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THE CALIFORNIA NUCLEAR GREEN FARM

By

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Abstract
The two most critical problems to solve for the economic and social future well being of California are environmentally clean energy and fresh water produced at a significantly low cost to the economy. The California Nuclear Green Farm is an engineering concept that can meet these requirements. By using the science and technology now available, the people of the state of California can ultimately obtain the vast majority of their energy requirements from the Pacific Ocean. The Nuclear Green Farm is a large complex of twelve 1000 to 1500-megawatt-e nuclear reactors. Some of the reactors would be water-cooled, some would be liquid metal cooled and some could be gas cooled. The ideal location for the nuclear green farm is in the first valley inland from the ocean. These reactors are ultimately powered from natural uranium obtained from the seawater that is also used to cool them. Since only about 35% of the energy from the fission reaction is used to produce electricity the other 65% is used to produce fresh water, and to provide heat for other processes of the nuclear green farm complex. The electricity and hot pure water are used to produce hydrogen and oxygen to be used for fuel cell and other forms of power for transportation. The salt brine left from the fresh water distillation is the source of the uranium fuel and other metals and minerals produced with the low cost electricity and the waste heat. Since there is warm freshwater and low cost electricity available they will be used to grow vegetables in hydroponic farms that are situated around the nuclear complex. The available warm and cold salt water combined with fresh water can be regulated to optimize the production of seafood in aquatic farms that also surround the complex. The waste from the hydroponic farms can be processed to provide feed for the aquatic farms and the waste from the aquatic farms along with some of the minerals from the salt brine can be processed with the low cost electricity for fertilizer for the hydroponic farms. The spent fuel is reprocessed and recycled back into the reactors. The fission products that have commercial value are sold and the ones that have no value are returned to the reactors where they absorb spare neutrons to be transmuted to non-radioactive or very low level radioactive elements. By this process there will be no high level radioactive waste. Since some of the reactors will be fast reactors they will produce transuranic elements for enrichment of fuel and also produce radioactive isotopes for medical, research and commercial use.

To summarize, here is a facility that takes water from the ocean and provides for the people of California electricity, fresh water, hydrogen, oxygen, fresh produce, fresh seafood, metals, minerals, ceramics, radioactive isotopes and radioactive preservation service for food. This plant is safe, efficient, quiet and has no waste that is dangerous to the environment and no pollution in the water, soil or the atmosphere.

INTRODUCTION

The two most critical problems to solve for the economic and social future well being of California are environmentally clean energy and fresh water produced at a significantly low cost to the economy. The California Nuclear Green Farm is an engineering concept that can meet these requirements.

Transportation is a major use of energy and a major source of air pollution and carbon dioxide production. According to the California Energy Commission, (CEC) (1) in 1999 there were 22 million gasoline-powered vehicles, 400,000 diesel-powered vehicles and 60,000 other petroleum powered vehicles registered in California. This does not include all the thousands of farm and off road vehicles and machines burning fossil fuel. The on-road gasoline demand is projected to increase from 14 billion gallons in 1999 to 20 billion gallons by 2020, while diesel usage is expected to increase from 2.4 billion gallons per year in 1999 to 3.4 billion gallons per year in 2020. The transportation and work provided by this energy source is critical for the society of California.

Electricity consumption in California is projected by the CEC to increase from 244 thousand GigaWatt hours, (GWh) per year in 1998 to 310 thousand GWh in 2010 with a 2.1% annual increase to 2020. According to the CEC long range forecast the energy sources for production of California's electricity in the year 2010 will be 53% natural gas, Coal 11%, nuclear 9%, hydro 21% and renewables 6%. This means that 64% of our electricity in the year 2010 will be generated by fossil fuel.

According to the CEC natural gas consumption, other than used for generation of electricity, will grow from 14 thousand (millions of therms) per year in 1998 to 16 thousand (millions of therms) in 2010 with about 0.8% annual increase expected.

All this energy consumption by the state of California is greater than most of the countries in the world. All of these projections are based on a significant improvement in efficiency and conservation in the use of energy by Californians. This projected use of energy is critical to the economic and social future of the citizens of California and, of course it has an associated effect on the rest of the country.

As indicated by the CEC projections about 80% of the energy will come from fossil fuels. There are two downsides to this projected use of fossil fuel for this essential energy. One is the effect on the environment and the other is the use of a limited critical energy source. As the other countries of the world continue to increase their use of fossil fuel for their energy needs the competition for this declining resource will bring serious conflicts among future generations. In order to provide the energy needed for the future of California and indeed the whole world alternate energy sources must be utilized. The best engineering solution to this energy problem is nuclear fission.

There are two alternative energy sources to nuclear energy that can play a very small role in meeting the needs of California and the world. While both of these sources do not put harmful elements into the atmosphere and the earth, they are very unsightly and take up an unreasonable amount of space for their productivity. Their energy production is much more expensive than nuclear plants. Wind turbines are very noisy and harmful to the bird populations. Both wind and solar power plants have a very low capacity factor so that the amount of energy production capability must be 5 times higher than the consumer demand and the excess capacity when operating must be stored for use when they are not operating. The best storage system used is pumped storage and this storage demand is far beyond what can be tolerated in California.

Nuclear fission energy is the most economical, practical, clean and safe energy source for the future of California. There is enough nuclear fissile material already mined, processed, and purified, ready to be used in nuclear reactors to meet all of the energy needs of the United States for the next 500 years. This source can meet our needs without mining any more uranium. We also would be able to meet our fossil fuel needs for aviation and manufacturing products from fossil organics with domestic oil sources, so we would not need to rely on foreign oil for our energy for hundreds of years.

The nuclear reactors at these sites would be both water-cooled thermal reactors and liquid metal cooled fast breeder reactors. The water-cooled thermal reactors would be started with fuel made from the stored depleted uranium 238 enriched to about 4% with U235 and plutonium 239 from our retired weapons. The fast breeder reactors would use fuel to start made from the stored depleted uranium enriched with U235 and plutonium 239 from the retired weapons. As time goes on the thermal reactors would be fueled by the natural uranium from the seawater slightly enriched from the reprocessed and recycled transuranic elements. The fast reactors would be refueled from the reprocessed and recycled uranium and plutonium from the spent fuel from both types of reactors.

Only about 35% of the thermal energy from the fission reaction in a nuclear power plant goes into the production of electricity. The other 65% is stored in the water used to cool the steam after it goes through the turbines. This energy can be further utilized to distill fresh water from the seawater. The excess fresh water beyond that used to produce hydrogen would be sold to help meet the freshwater needs of California.

