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WATER LAW PROBLEMS OF SOLAR HYDROGEN PRODUCTION

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I. INTRODUCTION

The recent energy problems of the nation have created water problems for the energy-rich western states. The West has been called upon to increase its energy production, and this increase involves a concomitant increase in water consumption.[1] Increased water usage is necessary for increasing the production rate of conventional energy resources[2] as well as for developing the newer energy alternatives such as geothermal,[3] oil shale,[4] and solar. These energy alternatives have been widely publicized and are now part of our common knowledge. However, there is another energy possibility that is not widely known but promises to be a major water consumer. This is the so-called "hydrogen economy."[5]

The concept of the hydrogen economy is straightforward.[6] The water molecule can be divided into its constituent elements of hydrogen and oxygen by applying either heat or an electric current to the water. The use of electricity to produce hydrogen and oxygen from water is known as electrolysis, and is a well known process. Many of the readers may have performed the electrolysis experiment in a chemistry lab. At present, research is being done on large electrolytic cells for hydrogen production.[7] The decomposition of water by heat

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1. Western States Water Council, Western States Water Requirements for Energy Development to 1990 (1974).

2. Comment, *The Transfer of Water for Use in the Oil Industry,* 5 LAND & WATER L. REV. 441 (1970); Trelease, *The Use of Fresh Water for Secondary Recovery of Oil in the Rocky Mountain States,* 16 ROCKY MTN. MIN. L. INST. 605 (1971).

3. C. Stone, Geothermal Energy and the Law (unpublished manuscript at U.S. Cal. Law Center 1973).

4. Dewsnup, *Assembling Water Rights for a New Use: Needed Reforms in the Law,* 17 ROCKY MTN. MIN. L. INST. 613 (1972).

5. The hydrogen economy is well known to the scientific community. The Technical Applications Center of the University of New Mexico, Albuquerque, N.M., maintains a continuously updated bibliography of publications concerning hydrogen energy. The number of publications listed therein is in the hundreds at present.

6. The general concept of the hydrogen economy is discussed by Gregory, *The Hydrogen Economy,* SCIENTIFIC AM., Jan. 1973, at 13-21 and Lessing, *The Coming Hydrogen Economy,* FORTUNE, Nov. 1972, at 138.

7. The technical literature concerned with the problems of water electrolysis is voluminous. Typical recent work in this area was presented at the 1st World Hydrogen Energy Conference in Miami Beach, Fla., on Mar. 1-3, 1976. Twelve papers on the subject were given by researchers from the U.S., France and Switzerland.

alone is a more recent concept than electrolysis, and is currently an active research field.[8] Other methods for decomposing water are also available, but the use of either heat or electricity presently holds the most promise for production of large quantities of hydrogen.[9]

Once the hydrogen has been produced, it can be piped around the country and used in a manner similar to natural gas. It is anticipated that hydrogen would be used for comfort heating and industrial processes,[10] as a fuel for electric generating plants,[11] and possibly as a fuel for automobiles and trucks.[12] It is important to note that *hydrogen is not an energy source.* An energy source in the form of heat or electricity is required to produce the hydrogen; hydrogen then becomes the medium by which the energy is stored, transported, and used. The advantage of hydrogen lies in the ease with which it can be distributed and utilized. Hydrogen is produced from water, and when it is burned it unites with oxygen to once again form water. This process of going from water to water has decided environmental advantages since the combustion is clean and the combustion product is water. The use or combustion of hydrogen may take place hundreds of miles from the site at which the hydrogen was produced, resulting in a net transportation of water from the site of production to the site of utilization.

One of the prime candidates as an energy source for hydrogen production is solar energy.[13] Solar energy can produce either the heat or the electricity necessary for hydrogen production.[14] The

8. Some of the results of research in this field were presented at the meeting referenced in note 7 *supra.* Twenty-eight papers on the subject were delivered by researchers from the U.S., France, Italy, West Germany, Belgium, and Japan.

9. A general discussion of hydrogen production methods is given by M. Eisenstadt, K. Cox, *et al.*, A Hydrogen Energy Carrier, Vol. II (NASA 1973).

10. *Id.* at ch. 5.

11. If hydrogen is used as a fuel for electrical generation, we have an inefficient process. First, electricity would be used to produce hydrogen. The hydrogen would then be transmitted by pipeline to a location a long distance from the site at which it was made. It would then be used as a fuel to produce electricity. The efficiency of converting hydrogen energy to electricity is theoretically limited by the Second Law of Thermodynamics and introduces an inherent inefficiency into the overall process. This inefficiency can be tolerated only if the energy required for transporting the hydrogen is considerably less than the energy loss due to direct electrical transmission.

12. Hydrogen powered vehicles is an active research field at present. For example, the Hydrogen Energy Conference, *supra* note 7, included six papers (from three countries) on this topic.

13. Eisenstadt & Cox, *Hydrogen Production from Solar Energy,* 17 SOLAR ENERGY 59 (1975). The Hydrogen Energy Conference, *supra* note 7, also included six papers on the solar-hydrogen conversion.

14. Readers interested in the current state of solar-electric conversion or conversion of solar to high temperature thermal energy should consult the Extended Abstracts of the 1975 meeting of the International Solar Energy Society. This was published by the Energy Research and Development Agency (ERDA).

solar-hydrogen combination also overcomes one of the inherent drawbacks of most solar energy utilization schemes. Electricity or heat can be produced from solar energy only while the sun shines. Thus, a plant producing electricity from solar energy would be inoperative at night and on cloudy days. In order to provide for electrical generation during these sunless periods, the solar plant must store heat during the sunny periods. This heat storage is both expensive and difficult. In the case of solar-hydrogen, hydrogen is only produced when the sun is shining and some of this hydrogen is stored for use during the sunless periods. Storage of gas is far simpler and cheaper than storage of heat. It has been estimated that enough hydrogen can be stored in abandoned gas and oil wells and in depleted acquifiers to provide the nation with an 80 day supply of gas, based on natural gas consumption in 1970.[15] With this type of hydrogen storage capacity available, it is possible to produce hydrogen from solar energy in the summer, when solar conditions are best, and store part of it until winter, when the hydrogen demand would be highest.

The areas of the United States that receive the most sunshine are the southwestern states and Florida. If solar-hydrogen plants were to be set up, they would be distributed among these areas. It is desirable to have geographical separation between the plants so that if inclement weather causes some plants to cease production, others will continue to operate. Thus, most of the hydrogen produced from solar energy would probably be produced in the water-short areas of the Southwest, assuming that the hydrogen economy and the solar-hydrogen concept do indeed come to pass.

