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NUCLEAR HYDROGEN AND CAPTURED CARBON DIOXIDE FOR ALTERNATIVE LIQUID FUELS

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A preliminary study was conducted which considered capturing carbon dioxide from fossil-fired power plants and combining it with nuclear hydrogen in order to produce alternative liquid fuels for transportation.

Among the alternative liquid hydrocarbons which can be used as fuel in internal combustion engines, the two that are most promising are methanol and ethanol. We choose these two because they are relatively simple compounds and can be used with only minor changes to the fuel systems of most automobiles today. In fact, there are some vehicles today which can operate with any combination of conventional gasoline, ethanol, or methanol.

We estimated the quantity of carbon dioxide that would be emitted by fossil-fired power plants in the future. We then use this information to determine how much ethanol or methanol can be created if enough hydrogen is made available. Using the quantity of hydrogen required and the thermodynamics of the reactions involved, we estimate the nuclear power that would be needed to produce the liquid fuel. This amount of liquid fuel is then used to estimate the effect of such a program on conventional gasoline usage, need for foreign oil, and decrease in CO_2 emissions.

I. INTRODUCTION

I.A. Motivation

The need for the development of alternative forms of energy has come to the forefront of both the scientific and political communities in the United States. There are multiple reasons for this interest. The population and economic growth of China and India, as well as other areas, and the increase in energy usage per person worldwide are expected to triple total global energy demand by the year 2050.[1, 9] This increase in energy demand is certain to raise the cost of energy over the next few decades. Although estimates vary as to the availability of natural resources, it is a certainty that only a finite amount of fossil fuels – most notably conventional crude – exists. Thus, it seems imperative that research into possible alternative energy sources be conducted. This study focuses on alternative liquid fuels for internal combustion engines.

Another major reason that the United States should engage in this research is of global consequence. Global warming has been linked to the amount of carbon dioxide emitted into the atmosphere. There is a strong movement worldwide to try to reduce the amount of carbon dioxide emitted into the atmosphere. If it is true that carbon dioxide emissions are a major factor in the global warming trends, then the increase in energy demand will only cause more problems unless alternative energy sources are found that will decrease the CO_2 emissions. In 2002, public electricity and heat generation and road transportation accounted for 52.5% of total CO_2 emissions worldwide and 66.4% of total CO_2 emissions in the United States.[2, 9]

The final motivation for this study involves national security in the United States. Being as energy independent as possible is in the national interest. This is especially true since a large portion of the oil used throughout the world originates in the highly volatile Middle East. In 2002, more than 58% of the petroleum used in the U.S. was imported.[6, 9] Decreasing this dependence on foreign oil will only strengthen the US energy infrastructure.

Although this work focuses chiefly on the civilian transportation sector, it should be noted that there has been a renewed interest in using synthetic fuels for ships and other military uses.[13] The work by Bogart et al was not available at the time the study was conducted for this current paper.

I.B. Overview of Relevant Conditions

I.B.1. Atmospheric Conditions

It is estimated that the CO_2 concentration in the atmosphere in the year 1000 AD was less than 280 parts per million by volume (ppmv). This concentration was maintained at nearly a constant level until some time in the 19th century. Since then, CO_2 concentration has risen steadily to the present concentration of about 380 ppmv. This rise coincides with the increase in industrial activity marked by the industrial revolution. This data is shown graphically in Figure 1.[2, 9]

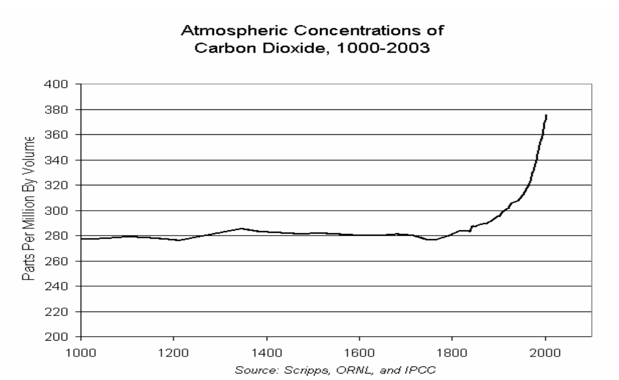

Fig. 1. Plot of atmospheric CO_2 from 1000 AD until 2003 AD.