Instead of fossil fuel to power our transportation system we can use hydrogen produced by separating hydrogen and oxygen from water using electricity from nuclear plants. Another process for producing hydrogen from water would use the sulfur iodine process and the high temperature provided by the gas-cooled reactors and liquid metal cooled reactors

Seawater contains all of the elements of the earth so the brine left from the distillation process is a valuable source of certain elements and minerals needed for our industry. Included in these elements is uranium, which will be separated and processed for fueling the reactors in the future.

The California sunshine, the warm fresh water, low cost fertilizer minerals and available low cost electricity can be combined to operate nearby hydroponic farms which can yield many times what ordinary produce farms can per acre

Since the location of these facilities is close to the ocean and there is plenty of warm seawater available this is also a prime location for aquatic farms for the production of seafood. The combination of the warm seawater and cold seawater available can be controlled to make ideal environments for efficient breeding and expedited growing of various aquatic species.

These produce sites provide an ideal situation for recycling. Waste from the hydroponic farm can be processed for feed for the aquatic farm and the waste from the aquatic farm along with some of the minerals from the brine and low cost electricity can be combined to produce fertilizer for the hydroponic farm.

The metallurgical and mineral processing plant would have two divisions. One would process and sell metals and minerals from the seawater brines. The other plant would process and sell the commercial fission products from the spent fuels and radioactive isotopes, made in the fast reactors, for research, industrial and medical use.

All fission products and transuranic isotopes that have no commercial value and recycled isotopes that are shipped back in for reprocessing will be processed into containers that are put into the reactors to use spare neutrons to transmute them to elements that are either non-radioactive or have very low levels of radioactivity and short lives so they can be stored for a short time and safely disposed of in the sea or in the earth with no harm to the environment of life.

In summary the California Nuclear Green Farm is an engineering concept that ultimately uses only seawater from the Pacific Ocean to produce electricity, fresh water, hydrogen for transportation, metals and minerals, farm produce, seafood and commercial radioisotopes for the residents of California without any harmful contamination to the environment and a minimal land use. This would also mean no more mining for uranium or coal, no more drilling for gas and oil and no more tankers coming to our shores.

The Future Energy Requirements for California

Some economists project world economic growth to be at the rate of 3% per year, and say this will double the 1990 output by 2050. Actually a 3% annual growth will make the 2050 output 6 times the 1990 output. There are projections that the world population will increase anywhere from 50% to double by 2050. In any event the use of energy will increase at a very significant rate between now and 2050. At this time 96% of the worlds commercial energy is from fossil fuels and this will not have a significant reduction in the next one or two decades.

California has the capability of significantly reducing the use of fossil fuels over the next two decades and can be almost free of fossil fuel usage by 2050. If we use the projected rate of the California Energy Commission the energy use in 2050 will be about double the use in the year 2000. Figure 1 shows the energy requirements for California through 2050 based upon the projections of The California Energy Commission. [1]

A 50 Year Plan For California Energy With Conversion To Nonpolluting Sources

Data in Billions of KiloWatthours

Year	Elec Gas/Oil	Elec Hydro	Elec Imports	Elec Nuc	Elec Coal	Elec Other	Nat Gas	Hyww/Rail Petr.	Hyww/Rail Nuc	Total All	Total Nuc
2000	96	28	70	37	29	45	345	750	0	1400	37
2010	111	28	85	44	34	60	360	859	16	1597	60
2020	118	28	103	53	36	66	360	765	160	1689	213
2030	110	28	125	271	24	87	285	650	350	1880	621
2040	76	28	153	343	23	112	165	517	633	2059	976
2050	0	28	186	529	0	142	0	0	1300	2185	1829

Note: While zero is a goal, achieving it is probably impossible

FIGURE 1. 50 YEAR PLAN FOR CALIFORNIA ENERGY REQ1UIREMENTS

The assumptions for the plan are that by the year 2050: 1. All the requirements for electrical production, which had been met with fossil fuel and old nuclear plants, as they are phased out, will be met by the California Nuclear Green Farms, 2. All the on road transportation energy will be met by hydrogen produced by the Nuclear Green Farms as petroleum production is phased down and 3. The energy needs that had been met with natural gas will be met by the Nuclear Green Farm as the use of natural gas is phased down. It would be assumed that the current percentage, 6%, of electrical energy produced by renewables would be maintained through 2050. It is assumed that the level, 28 thousand GWh, of Energy produced by hydro in 2010 will be maintained through 2050. It is assumed that the first Nuclear Green Farm will go on line in 2015.

Figure 2 shows the plan for converting to the nuclear green farms for electrical energy, transportation, heating & industrial and the amount to be provided by imports, hydro and other renewables. It also shows the number of nuclear plants and number of nuclear green farms needed and their schedule.

Californi Energy Conversion to California Nuclear Green Farm by 2050

Year	2000	2010	2020	2030	2040	2050
Total Energy Required	1400	1597	1689	1880	2059	2185
Total Nuclear Energy Required For Scheduled Fossil Replacement	37	44	53	271	343	528
Total Nuclear Energy Required to Prod Elec & H2 for Transportation	0	16	16 0	350	633	1300
Total Energy From Other Sources Imported & Renewables	143	173	197	240	293	356
Total Nuclear Energy	37	60	213	621	976	1829
Number of 1200 MegaWatt nuclear Reactors Needed at 85 %Capacity Factor	4	7	24	6 9	109	203
Number of CA Nuc. Green Farms Needed*		7	8	10	10	18

*Twelve 1200 megaWatt reactors per California Nuclear Green Farm
Units in billions of kiloWatthours

Figure 2. Fifty Year Plan For California Nuclear Green Farms

Figure 3. shows the rate of transition from fossil fuel to hydrogen fuel for road and rail transportation. This is a typical societal change, a parabolic transition curve of percentage of the new versus time. Note: it starts out with a very slight change, only 5% in the first ten years from 2000 to 2010, but 30% from 2040 to 2050.

