ROAD MAP FOR A COMPREHENSVE ENERGY POLICY

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FELLOWS OF THE COLLEGIUM

COSMOS VOUTSINOS

Cosmos earned a Bachelor's degree in Mechanical Engineering, System Dynamics & Control, from the University of Waterloo and a Master's degree in Mechanical Engineering, Thermo-Fluids, from McMaster University.

Cosmos' career progressed from system design in the Canadian nuclear industry to construction management in the USA nuclear industry in Taiwan. While in Taiwan he began a consulting career specializing in Engineering Economics. He designed Taiwan's power infrastructure to incorporate LNG ports/plants, coal ports/plants, oil fired, hydro and nuclear power plants to ensure that Taiwan had a reliable power supply in the event that military and/or political forces blocked external energy supplies.

Cosmos sold this company to Taiwan interests. Upon returning to Canada after a sailing sabbatical, he started Adtech Manufacturing Ltd. This new company designed and manufactured control systems capable of operating in hostile environments. His clients were in the nuclear, military and aerospace industries. In 2002 Cosmos sold his company and semi-retired to Lethbridge. He continues his involvement in the energy sector through his consulting company Technology Integration Ltd (TIL) and by serving as the Vice-Chairman for Alberta of the Canadian Nuclear Society.

ROADMAP TOWARDS A COMPREHENSIVE ENERGY POLICY

By Cosmos M. Voutsinos

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EXECUTIVE SUMMARY

This paper hopes to be the first step in a series of initiatives. The first being a scientific plan, followed by a business plan, and then in one order or another, a political plan to make things happen and a financing/governance plan to make sure that what is put in place is sustainable and well managed. This paper does not promote any particular energy form, but It lays down the pros and cons of the available energy options. This document then could form the basis for justifying the political and financing plan.

Energy, Economy and Environment form the "EEE trinity" and are three inseparable and interdependent[1,2] parameters that form a three dimensional Cartesian axis system. Together they define our standard of living. Any energy related solution must satisfy simultaneously both the economic and the environmental requirements. This paper assists in the process of policy making and in informing the public about the scientific realities. It charts a way forward that shatters conventional thinking and yet leaves one brimming with hope. Its intent is to change the way we think about energy and its relation to our economy and the environment. This becomes particularly important in our policy making process. The suitability of most energy projects can be determined by following the methodology outlined here. Similarly, a direction may be selected by using the elimination process resulting from the "EEE trinity" principle.

Energy policy decisions made today will form a pathway that will affect the lives and standard of living of our children and their descendants. Energy policies take a very long time, 20-30 years, and great effort before they become implemented. It takes just as long to undo mistakes. That is why it is very important that energy policy is made based on a complete picture of all options available and their long term implications in terms of the economy and the environment.

Free market players tend to have a much shorter time horizon for their investments. This does not necessarily result in a cohesive solution that will pave the way to phase out some future problematic energy technologies, nor results in the phasing in of the technologies that can provide reliable, stable, predictable, economic, environmentally acceptable and long term supplies for all of our energy needs. This includes electricity, transportation fuels and hydrocarbons for industrial use. Furthermore, free market players undertake to supply only a portion of these three energy needs. As a result energy projects do not necessarily complement each other nor can they be integrated into a common energy infrastructure. This is where Government is needed to lead rather than to follow. There is no need to define winners and losers. All that is needed is to implement a policy defining the criteria that each energy technology will have to meet in order to compete in the future. Then let the fittest market players survive.

Alberta is in a unique and advantageous position. It is the only region in the world that has an extensive hydrogen based economy. This results from the 6.0 million kg of hydrogen per day that Alberta industries produce and then consume to upgrade the bitumen to synthetic crude oil. This demand for hydrogen will keep increasing as oil sands production increases. As a result, the ensuing hydrogen market could provide a bridge to energy evolution which will prevent the rise of the forthcoming energy revolution.

It seems that a long term energy policy position is missing. It should be based on actual scientific/economic/environmental facts that will inform the various market players of what the likely future picture of our energy requirements will be and how to get there. It should also highlight the areas of R&D that could make each energy technology more competitive.

This paper separates the forms of energy in terms of **primary fuels, (**the fuels that we get out of the ground or air) and in terms of **energy currencies,** (the fuels that we manufacture from the primary fuels). The energy currencies are the fuels that we commonly consume - electricity, gasoline, diesel, jet-fuel etc. How much energy is lost in converting primary fuels to energy currencies and how many pollutants are produced at every step of the conversion process are shown. It concludes that a correct policy (in terms of science and broad picture economics) would be to influence the energy currencies and the way that they are produced rather than concentrating on the details of a few technologies while ignoring the overall need.

This approach seems to make business sense too, and will not only **not be** a long term burden on the taxpayers but quite the contrary – it will be a big economic winner first for Alberta, Saskatchewan and Ontario and then for all of Canada.

Through analysis of the processes that produce the green house gases (GHG) and other pollutants in the hydrocarbons industry, a conclusion is reached that the only way to stop the production of CO_2 or other pollutants is to begin producing the needed hydrogen for our hydrocarbons from non fossil sources (i.e. splitting water). A recently developed new technology for synthetic fuels(62,69) is further analyzed and evaluated. It is recycling CO_2 from the atmosphere, combining it with H_2 produced by splitting water using energy inputs from wind power assisted by nuclear power. The economics look favorable as reported by a US study(63) at US $3/gallon without including carbon credits. If carbon credits are used the cost drops to $2/gallon.

If we are serious about wanting to stop CO_2 emissions, there is a way to do it by changing the processes that produce our energy currencies, rather than by changing our energy currencies themselves. We will not need to change our energy infrastructures for the distribution and consumption of fuels. We need only to change the industrial infrastructure that makes our fuels. These changes can take place gradually as the various industrial installations age. We can get on with this plan right now and do it by way of complete control rather than depend on the most influential market players to do it for us.

This paper recognizes that the oil sands are the main driver of the economy in Alberta and perhaps in Canada for years to come. It analyzes areas where policy changes can help, and urges the Government to commit to making the oil sands clean by reducing its CO_2 emissions. It summarizes the options available to achieve this goal.

Analysis of the carbon capture and storage (CCS) process concludes that due to the massive amounts of CO_2 involved, one cannot expect to reliably sequester the CO_2 gas underground indefinitely. Also, the CCS process seems to continue the emissions of CO_2 at a reduced rate of 15%. As a result, CCS should be viewed as a temporary relief measure that provides a life support to our coal industry and time needed for R&D rather than a permanent solution for exploitation of the oil sands and a sustainable energy for the future.

When we are looking to produce energy without other constraints we are working with a one dimensional model of “Energy”. As a result we have several possible energy choices. When we are looking to produce energy at reasonable cost we are working with a two dimensional model of "Energy" and "Economy". As a result the number of choices is decreasing but we still have several possible options available. As soon as we add the constraints of "environmentally acceptable" we start working with a three dimensional model of the "EEE trinity" that includes the "Environment". As a result, most of the energy options are eliminated and our number of choices is drastically reduced and limited, but fortunately some remain. The advantage of this is that by defining our "EEE trinity" we narrow the search area and we eliminate unnecessary work and conserve our resources to focus on potentially successful integration of technologies that meet our predetermined criteria.

We can still use our energy currencies of electricity, transportation fuels and hydrocarbon feed stocks for industrial products that we have today. This was realized during the writing of this paper. It started by examining all our primary energy options, but towards the end, as we added economic and environmental restrictions, most of our options were eliminated and the field was narrowed down to the point that the conclusion appears to be more like an opinion or a proposed policy. This is not the case. It has been forced on us by scientific/economic facts. These are the maximum number of choices with which we are left.

By 2025 we could be in the middle of a transition period where the ultimate goal will be to get our energy currencies as follows:

a) Electrical base load currency generated from hydro, and some small and large nuclear reactors possibly distributed along the grid.

b) electrical peak loads currency generated from hydro plants and bio-fuels,

c) Transportation synthetic fuel currencies starting to be generated from CO_2 captured in the CCS process and then "clean synfuels" produced using wind power assisted by small nuclear plants. CO_2 is recycled from the atmosphere and H_2 is produced by splitting water.

d) Industrial feed stock currencies and oil exports derived from the oil sands upgraded by non fossil produced H_2.