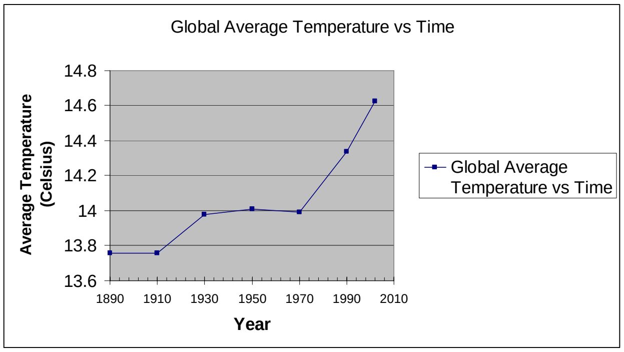

Fig. 2. Plot of global average temperature vs. time for the period 1890-2002.

The average global temperature has increased by nearly one degree Celsius since the late 19th century. This data, shown in Figure 2, when combined with the data in Figure 1, lends credibility to the theory that the increase in atmospheric CO_2 concentration is at least partly responsible for global warming.

The data presented in Figures 1 and 2 summarize the atmospheric conditions that compel us to try to find alternative forms of fuels that emit less CO_2 into the atmosphere.

I.B.1. Energy and Infrastructure Conditions

The current political and scientific trends are to promote what is generally termed the 'hydrogen economy'. This refers to an energy infrastructure that would support the use of hydrogen as a fuel without the unwanted side effects of greenhouse gas (GHG) emissions associated with fossil fuels and without the public relations issues associated with nuclear waste.

However, hydrogen does not exist in nature in a form that is useful for energy production. Another issue with pure hydrogen involves storage. In its gaseous state, hydrogen has a very low volumetric energy density. As a liquid, either very low temperatures or very high pressures are required.

Another issue that is currently at the forefront of the hydrogen energy transition is that nearly all the automobiles used today are powered by internal combustion engines (ICEs). Even if hydrogen were available as a fuel, converting the existing infrastructure to a state where the fuel could be used would take years, if not decades. Therefore, providing a fuel that can be used in current autos is of paramount importance. This is the motivation for researching alternative liquid hydrocarbons.

II. ENERGY USAGE, FUTURE PROJECTIONS, AND CO_2 EMISSIONS

Initially, when preparing to conduct this research, the only apparent energy consumption required is that energy which is used for transportation, which is currently derived chiefly from petroleum. However, the connections among the different types of energy used throughout the world are very strong. This may be even more so in the scenario that is proposed in this work. For example, the Department of Energy (DOE) classifies energy use by source (oil, natural gas, nuclear, etc.). Nuclear power is used chiefly in order to produce electricity. However, in our scenario, the nuclear energy production would contribute directly to transportation. Therefore, we chose to list all the major contributors to energy usage and the projections related to them. These energy usage quantities are then used to determine the fraction of oil that could be replaced both worldwide and in the United States alone.

II.A. Worldwide

II.A.1.Energy Usage and Projections

Each year, the United States Department of Energy's International Energy Outlook (IEO) produces a report that details energy usage for the year. The report breaks total energy usage down in different manners. Using this report, historical trends in energy usage can be calculated. Total primary energy usage throughout the world increased by more than 18% between 1990 and 2002.[5, 9] This amounts to an average of about 1.5% per year.

In this same report, projections are set forth to attempt to predict future energy usage. Three different scenarios are used: reference, low economic growth, and high economic growth. The projected growth in total energy usage from the year 2002 to the year 2025 is 56.7%, 42.4%, and 72.1%, respectively, for the three cases.[5, 9] Of particular interest to this study are numbers related to fossil fuels, i.e., oil, natural gas, and coal. The reference case scenario predicts increases of 52.8%, 70.3%, and 59.1% for these fuels.[5, 9] Tables I, II, and III present the data for the year 2002 and projections for the year 2025 for the various scenarios.