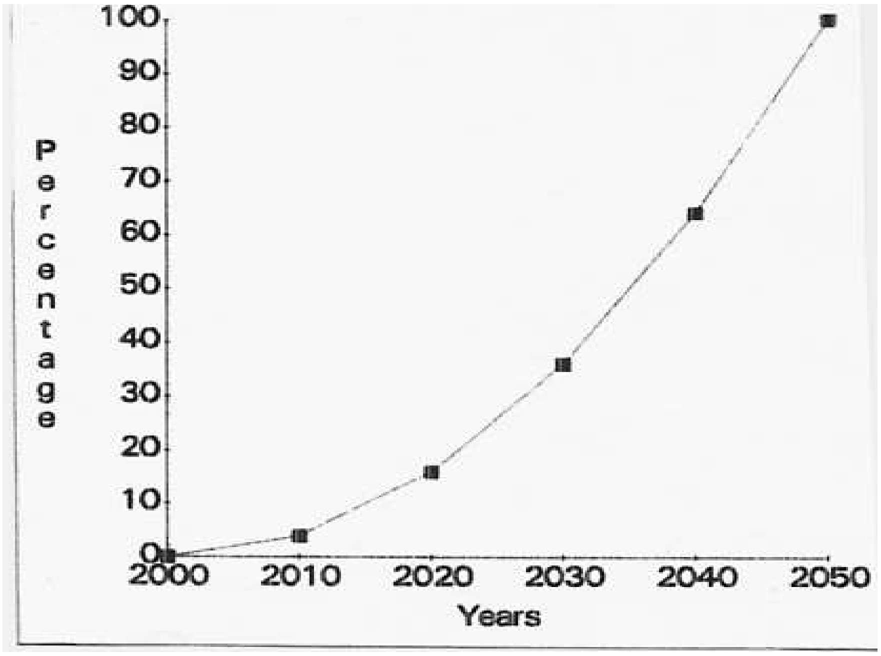

Figure 3 Transition Curve Fossil Fuel to Hydrogen Fuel

Where To Locate Nuclear Green Farms

The Nuclear Green Farms must be located close enough to the coast to have the seawater pumped in and out at a reasonable cost. They should be located at sites along the length of the state to minimize the length of the transmission lines in the grid. They should be located just inside the first hills from the coastline in a current fertile agricultural area so it would be practical to surround the nuclear power, fresh water and hydrogen production complex with hydroponic and aquatic farms.

The total area of the nuclear power, fresh water, hydrogen production, isotope production, fuel recycling and isotopic waste transmuting complex is estimated to be about two square miles. All these operations would be inside the security area and all personnel would be security certified, security and safety trained and technically and operationally qualified.

Integrated Surrounding Facilities of The Nuclear Green Farm

Other activities located close, to take advantage of the products of the core complex, would surround the complex in the environmentally beneficial area. The closest would be the plants involved in separating minerals and metals from the cooling water and brine from the fresh water production plant. Imbedded with these plants would be the businesses involved in making ceramic and metal products that could take advantage of process heat, low cost electricity, hydrogen and oxygen and refined metals and minerals.

Spread out in the surrounding area would be the hydroponic farms, aquatic farms, and fertilizer and feed producers for the hydroponic and aquatic farms. These facilities could extend out 3 to 5 miles and still take advantage of the output of the core complex.

Fresh Water From Seawater
Nuclear power plants use less than 50% of their thermal energy to produce electricity. The balance of the thermal energy can be used in conjunction with excess electricity to produce fresh water from the seawater that cools the power turbine condensers. California is running low on fresh water and can take advantage of this source. The usage of fresh water by California is shown in Figure 4. This shows a total of 38 billion, 900 million gallons per day total for the year 2000.

California Fresh Water Usage Year 2000

USGS Estimated California Fresh Water Usage Year 2000

Organization Served	Usage Million Gallons/Day
Public Service (Fire, Parks, Streets, etc.)	6,120
Domestic	286
Irrigation	30,500
Livestock	409
Aqua Culture	537
Industrial	188
Mining	153
Total	38,900

Figure 4. California Fresh Water Usage Year 2000 Estimated By USGS, [2]

It is estimated that the total fresh water production from all of the Nuclear Green Farms would be 1.5 billion gallons per day based upon 30,000 gallons per minute coolant exhausted above 212 degrees F for each reactor generating electricity at a 80% capacity factor and 50% efficiency in desalination. This probably would provide most of the domestic, aquaculture, hydroponic farming and industrial needs.

Seawater desalination is a significant source of fresh water in arid parts of the world. Saudi Arabia obtains 70% of their fresh water from desalination of seawater, and expects this to increase to 90% by 2010. Many other Middle Eastern Countries also obtain significant amounts of fresh water from seawater. Most of the Middle Eastern Countries use the multi-stage flash distillation process for their desalination of seawater. They all

Figure 5. Seawater Desalination

have an excess of natural gas coming from their oil wells to heat the seawater for distillation. They used to just burn this gas in the air to get rid of it.

Tampa Bay Water Company in Florida uses excess electricity produced at the Tampa Bay Electric plant to pump seawater through the reverse osmosis process to desalinate it and produce fresh water. This desalination plant produces over 35 million gallons per day. Some of these desalination plants and schematics of the two processes are shown in figure 5. [3], [4], [5] [6]

Middle Eastern Countries that have little or no sources of fresh water and do not have huge sources of oil and gas are planning to use nuclear desalination in the future. [7]

Some of California's government agencies have made studies of desalination for potable water for the state. [8]

Professor James Klausner and researchers of the University of Florida have developed a new desalination process under a funding by DOE. The process called a mass diffusion process. Pumps move saltwater through a heater and spray it into the top of a diffusion tower – a column packed with polyethylene with a large surface area. Pumps at the bottom pump warm air up through the column and the moist air goes to a condenser. This system can operate with water at a much lower temperature than the flash distillation process. [23] This is an ideal process for the California Nuclear Green Farm.

Hydrogen Production For Transportation

There are several reasons why California must rely on a hydrogen fuel system for transportation. One is that we must take responsibility for reducing the emission of greenhouse gases and harmful contamination produced by fossil fueled transportation. Two is that the escalating cost of fossil fuels will be devastating to the California economy. Three is that continued growing use of fossil fuels worldwide will very soon deplete the sources. A necessary level must be maintained for the future of the world's air transportation.

The only way to produce hydrogen in a manner that does not have an adverse effect on the environment is by separating water into hydrogen and oxygen. Hydrogen made by separating it from hydrocarbons leaves carbon dioxide as a waste product without using the energy produced by oxidizing the carbon. There are two processes being developed today for splitting water into hydrogen and oxygen. One is by electrolysis and the other is the sulfur iodine process. The ideal source of energy for both of these processes is nuclear fission reactors. Both of these processes have about 50% thermal efficiency. and will cost from $1.00 to $2.00 per Kg. This is equivalent to $1.00 to $2.00 per gallon of gasoline. One Kg of hydrogen provides the approximate mileage as 1 gallon of gasoline.

Since both processes can yield pure hydrogen and oxygen it may be practical to contain both to use for transportation power. If only hydrogen is used in fuel cells the oxygen used in the cell must be obtained from the air pumped in to the cell. Fuel cells are easily contaminated by hydrocarbon and other particles such as pollen and dust contaminants in the air. While it would mean refueling with both hydrogen and oxygen, using the two in fuel cells and in combustion engines may be more efficient than combining hydrogen with oxygen in the pressurized air.