Finally, it should be noted that we need all the above energy currencies in order to maintain our standard of living. Making available one or two is not enough. A solution must include all three.

TABLE OF CONTENTS

1.0 INTRODUCTION

Energy has always been the heart-beat of civilization. As our standard of living increases, our energy consumption also keeps increasing. There is no indication that this close relationship between our standard of living and our energy consumption will ever change. It has been observed recently that many people feel guilty for the amount of energy that we use. Each one of us could easily address their guilt by volunteering to take steps to reduce their own energy consumption. We are going through the motions, but in reality we aren't succeeding. Despite the good intentions, we have not been able to significantly decrease our consumption of energy. However, we may be able to reduce our collective consumption of energy by creating a more efficient industrial system for our energy production.

There is a close relationship between our standard of living and the ECONOMY. In turn, there is a close relationship between our ECONOMY and the ENERGY that we consume. Both are inseparable(1) factors that control our standard of living. When we make a change in one of them, automatically the other will change in the same direction and at about the same rate. In the study of system dynamics, this is called "proportional interdependence".

More recently, we have become aware of the ENVIRONMENT. This factor has always existed but has only just recently come into prominence due to the high amount of fossil fuels that we have been using for our energy production. ENVIRONMENT is also closely related to both the type of ENERGY we consume and to the ECONOMY(1,2). Energy, Economy and Environment form the "EEE trinity" which in turn defines our standard of living as we progress in time. They are closely related and un-separable. They can be visualized as a three dimensional axis (x,y,z) where the optimum solution would be a point satisfying simultaneously the requirements of all three axes. Every alternative solution may be represented by a point in our three dimensional axes of Energy, Economy & Environment.

This paper is not proposing any particular policy, neither is it a public relations document. Its purpose is to be used as a working reference by policy makers and people interested in energy, the economy or the environment. It attempts to summarize and then places into perspective all the technical, economic and environmental parameters and facts that need to be considered by our policy makers for each and every energy option available. This paper also emphasizes the importance and priority of the" EEE trinity" factors in the decision making. Instead of drawing conclusions, it provides a road map for thinking about the synergies that will hopefully supersede the opinions derived from political expediency or from the marketing attempts of various technology proponents.

In this paper, every concept, every proposal for the various energy technologies, and every process or project will be evaluated on the basis of the "EEE trinity" in order to obtain a complete and clear picture of its implications and interrelationship with Energy, Economy and Environment. **Having a complete and clear picture of a technology within EEE trinity is the necessary first step, prior to begin comparing the various energy technologies available.**

Most discussions of energy policy focus on some single fact. It is only when we look at all of the aspects in a connected way that the best approach becomes obvious. The EEE principle makes possible to examine each option and compare it to other options. At the end of this process we are ending directly with optimum and integrated solutions. Unfortunately these solutions are not many. The three dimensional restrictions imposed by EEE trinity nearly eliminated all options available. Fortunately, we are left with a couple of options that may give the impression that a definite recommendation is made with regards to policy direction. It is not. The reader must go through the elimination process himself, using scientific and economic facts from this booklet or elsewhere, to confirm that indeed if we want to stop the emissions of pollutants the options available are very limited.

The following chapter deals with the historical perspective – cause and effect- of the various fuels that we have used up to now. The next chapter examines the significance and the differences between the naturally occurring forms of energy and man-made forms of energy. The fourth chapter deals with the current state of the problem and explains why we need a comprehensive policy and how detailed it should be. The fifth chapter examines coal and its energy currencies (see chapter 3).

The sixth chapter examines the oil and its energy currencies. The seventh chapter examines the natural gas, its energy currency and deals with the current discoveries of shale gas. The eighth chapter examines renewable energies and the currencies that we derive from them. The ninth chapter examines nuclear power and its currencies. The tenth chapter examines hydrogen and the eleventh chapter examines the synthesis of fuels while recycling CO_2. The remaining chapters compare the various energy technologies and currencies for efficiency, cost, environmental impact, time to deploy, future implications, transition period implications and social problems.

Finally, some economic estimates are made to demonstrate in a big picture way that this approach makes a business sense too.

2.0 PRIMARY ENERGY. HISTORICAL PERSPECTIVE

Primary energy has been important in our lives since ancient times. The earliest known primary fuel appeared in ancient China and Egypt and was the cultivation of grains. Grains not only fed the general population but also the slaves and beasts of burden that did the work. Later on in ancient Greece grains were used to feed an expanding military that was embarking on expeditions. Cultivation of grains was so important in ancient times that the Romans considered the agricultural fertility of the land before they determined to conquer a country. Since ancient times most taxes were collected in the form of primary fuel (grain) for shipments to the rulers.[(3)]

In parallel wood was burned, but this was done on an individual basis not on an organized national basis. Hence it is not considered to be a primary form of fuel until later when wood was used in the making of charcoal. During the time that wood and charcoal were being used increasingly for domestic and industrial needs, improvements in the use of a renewable energy form - wind power- were being perfected by England, France, Portugal, Spain and others. The harnessing of wind power enabled long distance travel by sea and opened up North and South Americas. Wind mills were also increasingly used.

The next primary fuel, coal, launched the industrial revolution in Europe and catapulted England into a super-power status. At the same time steam-ships that originally burned wood were slowly converted to burn coal. By the late 1800's, the discovery and harnessing of oil and then the discovery of gas, a few decades later, launched the industrial might of the United States of America. Finally by the 1960's, uranium started being used to produce electrical nuclear power and it looks likely that by the end of this 21 century we may witness the harnessing of fusion energy.

1.1 Financial considerations in changing primary fuels

The above of course is common knowledge. The reason it is mentioned here is to highlight some observations common to each step that humanity took when it changed from one primary fuel to the next and developed new energy technologies to harness it.

a. Each time we replaced our primary energy fuel, the new fuel has had a two to three times higher energy content, per unit volume/weight, from the previous fuel. This is called ENERGY DENSITY. Furthermore, the new fuel was easier to handle. Both of these contributed to an increase in energy consumption, an increase in the efficiency of energy use, and as a result an increase in the economy and standard of living.

b. The country that adapted the use of the new fuel first, became more efficient, its products became more competitive, its economy grew faster and hence the country became a contemporary superpower.

c. The ENERGY DENSITY increase, in going from a hydrocarbons based primary fuel to uranium, is not 2 to 3 times more but 1,000,000 times more. This means that uranium/thorium fuels, if used safely and efficiently and without pollution and dangers, have the potential to improve the efficiency and the competitiveness of our country and our economy. Conversely, by not adopting this technology we may reduce our ability to compete with other countries that are now heading in this most efficient direction.

d. Each time we have changed our primary fuel, the technologies used have become more complex and more expensive. With oil for example, the crude fuel extracted from the ground could not be used directly. It needed refining and conversion to other types of fuel that are easier to use. The same can be said for gas, coal, uranium, etc.

e. One positive effect of increasing the energy density of our fuels has largely been ignored. The higher has been the energy density of the fuels that we burn, the less pollution we release to the environment per kg of fuel we use.

f. The more energy we use the more new technologies we are developing. See the extensive use of electronics and the explosion in communications and the effect they are having in our standard of living.

1.2 Environmental considerations in changing primary fuels

The pollution levels released to the environment, from all the fuels that we have used up to now, have been caused by the increasing amount of fuels we use for our energy needs. In other words, increasing population, increasing longevity and increasing standards of living[11] have resulted in acceleration in the production and release of pollutants to our environment. Nuclear power, by necessity, became the first energy producing technology to collect and control its own wastes. Now we are looking to retroactively collect and control the wastes from the burning of fossil fuels.

The pollution control at present is focused on the use of fossil fuels. This includes releases from the processing of hydrocarbons industries, the burning of coal and gas in electricity producing power plants, and in the steam reformation of gas to produce hydrogen: a) for upgrading the bitumen and b) for producing ammonia fertilizers. There are several pollutants but the major ones are: SO_x, NO_x, CO_2, CH_4, fly ash, bottom ash, arsenic, U, Th, Hg, Co and other heavy metals. There is a great debate going on at present whether CO_2 is actually a pollutant.

