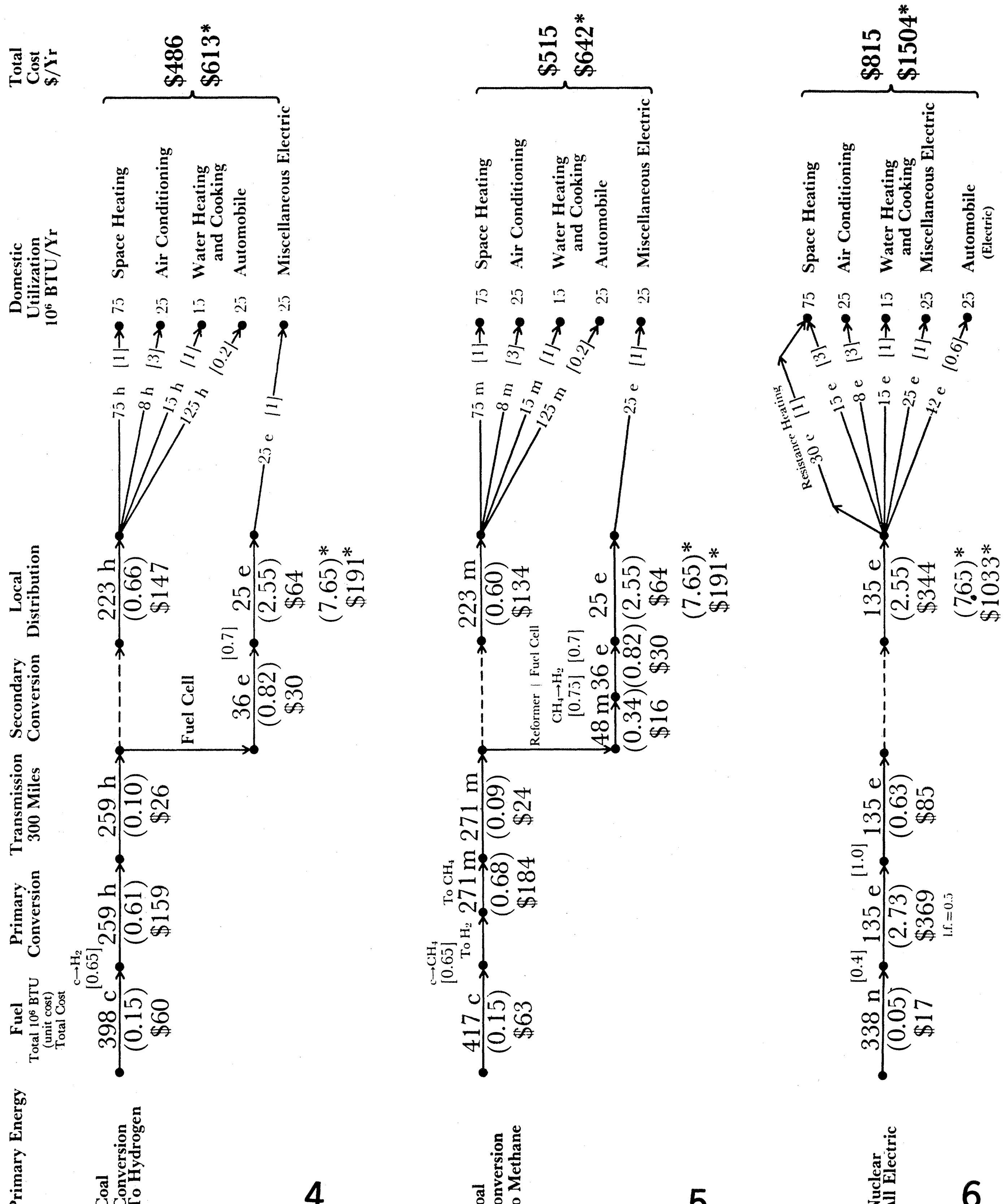

Fig. 4. System 4, in which hydrogen derived from coal supplies all domestic energy needs except the electricity required for small appliances. For further details see Fig. 1. Fig. 5. System 5, in which methane derived from coal supplies all domestic energy needs except the electricity required for small appliances. For further details see Fig. 1. Fig. 6. A reference system, system 6, in which electricity derived from nuclear energy supplies all domestic energy needs. For further details see Fig. 1.

drogen which in turn is converted to electricity in the fuel cell. As in systems 3 and 4 the reformer and fuel cell could be located in the residence.

System 6. This is another reference system. The primary energy source is nuclear which is used to produce electricity (see Fig. 6). The electricity is transported to the local region and is used to supply all the domestic energy needs. This includes the automobile which is assumed to be all-electric and to operate on storage batteries.