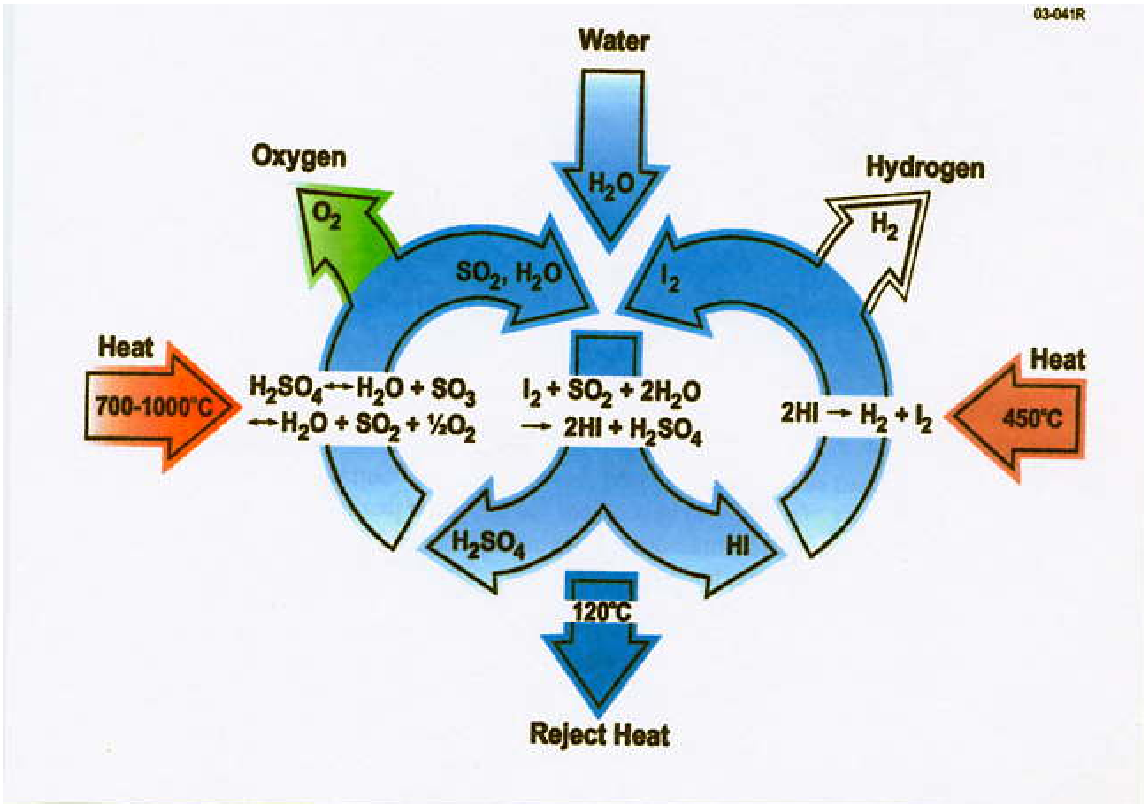

Figure 6. Iodine-Sulfur Process for Thermochemical Production of Hydrogen

The sulfur iodine process is illustrated in figure 6. [9] This process requires high temperatures, 900C to support the reaction between H_2SO_4 and H_2O to drive off oxygen. Iodine is added to the $SO_2 + 2H_2O$ yielding 2HI + H_2SO_4. The hydrogen iodide goes to a separate chamber held at 450C where hydrogen and iodine are separated, and H_2SO_4 is recycled back to the first chamber. The oxygen and hydrogen are contained separately

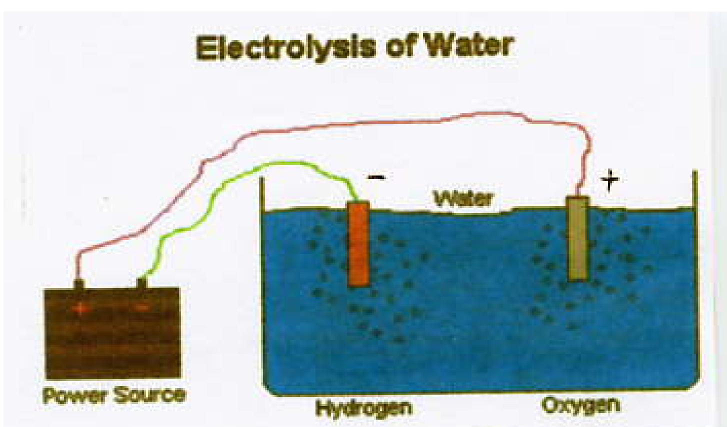

Figure 7. Electrolysis for Production of Hydrogen

A high temperature reactor must be developed for providing the heat required for the sulfur iodine process. DOE has had programs going for the past few years to develop the high temperature reactors needed. Three options are available: A gas cooled reactor, a molten salt cooled reactor and a liquid metal cooled reactor. The Sulfur Iodine Hydrogen Production Process is also under development. The major problem to be overcome is the materials required to withstand the sulfur compounds at the high temperatures. This program will be carried out under the new DOE Nuclear Hydrogen Initiative at The Idaho National Laboratory with the assistance of the other national laboratories, universities and industry. [10] It is much easier to design, build and operate water cooled reactors

The amount of California's energy requirement for production of hydrogen may be low in the totals shown in figure 2. if the projections by Paul Kruger are required by 2050.[11]

Incorporating the nuclear/hydrogen cycle into the California energy program will prove a great benefit for the environment and economy.

Hydroponic Farming

The fresh water, hot and cold along with the low cost electricity for pumping and lighting make the area surrounding the nuclear green farm core an ideal place for hydroponic farming. Also, minerals gleaned from the seawater brine can be a source for many of the required hydroponic nutrients.

Europe has been a leader in hydroponic farming and it is growing fast in Asia. There is over 30,000 acres of hydroponic farming worldwide but we have only 800 acres in the U. S. California is an excellent location for hydroponic farming. Lots of sunshine and warm to mild, fairly dry climate make ideal conditions.

Hydroponic farming has a technical edge over organic farming and irrigated truck farming. Plant root hairs can only take up inorganic mineral salts in water solution. In organic farming bacteria must be relied on to convert organic manure fertilizers and soil minerals into nutrients in the water in the soil. Truck farms must also use high quantities of water in the soil to dissolve the nutrients and provide the solution for the root hairs to take up. For this reason hydroponic farming uses only 25% of the fresh water that is used by organic farming and truck farming. Recycling most of the hydroponic water can also make it less soil contaminating than irrigated soil. Consider high mineral contamination of the California irrigation runoff we now have to deal with. The advantages of hydroponic farming versus organic farming and conventional truck farming produce are illustrated in figure 8. Some of the hydroponic farming systems are also shown in figure 8. [12,13,14]

Aquatic Farming

Aquatic farming, sometimes called aquaculture is one of the fastest growing food-crop industries in the world. California is an ideal location for aquatic farming and the California Nuclear Green Farm is an ideal center for provision of all elements required for profitable aquaculture.