Some of the most serious pollutants have been reduced during the last 20 years, except for green house gases,(GHG) some of which have increased by some 50% in our atmosphere (CO_2 & CH_4). Without saying who is right in the ongoing argument between experts, as to whether observations of Earth warming are due to this excess of GHG or not, we have to take conservative actions and err on the safe side. It becomes clear that not only must we prevent the pollutants from being released to our environment but also to minimize their production.

3.0 DIFERENTIATION OF PRIMARY ENERGIES AND ENERGY CURRENCIES

We mentioned above in 1.1 (d) that as we increase the energy density of the primary fuels that we consume, the technologies involved become more complex. The reason for this is that humanity rarely consumes directly the primary fuel that we get out of the ground. Instead, we use the primary fuel to make man made secondary fuels which are easier to use. These secondary fuels are made and spent like currencies - hence the term ENERGY CURRENCY. In this report, we differentiate between “primary fuels”, the fuels that we extract out of the ground, the sea or the air and “energy currencies”, the fuels that we use and which are manufactured from the primary fuels.

When converting a primary fuel to an energy currency there is a conversion cost, not only in terms of financial cost but also in terms of energy used and in terms of pollution produced. Let me provide some examples:

a) We get out of the ground a primary fuel, crude oil. We **refine** it to make one of our transportation fuels (diesel, gasoline or jet fuel). These manmade fuels or energy currencies, have only 70 %(4) of the original energy content of the crude oil. The other 30% was used or lost in the refining (conversion) process producing byproducts, heat, wastes and pollutants.

b) We get out of the ground a primary fuel natural gas. We refine it and divert it to a **gas turbine** power station to produce electricity. The energy currency of the electricity that we get has only 50%(5) of the original energy content of the gas. The other 50% is lost producing heat and pollutants during the energy conversion process.

c) At the oil sands, we get out of the ground a primary fuel called **bitumen**. We use **natural gas** to upgrade it and to produce crude oil. We then refine the crude oil to produce a transportation fuel (diesel, gasoline or jet fuel). This energy currency that we get from the transportation fuel has only 50%(6) of the original energy contained in the bitumen and the natural gas. The remaining 50% has been lost as heat, wastes, byproducts and pollutants. Note that the use of two energy conversion processes, compounds the production of wastes and further decreases the energy currency obtained

d) We get out of the ground a primary fuel, **coal**. We then transport it to a power station to burn and produce electricity. The energy currency of the electricity that we get has about 35%[7] of the original energy content of the coal. The other 65% has been lost as heat, waste and pollution products.

e) We get water out of a river or a lake and divert it to an electricity producing power station. There we use the electricity for **electrolysis** of the water to produce hydrogen (H_2). The hydrogen produced has 70% the energy currency of the electrical energy input[8,58]. We are not talking here about the water used in hydro power plant because in this situation the water is not consumed.

f) We buy electric cars in order to eliminate pollution and to conserve on our resources. These electric cars will be charged from the electric grid. If the electricity comes from a gas fired power plant, then we get an electrical energy currency of only 50% of the energy contained in the gas. Now compare this with the Calgary taxis that have had their carburetors changed to burn natural gas directly in their engines. They get an energy currency of almost 100% of the energy contained in the gas. The comparison of the two options, including the different consumption efficiencies of charging the batteries and running an electric motor against the running a gas engine, clearly shows that the only benefit we get from the electric car option is a reduction of the pollution to the atmosphere by about 30% and no conservation of our resources. Is this solution pollution free and sustainable?

There are some points to be raised from the above. First, the primary fuels are always used as the feed-stock in the industries that produce the energy currencies that we use. We don't burn coal, bitumen, crude oil, uranium or wind power in our homes. Even the natural gas that we burn at home has undergone a certain processing[9] to remove some impurities. We the public consume only energy currencies which are produced by several different processes. Yet instead of concentrating on the fuel currencies that we use and have some control over, we seem to be focusing on the primary energy fuels that we don't directly use and don't control. It follows then that unless we start considering our energy currencies and the processes that produce them, the pollution problem will persist and increase.

Second, the processes that produce our energy currencies employ complex technologies that vary from very efficient to very inefficient. By selecting the most efficient processes to produce our energy currencies we can actually reverse the pollution trend in our environment. At the same time we can improve our economies without cuts to our energy needs and our standard of living. Efficiency here is intended for environmental criteria which are not necessarily in agreement with economic criteria.

Thirdly, every proposed energy solution needs to be evaluated and assessed simultaneously with common economic, technical and environmental criteria. Each evaluation must **include all the steps of energy conversion from primary fuel to the end consumption of the product.** Only then one can have a complete picture of the overall efficiency and viability of the solution. Not following a proper and complete method of evaluation leads quite frequently to misunderstanding and propagation of misinformation. This in turn results in projects that waste valuable resources while at the same time they may amplify the problems that they intend to solve.

Finally, but not lastly, in example (f) above it can be seen how some apparently simple, beneficial and popular concepts could actually be damaging over the long term if not used and optimized in the context of the overall "sustainable energy efficiency" picture and the "EEE trinity" criteria. Think how much environmental benefit we get out of electric cars if we produce our electrical energy currency using coal as the primary fuel with its 35% efficiency of coal conversion to electricity and 1000 gCO2/kWh emissions.

The bad news with all the conversion processes described above, is that they consume very large amounts of energy and they release very large quantities of pollutants and CO_2. The good news however is that they vary considerably in their emissions of CO_2. This variation ranges from: a maximum, realized by the burning of coal to produce electrical currency, without scrubbers which releases to the atmosphere 1,050 grams of CO_2/kWh[10], to a minimum, realized by the synthesis of hydrocarbon transportation fuel currency, using nuclear or wind power with water and CO_2 which removes CO_2 from the atmosphere. See Ch. 11.

Table 1.0 shows the energy currencies that we use, the primary fuels that can supply them and the processes used and yields obtained to convert primary fuels into energy currencies.

ENERGY CURRENCY	YIELD %	CONVERSION PROCESS	WHICH PRIMARY FUEL IS USED TO PRODUCE THIS CURRENCY
Electricity	33	Steam turbine	Coal, Uranium, Thorium, Wood, Bio-fuel
Electricity	50	Gas turbine	Natural Gas,
Gasoline	70	Refining	Crude oil,
Gasoline	*	Synthesis	Uranium, Thorium (H_2O and Carbon)
Diesel	70	Refining	Crude oil
Diesel	*	Synthesis	Uranium, Thorium (H_2O and Carbon)
Propane	60	Refining	Natural Gas
Propane	*	Synthesis	Uranium, Thorium (H_2O and Carbon)
Jet fuel	70	Refining	Crude oil
Jet fuel	*	Synthesis	Uranium, Thorium (H_2O and Carbon)
Butane	60	Refining	Natural Gas
Synthetic crude	80	Upgrading	Ashphaltine and Coke
Synthetic fuels	*	Steam reform	Coal, Coke
Synthetic fuels	*	Synthesis	Uranium, Thorium (H_2O and Carbon)
Hydrogen	22	Electrolysis cool	Coal, Nat. gas, Uranium, Thor, Wind
Hydrogen	27	Striping	Natural gas
Electricity	10	Photo-voltaic	Solar power renewable
Electricity	25	Wind turbine	Wind power renewable
Electricity	28	Thermo-electric	Solar Power renewable
Electricity	33	Steam turbine	Natural Biomass

Notes: * The process of synthesis is the using of carbon, from CO_2 in the atmosphere, and water to synthesize $(CH_2)_{n.}$ (n is number of CH_2 chain). Carbon can also be obtained from coal, coke etc. The process requires energy input to complete the reaction shown here.

$$\mathbf{C+H_2O+Energy = CH_2+1/2\ O_2}$$

For details of this process, yields and costs see Chapter 11

Also, the efficiency of conversion varies with the primary fuel used for energy and feeds

4.0 DO WE NEED AN ENERGY POLICY IN 2010 AND WHAT ARE THE CRITERIA ?

At this point in human history we find ourselves with a tremendous increase in the world demand for energy and a continuously decreasing number of options to produce it. Our "energy demand" is defined by increasing population, an increase in human longevity, and an increasing standard of living in the developing world[11]. Our energy supply is marked by a decreasing number and quality of new oil wells that yield less oil per well and need higher inputs of energy to get the production out[11,75]. On top of this, environmental considerations now pressure Alberta oil producers to "clean" their oil produced from the oil sands. Coal power plants are pressured to curtail the releasing of CO_2 to the atmosphere. Both industries need to capture and sequester their CO_2 emissions as a condition for continuing their operations. However, there are no off the shelf technologies available at this moment to achieve these goals. Meeting these requirements involve extensive research and development.