It is of interest to estimate the amount of water required for hydrogen in the hydrogen economy, and compare this to the availability of water in the Southwest. The total energy demand of the United States in 1970 was 67.8×10^{15} BTU (67.8 Quads), and the estimated usage for 2000 is about 150 Quads.[16] Thirty-three percent of the 1970 demand was supplied by natural gas.[17] If we use the assumption that 50 percent of the energy demand in 2000 will be supplied by hydrogen, we find that hydrogen will supply about 75 Quads of energy per year. A calculation shows that this will require about 4.7 million acre feet of water per year converted to hydrogen.[18] If we also include the cooling water required by the

15. *See* M. Eisenstadt, K. Cox, *et al.*, *supra* note 9, at 64.

16. *Id.* at 82.

17. *Id.* at 81.

18. This estimate is based upon hydrogen supplying 75 Quads (75×10^{15} BTU) of energy. One pound of hydrogen will supply 61,084 BTU; therefore, the mass of hydrogen required is $(75 \times 10^{15})/61{,}084 = 1.23 \times 10^{12}$ pounds. One pound-mole of hydrogen weighs

various processes involved in hydrogen production, this figure can probably be doubled. Thus, we are dealing with a water requirement of about 9 million acre feet per year. This is an astronomical amount of water by southwestern standards. As a comparison, the average yearly flow of the Rio Grande at Albuquerque is 755,700 acre feet.[19] In terms of the flow of the Colorado River, which is the largest southwestern river, 9 million acre feet per year represents more water than is promised to the lower Colorado River Basin states of Arizona, Nevada, and California by the Colorado River Compact.[20] Both of these rivers have their waters fully appropriated at present.

If the hydrogen economy becomes a reality and southwestern surface water is used for hydrogen production, the water requirements could cause the drying up of the southwestern rivers. It may be possible to use brackish groundwater for hydrogen production, thereby alleviating the problem at least until these groundwaters are depleted. This paper will attempt to define the legal problems associated with the massive use of both surface and groundwater for hydrogen production in the arid Southwest. Solutions to the problems are not offered here; defining the problems is the function of this paper. More modest hydrogen requirements currently exist. Hydrogen can be used in the coal gasification process, which appears to be part of the short-range solution of the nation's energy problem. If hydrogen is used for coal gasification, the amount of water required to gasify the coal (at the gasification site) would be reduced significantly; this might help to solve the present water problems in the water-short western coal fields. This problem will also be considered. The chart below diagrams the three situations that will be considered in the remainder of this paper.

	SURFACE WATER	BRACKISH GROUNDWATER
HYDROGEN ECONOMY	1	2
COAL GASIFICATION		3

two pounds; therefore, the number of pound-moles of hydrogen (H_2) required is $(1.23 \times 10^{12})/2 = 0.615 \times 10^{12}$ pound-moles. This is the same as the number of pound-moles of water required; however, water weighs 18 pounds per pound-mole. Thus, the mass of water required is $(18)(.615 \times 10^{12}) = 11.07 \times 10^{12}$ pounds. Since water weighs 62.4 pounds per cubic foot, the volume of water required is 1.77×10^{11} cubic feet. One acre foot of water contains 43,560 cubic feet; therefore, the water required is $(1.77 \times 10^{11})/43{,}560 = 4.06 \times 10^{12}$ acre feet.

19. This data was provided by the Albuquerque Office of the U.S. Geological Survey.

20. 70 CONG. REC. 324 (1928).

II. HYDROGEN ECONOMY WITH SURFACE WATER

Hydrogen production facilities might be set up in the arid Southwest by either private enterprise or the federal government. The federal government has been involved in the production and sale of hydroelectric energy in the West for a number of years,[21] and could become involved in hydrogen production as well. The party producing hydrogen, be it the federal government or private enterprise, must have water and must therefore acquire water rights from the state, from private individuals, or otherwise. The methods of acquiring these rights will depend upon whether the particular state in which the production facility is located uses prior appropriation water law or riparian water law. Only prior appropriation law will be considered since this is the water law theory used by the western states.

Before considering the legal problems of acquiring water rights for hydrogen production, there is another question that must be resolved. The southwestern states may decide that they do not want their water used for hydrogen production and may therefore attempt to block the export of hydrogen from the state. The problem of such an attempted embargo will be considered first.

A. *Can a State Block the Export of Hydrogen?*

A number of Western States have statutes prohibiting the export of water from the state. For example, both Wyoming and New Mexico have such laws.[22] The federal courts have handled cases involving such laws, and the present state of affairs is somewhat uncertain. *Hudson County Water Co. v. McCarter*[23] involved a non-export law by the State of New Jersey. The defendant contracted to deliver New Jersey water to New York, with the contract being made after the law was passed. The Court held that the New Jersey statute was valid and enforceable; however, the decision was based largely on principles of riparian law.

A similar case arose in Texas in 1966,[24] in *City of Altus, Okla. v. Carr.* There, the defendant's predecessor in title had contracted with the City of Altus to supply water. The wells were in Texas, and the

21. The federal government has been licensing dam sites under the authority of the Federal Power Act of 1920, 16 U.S.C. §§791-828 (1970). It has been in the business of generating and selling hydroelectric power from dams which were built under the authorization of the Reclamation Act of 1902, 43 U.S.C. §§371-616 (1970). Perhaps the prime example of such a dam is Hoover Dam, which was constructed under authority of the Boulder Canyon Project Act, 43 U.S.C. §§617-18 (1970).

22. WYO. STAT. §4-10.5 (1975 Supp.); N.M. STAT. ANN. §75-11-20 (Repl. 1968).

23. Hudson County Water Co. v. McCarter, 209 U.S. 349 (1908).

24. City of Altus v. Carr, 255 F.Supp. 828 (W.D. Tex. 1966), *aff'd per curiam*, 385 U.S. 35 (1966).

City of Altus was in Oklahoma. The Texas Attorney General had given an opinion in 1963 that sale of Texas water to an out of state buyer was lawful. After the contract was signed, Texas passed a statute prohibiting the export of water. The court held that the Texas statute imposed a discriminatory burden on interstate commerce and was therefore unconstitutional. The water was held to be a legitimate item of interstate commerce and could not be removed from that commerce by the Texas statute.

These cases and the question of whether or not water export can be prohibited by state law have been discussed in detail by Zunker.[25] He concluded that the state may be able to argue that its duty to assure maximum permanent beneficial use of the water permits it to prohibit water export. In the present case we are concerned with the export of hydrogen produced from water, and not the water itself. Even if we assume, *arguendo,* that water export can be prohibited, this does not necessarily preclude exportation of hydrogen. Although the origin of the hydrogen can be traced directly to the water, the nature of the hydrogen is far different from that of water. Hydrogen is a gaseous fuel, and resembles natural gas far more than it resembles water. Supreme Court cases have dealt with the problem of a state seeking to prohibit the export of natural gas, and such a prohibition was considered an unconstitutional burden on interstate commerce.[26] An attempt by a state to prohibit export of hydrogen would probably be disposed of in the same way. In addition, it is doubtful that the Commerce Clause would permit a state to place an embargo on products made with state water. Such an embargo would prohibit the export of agricultural produce grown by irrigation.