TABLE I. Reference Case World Energy Usage and Projections (MJ). Data taken from reference 5.

Energy Source	2002	2025	% Change
Oil	1.68E+14	2.57E+14	52.7
Natural Gas	1.00E+14	1.71E+14	70.3
Coal	1.03 E+14	1.65 E+14	59.1
Nuclear	2.84 E+13	3.60 E+13	26.8
Other	3.39 E+13	5.16 E+13	52.3
TOTAL	**4.34 E+14**	**6.80 E+14**	**56.6**

TABLE II. Low Economic Growth Case World Energy Usage and Projections (MJ). Data taken from reference 5.

Energy Source	2002	2025	% Change
Oil	1.68E+14	2.32E+14	37.9
Natural Gas	1.00E+14	1.52E+14	51.8
Coal	1.03 E+14	1.52 E+14	46.6
Nuclear	2.84 E+13	3.60 E+13	26.8
Other	3.39 E+13	4.63 E+13	36.8
TOTAL	**4.34 E+14**	**6.18 E+14**	**42.4**

TABLE III. High Economic Growth Case World Energy Usage and Projections (MJ). Data taken from reference 5.

Energy Source	2002	2025	% Change
Oil	1.68E+14	2.85E+14	69.4
Natural Gas	1.00E+14	1.90E+14	89.3
Coal	1.03 E+14	1.82E+14	75.6
Nuclear	2.84 E+13	3.60E+13	26.8
Other	3.39 E+13	5.44E+13	60.7
TOTAL	**4.34 E+14**	**7.47E+14**	**72.1**

In 2002, approximately 7.30 billion barrels of conventional gasoline was used for road transport. Each barrel of gasoline contains approximately 5140 MJ of energy. This equates to about 3.75×10^{13} MJ of energy in the form of conventional gasoline that was used for road transport in the year 2002.[6, 9] The assumption for this work is that the energy needed from a replacement for conventional gasoline is one-to-one. In other words, if we want to replace 100% of the conventional gasoline used in 2002 with an alternative fuel, we must have enough of the alternative to produce 3.75×10^{13} MJ of energy. The rationale for this is that there are differing opinions on the efficiency with which the energy from the alternative fuels can be utilized.

II.A.2.CO_2 Emissions

It is estimated that about 24.1 billion metric tons of CO_2 was emitted by various processes performed by humankind in the year 2002. Of this amount, approximately 8.51 billion metric tons was emitted due to fossil-fueled public heat and electricity generation; also, about 4.28 billion metric tons was due to road transportation energy.[6, 9]

It is estimated that about 38.9 billion metric tons of CO_2 will be emitted in the year 2025. Of this amount, about 13.73 billion metric tons will be emitted by fossil-fired power plants and 6.91 billion metric tons will be emitted by road transportation.

II.B. United States

II.B.1.Energy Usage and Projections

The IEO also outlines energy usage and growth projections for the United States alone. Between 1990 and 2002, total primary energy consumption increased by nearly 16%.[5, 9] This amounts to an average of just more than 1.3% per year. Oil consumption increased by nearly 16%, also. Besides the implications related to GHGs, this is an important issue for the United States. In 2002, over 58% of all petroleum used in the United States was imported.[6, 9] While tracking the source of petroleum is difficult, we know that much of the world's oil production takes place in the Middle East, which is a very volatile region of the world. Thus, the energy infrastructure of the United States could be greatly strengthened if alternative sources of transportation fuels were developed.

The IEO presents projections for future energy consumption for the United States, also. For the reference, low economic growth, and high economic growth cases, the increase in total primary energy consumption is expected to increase by 35.0%, 27.2%, and 44.7%, respectively.[5, 9] Tables IV, V, and VI present the data for the year 2002 and corresponding projection for the year 2025 for the various scenarios.

It should be noted that the historical increases in nuclear energy consumption have far outdistanced the IEO's projections. According to the Organization for Economic Cooperation and Development[7, 9], total energy production in the United States increased by 2.1% between the years of 1993 and 2003; during that same time span, nuclear power production increased by 21.8%. The projections for the coming years also appear to be low, in the authors' opinions. The IEO has chosen to ignore the potential growth of nuclear energy due to new nuclear power plants. It prefers to assume that new plants will not attract investors. The high price of natural gas in 2005 and 2006, coupled with government incentives for the first 6000 MWe of nuclear power additions are likely to prove the IEO wrong.