The solutions to these challenges are not short term. Contrary to popular beliefs, new energy systems cannot be built quickly and or cheaply. Our energy infrastructure is so large that it will take decades, huge sums of money, and tireless effort by generations of scientists, engineers and policy makers developing new technologies[12].

It normally takes about 6-10 years to commercialize a new technology from the laboratory test and development stage. Once you have the first commercial plant prototype, it takes another 15-25 years for this new development to get a start in the world energy scene. This is the reality and the general public, especially the policy makers, should be aware of the magnitude and complexity of the problem and the long time-frame needed to implement solutions. Meanwhile, the continuing growth in population and standards of living is generating a serious gap between the energy that we need and what we are supplying. Additionally, we have to anticipate that a perceived correct policy made today, may become a wrong policy by the time of its implementation, due to new developments and relentless growth.

If all the above problems were not enough, policy makers are subjected to a continuous assault by marketing schemes that confuse the issues. Let's examine a couple of examples.

Example 1

An Alberta think tank institute published earlier last year a "Green" study. In it, they propose that we stop all developments for other energy technologies and concentrate all our efforts on wind power. This study has appealed to the public's infatuation with clean power. Under further examination and scrutiny, it was found that this study does not include economic considerations. A fancy disclaimer about the accuracy of this study has been issued, the writers have refused to discuss it with experts, and finally, further scrutiny has revealed that the think tank institute has entered into a contractual arrangement to collect commission payments from the sale of wind mills. There is nothing wrong with the institute trying to make some money. The problem is that the public was misinformed when it was not provided with the information that a highly respected think tank had in fact become a sales agency for wind power, and was thus unable to judge their studies accurately.

Example 2

If an Electrical Utility wanted to increase its revenues, the easiest thing to do would be to eliminate the competition. By opposing the building of transmission lines to carry electricity from other areas, the Utility can establish a monopoly for itself. The Company can build a gas plant that has a low capital cost, sign contracts for the purchase of gas, now that the gas prices are low, and then start charging monopoly rates for the electricity. Did anybody see the prices of electricity go down as the prices of gas dropped during the last year? Remember, changes in energy infrastructure take a long time to be implemented and it will take an equally long time to correct mistakes. Opposing the building of transmission lines is a good short term marketing ploy but it creates confusion in the public and a long term problem for the Government that is sensitive to voter's opinion.

In summary the field of energy and the production and consumption of energy currencies is very large, and complex. Massive amounts of resources, time and material, are required and the technologies involved can change, due to new developments. Consequently, no energy technology should be dismissed. Policies should be flexible and have a long time horizon. They should build options for down the road adjustments and lead to adaptable solutions in the future. **At this stage we need to optimize our resources and use them wisely for projects that can satisfy both, short term and long term energy needs.**

Free market players tend to have a much shorter time horizon for their investment. This does not necessarily result into a cohesive and optimized solution that will satisfy our short term needs without creating problems for the longer term. Technologies that cannot be modified to meet "EEE trinity" criteria, should be phased out while technologies that can be modified and meet the criteria should be phased in. The definition of the "EEE trinity" criteria includes energy technologies that are reliable, stable, predictable, low cost, environmentally acceptable and be able to provide our energy needs for hundreds of years. Our energy needs include a) electricity, b) transportation currencies and c) feed stocks of hydrocarbons for industrial products. If any of those three energy currencies is missing, our standard of living will likely decline. Yet most of the free market players can supply only a portion of these energy currencies. **That is where the Government is needed to lead**. There is no need to define winners or losers. All it needs is to endorse the "EEE criteria" in a policy statement and set a target date for all market players to meet it. Such a move will result in a tremendous level of R&D to help the various technologies qualify in real terms, instead of being disguised as green energies, as is the case now.

Alberta does not have a central Utility responsible for the production and the distribution of electrical power. There is not a group of professionals with expertise in all energy technologies and without conflict of interest who could be capable of optimizing our system over the long term. As stated above, production and distribution of electricity is left mostly free to market forces. Each of the market players however, has his own short term commercial interests to pursue. Hence, instead of getting long term beneficial solutions for the Province we get a lot of one sided, short term marketing promotions that tend to confuse and make the problem worse for the longer term.

The only single body capable of leading, without conflict of interest, is the Government. The key questions however, are: How does a Government develop a solid policy when it has not mastered the necessary expertise to evaluate accurately all the available technologies? How can a policy be made when market players tend to confuse the Government with their marketing moves and promotions? How does a Government avoid political expediency when solving these problems and use its options based only on technical, economic and environmental criteria?

This paper attempts to address some of these issues. It provides a methodology, within the "EEE trinity" for the complete evaluation of each option. It also provides a detailed analysis of each energy technology and places it into perspective, relative to the EEE trinity parameters. It facilitates comparison between any two options on the basis of the same criteria. It is the hope of the author that this paper will assist the public to grasp the realities of energy and the policies needed.

A sound energy policy should give incentive to market players to minimize the number of energy conversions (lower efficiency and pollution) and to use the most desirable processes, instead of the cheapest ones, to produce our energy currencies. It should also provide a disincentive to producing energy currencies with non acceptable processes. Finally they should have a long term horizon and be flexible enough to accommodate and adapt to future developments. The low cost of energy is necessary to make our products more competitive. Perhaps an institutional solution could be adopted such as an Alberta Energy Commission with the tasks of undertaking this kind of optimizations.

Electrical energy distribution (transmission lines) is an integral part of an electric energy production and it should be examined simultaneously with the applicable energy currency concept. It should include considerations such as the losses of 6%[aeso] realized by the grid transmission lines. Above all, the key to a successful policy is in mastering the knowledge and developing the expertise to examine the **complete picture** of the various options and to be able to mix various technologies of energy, by integrating their positive characteristics.

If Alberta is encouraging the submission of applications for commercial power projects, it must develop the necessary expertise to think out of the box and to be able to evaluate them on their real merits which as a minimum should include:

- development of the "complete picture" for each of them,
- extrapolation into the future and see where they lead us,
- examination for compliance with EEE trinity
- examination for complementing existing policies and comparison to approved projects for cohesiveness and possible integration.

5.0 THE CURRENT STATE OF CONVERTING COAL INTO ENERGY CURRENCIES

Energy Considerations

Coal is a combustible fossilized organic material that contains mostly carbon and some sulfur, hydrogen, oxygen and nitrogen. It also has traces of metals including cobalt, uranium and thorium. Its energy density can be appreciated by the fact that it will take a little less than half a ton of coal (966 lbs) to power a computer for one year[(13)].

The burning of coal to produce steam provides heat at an average energy density of about 24 MJ/kg[(14)]. (mega joules/kilogram). In the past, the steam was used to drive piston steam engines for trains and ships. Now the steam is used in steam turbines in coal fired power plants that produce the energy currency -electricity. The electric currency produced has only 1/3 of the potential energy of the coal[(7)]. The remaining 2/3 of the currency is lost as heat released to the environment, via the water cooling of the plant's turbine, and as pollutants. It takes 438 kg of coal to produce 100 watt of electricity for a year[(15)].

Economic considerations

British Petroleum in its annual report 2007, estimated that at the end of 2006, there were enough proven coal reserves worldwide to power humanity for 147 years[(16)]. It would be reasonable, however, to expect that a significant amount of coal beds are still waiting to be discovered and included in the "proven reserves" category. Alberta may have about 1000 year reserves for its own use.

The price of coal averages about \$55-\$65[(76)] per short ton. It has varied from a high of \$210/ton (2008) to a forecast at \$85/ton (2010). These numbers fluctuate wildly with heat content factors. In Alberta it goes as low as \$20/tone. In spite of the high pollution levels coal fired power plants are the most abundant because of the low cost of electricity that they produce and because of the reliability of the fuel supply. The production cost of electrical energy currency is at present one of the lowest, provided that the power plant is built in the proximity of a coal mine to minimize the transportation costs. Coal plants have been producing electricity for several years now at \$0.05 to \$0.06 per kWh wholesale prices[(17)].This competitiveness will begin evaporating with the introduction of carbon taxes, cap and trade regulations, or the requirement to capture and sequester their CO_2.