B. *Acquisition of Surface Water Rights by Private Enterprise for Hydrogen Production*

States that follow prior appropriation water law generally consider beneficial use of water to be the basis, the measure, and the limit of a water right.[27] Thus, a person is entitled to no more water than he can beneficially use. There are many beneficial uses to which the water may be put; however, the measure of a water right does not depend upon the particular type of beneficial use for which the water is

25. Comment, *It's Our Water!—Can Wyoming Constitutionally Prohibit the Exportation of State Waters?,* 10 LAND & WATER L. REV. 119 (1975).

26. Pennsylvania v. West Virginia, 262 U.S. 553 (1922); West v. Kansas Natural Gas Co., 221 U.S. 229 (1911). There is also an Indiana Supreme Court decision to the same effect, State ex rel. Corwin v. Indiana & Ohio Oil, Gas & Mining Co., 120 Ind. 575, 22 N.E. 778 (1889).

27. *See, e.g.,* N.M. CONST. art. 16, §3.

appropriated. In some states, however, a hierarchy of preferred uses was established by statute[28] and in order to transfer or sell a water right, the use of the water could not go from one use to a less preferred use. It could go to either the same use or one of higher preference. At present, water rights are generally transferable and salable in most southwestern states, subject to various restrictions.[29] The water rights are treated as property and can be bought and sold as such.[30]

Although preferred uses no longer influence the buying and selling of water rights, the concept of "higher" uses remains with us, but now it is used in an economic sense. One use is considered to be "higher" than a second use if the first has a greater dollar return per gallon of water. An excellent example of the hierarchy of uses, based on economic return, is given in Lansford's study of the water uses in the Rio Grande Basin in New Mexico.[31] There, the various water uses are listed and the water consumption and economic value of the water for each of these uses is tabulated. Those considered were agriculture, mining, manufacturing, trade, and services. The use becomes higher as we progress along the list from agriculture to services (which includes municipal services). It has been suggested that if each of the uses and the costs, including social costs, can be mathematically quantified, computer programs could find that mix of the various uses which would result in the optimum water management program.[32] It is usually difficult to define these uses and costs mathematically for a complex water system.

It has also been suggested that water use would be optimized in a free market by making water rights readily transferable.[33] If this were done, those who need the water for the "higher" or more valuable uses would be able to pay a higher price for water rights and would therefore be able to acquire them. Under either of these

28. WYO. STAT. §41-3 (1957) is an example of a statute defining a hierarchy of preferred uses.

29. Arizona is one of the exceptions to the transferability of water rights. There, a water right is appurtenant to a particular piece of land and cannot be moved. Salt River Valley Users' Ass'n v. Kovacovich, 3 Ariz. App. 28, 411 P.2d 201 (1966).

30. Trelease & Lee, *Priority and Progress–Case Studies in the Transfer of Water Rights,* 1 LAND & WATER L. REV. 1 (1966).

31. Lansford, Ben-David, Gebhard, Brutsaert & Creel, *A Socio-Economic Evaluation of Alternative Water Management Policies on the Rio Grande in New Mexico,* 15 NAT. RES. J. 307 (1975).

32. Mathematical optimization is discussed by Kneese, *Economic and Related Problems in Contemporary Water Resources Management,* 5 NAT. RES. J. 236, 252 (1965); and Hufschmidt, Research on Comprehensive Planning of Water-Resources Systems, *5 NAT. RES. J. 223 (1965).*

33. Note, *The Efficient Use of Utah's Irrigation Water: Increased Transferability of Water Rights,* 1975 UTAH L. REV. 158; Comment, *supra* note 2.

schemes (mathematical optimization or easy transferability), the use of water as a chemical feedstock for hydrogen production must come out very high in the use hierarchy; it is certainly more valuable than water used for irrigation and may even have greater value than water used to flush toilets. Thus, private enterprise should encounter no problems in acquiring water rights for hydrogen production at a price it can afford to pay.[34] This is made even more likely by the fact that most of the water in the Western states is used for irrigation, which is one of the "lowest" economic uses for water. From a strictly economic point of view, private enterprise can acquire its water.

Strict economics may not be the only consideration in determining whether or not private enterprise can acquire the necessary water. In a paper concerned with water policy, Trelease identified a number of considerations other than strict economics that should be taken into account when making a water law policy decision.[35] He agrees that the water should go to the highest valued use *if there is no public interest* in who gets the water. In that case, the optimization principles discussed above can be applied. When there is a public interest, however, the thing which "is to be maximized is welfare from water use, not water use itself."[36] Maximizing the welfare from the water use requires that the public interest be represented in some manner, usually through a state regulatory scheme. Some regulation is required to protect the public interest since, as Trelease says, "unregulated private activity will permit the water user to shift or impose some of the costs of his water use to other persons or to the public."[37] Can any public interest be identified which would be harmed by private enterprise acquiring massive water rights for hydrogen production?

It is reasonable to assume that the water rights acquired for hydrogen production would come from farmers, since irrigation consumes most of the water in the southwestern rivers. Thus, large quantities of water previously used for irrigation would be used for hydrogen production. Land previously irrigated would revert to desert, causing harm to the general public in a number of ways. Aside from the negative esthetic effect of losing a green belt in an arid region, a shift from agriculture to hydrogen production would cause a major up-

34. The cost of transferring water rights can be significant and can be an impediment to transfer in some cases. However, later in the paper it will be shown that the hydrogen derived from an acre foot of water has a value of about $16,000. Under these conditions, the transfer cost becomes negligible.

35. Trelease, *Policies for Water Law: Property Rights, Economic Forces, and Public Regulation*, 5 NAT. RES. J. 1 (1965).

36. *Id.* at 4.

37. *Id.* at 42.

heaval in the economic base of the southwestern states since agriculture would be greatly diminished. Fishing would suffer, not because of lack of water in the rivers (this might remain the same since the hydrogen production plant could only consume as much water as the farmers did previously) but because fish life depends upon land vegetation and insects to some extent. Hunting during the yearly migrations of waterfowl could also suffer since these waterfowl depend upon the irrigated river valley regions to provide them with food during their seasonal north-south migrations. Lack of irrigation water and agriculture might deprive the waterfowl of some of their major flyways, such as the Rio Grande and Colorado Rivers, and might ultimately affect the species. Elimination of much of the vegetation in the river valleys might also create an air quality problem. The reversion of farmland to desert would increase the concentration of particulate matter (dust) in the air. Since most major population centers of the arid Southwest are located on rivers, this increase in particulates could affect large segments of the southwestern population.[38] These injuries to the public provide at least two arguments by which a state can either regulate or prevent a private company from acquiring massive water rights for hydrogen production. One of these rests upon a combination of the public trust doctrine and appropriation water law, while the second relies upon the Clean Air Act.