The nuclear green farm core system can provide fresh water and seawater at various temperatures, various salinities and controlled flow for creating the ideal environment for spawning, hatching and growing both fresh water and ocean seafood. Low cost electricity for pumping and lighting can also be a benefit. Waste from the hydroponic farms can also be recycled for food for the aquatic farms.

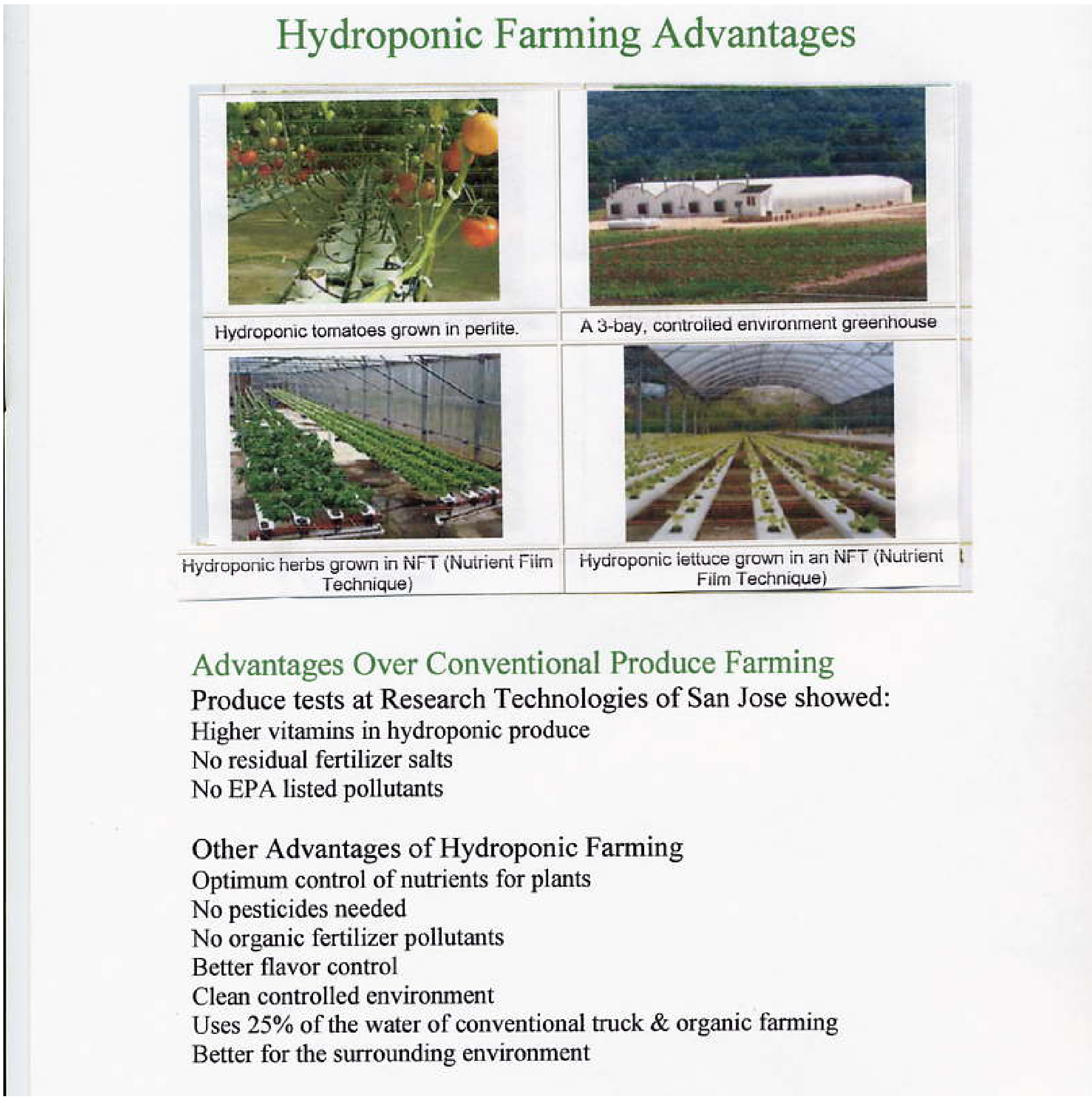

Figure 8. Advantages of Hydroponic Farming Versus Conventional Farming

Aquaculture is the fastest growing sector in the world economy. It increased 11% per year in 2003. World aquatic farm production was 13 million tons in 1990 and jumped to 31 million tons in 1998. World's fish farming is expected to overtake cattle ranching worldwide by 2010. Both world ocean fishing and cattle ranching leveled off since 1990.

Aquatic farming is good for the environment when compared to cattle farming. Cattle require 7Kg of grain to produce 1 Kg of live weight. Fish only require 2Kg of grain to produce 1Kg of live weight. It takes 1,000 tons of water to produce 1 ton of grain. [15]

According to the USDA Western Region Aquaculture Industry Situation and outlook report, Volume 6, California had an aquaculture production of 71.7 million dollars in 1999. [17] While oyster production had dominated California's aquaculture output for years, it started dropping in 1999 and was overtaken by catfish in the year 2002. Oyster production appears to be on an upward trend again. Tilapia has a great potential for a California crop. [16] Figure 9 shows the California aquaculture output for various types grown from 1986 through 1999 with future projections for the year 2004 taken from the USDA Western Region Aquaculture Report for California. [17[