Carbon Capture and Storage (CCS) has been estimated to cost $81/tone to capture CO_2 and deliver it at the sequestration site[18]. By the time a suitable site is developed, the total cost, to have the gas pumped underground, will be in the order of $110/ton. It will also have consumed a lot of additional energy in implementing all the required processes involved. How will the compressors be powered and how much CO_2 will be generated and released to the environment?

This means that any carbon tax or cap and trade regulations, which are lower than the real cost of CCS, will not provide a proper incentive to the polluters to change their ways and reduce their emissions. It will be cheaper for them to pay the taxes and trade on CO_2 contracts than to integrate CCS in their processes. The question that follows then is that if carbon taxes or cap and trade, are not going to reduce the overall emissions of CO_2 to our atmosphere, what is the reason for introducing them? Right now 53% of Alberta's electricity is produced by coal fired power plants that produce 43 million tones of CO_2 per year[19]. The oil sands produce as much now and the plan is to triple production in the near future. How are taxes or cap and trade going to reduce this?

Environmental Considerations

In terms of Energy and Economy coal provides the best performance option. It fails very badly when examined in terms of Environmental criteria. Are we accepting that the earth warming is taking place and its cause is anthropogenic, or not? If we accept that it is anthropogenic or that we don't know but we should err in the safe side, then we should make policies that lead to a "phase out plan" to curtail our releases as fast as possible. If we don't accept that it is anthropogenic then we should make appropriate policies and stop talking about it. The confusion exists because both Albertan and Canadian Governments appear to accept that the problem is anthropogenic but then do nothing to correct it. This issue will only be resolved by a solid scientific solution, not by political moves.

The burning of coal in power plants produces a lot of wastes in the form of SO_x, NO_x, CO_2, fly ash, bottom ash, arsenic and heavy metals: U, Th, Hg etc. The SO_x and NO_x emissions have been controlled during the last 20 years by using scrubbers at the power stations flue. CO_2 emissions are still produced at a rate of approximately 1050 grams of CO_2/kWh of electricity produced by a coal power station without scrubbers. If the power station has been equipped with scrubbers the CO_2 emissions are a little lower at 960 g CO_2/kWh(10). The SO_x and NO_x are controlled along with some of the heavy metals. These numbers can vary depending of the type of coal used. In this paper, we will use an average of 1000 g of CO_2/kWh. This corresponds to releasing to the atmosphere a little less than half a ton of CO_2 and 1,752,000 Wh/year of heat to produce the electrical currency needed to have a 100 Watt incandescent light bulb ON all the time for a year.

In addition to the CO_2 released the coal fired power plant produces a large amount of bottom ashes which are now recycled and used in the production of concrete. There they are captured and no longer present an environmental problem. There is interest now in removing all the minerals and metals contained in these bottom ashes and flu sludge, prior to mixing the ashes in the concrete.

Finally, carbon capture and storage (CCS) is capable of removing 85-90% (21)of the CO_2 present. Scrubbing also removes from the flu some of the heavy metals in the form of sludge. The fly ash removed by the precipitators, contains some CO_2 along with particles containing some mercury, uranium, thorium, arsenic and other heavy metals. The plant exhaust still contains some CO_2 , fly ash and particles which will still be released to the atmosphere even after CCS has been introduced. In 2008 the USA Department of Energy conducted a study and found that the general population in the US receives a larger dose of radiation from coal fired power plants than from nuclear plants(21). In interpreting this statement, one should consider that there are many more coal fired power plants than nuclear plants in the US. In any case, this is not considered to be a radiation health risk to the public because all the emissions of radioactive elements are well below the levels of background radiation. (see chapter 9).

With the implementation of CCS, the reduced release of CO_2 to the atmosphere will still be at an approximate rate of 100 to 150 g CO_2/ kWh (i.e. 10 to 15% of the current rate).

This is by far more important than any release of radioactive elements. CCS will improve drastically the rate of release of CO_2 to our atmosphere problem. But it will not eliminate it, unless the efficiency of the CCS process itself is improved to remove 100% of the CO_2.

Clean Coal is an umbrella term that includes: washing minerals out of the coal, gasification, and various other processes. It will still produce large quantities of CO_2 . The clean coal term is used to avoid criticism rather than to solve the problem. For example, when we produce H_2 (hydrogen) from the process of steam reform gasification, even though the hydrogen is now a clean form of energy currency, we have produced 664 g CO_2/kWh[22] of electricity equivalent in the making of it.

Carbon Storage is another area that needs caution. CO_2 gas is heavier than air. Any leak of the gas from underground storage will tend to settle on the surface of the earth and displace oxygen. This will cause a suffocation of life (people and animals such as in lake Nios)[3]. As we develop the CCS process, storing the CO_2 in solid or liquid forms should be the preferred method, especially, if the new high carbon solids or liquids could be made to have a commercial value.

We must remember however that we cannot pump CO_2 gas underground indefinitely and expect it all to stay there forever through geological events. As a result the CCS process should be viewed only as a temporary measure that provides life support to our coal industry. Our oil industry does not seem to participate in the CCS projects and hence it is reasonable to assume that the oil sands will not benefit from CCS for a long time. As a result CCS cannot be considered as a universal or as permanent solution. Storing the CO_2 in liquid or solid form will extend the period of this measure. Only processes that do not produce CO_2 will be able to provide us with a sustainable solution in the future. Even as a temporary solution the first CCS application, at best, is expected to be in place for the (Keephills 3) coal power station in about 10 years.

In summary , coal is an abundant, low cost primary energy source. Its' only problem is the extreme pollution it causes. Current technologies for producing clean energy currencies, clean coal, including CCS, only reduce the problem, but they don't solve it. Continuing R&D may produce some solution, but for now we seem to be at least 10 - 15 years away from success on this front.

6.0 THE CURRENT STATE OF CONVERTING OIL INTO ENERGY CURRENCIES

Energy Considerations

Since the late 1800's oil has provided most of the energy currencies that we need, including electrical energy currency, transportation energy currencies, Industrial currencies for the production of about 5000 products. It makes no difference whether peak oil has occurred yet or not(75). What is important to policy makers to consider is that peak oil will have taken place sometime between the year 2005(23) and in the not too distant future. As stated before, energy developments take a very long time to be established and policy makers have to be extremely pro-active. Plus or minus 30 years, in the exact timing of peak oil, make no difference for the formulation of a sound policy.

Oil is a fossilized and concentrated form of decayed organic materials. It is a naturally occurring flammable liquid found in rock formations in the earth. It consists of a complex mixture of hydrocarbons $(CH_2)_n$ with various molecular weights plus other organic compounds. Its sister bitumen (removed from the oil sands) is heavy oil from reservoirs of partially biodegraded oils. 5kg of liquid hydrogen per barrel of bitumen is required to convert the bitumen into "synthetic "crude oil(3,11).

Crude oil is composed of hydrocarbon chains of different lengths. Because of this property, the various hydrocarbon chemicals can be separated by distillation in a refinery and treated by other chemical processes to produce a variety of petroleum products. These products are used as currency fuels: Diesel, Gasoline, Jet fuel, Kerosene etc. In addition, other industrial currencies are produced such as alkenes to make plastics, Lubricants, Wax, Asphalt, Tar, Coke, etc.

The energy density of crude oil is 46.3 MJ/kg(mega joules/kg)(24), about double that of coal. The transportation currency fuels produced from crude oil have energy densities as follows:

Gasoline	46.4 MJ/kg(24)
Diesel	46.2 MJ/kg(24)
Jet fuel	42.8 MJ.kg(24)

As mentioned earlier, the energy currency of the transport fuels is only 70% of the original energy content of the crude oil and 50% if bitumen and natural gas have been used as the primary fuels. The 30% loss is reflected in the 30% conversion (loss) of the mass of crude oil during processing in the refineries. The remaining 20% is lost in the converting of bitumen to crude oil.

Economic considerations

The remaining world oil reserves will last us for about 80 years[11], accommodating current rates of usage increase and including the oil sands of Canada and Venezuela. For policy purposes, it is reasonable to assume that any new found wells will not be of such significant size to make a difference, in the world supply, by more than 10 years.