A water right in a prior appropriation state does not give the owner of the right the ownership of the water; he has only the use of the water. A water right gives a usufruct, with the title to the water remaining with the state. If the water is not put to beneficial use, the owner of the right may lose it either through forfeiture or abandonment.[39] In case of forfeiture or abandonment, the water right reverts to the state; "the continuance of the title to a water right is based upon continuing beneficial use, and where the right is not exercised for a certain period of time (four years), the statute declares that the right to the unused portion is forfeited."[40] The state thus has an obligation to insure that the appropriated waters of the state are put to use for the benefit of the state and its citizens. This policy can be stated as a Public Trust Doctrine, which says that the state holds the waters in trust for the people of the state and is obligated to use

38. This argument does not apply to the major population centers located on the seacoast, and the anticipated increase in particulates would probably not affect most of the California population.

39. For example, the forfeiture scheme in New Mexico is described by N.M. CONST. art. 16, §§1-3 and N.M. STAT. ANN. §75-11-8 (Repl. 1968).

40. State ex rel. Reynolds v. South Springs Co., 80 N.M. 144, 452 P.2d 478, 481 (1969).

these waters for their benefit. The obligation is commonly discharged by permitting appropriation of water by people who plan to use it beneficially; i.e., for agricultural, mining, industry, municipal water supplies, or other application that are useful to the state and its citizens. The appropriation is done by means of permits. In most appropriation states, these permits are granted by the Office of the State Engineer. In this manner, the state has control of granting appropriations to beneficial users and also has control of the transfer of water permits.

There are generally two conditions that must be met for a valid transfer of water rights. These are:

1. The transferee must put the water to a beneficial use.
2. The transfer must not harm any other water appropriator. This requirement is backed up both by statute[41] and by case law.[42]

In transfers not involving public interest questions, if the two conditions stated above are met, the transfer will result in beneficial use, and the state will have met its obligation under the public trust doctrine. In the case we are considering, however, the general public is involved, and the situation is more complex than that involving only the transferor, transferee, and a possibly damaged third party appropriator. Here we have the general public being damaged while the state has the obligation of using the state's water *for the benefit of the people of the state*[43] under the Public Trust Doctrine. The use to which the water will be put by the hydrogen production plant is a beneficial one in the normal interpretation of "beneficial use," but this beneficial use will damage the public. In this case, it may be necessary to retain this "beneficial use" concept; perhaps the advantage gained from the hydrogen plant should be balanced against the damage done to the public.

There is an argument against this line of reasoning. If this reasoning is carried to its extreme, it would not be possible to convert any irrigation water to industrial use since this would cause a decrease in cultivated land. This decrease has all of the disadvantages for the general public listed above. If irrigation water cannot be transferred to industrial use, the industrial development of the entire arid Southwest will not take place to the detriment of the economic well-being of its inhabitants. A tradeoff point must be found between the two interests. It is not the purpose of this paper to determine where the

41. WYO. STAT. §41-4.1 (1975 Supp.).
42. W. S. Ranch Co. v. Kaiser Steel Corp., 79 N.M. 65, 439 P.2d 714 (1968).
43. Illinois Cent. R.R. Co. v. Illinois, 146 U.S. 387 (1892); Boone v. Kingsbury, 206 Cal. 148, 273 P. 797 (1928); Colberg, Inc. v. State, 62 Cal. Rptr. 401, 432 P.2d 3 (1967).

tradeoff point lies. As stated in the introduction, the writer is merely trying to define the problems, not to solve them.

C. Acquisition of Surface Water Rights by the Federal Government for Hydrogen Production

The power of the federal government to acquire water has been greatly enhanced over the past two decades by a series of court decisions. The various means by which the federal government might acquire water for hydrogen production are discussed below. It will be seen that the federal government has a much greater probability of acquiring the necessary water than does private enterprise.

1. Federal claims to unappropriated water

As the Western territories were acquired by the United States, they became part of the public domain, and the federal government had control of both the land and the water. The federal government was anxious to have these western lands settled, and in order to stimulate such settlement it passed the Desert Lands Act of 1877.[44] This Act permitted the people settling the land to claim it, but water rights were not considered to be part of the land. These rights were to be claimed under state law, and it was generally considered that the Desert Land Act had severed the water from the land and then placed control of the water with the states. This interpretation has since been upheld by the Supreme Court.[45] Some question still exists as to whether the water under state control was only that water which was appropriated, with unappropriated water remaining with the federal government, or whether the state had control of all of the water touching the lands of public domain. One point of view holds that the states can continue to exercise their jurisdiction over this water unless the state laws are superseded by a federal law that disposes of the water.[46] For the most part, the question is not of great significance since southwestern waters affected by the Desert Land Act are generally either fully appropriated or over-appropriated, with few exceptions.

2. Federal claims to water for federal reservations

Not all of the western land owned by the United States was part of the public domain. Thus not all of this land was available for settlement under the Desert Lands Act. Parts of the land were re-

44. 43 U.S.C. §§32-39 (1970).
45. California Ore. Power Co. v. Beaver Portland Cement Co., 295 U.S. 142 (1935).
46. F. TRELEASE, CASES AND MATERIALS ON WATER LAW 33 (1974).

served for particular purposes such as Indian reservations, military reservations, National Parks and Forests, construction of power dams, etc. The Federal Reservation Doctrine provides that when the federal government reserved land for a specific purpose, it also set aside a quantity of water that was commensurate with that purpose. This doctrine was first pronounced in a somewhat different form in the case of *United States v. Rio Grande Dam and Irrigating Co.*[47] There the Court held that although the states could use the law of prior appropriation, that law could not be applied by the states to destroy the rights of the federal government (as owner of lands bordering a stream) to the continued flow of the waters. The federal government was entitled to at least as much water as *may* be necessary for the beneficial uses of the government property.