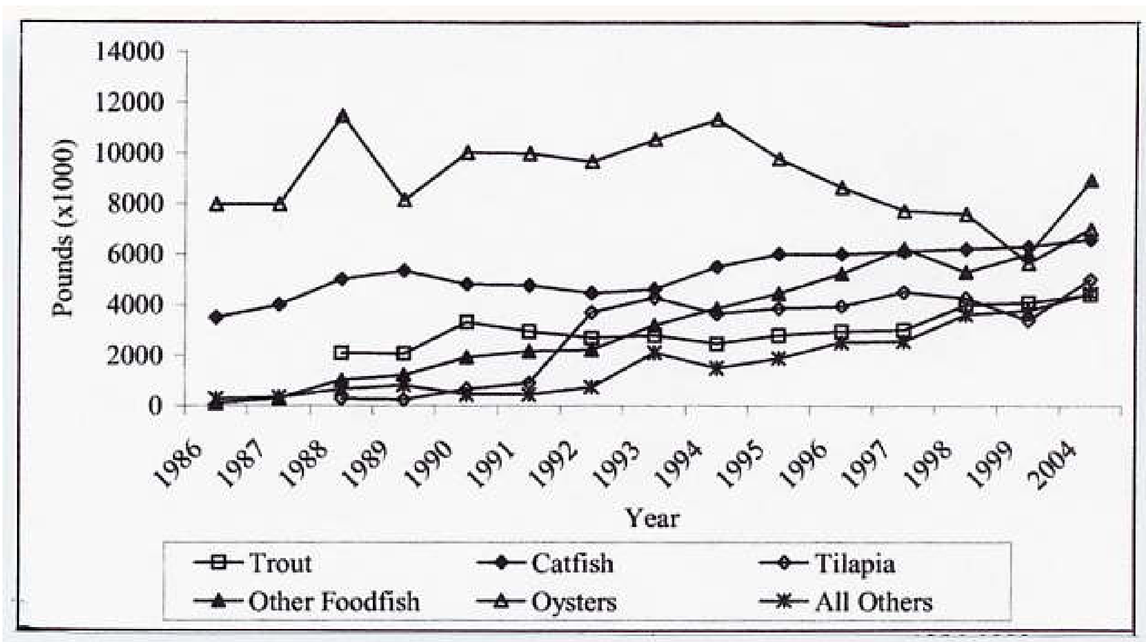

Figure 9. California Aquaculture for Various Types Grown From 1986-1999
With Future Projections for The Year 2004

Recycling Hydroponic and Aquatic Farm Waste
Besides grain, some of the waste from the farm produce can be made into nutrients for the aquatic farm. In the aquatic farm, 1 ton of live fish produces.280 grams of ammonia Per day. [18] This can be combined with minerals from the seawater to produce fertilizer nutrients for the hydroponic farms. Also, waste from the fish cleaning & cutting can be recycled for the hydroponic farms. EPA requirements will demand that any water returned to the environment be properly treated. The low cost electricity and water treatment capabilities will be a special asset for these farms.

Recycling Spent Nuclear Fuel
Nuclear energy is used to produce heat that is used to produce steam that powers steam turbines that turn generators to produce electricity. This heat is generated by uranium atoms absorbing neutrons and splitting, called fissioning, thus releasing energy in the form of heat. The various atoms created when the uranium atoms split are called fission

products. Each load of nuclear fuel only has about 1% of the uranium fissioned when it is removed from the reactor for replacement. This amounts to approximately 1 gram of fission products per megawatt day of electricity generated.

Spent Nuclear Fuel Components

Spent nuclear fuel to be recycled is removed from the stainless steel support structure. One metric ton, 1000 kg, of spent nuclear fuel rods consists of the elements and isotopes as shown in figure 10. These elements, particularly metallic elements are generally in the oxide form. As indicated in figure 10 the spent fuel components can be segregated into 8 categories for purposes of separation, recycling, commercialization and transmutation for low level, short life, waste storage. Isotopic data for figure 10 was provided by email message from Wu Tang of General Electric Company Nuclear Engineering and the Chart of The Nuclides by Knolls Atomic Power Laboratory. [19], [20] The spent fuel isotope list provided by Wu Tang was based upon one metric ton of original fuel enriched 3.2 weight % discharged with exposure of 33 gWd/ton and aged 50 years. Most of the isotopes would be of the same quantity after aging only one or two years, but some minute quantities would be different. It is assumed that the spent fuel would be taken from the reactor and stored for one or two years in a vessel with a heat exchanger for the flow of salt water to be warmed by the decay heat for desalination.

The first group of elements to be separated would be the actinides, which consists of the major part of the spent fuel. The actinides would be recycled back into new fuel with proper adjustment of the enrichment. Slight amounts of the highly radioactive fission products would be carried through with the actinides so they would have to remain inside the shielded facility and could not be considered for weapons material.

The next separation would be the highly radioactive heat producing isotopes, primarily strontium90 and cesium137 that would be used for commercial heat sources. They could be used in the nuclear green farm as a source of heat for desalination

The next group to be separated would be the elements with long life, highly radioactive isotopes to be transmuted to low level short-lived isotopes for waste storage.

The nest group to be separated would be the elements with natural radioisotopes plus some fission products that have low levels of radioactivity compared with the naturally radioactive isotopes of the elements. These can be stored or sold commercially for the use of the metal.

Spent Fuel Components

Actinides 966,000 gr

Th239 0.03 gr Th232 0.006 gr U232 0.001 gr U233 0.009 gr U234 225 gr U235 7,974grU236 3,971 gr U238 944,100 gr
Np237 503 gr Pu238 95.3 gr Pu239 5,025 gr Pu240 2,302gr
Pu241 110.5 gr Pu242 454.1 gr Pu244 0.02 gr Am241 1,084 gr Am242m 0.5 gr Am243 85.2gr
Cm242 0.001 gr Cm243 0.1 gr Cm244 3.52 gr Cm245 0.85 gr Cm246 0.1 gr

Fuel Cladding Zirconium 3,942 gr

Zr90 391.1 gr Zr91 589.8 gr Zr92 639.2 gr Zr93 718.1 gr RA beta 0.080 gamma 0.030 Zr94 740.5 gr
Zr96 7987 gr

Technetium for Commercial Alloy Use 770 gr

Tc98 0.006 gr Tc99 770.2 gr

Highly Radioactive Heat Sources 2,317 gr

Sr86 0.4 gr Sr87 0.003 gr Sr88 349.5 gr Sr90 391.1 gr 0.93 Watts/gr
Cs133 Stable 1,125 gr Cs135 beta 300 gr Cs137 Beta Gamma 0.42 Watts/gr 377 gr

Total Mass of Stable Elements 16,869 gr

Li 0.00015 gr Ge 0.65 gr As 0.2 gr Br 21.6 gr Mo 3,345 gr Ru 2,177 Ag 76.2 gr
Cd 107.8 In 2.6 gr Xe 5,332 gr Ba 2,311 gr Ce 2,366 Pr 1,115 gr Tb 2.6 gr Dy 1.4 gr Er 0.06 gr Tm 0.000056 gr

Total Mass of Stable Elements with Natural RA Isotopes 6,098 gr

Rb85 stable 121 gr Rb 87 beta 0.273 244 gr Te122 stable 0.5 gr Te1230 stable 0..08 gr
Te124 stable 0.4 gr Te125stable 18.8 gr Te126 stable 0.7 gr Te128 stable 110.1 gr
Te130 stable 354 gr La 138 beta0.26 gamma 1.46 0.005 gr La 139 stable 1,215 gr
Nd142 stable 25 gr Nd143 stable 780.2 gr Nd144 a 1.83 1,326 gr Nd145 a? 672 gr

Element with Natural Radioisotopes + Fission Isotope 800 gr

Sm Fis 0.0.007 gr Sm 147 nat 202 gr Sm148 nat 168 gr Sm149 nat 2.8 gr
Sm150 stable 151 gr Sm151 Fis 4gr Sm152 stable 0.002 gr Sm154 Stable 37.3 gr

Total Mass of Elements With Long Life, Highly Radioactive Isotopes To Be Separated & Transmuted 3,204 gr

Eu 111 gr Be 0.000015 gr Se 56 gr Kr 346 gr Y 456 gr Nb 0.0174 gr Rh 467 gr Pd 1,390 gr Sn 90 gr Sb 18 gr I 234 gr Ho 0.14 gr

Total 1 Metric ton 1 ,000,000 gr

Figure 10 Spent Fuel Components Grouped For Separation

The next separation would be the zirconium isotopes, which would be recycled back into cladding robotically, or in a controlled facility because of the low level radioactivity of Zr93 isotope, which makes up 18% of the total zirconium metal.