The price of a barrel of oil has been very volatile in the past 2 years. It has ranged from $30/barrel to $140/barrel. At the time of writing it is $78/barrel[25]. This price is expected to increase in the future due to demand increasing faster than the capacity to produce transportation fuels.

In the last 10 years the price of oil has increased, and as a consequence oil fired power plants have been retired at a steady pace as they became uneconomical. The few remaining plants that exist will not be renewed and it looks like oil will no longer be used for the production of our electricity currency. It has steadily being replaced by coal fired plants and natural gas fired plants.

The production of transportation currency fuels and industrial currency feed stock is continuing and increasing at a rate of 2% per year. World consumption has reached 86 million barrels/day eq. Note that industrial products such as car tires and plastics are actually sequestering carbon into a solid form. Consequently, the use of this industrial currency of hydrocarbons is not so subject to environmental pressures.

The implementation of carbon tax or cap and trade regulations will affect not only the consumption side of the crude oil based fuel currencies, but also their production when processed from bitumen. As in the case with coal, carbon taxes and cap and trade regulations will have no effect in reducing the production of CO_2 unless their costs exceeds that of CCS at about $110/tone of CO_2 emitted to the atmosphere.

Environmental Considerations

The principal environmental concern with the crude oil currencies is with the consumption of gasoline, diesel and jet fuel, in cars, trucks, trains, boats and airplanes. Furthermore, the production of crude oil energy currencies, especially from the oil sands bitumen seems to concern the public even though Canada emits 544 million tones/year from all forms of energy related activities. This is only 1.9% of the world's total(26).

The burning of diesel to generate electricity produces 778 g CO_2/kWh(27) of the electricity produced. Gasoline is very much in the same ball park. Compared to coal fired plant producing at 1000 g CO2/kWh it is better but still very high.

The burning of diesel or gasoline for transportation (private cars only) produces an average of 175 grams of CO_2/km driven(28). The minimum is 89 g/km for small cars and the maximum is 500 g/km for big ones. In addition, one has to double these emissions to cover the releases made to the atmosphere from the production processes used to convert bitumen to crude oil and crude oil to fuel currency. Hence driving a car (diesel or gasoline) that is filled with a fuel currency derived from bitumen will be producing directly and indirectly, on the average, 350 g CO_2/km.

In summary, crude oil and bitumen can still provide us with the energy currencies we need for the next 80 years. They are no longer competitive in producing electrical currency, but they are competitive as fuels for transportation. The problem arises from environmental concerns because they are still very polluting. Also, hydrocarbons can be used as industrial currencies for the manufacture of some 5000 products. This process sequesters carbon in solids and from an economic as well environmental point of view it should be encourag

7.0 THE CURRENT STATE OF NATURAL GAS AND ITS CURRENCIES

Energy considerations

Natural gas is found in porous rock usually in the proximity of other fossil fuels. It is found either in raw natural gas wells, crude oil wells or from coal seams. It is the lighter end of the $(CH_2)_n$ and CH_4 methane molecules of the hydrocarbon chains. The higher is the hydrogen content the higher becomes the energy density of the gas and the cleaner it burns. Natural gas has a density of 55.6 MJ/kg(29). Natural gas energy densities are higher than those of the transportation currencies (diesel, gasoline & jet fuel), and much higher than that of coal.

The gas that is coming out of the ground at the "wellhead" is mostly methane (CH_4) but it contains some ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}) & longer chains of hydrocarbons and water. Then the water is removed to produce the "utility gas" that is consumed inside the producers operations. The rest of the gas is purified further to remove the heavier elements before sending it to the consumers. One problem not known widely is that the process of extracting natural gas, releases CO_2 pent up in the same well as natural gas. This adds a significant quantity of CO_2 to the environment that is not normally being acknowledged, monitored, recorded or considered more than represented by the term "fugitive" emissions.

Natural gas currency is used for residential heating, transportation fuels, and the production of fertilizers and pesticides. It is also used to power gas turbines for the production of electricity. Conversion losses from "wellhead" natural gas, to commercial natural gas, is about 5% depending on the type of well, the amount of water present and the refinery. Conversion of commercial natural gas to electricity has losses of 50%(5). Hence, at least 55% of the electrical energy currency from the gas is lost as heat and pollution to the environment.

Another use of natural gas is to use it as a feedstock for the plant that produces hydrogen in the upgrading of the bitumen into crude oil. 35.31m^3 (1000 cubic feet) of gas is consumed and 5 kg of hydrogen is produced and used for every barrel of crude oil produced at the oil sands.

Economic considerations

Up to 2006 the gas reserves in North America were depleting rapidly and it appeared that our reserves will be depleted in about 25years[11]. Then a new process was developed to extract gas (a combination of horizontal drilling and hydraulic fracturing of the rock). This process used on the shale resulted in a glut of gas at the time. Based on initial flows from the gas wells it was estimated that gas was going to last for 60+ years and supplies were rising fast, as Tony Hayward, BP's Chief executive told the World Gas Conference in Oct 2009. Subsequently, it seems that the initial flow rates at the gas wells are rapidly declining.

At the writing of this paper the wholesale price of gas has risen from \$4.50 to \$5.34/kJ[30]. All gas storage areas are full and production is slowed down due to this glut. Gas fired plants, for the production of electricity, are being built more frequently in order to help with the global warming problem, since the gas burns cleaner than coal and hence we solve our CO_2 problem. At least this is the popular thinking and belief.

As we will see later on Chapter 8, gas fired power plants are also built to compensate for the instabilities of the wind power and the solar power stations and to keep producing electricity for the grid when these green sources are not available. We will see that 70% of the installed capacity of wind power is produced by gas fired power plants, (see page 30). We are going to examine this issue in later chapters. For now, we should become aware that for a variety of reasons we are replacing coal fired power plants with gas fired power plants – not wind power, as many people believe.

The only economic drawback is that when the gas supplies are diminished we will no longer have the low cost gas to make fertilizers and pesticides for our agriculture. This means that hydrogen would be produced by different means which in turn would impose higher prices for our food.

Large combined cycle gas fired plants cost (2009) \$2800/kW in capital cost, \$8/MWh for O&M, \$6/MWh for natural gas and increasing for each \$1 increase in the price of natural gas.

Environmental considerations

A natural gas fired electric power station produces 443g CO_2/kWh[(31)] that is considered to be a pollutant. This is a little less than half the pollution rate of a coal fired plant. Yes, it is an improvement but continuing releasing to the atmosphere, at half rate the substance that is considered to be a GHG, does not make much sense as a policy. If CO_2 is damaging indeed, then going through all the trouble just to reduce to half its rate of increase seems insufficient in this case. For policy purpose, reduction of existing CO_2 in our atmosphere, or at least stop its release, should be more prudent and worth the effort. In going along the current path all that we achieve is to deceive ourselves that we are addressing a problem that may exist.

The use of 35.31 m^3 (1000 cubic feet) of natural gas per barrel of crude oil produced is another area that needs attention. The 5-10 kg of hydrogen/bl, that is stripped from natural gas, although convenient, is clearly the wrong direction. It not only depletes a valuable commodity, but also releases to the atmosphere much of the CO_2 from oil sands production, that causes the world to call Alberta oil a “dirty oil” .

$$\mathbf{CH_4+2H_2O = 4H_2+CO_2}$$

A policy should encourage other cleaner and more efficient ways to produce hydrogen and at a reasonable cost. They do exist[(79)]. The problem is that in formulating an energy policy one needs objective information. Mastering the knowledge needed to see past marketing ploys and transition problems is very time consuming. Hence, the advantages and disadvantages of the processes used in energy currency production are going unnoticed.

The more criticism oil companies get about CO_2 emissions the more tempted they become to ship to the USA raw bitumen. Yes this reduces the CO_2 emissions from Canada, but also the value added of upgrading disappears along with higher royalties. On the other hand the US refineries still produce hydrogen from striping gas and causing the same amount of pollution. Would it not be better to upgrade bitumen at home with clean produced hydrogen?