TABLE IV. Reference Case U.S. Energy Usage and Projections (MJ). Data taken from reference 5.

Energy Source	2002	2025	% Change
Oil	4.23E+13	5.86E+13	38.5
Natural Gas	2.49E+13	3.35E+13	34.5
Coal	2.08E+13	2.94E+13	41.3
Nuclear	8.65E+12	9.20E+12	6.4
Other	6.23E+12	8.77E+12	40.8
TOTAL	**1.03E+14**	**1.39E+14**	**35.0**

TABLE V. Low Economic Growth Case U.S. Energy Usage and Projections (MJ). Data taken from reference 5.

Energy Source	2002	2025	% Change
Oil	4.23E+13	5.56E+13	31.4
Natural Gas	2.49E+13	3.17E+13	27.3
Coal	2.08E+13	2.72E+13	30.8
Nuclear	8.65E+12	9.20E+12	6.4
Other	6.23E+12	8.13E+12	30.5
TOTAL	**1.03E+14**	**1.31E+14**	**27.2**

TABLE VI. High Economic Growth Case U.S. Energy Usage and Projections (MJ). Data taken from reference 5.

Energy Source	2002	2025	% Change
Oil	4.23E+13	6.44E+13	52.2
Natural Gas	2.49 E+13	3.43E+13	37.8
Coal	2.08 E+13	3.16E+13	51.9
Nuclear	8.65 E+12	9.20E+12	6.4
Other	6.23 E+12	9.40E+12	50.9
TOTAL	**1.03E+14**	**1.49E+14**	**44.7**

II.B.2.CO_2 Emissions

It is estimated that about 5.65 billion metric tons of CO_2 was emitted by various processes performed in the United States in the year 2002. Of this amount, approximately 2.27 billion metric tons was emitted due to fossil-fueled public heat and electricity generation; also, about 1.48 billion metric tons was due to road transportation energy.[6, 9]

It is estimated that the United States will emit about 7.62 billion metric tons of CO_2 in the year 2025. Of this amount, about 4.01 billion metric tons will be emitted by fossil-fired power plants and 1.93 billion metric tons will be emitted by road transportation.

III. METHODOLOGY

The major thrust of this work was to estimate the feasibility – from a technical standpoint – of capturing CO_2 from "point sources", i.e., power plants, and combining this CO_2 with hydrogen produced via nuclear power in order to create alternative liquid fuels for transportation. As part of this work, estimating the amount of liquid fuel needed and the amount of CO_2 available was required. In order to do this, a literature review was performed to document several quantities pertinent to the calculations. These quantities include CO_2 emitted and energy used in various forms – most notably for road transport. Historical data for the year 2002 and projections for the year 2025 were collected for both the United States and for the entire world.

A review of the various fuels that can be created from CO_2 and H_2 was performed. Ethanol and methanol were chosen as the two fuels upon which to focus. There are multiple reasons for this choice. Firstly, the technology to use both ethanol and methanol in ICEs exists. In fact, most major car manufacturers currently produce Flexible Fuel Vehicles (FFVs). These vehicles can operate on various mixtures of EtOH, MeOH, and conventional gasoline. Secondly, EtOH and MeOH are two of the simplest hydrocarbons; therefore, if a more complex hydrocarbon is desired, this is still a starting point.

Next, a review of multiple hydrogen cycles was executed. Ultimately, we chose High Temperature Steam Electrolysis (HTSE) as the cycle of choice. HTSE was chosen for two reasons. First of all, electrolysis in general is known to be possible immediately. The technology exists today to produce hydrogen from electrolysis. Secondly, using high temperature, the efficiency can be increased over conventional (low-temperature) electrolysis. Since one our goals was to show that the technology exists to replace some our conventional gasoline usage immediately, then this was the cycle of choice.