The principle was applied in *Winters v. United States,* and that case framed the well known Winters Doctrine.[48] There, Winters was a farmer living upstream of the Ft. Bellknap Indian Reservation, and he was appropriating water in accordance with Montana law. After this appropriation was established, the Indians wanted the water for a project on the reservation. The court held that the federal government had reserved water for the Indians when the reservation was formed and that since the priority date of the Indians was earlier than that of Winters, the Indians were the senior appropriators and were entitled to the water. The Winters Doctrine has since been upheld in other cases,[49] and most recently in *Arizona v. California.*[50] In that case, the Court found that enough water had been reserved by the federal government for the Indian reservations along the Colorado River "to satisfy the future as well as the present needs of the Indian Reservations. . . ." The measure of the amount of water was "enough water . . . to irrigate all of practicably irrigable acreage on the reservations."[51] It *might* appear that the words "to satisfy future as well as present needs" anticipates that the reservations would not remain agricultural but would industrialize. If so, it might be possible for the Indian Reservations to take sufficient water from the Colorado River for large scale hydrogen production, without having to compensate anyone. The exact interpretation of the above words in *Arizona v. California* has not been forthcoming. This problem is discussed in papers by Veeder[52] who favors a wide interpreta-

47. United States v. Rio Grande Dam & Irrigation Co., 174 U.S. 690 (1899).

48. Winters v. United States, 207 U.S. 564 (1908).

49. *See, e.g.,* Pyramid Lake Paiute Tribe of Indians v. Morton, 354 F.Supp. 252 (D.C.D.C. 1972).

50. Arizona v. California, 373 U.S. 546 (1963).

51. *Id.* at 600.

52. Veeder, *Indian Prior and Paramount Rights to the Use of Water,* 16 ROCKY MTN. MIN. L. INST. 631 (1971).

tion, and by Bloom[53] who favors a narrower one. If the wider interpretation is accepted and the Indians whose reservations border the southwestern streams have a right to sufficient water for national hydrogen production under the Winters Doctrine, it may be possible for private enterprise to buy the water from them or to set up hydrogen production plants on the reservations.

The *Arizona v. California* decision also held that the federal government had reserved sufficient water for other government reservations on the Colorado River.[54] These reserved water rights are for recreation areas, wildlife refuges, and a national forest.[55] Since the federal government can only take water for these reservations in order to accomplish the purpose for which the reservations were created, it is doubtful that the government could use the Federal Reservation Doctrine, as applied to these uses, to obtain water for hydrogen production. It should be noted that one of the sources of power cited by the Court for the Federal Reservation Doctrine is the Property Clause of the U.S. Constitution.[56]

3. Federal claims to water under the navigation power

The Commerce Clause of the Constitution gives the federal government power "To regulate Commerce ... among the several States. . . ."[57] In the case of *Gibbons v. Ogden,* Justice John Marshall interpreted this clause as giving the federal government power to control interstate navigation.[58] The navigation power has been used and expanded to give the federal government extensive power over the Western rivers and their irrigation waters. In *United States v. Rio Grande Dam and Irrigation Co.,* the Court held that although a state could use prior appropriation law rather than riparian law, it could not interfere with the "superior power of the General Government to secure uninterrupted navigability of all navigable streams within the limits of the United States."[59] The navigation power was used to give the federal government control over obstructions in navigable waters, such as dams,[60] and was later expanded to include the tributaries of navigable waters since control of the tributaries was

53. Bloom, *Indian "Paramount" Rights to Water Use,* 16 ROCKY MTN. MIN. L. INST. 669 (1971).

54. Arizona v. California, 373 U.S. 546, 601 (1963).

55. These reservations are the Lake Mead National Recreation Area, Havasu Lake National Wildlife Refuge, Imperial National Wildlife Refuge, and the Gila National Forest, *id.* at 601.

56. *Id.* at 597-98. The Property Clause is found in U.S. CONST. art. IV, §3, cl. 2.

57. U.S. CONST. art. I, §8, cl. 3.

58. Gibbons v. Ogden, 22 U.S. (9 Wheat.) 1 (1824).

59. United States v. Rio Grande Dam & Irrigation Co., 174 U.S. 690, 703 (1899).

60. United States v. Appalachian Elec. Power Co., 311 U.S. 377 (1940); First Iowa Hydro-Electric Coop. v. Federal Power Comm'n, 328 U.S. 152 (1946).

necessary for flood control.[61] In many cases, projects built by the federal government under the Reclamation Act of 1902[62] perform the multiple functions of improving navigability, flood control, and power generation.[63]

The combination of navigation and flood control gives the federal government significant power in practically all of the western streams, but the basis of that power is the Commerce Clause and its mandate for maintaining and improving navigability. If the federal government removes large quantities of water from southwestern waterways for hydrogen production, it is difficult to see how this would aid the navigability of the streams. There may be some special circumstances in which it would, such as impounding flood waters on the tributaries of navigable streams, but we are dealing here with a project that has the potential of lowering the level of southwestern rivers significantly. It would probably be difficult to explain the lowering of the water level as an aid to navigation.

Traditionally, the Commerce Clause and the navigation power have been the most commonly used methods for expanding federal power over water. In this case, these powers would probably not permit the federal government to remove the water required for hydrogen production because the magnitude of the water requirement would lower the water level of the streams. It is this magnitude which takes the present problem out of the framework of the previous federal water appropriation problems. For example, if the Winters Doctrine permits the Indians to remove over 9 million acre feet per year for hydrogen production, there may be a political cry for a reinterpretation of the Winter's Doctrine or a rush of investors to the reservations. At the same time, it is the magnitude of the project that gives it a great potential as an aid in the solutions of the nation's energy problems.

4. Federal claims to water under the general welfare power

During the first half of the twentieth century, the Supreme Court broadened the water powers of the federal government under the Commerce Clause and the navigation power. In the 1950's, it became evident that the navigation power concept was being stretched to the point of unreasonableness, and that a different source of power was necessary if the expansion of federal control over the waters of the nation was to continue. Congress apparently wanted the expansion

61. Oklahoma ex rel. Phillips v. Guy F. Atkinson Co., 313 U.S. 508, 525 (1941).
62. 43 U.S.C. §§371-616 (1970).
63. The Boulder Canyon Project, with Hoover Dam as the major component, is an example of such a project.

to continue since it wanted to consider the waterways of the nation as a system without the inhibiting effect of state boundaries. This is evident from some of the language in the Federal Water Pollution Control Act of 1972.[64] Section 101(a) states that the purpose of the Act is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[65] References are made to specific stream-flow impoundments having beneficial effects that are "national in scope,"[66] and river basin management is encouraged as opposed to management within a state boundary.[67]

In the 1950 case of *United States v. Gerlach Live Stock Co.*, the Court said "the power of Congress to promote the general welfare through large scale projects for reclamation, irrigation, or other internal improvement, is now as clear and ample as its power to accomplish the same results indirectly through resort to strained interpretation of the power over navigation."[68] This appears to be the first case in which the General Welfare Clause of the Constitution has been invoked in a water law case.[69] That clause states "[t]he Congress shall have the power to . . . provide for . . . the general Welfare of the United States. . . ." *Gerlach* involved the Central Valley Project in California,[70] which was a reclamation project being constructed under Congressional statutory authorization. The above quote from Gerlach was used in two later cases, *Ivanhoe Irrigation District v. McCracken* and *Arizona v. California.*[71] Both of these cases involved Bureau of Reclamation projects.