8.0 THE CURRENT STATE OF RENEWABLE ENERGIES

Renewable energies is an umbrella term that includes, solar power, wind power, bio-fuels power, geothermal and hydro power. Green, meaning environmentally friendly primary source that renews itself. As a result, the general population's thinking is very favorably pre-disposed towards all of them. In fact there is a significant amount of infatuation towards green energies. This chapter will highlight the advantages and disadvantages for each one of these technologies.

SOLAR

The solar constant describes the Solar Radiation that falls on an area above the atmosphere at a vertical angle: $s=1.37 kW/m^2$. In space, solar radiation is practically constant; on earth it varies with the time of day and year as well as with latitude and weather. The maximum value on earth is between 0.8 and 1.0 kW/m^2, depending on the region. If all of this energy could be captured and converted to energy currency, humanity's energy requirements would have been solved easily by just developing the energy sources for getting power at night. Each house would need about 10 to 20 m^2 of solar panels.

The solar panels (PV) that we have today however, can convert about 10 to 12% of the energy coming from the sun, about 120 watts per m^2. When the sun's angle is not perpendicular to the earth's surface the amount of power drops with decreasing angle of incidence. As a result, the maximum amount one can expect to get from a one m^2 solar panel, on the roof, is about 200 to 300 watts per sunny day, depending on the latitude[33].

During the operating period a solar panel needs to be washed frequently with soap, otherwise its performance of absorbing and converting solar energy, downgrades quickly. This technology however, has proven very competitive in remote locations for charging batteries in small installations.

It is just this low conversion ability that has deprived solar power from being used as a large scale primary source of power. Many people are proposing solar as a solution, but in reality "easy answers" are not answers at all.

The output of our current solar panels is so low that to produce just 1% of US electricity demand in the year 2000 it would have required three times the world production of germanium, or 20 times the world production of gallium.

Economic considerations

The cost of a solar panel is about \$500 for 1 m^2. Hence not only the performance is very low but also the capital cost is very high. Thus the cost of power from today's PV solar panels is of the order of \$0.80/kWh(34) , this is about sixteen times higher than the cost of wholesale power now. This cost does not include the cost of batteries or the back up power for nights and cloudy days. All together solar power represents a significant financial burden to the consumers for practically very little benefit, if any.

Environmental considerations

Solar panels last about 20 years. Disposal of used panels is very difficult because solar panels include toxic materials, explosive gases and carcinogenic solvents. Incineration or recycling is also very difficult and expensive as it will have to take place in a controlled and fully enclosed environmental cell, all of which add to the cost. In addition to the toxic materials and solvents that go into their construction, the materials and manufacturing of solar panels releases a small amount of CO_2 in the atmosphere. It corresponds to 32 g of CO_2 for every kW hour they produce during their lifetime(35).

In summary, contrary to the popular beliefs, solar power is neither cheap, nor efficient, nor is it as environmentally friendly as it is perceived. Simply put it cannot meet our needs in a major way. At least this is the status for the solar panels that exist today. Extensive R & D could develop a better technology in the future and capture more of the sun's energy. For now, we can only use them for isolated specific applications in remote locations, where they can be most competitive. Under these circumstances, solar power cannot be scaled up and used to provide any of our collective energy currencies. The only successful direct application of using solar power economically is to heat water on top of a house for domestic consumption. This has been done efficiently south of the 38th parallel.

Another type of application is to concentrate solar energy to heat water and drive steam turbines. This provides a small improvement, but still the performance realized does not justify the cost. Projects have been built, but plants like this are experimental prototypes which again, have not provided performance and cost information that would encourage investors for large scale commercial deployments.

Further development is needed not only to improve the performance of solar power, but also to make it responsive to the needs of the grid. Even then, solar will always need a backup power station or expensive energy storage to keep the lights on at nights and on cloudy days.

BIOFUELS

Energy from bio-fuels includes a number of processes which convert oils and fats into a variety of fuels (biodiesel, biogas, methane, ethanol etc.). There are several generations of bio-fuels, most of which are occupying niche markets, such as collecting waste material from meat processing and converting it into biogas(36). Specialized applications of this type have a wide appeal, because on the one hand they resolve the problem of disposal of a particular waste, on the other hand they produce a useful fuel energy currency. The disadvantage of these processes is that these niche markets cannot be expanded into large scale energy production processes for a widely used energy currency. This is because of the limited volume of waste fats and oils that can be made available.

Another form of bio-fuels is the fuels made from cultivated crops to produce ethanol as an additive to gasoline and biodiesel. This could be expanded into a large scale energy production. However, crops need water fertilizers and pesticides, they need farming equipment to cultivate, to irrigate and to transport. All these activities consume a significant amount of conventional hydrocarbons and natural gas. In summary, 1 barrel of oil equivalent is consumed for every 2 barrels of ethanol produced. Also, 1 barrel of oil equivalent is consumed for every 3 barrels of biodiesel produced(11,37). In addition, cultivation and the production of crops for both ethanol and biodiesel consume a tremendous amount of water.

In this regard, bio-fuels, based on agricultural crops, are not really renewable because of their dependence on hydrocarbons. Of course, there is the close relationship of cultivation for bio-fuels that competes against cultivation for food. The lack of spare cropland and water seems to affect the price of food worldwide.

There is a tremendous amount of research taking place in this field and some interesting areas are being developed[73] but one should be cautious for making policies based on (preliminary results or based on claims that have not been fully analyzed. Here are two examples. One of the processes is “Helioculture” which it is claimed to yield 20,000 gallons of fuel per acre per year. It also claims to remove CO_2 from the atmosphere using only solar power. But if someone analyzes this statement, they will find that all plants and trees have processes that remove CO_2 from the atmosphere using only solar power. Helioculture does the same but more efficiently. Another process claims to produce bio-hydrogen. This sounds good until one goes through the process and finds that the production of hydrogen is done by a kind of steam reform of methane. This is the process used now at the oil sands, to produce hydrogen from natural gas that releases a lot of CO_2 to the atmosphere.

A promising new area for bio-fuels is now being developed by the US Navy together with various commercial airlines. They get bio-fuels from algae and the plant jatropha. Also, the Navy gets algae derived diesel from camelina, a non food related plant[38].

As an indication of the relative costs of bio-fuel produced electricity, the Ontario Power Authority (OPA) has published a price list. This shows the cost of grid-electricity from the various biogas projects is $0.19.5/kWh[34,73]. One however should expect a great variation in prices, as there is a great variation in the processes employed.

From the environmental point of view, bio-fuels burn a little cleaner than oil based hydrocarbons, but still emit comparable amounts of CO_2 like oil. The reason claims are made that bio-fuels are CO_2 free is that they do not introduce new (or old fossil) carbon into the atmosphere. Growing plants are assumed to remove it from the atmosphere. The cleanest biogas, produced through an anaerobic digester produces electricity with emissions of 11 g CO_2/kWh[39]. The key consideration here is how much CO_2 is produced through the series of preceding complex processes, to produce the biogas or the bio-fuel currency.

GEOTHERMAL ENERGY

This kind of technology has been proven in areas where underground water and large rock enclosures favor its use. Underground water picks heat and expands. Since it cannot expand horizontally through the walls of the rock enclosure it expands upwardly and rises close to the surface. There the steam can be used for heating or for driving a turbine to produce electrical power.

When someone is trying to create artificially the same conditions, he will need to pump underground substantial amounts of surface water, in the hope that there may be an existing rock enclosure with fully enclosed vertical walls. A geothermal project in Basel Switzerland was cancelled when they noticed that pumping water underground had caused 10,000 earthquakes per week measuring up to 3.4 on the Richter scale[40]. A similar project in California was cancelled for the same reasons. It becomes quite clear that this type of energy can only be used in a limited number of places. It cannot be created artificially anywhere in a scale, large enough, to become a primary energy to a country. Alberta's underground formations do not seem to favor artificial geothermal energy for large scale use.

Deep drilling with localized pipes that pump water down, remove heat and then recover it, is also possible. Here again, one would expect a limited number of successful sites, each one with a limited capacity. On this basis, Alberta could not become a large scale user of geothermal as a primary source of energy. These types of power plants emit 32 g CO_2/kWh[41,71] of the electrical power they produce which is lower than any fossil.

In summary, this technology is a viable and tested technology, however; its application will be limited to only some areas, or a few industrial plants.