Based on the choice of HTSE as the hydrogen cycle, a review of relevant reactor designs was conducted. We chose a design proposed by Yildiz et al[3] which took advantage of the Advance Gas-Cooled Reactor (AGR) design with a supercritical CO_2 Brayton power cycle (S-AGR). Other reactor designs have been proposed for hydrogen production. For example, Richards et al propose to use the Modular Helium Reactor to produce hydrogen.[10, 11, 12]

A literature review of CO_2 capture processes was then carried out. Based on this review, it was determined that a capture efficiency of 90% of the CO_2 emitted by fossil-fired power plants was a reasonable estimate.[4] This is the estimate that is used throughout the work for calculations referring to CO_2 capture.

It is assumed that the power plant uses traditional MEA technology to remove the CO_2 from exhaust gases. This technique follows these steps.

1) CO_2 is absorbed by aqueous Monoethanolamine (MEA).
2) CO_2 is recovered from the solvent by using low-grade heat.

There are numerous documents that explain the MEA process in detail.

For this work, we assume that the energy required to capture the CO_2 is absorbed by the utility generating the CO_2. This would be realized by an effective reduction in the rated power of the fossil-fired plant. This is a plausible scenario since it is likely that the capture process will be prompted by taxes placed on CO_2 emissions or some other sort of urgency related to CO_2 emissions. The CO_2 could then be sold to an organization which plans to combine it with H_2 in order to produce liquid fuel. Since an economic analysis is not presented in this study, the cost to the organization producing the alternative fuel does not affect the results of the study.

Once the data was collected, relationships for the reactions that produce the EtOH and MeOH from CO_2 and H_2 were formulated. The two reactions used are:

Ethanol

$$2CO_2 + 3H_2 \rightarrow C_2H_5OH + \frac{3}{2}O_2 \qquad \text{Rxn. 1}$$

Methanol

$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O \qquad \text{Rxn. 2}$$

Two different scenarios were then considered in order to calculate the quantities of EtOH and MeOH required. In the first scenario, it was assumed that enough alternative fuel to replace all conventional gasoline is created. In the second scenario, it is assumed that 50% of all fossil-fired power plants participate and the average capture efficiency for the CO_2 is 90%. Therefore, 45% of all CO_2 emitted is captured. This CO_2 quantity is then used in order to calculate the required amount of H_2 and the resulting quantity of liquid fuel.

After the H_2 quantity is calculated, the number of Reactor-years required to produce the H_2 is estimated. This estimate relies on the H_2 efficiency quoted by Yildiz et al.[3]

It should be noted that Reaction 1 is highly endothermic at all temperatures from 25°C to 1000°C. At 25°C, the change in enthalpy is about 509.44 kJ/mol of ethanol produced. Since ethanol has a molar mass of about 46.068 grams and a mass density of 0.789 grams per cubic centimeter, this equates to about 1391 MJ of heat energy – at a minimum – that must be added for every barrel of ethanol produced.

Reaction 2 is slightly exothermic. We did not assume that the sensible heat from this reaction was recovered. This will slightly increase the estimated number of reactors that will be needed to produce the hydrogen.

Lastly, the decrease in CO_2 emissions and the effect on U.S. oil imports are estimated. The decrease in CO_2 emissions comes from two different sources. Firstly, the captured CO_2 contributes to the decrease. Secondly, the alternative fuels both emit less CO_2 per vehicle mile traveled (VMT) than conventional gasoline.

The equations used in order to calculate the required quantities are below (Eqns. 1-6). In order to use these equations, at least one of the variables has to be calculated based on the scenarios presented above. Usually, this is either the amount of alternative fuel needed (X_E or X_M) or the amount of CO_2 available (Y_E or Y_M). We list the equations as if the variable ‘X’ is known. The development of these equations is described in [Middleton and Kazimi].[9] Our calculations were performed and the data presented for the year 2025. However, it should be noted that the equations can be used for any time span. The only requirement is that the hydrogen efficiency and one other variable be known a priori. The rest of the calculations are based solely on ratios. The notation is as follows:

$\eta_H \equiv$ Net Hydrogen Efficiency

$X_E \equiv$ Number of barrels of EtOH

$Y_E \equiv$ Number of metric tons of CO_2 to make EtOH

$Z_E \equiv$ Number of metric tons of H_2 to make EtOH

$N_E \equiv$ Number of 1500 MWth Rx - years to make EtOH

$X_M \equiv$ Number of barrels of MeOH

$Y_M \equiv$ Number of metric tons of CO_2 to make MeOH

$Z_M \equiv$ Number of metric tons of H_2 to make MeOH

$N_M \equiv$ Number of 1500 MWth Rx - years to make MeOH

$$Y_E \approx 0.24 X_E \qquad \text{Eqn. 1}$$

$$Z_E = \frac{3}{44} Y_E \qquad \text{Eqn. 2}$$

$$N_E = \frac{2.5266x10^{-6}}{\eta_H} Z_E + 2.9395x10^{-8} X_E \qquad \text{Eqn. 3}$$

$$Y_M \approx 0.17 X_M \qquad \text{Eqn. 4}$$

$$Z_M = \frac{3}{22} Y_M \qquad \text{Eqn. 5}$$

$$N_M = \frac{2.5266x10^{-6}}{\eta_H} Z_M \qquad \text{Eqn. 6}$$

The asymmetry Equations 3 and 6 is due to the large difference in the Gibbs free energy for the two reactions, as explained above.

IV. RESULTS

Using Equations 1 through 6 and the data presented in Section II above, values are calculated for all the variables listed in the equations. Projected reductions in CO_2 emissions and in oil imported into the United States can are also calculated based on the fraction of CO_2 that is captured and the reduction in CO_2 emitted by vehicles that use alternative fuel. The quantity of CO_2 emitted per VMT by the various fuels is documented in Table VII. Worldwide results are presented for the year 2025.

Tables VIII and X present estimates for the number of reactor-years needed in order to produce the required hydrogen for the various scenarios. It should be noted that the number of reactor-years is just the number of reactors operating at full power multiplied by the number of years that they are operating. If the system is at steady state, then the number of reactor-years is equal to the number of reactors in all the results presented in this paper. The upper and lower estimates are produced by using a conservative value of 0.386 for the hydrogen efficiency and a best estimate value of 0.522. These efficiencies are taken from Yildiz et al.[3]

TABLE VII. CO_2 emissions (per VMT) for the various liquid fuels considered in this study.

CO_2 Emissions per Vehicle Mile Traveled from Gasoline and Alternative Fuels (grams/mile)	
Conventional Gasoline	344
Ethanol	324
Methanol	313

IV.A. Scenario 1 – Replacing all conventional gasoline with Alternative Fuel

In this scenario, it is assumed that enough alternative fuel is created in order to completely replace the conventional gasoline that is used for road transport.

Results for the amount of fuel needed to replace conventional gasoline throughout the world in the year 2025 as well as the amount of carbon dioxide and hydrogen required to create the fuel are presented in Table VIII. The assumptions are that IEO's reference case (Table I) hold and that the fraction of oil used for road transport in 2025 is the same as that in 2002.

TABLE VIII. Quantities of fuel and reactor-years required for Scenario 1 – Assume enough alternative fuel is produced to replace all conventional gasoline using IEO's reference case. Data taken from Reference 9.

Reference Case Year 2025 Projection Summary for Scenario 1 (Creating Enough Alternative Fuel to Replace Conventional Gasoline)		
Projected Gasoline Used in Year 2025	11.1 billion barrels projected to be used in year 2025	
	EtOH	**MeOH**
Alternative Fuel Required to Replace Gasoline (billions of barrels in 2025)	16.87	22.49
Carbon Dioxide Required to Created Alternative Fuel (millions of metric tons in 2025)	4050	3900
Hydrogen Required to Create Alternative Fuel (millions of metric tons in 2025)	276.1	532.4
Lower Estimate for Number of Reactor-Years Needed in 2025	1832	2577
Upper Estimate for Number of Reactor-Years Needed in 2025	2303	3485

Projected reductions in the amount of CO_2 emitted are calculated using the IEO's projections for the CO_2 that will be emitted in the year 2025 and the GREET v. 1.7 software.[6, 8, 9] This data is presented in Table IX.