The language in *Gerlach* does not limit Congress to reclamation projects in promoting the general welfare, but includes projects for "other internal improvements." The general welfare power should include Congressional power to legislate for the energy needs of the nation; this would include the power to legislate for hydrogen production plants. Thus, the federal government could probably acquire all of the water rights that it needed for the production of hydrogen under the powers given to Congress by the General Welfare Clause.

If Congress did legislate for hydrogen plants, the necessary water would be acquired by obtaining the water appropriations of present water users. There is a question of whether the federal government

64. 33 U.S.C. §§1251-1376 (Supp. V 1975).
65. *Id.* §1251(a).
66. *Id.* §1252(b)(5).
67. *Id.* §1252(c).
68. United States v. Gerlach Live Stock Co., 339 U.S. 725, 738 (1950).
69. The General Welfare Clause is found in U.S. CONST. art. I, §8, cl. 1.
70. 16 U.S.C. §695d to j (1970).
71. Ivanhoe Irrigation Dist. v. McCracken, 357 U.S. 275, 294 (1958); Arizona v. California, 373 U.S. 546, 587 (1963).

would have to compensate these users for their water rights. State law determines the substance of a user's water right. Since most southwestern states permit the transfer of water rights, they must have an ascertainable money value and are generally treated as a form of property. Thus, if the water rights were taken without compensation, it would be a taking of property and might therefore violate the Fifth Amendment. If the property is taken under the police power, the Fifth Amendment is not violated. If the police power is not invoked, however, the property must be condemned and taken under the power of eminent domain. The problems of the government's acquiring property under the police power versus eminent domain have been debated extensively.[72] The results of these debates were summarized by the 10th Circuit in the case of *Harris v. United States.*[73] The court said "[a] compensable taking under the federal constitution . . . is not capable of precise definition. And the adjudicated cases have steered a rather uneven course. . . ." Fortunately, we do have precedents for the taking issue in th water law cases. *Gerlach* was concerned with whether the plaintiff should be compensated when his water right was rendered useless by the federal government. The government was acting in accordance with the mandate it received from Congress to construct the Central Valley Project. The Supreme Court held that the plaintiff was to be compensated for the loss of his water right. A similar situation arose in *Dugan v. Rank,*[74] but there the plaintiff sought to enjoin the United States from proceeding with the portion of the Central Valley Project that affected his water right. The Court held that while the plaintiff could not enjoin construction of a project authorized by Congress, he was entitled to compensation for his water right. From a practical point of view, the question of compensation is not of great importance to the federal government. The water rights would be acquired for a price close to the market price for irrigation water rights, and the water would then be put to a much more valuable use as a chemical feedstock in the hydrogen production process. Thus, even with compensation, the government would acquire the water rights at the agricultural price and would apply them to a more valuable use. The environmental issues that were discussed in a previous section in the context of the Clean Air Act are relevant to the taking issue as well. In addition, the federal government would have to comply with the

72. *See, e.g.,* Michaelman, *Property, Utility, and Fairness: Comments on the Ethical Foundations of "Just Compensation" Law,* 80 HARV. L. REV. 1165 (1967); Olson, *The Role of "Fairness" in Establishing a Constitutional Theory of Taking,* 3 URB. LAW. 440 (1971).

73. Harris v. United States, 205 F.2d 765, 767 (10th Cir. 1953).

74. Dugan v. Rank, 372 U.S. 609 (1963).

requirements of NEPA and file an Environmental Impact Statement[75] for the proposed hydrogen production facility.

III. HYDROGEN ECONOMY WITH BRACKISH WATER

The possibilities presented in the previous sections are not very pleasant to contemplate. While the hydrogen economy would be quite attractive if it is economically feasible, the reduction of agriculture in the southwestern river valleys is an unattractive prospect. This section will discuss the possibility of using brackish water for hydrogen production, with that water coming from brackish groundwater basins. It will be shown that sufficient brackish groundwater may exist for hydrogen production facilities, and that brackish water presents a reasonable alternative to surface water. Also, the use of brackish water is one of the alternatives that the federal government would have to include in an Environmental Impact Statement if Congress legislated hydrogen production under the General Welfare Clause.

A. Technical and Economic Considerations in Producing Hydrogen from Brackish Water

Presently available electrolysis equipment requires high purity water as a raw material. If the impurity level in the water is excessive, several adverse effects will result. The impurities will decrease the efficiency of the process, resulting in the use of more electricity for a given quantity of hydrogen produced. In addition, exposure to the impure water will corrode the equipment. The impurity concentration within the equipment will build up with time, and the plant will have to shut down periodically for cleaning and maintenance. These problems occur with both sea water[76] and brackish water.[77] In order for the electrolyzers to function properly, the water used must be of about the same purity as the water used in steam boilers, or better.[78] This means that brackish water (or sea water) requires distillation before being used in an electrolysis process. Surface water might also need to be distilled. However, if the impurity content of

75. Section 102(2)(C) of the National Environmental Policy Act of 1969 (NEPA), 42 U.S.C. §4332(2)(C) (1970), requires that an environmental impact statement be made for any "major Federal actions significantly affecting the quality of the human environment. . . ."

76. L. Williams, Electrolysis of Sea Water (THEME Conf. Proc., Miami Beach, Fla., March 1974).

77. D. Gregory & V. Gitlis, Impure Water Electrolysis (in Survey of Hydrogen Production and Utilization Techniques, NASA, 1974).

78. The allowed impurity levels in boiler water are given in STEAM 34-13 (1972).

the surface water is low enough, it may be possible to treat it by processes that are cheaper than distillation.

The energy required for the distillation of brackish water can come partially from the waste heat of the hydrogen producing process, from solar energy, or both. Since this entire paper assumes that solar energy is the energy source used for hydrogen production, we can assume that the plant will be located in a prime solar area and that the use of a solar still for water purification may therefore be feasible. Solar stills have been used for many years and are presently being researched actively.[79] The technology required for desalting (or distilling) brackish water is well known, and there are a number of desalting techniques that can function with solar energy.[80]

The cost of water distillation using oil or natural gas as a heat source was estimated at about $110 to $180 per acre foot in 1970.[81] A recent preliminary study of the cost of desalinating brackish water in the Tularosa Basin of New Mexico indicates prices between $160 and $204 per acre foot, using nuclear energy as the heat source.[82] It is anticipated that if solar distillation is used, it would bring these costs down somewhat, or there would be no point in using it. As a figure of comparison, agriculture can afford up to about $50 per acre foot for irrigation water. Thus, if this brackish water is to be distilled and utilized, it must be by a use that is "higher" than irrigation, and hydrogen production is one such use.