System 7. This is another reference system which is similar to system 1 in all respects except that the primary source of energy is coal.

Discussion

Data from the seven systems are summarized in Table 7 and are shown in the form of energy flow diagrams in Figs. 1 to 7. In each energy flow diagram, the number above each arrow is the total amount of energy used annually, expressed as 10^6 Btu per year. The unit cost of the energy in dollars per 10^6 Btu is shown in parentheses below each arrow. The total annual cost of that operation in the energy system is shown below the unit cost and is expressed as dollars per year. For example, in system 1, 233×10^6 Btu per year of nuclear fuel are required; this fuel costs $0.05 per 10^6 Btu and the total cost of the fuel used to supply energy to one household is $12 per year. The efficiency factor for converting the primary fuel to the ultimate energy form (hydrogen or electricity) is shown in square brackets. In the case of air conditioning or heat pumping, the efficiency factor becomes a utilization factor and is therefore greater than unity.

For local electrical distribution, two cost figures are given. The first two numbers below the arrow correspond to the unit cost and total cost per year of local electric transmission by means of overhead cables. The numbers below these that are marked with an asterisk correspond to the unit cost and the total cost per year of underground electrical distribution, the cost being increased by a factor of 3 in comparison with overhead distribution (*16*). The costs at the extreme right of each energy flow diagram show the total annual costs of energy supplied to the domestic user; the costs marked with an asterisk indicate the use of underground cables for local electrical distribution.

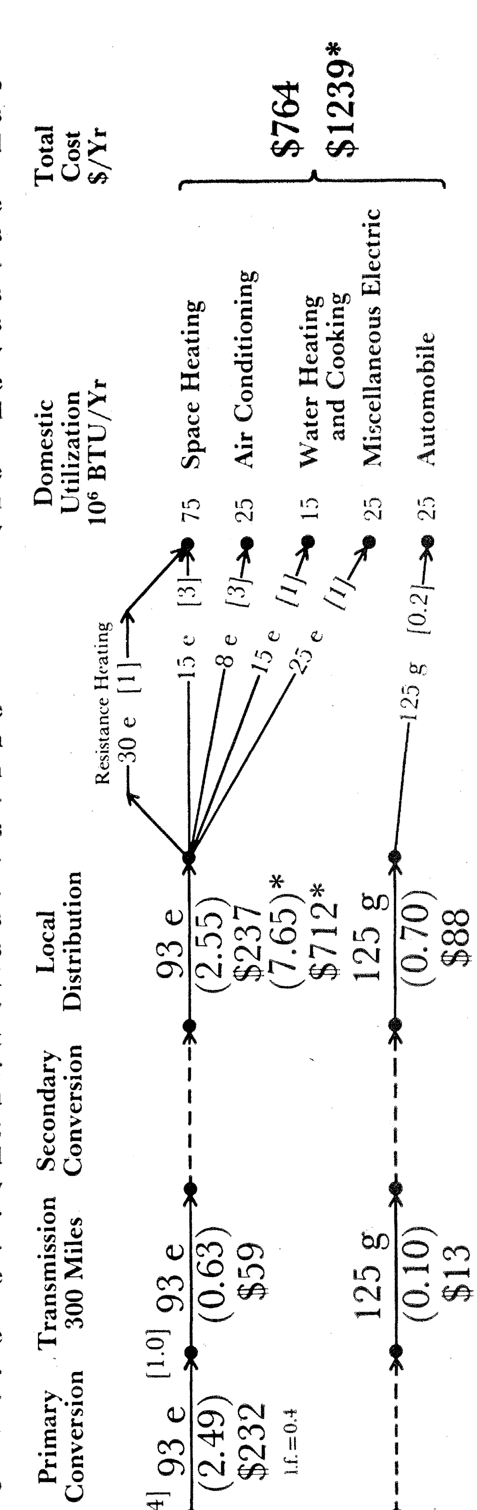

Fig. 7. A reference system, system 7, that resembles system 1 except that the primary sources of energy are coal and gasoline derived from petroleum. For further details see Fig. 1.

The data for these seven systems show that the delivery of hydrogen energy is economically competitive with the delivery of conventional energy sources (for example, compare systems 2 and 3 with the reference systems 1 and 7). This is primarily because of the lower cost of transmission and distribution of a gaseous fuel compared with electricity, and the fact that only a small fraction, 15 percent of the total domestic energy need is electrical. Thermal energy can satisfy the major fraction of the domestic energy needs including refrigeration and air conditioning. To supply the total domestic energy need with electricity is expensive even when the automobile uses gasoline as a fuel (see reference systems 1 and 7). This is due primarily to the high cost of electrical transmission and distribution.