The nest separation would be the stable elements with naturally radioactive isotopes. These elements would be the same as the natural elements and could be sold commercially.

The next group would be technetium, which would be sold commercially for alloying. [21]

The final group left would be the stable elements that have no radioactive isotopes. The elements in this group can be separated individually with metallurgical processes, later, to yield the commercial metals.

The commercial sale of the fission products will help offset the separation costs of the spent nuclear fuel.

For recycling the fuel the steel components are removed mechanically and recycled for reuse. Because the steel has absorbed neutrons it contains some radioactive isotopes, therefore, it must be recycled in a robotic, shielded facility like the spent fuel.

Separation Processes
The spent fuel rods must be put in solution, either chemically by acid solution or by an electrochemical process in a high temperature salt bath. The acid chemical separation called the Purex Process and similar ones have been used for the past 60 years for the separation of the fission products and the actinides from the uranium. The uranium and the plutonium have been reused for fuel in Europe and are just now getting ready for reuse in the United States and Japan. Figure 11 shows some of the typical equipment used for this process. This type of equipment was used in the Rocky Flats Plant and in other separation plants such as Hanford and Savanna River. In the future the separation processes will be carried out robotically as that technology continues to progress. This will continually reduce the cost of recycling fuel.

The electrochemical, pyro-process for recycling fuel has been under development at The Argonne National Laboratory in the U. S. and at the Institute for Transuranium Elements in Germany for the past few years with excellent success in separating the various elements of the spent fuel. Results of the work in both laboratories are shown in figure 13. Electrorefining of the various elements in the spent fuel allows any one element to be separated out or they can be grouped together. In order to have a process that is immune to proliferation of weapons grade plutonium the nuclear green farm will keep the actinides and some of the fission products with the uranium so that it is impossible to remove a weapons grade product from the site.

The nuclear reactors of the nuclear green farm will be of two types, thermal and fast breeder. This is essential for the continued use of natural uranium from the seawater that must be enriched by the plutonium produced in the breeder reactors and the thermal reactors. Once equilibrium is reached, each green farm should be self sufficient in the required ratios of plutonium and uranium isotopes needed for continuing operation.

From that point on no fuel materials would have to be shipped in or out of each nuclear green farm.

How Much Low Level Nuclear Waste Would Have To Be Stored?

As can be seen from figure 10 there is 3,204 grams of long life, highly radioactive isotopes to be separated, transmuted to low level short life isotopes and stored This 3,204 grams results from production of 33,000 megaWatt days (thermal). This means the waste to be transmuted to short lived low level isotopes for storage is 3,204 gr per metric ton of used fuel producing 86,500 KWhr. of electricity.. .

Based upon 1500 billion kilowatt Hrs. of energy usage by California for the year 2005 this would equal only 17.34 metric tons, 38.35 English tons, of low-level short-lived nuclear waste to store for the states entire years energy usage. If we divide this by 35 million, the states rough population for that year it comes to 0nly 0.5 gram of waste for every person.

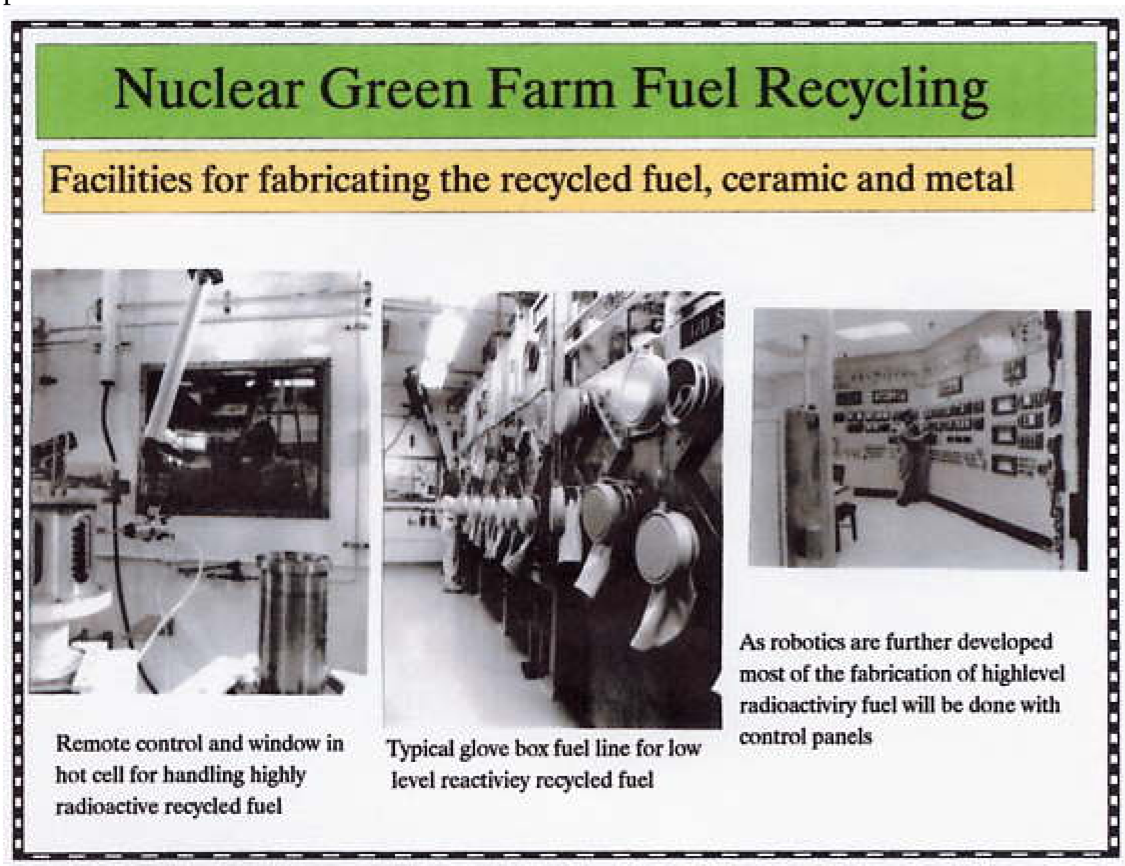

Figure 11. Typical equipment used in chemical recycling spent fuel

If we consider the volume of waste it would amount to about the size of one M&M candy for each person, as shown in figure 12, for all of their energy usage including their heating electrical devices and all the state spends on services and all spent on providing all their commercial services and manufacturing goods for sale at home and abroad. No other energy system can come close to this kind of environmental friendliness.