It is of interest to determine what fraction of the retail value of the hydrogen is spent in the distillation process. An acre-foot of water will produce enough hydrogen to supply about 16×10^9 Btu. If we assume that the present cost of fossil fuel is about $1 per million Btu,[83] then the hydrogen produced from an acre-foot of water has a retail value of about $16,000. If we take the cost of distillation as $200 per acre-foot, *the distillation cost comes out to a little more than one percent of the retail cost of the hydrogen.* With cost figures like this, it makes little difference to the consumer whether the hydrogen comes from brackish or surface water.

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79. *See, e.g.*, Garg & Mann, *Effect of Climatic, Operational, and Design Parameters on the Year Around Performance of Single Sloped and Double Sloped Solar Still Under Indian Arid Zone Conditions*, in EXTENDED ABSTRACTS OF THE 1975 MEETING OF THE INTERNATIONAL SOLAR ENERGY SOCIETY 432 (1975).

80. C. Wong & J. Strobel, Special Report on Status of Desalting (Office of Saline Water, Interior Dep't, Nov. 1970). This report contains both technical and cost information on water desalination.

81. *Id.* at 41.

82. R. Landsford, A Preliminary Economic Feasibility Study for the Establishment of an Energy-Water Complex in the Tularosa Basin (unpublished, N.M. St. U., 1975).

83. According to the writer's last home gas bill, the residential rate for natural gas in Albuquerque, N.M., is about $1.50 per million Btu.

B. Availability of Brackish Water

The saline water resources of a number of states have been inventoried by the U.S. Geological Survey. The saline waters of New Mexico are described in a publication by Hood and Kister.[84] These saline water resources consist of both groundwater and surface water; however, the quantity of saline groundwater is much larger than that of surface water. Therefore, saline surface water will not be considered. Hood and Kister's publication contains a great deal of detailed information concerning the various saline groundwater basins in New Mexico, but the discussion will be limited to the largest of these since the largest basin is capable of supplying more water than is needed by the hydrogen economy.

The largest underground body of brackish water in New Mexico is the Tularosa Basin. That aquifer has been fairly well investigated and estimates of the amount of water in the basin have been made by Herrick. Herrick and Davis[85] have estimated that there are 170 million acre feet of irrigation quality water, while McLean[86] says that the amount of brine available is about 25 times this quantity. Thus, the amount of brackish water in the Tularosa Basin is about 4 billion acre feet. If we assume that only one third of this water can be recovered, and that it is used to support a full hydrogen economy at the rate of 10 million acre feet per year, there is enough water to last for over 100 years *in this basin alone.* Thus, it can be concluded that sufficient brackish water is available for hydrogen production.

C. Legal Aspects of Using Brackish Groundwater for Hydrogen Production

Groundwater can be found in isolated aquifers and in reservoirs that are in contact with surface water systems such as rivers. When the groundwater is in contact with the surface water, removal of the groundwater affects the surface water (usually by lowering the surface water level). In recognition of this interaction, the southwestern states consider that the groundwater and the surface water are part of the same system and therefore the law treats both of them in the same manner.[87] Appropriation of groundwater by pumping is con-

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84. J. Hood & L. Kister, Saline-Water Resources in New Mexico (Geological Water-Supply Paper 1601).
85. E. Herrick & L. Davis, Availability of Ground Water in Tularosa Basin and Adjoining Area, New Mexico and Texas (Hydrologic Investigations Atlas HA-191, U.S. Geological Survey, 1965).
86. J. McLean, Saline Water Ground Resources of the Tularosa Basin, New Mexico (Office of Saline Water, Interior Dep't, Research & Development Progress Rep. No. 561).
87. Flint, *Groundwater Law and Administration: A New Mexico Viewpoint,* 14 ROCKY MTN. MIN. L. INST. 545 (1968).

sidered the same as the appropriation of surface water by means of a ditch, and it is possible to transfer a surface water right in a river system to a ground water right in the same system but at a different location.[88] This category of groundwater would be subject to the same federal controls as the surface waters.

The category of groundwater of most interest for our purposes is the isolated aquifer. As the word "isolated" implies, these aquifers are not replenished as the water is removed; therefore, the water is eventually depleted. The isolated nature of these underground reservoirs prevents them from being in contact with any navigable waters; therefore, the federal government cannot control them by any Commerce Clause power. If the existence of the aquifers was unknown at the time that a federal reservation was created above the aquifer, it is doubtful that the federal government could claim the water under the Federal Reservation Doctrine, particularly if the water is brackish. Thus, the federal government likely could not exercise control over isolated aquifers. The control of these waters would rest with the states. Consequently, the states are free to adopt their own regulations regarding the mining of water.[89]

In New Mexico the waters found in isolated aquifers are public waters,[90] and their use is sanctioned by the state.[91] The procedure by which these waters are appropriated is very similar to that used for surface water. The State Engineer declares an underground water basin by defining the boundaries of the basin, after which appropriation of water in that basin is on a prior appropriation basis. The same permit system is used for appropriation of water from an underground basin as for appropriation of surface waters. Ownership of the land above the aquifer does not give one ownership of the aquifer, just as ownership of the land on each side of a stream does not give ownership of the stream. Licensing of water rights in isolated aquifers presents at least one unique problem. The greater the number of water rights given, the faster the aquifer will be depleted. This problem is generally solved by having the State Engineer determining how long the water in the aquifer should last and then basing "full appropriation" on that determination. As might be expected, different State Engineers make different determinations. In New

88. Templeton v. Pecos Valley Artesian Conservancy Dist., 65 N.M. 59, 332 P.2d 465 (1958).

89. The pumping of water from an isolated aquifer is called "mining" the water, implying that a non-replaceable resource is being removed.

90. *See* N.M. STAT. ANN. §75-11-1 (Repl. 1968) and State v. Dority, 55 N.M. 12, 225 P.2d 1007 (1950).

91. Bagley, *Water Rights Law and Public Policies Relating to Ground Water "Mining" in the Southwestern States*, 4 J. L. & ECON. 144 (1961).

Mexico, for example, full appropriation of an underground water basin would leave one-third of the water in the basin after 40 years of pumping,[92] while Colorado defines 40 percent depletion in 25 years as full appropriation.[93] No determination of full appropriation from a brackish water basin has ever been made because the need has never arisen, but presumably brackish water would be treated in the same manner as fresh water unless there was a good reason for doing otherwise.