Coal is an especially economic source of energy when used as the primary source in a hydrogen energy system, as shown by a comparison of systems 3 and 4. The costs of energy from conventional systems using coal or nuclear power are similar, as shown in systems 1 and 7. It is more realistic to consider a mixed system in which a number of primary energy forms are used, such as nuclear power and coal as in system 2. In this system also the use of hydrogen derived from coal and off-peak electricity is competitive with the reference system 1.

Methane derived from coal is also economically attractive; however, hydrogen can be produced as easily as methane. The cost difference in systems 4 and 5, for example, are probably insignificant because of the relatively arbitrary assumptions made for the cost of transporting hydrogen. The merits of hydrogen as opposed to methane must be compared on some basis other than cost.

An important element in the energy utilization system is the automobile which now accounts for over half of the total energy consumed by a household. Development of the technology of hydrogen utilization in automobile engines would make a hydrogen energy distribution system an economically competitive alternative to the present energy delivery systems. It is of interest to determine how the price of electrolytic hydrogen relative to gasoline is affected by the cost of electricity. In Table 8 we show results derived from system 3 in which the cost of electricity is 6.8 mills per kilowatt hour (*12*). In this case the cost of hydrogen is slightly greater than twice the cost of gasoline. However, if the cost of electricity were reduced to 1.5 mills per kilowatt hour, hydrogen would be competitive with gasoline as an automotive fuel. Off-peak electric power can be available at such low rates, as shown in system 2.

Table 7. Summary of annual cost of energy to residential sector.

System	Distribution cost (dollars per year)	
	Overhead	Underground
1. Nuclear-electric energy and gasoline	822	1297
2. Hydrogen derived from nuclear energy and from coal	815	1290
3. Nuclear energy conversion to hydrogen	928	1055
4. Coal conversion to hydrogen	486	613
5. Coal conversion to methane	515	642
6. Nuclear-electric energy only	815	1504
7. Coal conversion to electricity and gasoline	764	1239

If we focus only on the automotive sector in the energy system, hydrogen is not competitive with gasoline unless off-peak power is used. If we examined the total energy need, including the automotive sector, hydrogen energy delivery systems can be competitive with conventional systems involving electricity and gasoline, as in system 1. Even if the hydrogen must be converted to a more easily stored fuel for automotive use, such as methanol, ammonia, or even propane, some form of hydrogen energy distribution system is an attractive alternative which should be examined in more detail.

A significant advantage in the application of hydrogen to the automotive sector is the reduction in the amount of automotive emissions such as carbon monoxide, hydrocarbons, and lead. Although nitrogen oxides are emitted in the combustion of hydrogen it should be much simpler to control these emissions than those of hydrocarbon fuels because of the cleaner exhaust gases. If the hydrogen is produced from nuclear energy there will be an increase in the production of radioactive fission products. For example, in the year 2000, the available off-peak power (nuclear and fossil) could supply hydrogen to 50 percent of the private automobiles. This would increase the total radioactivity produced by 23 percent. Additional fossil fuel would have to be burned; however, if the energy were all nuclear and supplied the same need, the amount of radioactive fission products would not increase by more than 59 percent over the amount projected to be produced in the year 2000.

Summary

In examining the potential role of hydrogen in the energy economy of the future, we take an optimistic view. All the technology required for implementation is feasible but a great deal of development and refinement is necessary. A pessimistic approach would obviously discourage further thinking about an important and perhaps the most reasonable alternative for the future. We have considered a limited number of alternative energy systems involving hydrogen and have shown that hydrogen could be a viable secondary source of energy derived from nuclear power; for the immediate future, hydrogen could be derived from coal. A hydrogen supply system could have greater flexibility and be competitive with a more conventional all-electric delivery system. Technological improvements could make hydrogen as an energy source an economic reality. The systems examined in this article show how hydrogen can serve as a general-purpose fuel for residential and automotive applications. Aside from being a source of heat and motive power, hydrogen could also supply the electrical needs of the household via fuel cells (*19*), turbines, or conventional "total energy systems."

The total cost of energy to a residence supplied with hydrogen fuel depends on the ratio of the requirements for direct fuel use to the requirements for electrical use. A greater direct use of hydrogen as a fuel without conversion to electricity reduces the overall cost of energy supplied to the household because of the greater expense of electrical transmission and distribution. Hydrogen fuel is especially attractive for use in domestic residential applications where the bulk of the energy requirement is for thermal energy.