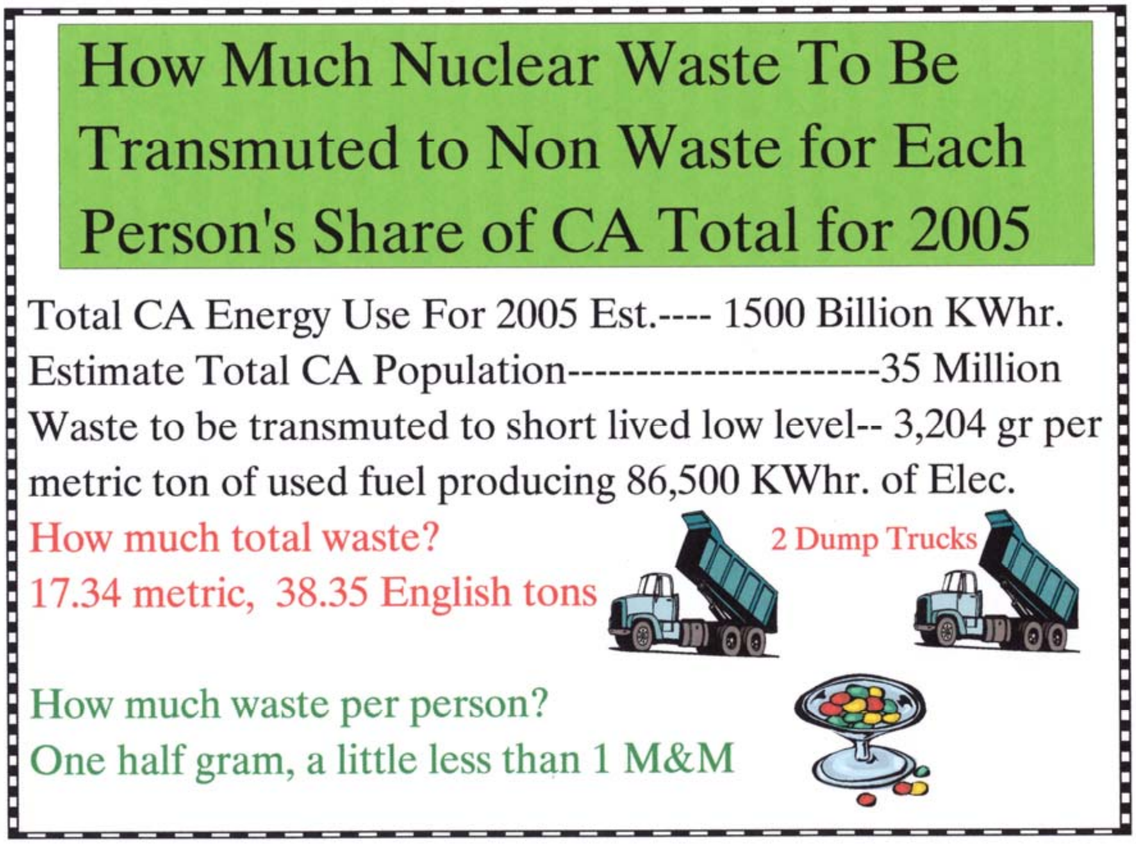

Figure 12 How Much Nuclear Waste Per Person & Total for State in 2005

Producing Other Useful Radioisotopes
Radioisotopes are routinely used by our civilized societies today for the good of mankind. In addition to the fission product radioisotopes for commercial use mentioned above other radioactive isotopes are produced for many uses
Nuclear medicine uses hundreds of different radioisotopes every year
"Nuclear medicine uses radiation to provide diagnostic information about the functioning of a person's specific organs, or to treat them. Diagnostic procedures are now routine Radiotherapy can be used to treat some medical conditions, especially cancer, using radiation to weaken or destroy particular targeted cells.
Millions of nuclear medicine procedures are performed each year, and demand for radioisotopes is increasing rapidly". [22]

The United States,. DOE closed down the last fast reactor that could be used to produce special radioactive isotopes so all radioisotopes used in this country for medical, research and commercial purposes must be produced by foreign sources.

The reactors and the separation facilities of the California Nuclear Green Farms will provide the capability to produce these critical products while creating jobs for citizens of California.

Figure 13 New Electro-Pyrometallurgical Separation Process Development

Estimated Cost
It is estimated that installation cost of the electrical power systems part of the California Nuclear Green Farm will average about $1,000 per kilowatt. Undoubtedly, The original cost will run above $2,500 per kilowatt, but, with a consistent design, a reasonable learning curve over 40 years and with evolutionary development the cost should drop dramatically for the $1,000 average. With recycling and the possible commercial values of fission products, radioactive isotopes, minerals and metals and fresh water coming from the nuclear source it is expected that the energy cost will be less than 3 mils per kilowatt hr.

Continuing Development
The technology required to develop and build the California Nuclear Green Farms is already available. Continuing development will be integrated into the nuclear plant, the fuel recycling and reprocessing, particularly robotic development, the desalination processes, the hydrogen production processes, the minerals and metals recovery processes, including recovering uranium from the sea salts. New technologies in hydroponic farming and aquatic farming are also expected. All of these future developments are expected to improve the efficiency and cost of building and operating all of the facilities.

Summary
The California Nuclear Green Farms concept is a fifty-year plan to provide the development of a system that can provide all of the energy needed for the future of California. The California Nuclear Green Farm can provide Electrical energy, fresh water from seawater, hydrogen and oxygen from water for transportation, energy and fresh water hot or cold for ideal hydroponic farming, fresh and salt water hot and cold for ideal aquatic farming, fertilizer, minerals, metals, and radioisotopes. When they are running at equilibrium the uranium required for the reactor fuel can be separated from the seawater used for cooling. This can all be achieved with complete safety, with no contamination to the atmosphere or the land and with no high-level long life radioactive waste to dispose of. This source of energy for California will be at less cost than any other source including coal, gas, petroleum and all of the renewables.

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