Consideration of the economic, technological, and legal aspects of the problems involved in using brackish water for hydrogen production indicate that both the brackish water and the technology are presently available. The legal problems involved are certainly no more complicated than those involved with using surface water, and are probably simpler and more predictable.

IV. COAL GASIFICATION WITH BRACKISH WATER

There is a present opportunity to test some of the concepts used on the previous pages. A coal gasification complex is being planned in northwestern New Mexico. Coal gasification uses significant quantities of water, in an area that is water short. The amount of water consumed could be greatly reduced if hydrogen was available at the gasification site. This hydrogen could come from a hydrogen production plant operating in the Tularosa area, using brackish water. The hydrogen produced there would be transported to the coal fields in a pipeline for use in the gasification process.

A. *The Coal Gasification Process*

Coal is primarily carbon (chemical symbol is C) while the gas that is produced by the coal gasification process is methane (chemical symbol is CH_4). The gas is composed of both carbon (C) and hydrogen (H). In the process normally used for coal gasification, the hydrogen required comes from water. The overall reaction of the coal gasification process is described by the chemical reaction:[94]

$$2C + 2H_2O \rightarrow CH_4 + CO_2.$$

This equation shows a couple of interesting characteristics. First, in order to produce one molecule of methane, two molecules of water must be consumed. Secondly, for every molecule of methane that is

92. Mathers v. Texaco, Inc., 77 N.M. 239, 421 P.2d 771 (1966).

93. Fundingsland v. Colorado Ground Water Comm'n, 171 Colo. 550, 468 P.2d 835 (1970).

94. Cox, *A Comparison of Hydrogen with Alternate Energy Forms from Coal and Nuclear Energy* (to be published in ENERGY CONVERSION).

produced, one molecule of carbon dioxide (CO_2) is produced, and the CO_2 is useless. Note that the two carbon atoms that we started with came from the coal, therefore half of the coal is being burned since half of the carbon enters the atmosphere as carbon dioxide. If hydrogen was available, the reaction would be:

$$C + 2H_2 \rightarrow CH_4.$$

Thus, when hydrogen is available, no water is required and all of the carbon from the coal appears in the methane. The reason for using the first process is because it is cheaper to burn half of the coal to produce the gas than it is to buy or produce hydrogen at present prices.

Estimates of the water consumption of coal gasification plants in the four corners area of northwestern New Mexico have been made by Davis and Wood, and their figures show that water consumption could be reduced by about 35 percent if hydrogen was used in the process.[95] This would constitute a significant water saving in an arid area, particularly since the water that would be used in producing the hydrogen would be brackish water that had no other present use.

The proposed scheme of producing hydrogen from Tularosa Basin water and piping it to the four corners area is not offered as one that is economically sound at present, but rather as a project to determine the practicality of the concepts. Solar generated electricity is currently a very active research field and should yield electricity in pilot plant quantities in the near future.[96] Maps showing the quantity of solar energy falling on various parts of the country illustrate that the Tularosa Basin in southern New Mexico is one of the best areas in the United States for a solar facility. Assuming that the schemes for the production of electricity from solar energy are successful, an electric generating facility could be placed at the Tularosa Basin to provide power for the electrolysis of water. This facility would provide operating experience with the combination of solar electrical generation, solar distillation of water that is to be used in electrolysis, and

95. G. Davis & L. Wood, Water Demands for Expanding Energy Development (Dep't of Interior, Geological Survey Circular 703, 1974). It is important to note that the proposed scheme does not reduce the overall consumption of water in the coal gasification process. Less water would be required from the four corners area; however, brackish water from the Tularosa area would be consumed to produce the hydrogen. Thus, while the overall water consumption would be the same, some brackish water from the Tularosa Basin would replace usable water from the four corners area. In addition, a significant reduction in coal consumption would be realized.

96. Sandia Laboratories in Albuquerque, N.M., is presently building a pilot plant that will use solar energy to produce high temperature steam. The steam will then produce electricity by means of a conventional turbo-generator.

the operation of electrolysis cells that use an electrical power source that fluctuates with the sun.

The hydrogen pipeline to the coal fields would provide operating experience with the long distance transportation of gaseous hydrogen. Such experience must be acquired before the hydrogen economy can become a reality. While no theoretical barriers exist to the long range transportation of hydrogen,[97] operating experience must be acquired before a network of hydrogen pipelines is constructed. Hydrogen has some unique safety problems,[98] and these must be resolved in a working situation before the gas can be safely used in the home. Under the proposed scheme, the users would be industries in the coal field area. Thus, the hydrogen would be used first by professionals who have experience with handling dangerous gases. Their experience should prove very valuable if and when hydrogen usage becomes commonplace.

V. SUMMARY AND CONCLUSIONS

If solar energy is used for the large scale production of hydrogen, a number of hydrogen plants will undoubtedly be sited in the Southwest. These plants will need large quantities of water, which can come either from surface streams or from underground aquifers. If water that is presently used for irrigation is channeled into hydrogen production, the consequences would be adverse to the interests of those living in the southwest, since areas that are presently cultivated would revert to desert.

A logical alternative to using surface water would be the use of brackish groundwater, contained in isolated aquifers. While the cost of using brackish water would be slightly higher than the cost of using fresh water, that cost might be warranted since it would prevent damage to both the ecology and life style of the southwestern citizens. The water used in the hydrogen production process has a high economic value, and it is precisely the magnitude of this value that would permit a solar plant operator to pay the cost of distilling brackish water.

It is evident that the federal government could acquire as much surface water as it needed to produce hydrogen, if it chose to do so. It would probably do so under the General Welfare Clause of the Constitution. It is well to remember that the general welfare of the country includes the general welfare of the Southwest. The results of the federal government's using this surface water are probably suffi-

97. Eisenstadt, Cox, *et al.*, *supra* note 9, at ch. 4.
98. *Id.* at ch. 6.

ciently detrimental that the federal government could be required to pay a little more for water and use underground brackish water. Section 102(2)(B) of NEPA requires that federal agencies consider "environmental amenities" in their decision making. Section 302(b)(1) of the Federal Water Pollution Control Act of 1972 requires that the relationships between economic and social costs be determined at public hearings. Respected commentators state that the factor to be maximized is the welfare derived from the use of water, not the water use itself.[99] All of these commentators seem to say that the damage done to the environmental amenities must be balanced against the economic advantage of using fresh surface water instead of brackish groundwater. The information presently available indicates that the retail price of hydrogen should not increase by more than one or two percent if brackish water is used.

It is important that this question be resolved before drawings are made and equipment is purchased for hydrogen production plants. The type of water treaters to be included in the plants will depend upon whether fresh or brackish water is to be used. It is easy to change from one to the other during the planning stages, but once construction has begun, the inertia of the money invested makes change difficult and costly.

99. *See* Trelease, *supra* note 35.