Although a considerable amount of research is required before any hydrogen energy delivery system can be implemented, the necessary developments are within the capability of present-day technology and the system could be made attractive economically. Techniques for producing hydrogen from water by electrolysis, from coal, and directly from thermal energy could be found that are less expensive than those now available; inexpensive fuel cells could be developed, and high-temperature turbines could be used for the efficient conversion of hydrogen (and oxygen) to electricity.

The use of hydrogen as an automotive fuel would be a key factor in the development of a hydrogen energy economy, and safe storage techniques for carrying sufficient quantities of hydrogen in automotive systems can certainly be developed. The use of hydrogen in automobiles would significantly reduce urban pollution because the dispersed fossil fuel emissions would be replaced by radioactive wastes generated at large central stations. The conversion of internal or external combustion engines for combustion of hydrogen fuel would probably have less economic impact on the automotive industry than the mass introduction of electric automobiles. However, this is a subject that requires more detailed study.

Table 8. The influence of the cost of electricity on the relative cost of electrolytic hydrogen and gasoline of equal energy equivalents at the pump. The ratio of the cost of electrolytic hydrogen to gasoline is given by

$$\frac{\text{Cost of electrolytic } H_2}{\text{Cost of gasoline}} = 0.65 + 0.23\, g \left(\frac{\text{mills}}{\text{kwhr}}\right)$$

where g is the cost of electricity in mills per kilowatt hour. The value 0.65 represents the cost of transportation and distribution.

Cost of electricity (mills per kilowatt hour)	Electrolytic hydrogen/ gasoline* (ratio of costs)
0.0	0.65
0.2	0.69
0.4	0.74
0.6	0.78
0.8	0.83
1.0	0.88
1.5†	0.99
2.0	1.1
4.0	1.6
6.0	2.0
8.0	2.5
10.0	2.9
12.0	3.4

* No credit has been given for the by-product oxygen. The cost of the hydrogen fuel tank, that is, hydrogen stored in a Mg_2NiH_4 alloy, will be \$70 to \$100 per year. This assumes that the tank costs two to three times the price of the alloy and is amortized over 10 years at 10 percent interest. † This is the break-even point where electrolytic hydrogen at the pump is competitive with gasoline which is assumed to cost \$0.19 per gallon at the pump exclusive of state and local taxes.

All of the safety aspects of hydrogen utilization will have to be examined, especially the problems of safety in the domestic use and the long distance transport of hydrogen in pipelines at high pressures.

It is our opinion that the various energy planning agencies should now begin to outline the mode of implementing hydrogen energy delivery systems in the energy economy. The initial transition to hydrogen energy derived from available fossil fuels such as coal should be considered together with the long range view of all the hydrogen being derived eventually from nuclear energy. By the year 1985 when petroleum imports may be in excess of the domestic supply, these plans could set the stage for the transition period from fossil to a predominantly nuclear energy economy able to supply abundant synthetic fuels such as hydrogen. Synthetic fuels will obviously be more expensive than fuels now derived from petroleum; however, there may be no other viable choice. Thus, it is essential that the analysis and technological feasibility of a hydrogen energy system be considered now. It is of vital importance to the nation to develop some general-purpose fuel that can be produced from a variety of domestic energy sources and reduce our dependence on imported oil.

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Atherosclerosis and the Arterial Smooth Muscle Cell

Proliferation of smooth muscle is a key event in the genesis of the lesions of atherosclerosis.

Russell Ross and John A. Glomset

Atherosclerosis is a disease of large- and medium-sized arteries, and is characterized by focal thickening of the inner portion of the artery wall in association with fatty deposits. Most commonly affected are the aorta and the iliac, femoral, coronary, and cerebral arteries. Because atherosclerosis can progressively or abruptly interfere with blood flow, particularly through the heart and brain, it often causes serious clinical consequences such as heart attack and stroke. Indeed, a recently published report (*1*) by a task force of the National Heart and Lung Institute (NHLI) indicates that atherosclerosis is the chief cause of death in the United States. Nevertheless, relatively little is known about the genesis of the disease. Studies have shown clearly that factors such as lipid concentrations of the plasma, blood pressure, and smoking habits strongly influence the development of clinical symptoms, but the sequence of pathological events at the cellular level remains to be clarified. Only recently have investigators begun to explore the disease process in terms of the biology of the major cell types involved. In this article we will focus on one of these, the arterial smooth muscle cell, with discussion of some fundamental questions regarding its biology and pathobiology, and description of some experimental approaches that we are using to investigate these questions.

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