TABLE IX. Percent reductions in CO_2 emissions for Scenario 1 – Assume enough alternative fuel is produced to replace all conventional gasoline using IEO's reference case. Data taken from Reference 9.

Reductions in Carbon Dioxide Emissions in the World Assuming 45% of Fossil Plant CO_2 Emissions are Captured. Percentages Calculated based on Total Emissions of 38.9 billion metric tons.			
	% Reduction Due to Capture	**% Reduction Due to Road Transport**	**% Reduction Total**
EtOH	15.89	1.03	16.9
MeOH	15.89	1.60	18.2

IV.A. Scenario 2 – Capture of 45% of CO_2 Emitted by Fossil Plants

In this scenario, it is assumed that 45% of all CO_2 emitted by fossil plants is captured and used to create alternative fuels. Due to the exorbitant amount of CO_2 emitted, this scenario produces an excess of fuel.

Results for the amount of fuel produced due to this capture and subsequent production of hydrogen as well as estimates for the number of 1500 MWth reactor-years required to produce the hydrogen are presented in Table X. Results for the decrease in CO_2 emissions are presented in Table XI. The assumptions are that IEO's reference case (Table I) hold and that the fraction of oil used for road transport in 2025 is the same as that in 2002.

It should be noted that the percent reductions in CO_2 emissions are much more dramatic for the United States alone, with total reductions totaling approximately 20% for both Scenario 1 and Scenario 2. This is due to the fact that a larger percentage of total emissions in the U.S. come from electric power production than in the worldwide case.

Also, for the United States alone, the data suggest that the U.S. could reduce its oil imports by anywhere from 65% to 90%.

TABLE X. Quantities of fuel produced and reactor-years required for Scenario 2 – Assume 45% of all fossil plant CO_2 emissions are captured. Data taken from Reference 9.

Reference Case Year 2025 Projection Summary for Capture of 45% of CO_2 Emitted by Fossil Plants.		
Projected Gasoline Used	11.1 billion barrels	
	EtOH	**MeOH**
Alternative Fuel Created (billions of barrels)	25.75	35.60
Excess Fuel Created (billions of barrels of conventional gasoline equivalent)	5.84	6.47
Excess Fuel Created (%)	52.6	58.3
Carbon Dioxide Captured (millions of metric tons)	6180	6180
Hydrogen Required to Create Alternative Fuel (millions of metric tons)	122.7	245.5
Lower Estimate for Number of Reactor-Years Needed	780	1188
Upper Estimate for Number of Reactor-Years Needed	989	1607

TABLE XI. Percent reductions in CO_2 emissions for Scenario 2 – Assume 45% of all fossil plant CO_2 emissions are captured. Data taken from Reference 9.

Reductions in Carbon Dioxide Emissions in the World Assuming all Conventional Gasoline Replaced with Alternative Fuel. Percentages Calculated based on Total Emissions of 24.1 billion metric tons.			
	% Reduction Due to Capture	**% Reduction Due to Road Transport**	**% Reduction Total**
EtOH	10.41	1.03	11.4
MeOH	10.03	1.60	11.6

V. CONCLUSIONS AND FURTHER RESEARCH

Based on the calculations we have performed, a few conclusions can be drawn. First, we show that capturing CO_2 emitted by fossil plants and combining this with hydrogen produced using nuclear energy will significantly reduce total CO_2 emissions. Also, the data indicate that the United States could significantly reduce its dependence on foreign oil by pursuing this line of research.

The significant number of nuclear reactors required in order to produce the hydrogen indicates that it would take a massive effort on the part of the nuclear community in order to replace petroleum with synthetic fuels made from nuclear produced hydrogen. However, if implemented gradually, some of the positive results of this study could be realized in within a decade or so.

Other research presented in the report from which this paper was taken[9] indicates that nuclear power could also be used to aid in the production of oil from tar sands, oil shale, and heavy crude. The authors believe that this research should be pursued. It is also suggested that a study be performed to determine the economic feasibility of the technical results presented in this paper. Another interesting topic would be to pursue a study of the integration of alternative fuel production with the operation of planned fossil plants.

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