WIND POWER

This technology is a proven technology, however, its application has been focused in the wrong direction, mainly because of Government subsidies in the wrong direction. A wind mill produces electricity only when the wind speed is roughly above 11km/hr (6 mph). Below this speed no electricity is produced[(42)]. The wind mill also has an upper limit at 93km/hr (52mph), above which the blades are trimmed and stop, to protect the wind mill from damage. These limitations cause the wind mills to produce about 25 to 35%[(43)] of its nameplate electricity capacity, on an annual basis.

When the wind is between 11 and 93km/sec. it is seldom steady because the wind usually blows with gusts. Doubling the wind speed produces 8 times the power surge. Conversely, reducing to one half the wind speed reduces power output to 1/8 th. This means that wind mills amplify the instabilities of the wind and this is reflected in their power output. If one was to connect their house directly to a wind mill, instead of the grid, the lights will be fluctuating up and down like you had a 3 year old child playing with the dimmer switch. This is because wind power is not responding to fluctuations in demand. If you had an elevator in your house its speed would fluctuate faster and slower every time a light went on or the freezer started running. This is what is called “wind instability”.

The electric grid on the other hand, is a set of transmission wires that only transmit electricity. They cannot store very much. When a large motor goes on, the voltage in the grid will drop a little. A power station will detect this lower voltage and speed up to bring the voltage back to let’s say 120v. While this power station runs faster to maintain the grid voltage constant, it actually produces the electricity that your motor is consuming. When the motor stops, the voltage will increase, the power station will detect it and slow down a little to maintain the same 120 volt in the grid.

In other words, the electrical grid is a dynamic system that responds to the demand of the consumers. A wind mill however, not only does not respond to the consumers demand, but also, it imposes its own instability demands on the grid as variations in wind speed reflect in its output. To correct this instability, the grid needs to run another power plant at the same time. This stabilizing plant runs in tandem with the wind farm 24/7 and powers up when the wind drops, it powers down when the wind speeds up. It also produces maximum power when the wind mill stops - below 11km/hr or above 93 km/hr. On an annual average the stabilizing power plant produces 70% of the wind farm name plate capacity. This is more than double the amount of the wind mills.

A stabilizing power plant can be any one of three different types. Hydro, coal fired or gas fired. (Nuclear plant may do it, but it is avoided due to stresses caused from continuous fluctuation). We must keep in mind that each back up power station must have the same or greater capacity as the wind farm name plate capacity in order to produce the demand power on windless days. Let's examine separately each option:

1) A hydro power plant with water storage is ideal for this case. When there is wind you save water, when there is no wind you use the water. It can respond quickly to the variations of demand. The net contribution from the wind farm is 30% of the demand. 70% comes from the hydro plant. The best way to integrate wind and hydro power technologies was achieved in Denmark with their existing hydro plants.

   Here we need a clarification. Denmark has claimed to have 19% of its installed capacity in wind farms. And this is true. We must note however, that Denmark shares their grid system with the other Scandinavian countries which have an abundance in hydro power and no wind mills. The clarification is that the Danish wind mills form a much smaller % of the Nordic grid.

2) The Coal fired plant provides exactly the same compensation to wind power as the hydro plants in Denmark. The only difference is that one had to build a standby coal fired plant, which nearly doubles the capital cost/kWh. It also has to run the coal fired plant at partial load 24/7 in order to be ready to respond to instabilities. Finally, the stabilizing coal fired plant produces 70% of the demand power and wind power produces a maximum of 30% .

   This has been done in Germany during the last 20 years of working with wind power. The CO_2 produced from the combined operation of the two plants is 70% of the coal emissions plus 30% of the wind power emissions. Hence, the overall pollution level will be 1000x70%+11x30%=703 g CO_2/kWh.

   Since the coal plant is idling 24/7 the CO_2 emissions level will actually be higher.

3) In Alberta we don't have many sites to build hydro plants, except far North. Also, as we saw in (2) above coal plants produce high pollution. Consequently, the only wind stabilizing power plants in Alberta have been natural gas fired turbines. They have a relatively low capital cost and can provide fast response to instabilities. Hence, whenever we build a wind farm, we also build a gas fired plant with the same name plate capacity. The gas plant runs at partial load all the time and produces 70% of the electrical demand while the wind farms produce their 30%, on an annual average.

   Again we have substantially increased our capital cost (wind farm and the gas fired plant), since we have two power plants to do the work of one. The CO_2 produced is 70% from gas and 30% from wind. The combination of the two is

   443 g/kWh x 70% + 11g/kWh x 30% **= 313 g CO_2/kWh.**

Actually since both the coal plant and the gas plant run 24/7, at partial loads, the rate of pollution will be much higher. In any case the conclusion to be drawn here is that regardless of how many wind mills are placed in the electrical grid, the amount of pollution is only reduced to 313 g CO_2 /kWh . It is not eliminated. In Alberta we think that we are replacing coal fired power plants with wind power. In reality we are replacing coal fired plants with gas fired plants. And the emissions of what we call to be pollutants, continues at 313 g CO_2/kWh, day after day, year after year.

Europe's experience with wind energy, over the last 20 years, is confirming the theoretical calculations: No fossil plants are closed, energy use and CO_2 are up, energy costs are up and no compensating benefits are apparent[(44)]. Also, in the UK they conducted a modeling analysis to evaluate the maximum amount of wind instability that a grid can tolerate. They reported that up to 10% installed wind capacity can be accommodated by an electrical grid system[(45)].

When one is making a policy on wind power they must become aware that on the one side we have green environmentalists, naïve as they may be and on the other we have wind developers and others who are motivated by a different kind of green. So we have an unholy alliance that includes even some Churches lately. This alliance exerts an influence on governments. Acquiring technical expertise is of paramount importance.

Economic considerations

Electricity produced for the grid by land based wind mills costs a wholesale price of \$0.13/kWh[34,74]. The offshore wind mills produce power at \$0.19.5/kWh[34,74]. The capital cost for Enbridge's Talbot project (the most recent) is costing \$2.8 million/MW (megawatt), electrical capacity installed. This is about double the cost of 3 years ago.

In conclusion, contrary to popular beliefs, when some of our electricity currency comes from wind power, the system is neither green, nor clean. It is very expensive and can hardly produce more than 10% of the electrical energy currency that we need as it was confirmed by the British grid modeling study. Ontario's "Green Energy Act" appears to be a political plaything instead of a solid energy plan. This bubble waits to be burst, consequently, it should not be relied on as a valid example of sound technical/economic thinking[82].

In 1986 a frightened Europe, following the Chernobyl nuclear accident, made policies and passed laws to eliminate all nuclear power plants and to replace them by renewables. Some countries like Italy shut down their nuclear plants immediately. Others adopted a phase out plan of several years.

For the last 23 years they have been employing a massive effort, resources and subsidies trying to overcome the wind instabilities and the low solar output. Last year in Germany alone they paid subsidies worth 5 billion Euros, for less than 5% of their demand, to come from renewable sources[46]. Meanwhile the price of electricity in Europe (except France) hit the roof and countries started turning around 180 degrees and committing themselves to nuclear power again. They realized that renewables could not meet their demand. Starting with Finland all European countries, like falling dominoes[47,48,49], one after the other have been turning around. They didn't actually stop R & D for renewables. They are reducing their operating subsidies and are making commitments for 30-40% of their grids for nuclear power ASAP. At the writing of this paper, the only country to hold out has been Spain, and even it has extended the lifetime of their nuclear plants and stopped operating subsidies to solar power. As the German magazine SPIEGEL ON LINE wrote: "Climate has not profited from these developments, not even a single gram of CO_2 was saved. The number of CO_2 emission certificates is the same".

The old European trend of renewables has hit North America as the Europeans are now getting out of it. It was stated above that wind power is a useful technology that is focused in the wrong direction. What was meant by this statement is that Governments everywhere have been offering politically motivated subsidies and tariffs to technologies with unstable output to supply the grid power currency that is required to have extremely steady voltage and frequency and to be responsive to demand.

Let's suppose that our Government decided to subsidize wind power to produce the hydrogen currency through electrolysis, instead of electricity to the grid, as it does now. When there is wind there will be production of hydrogen. When there is no wind there will be no production of hydrogen. A pipeline, truck or rail could connect the wind farms to the upgraders, store and supply the hydrogen that the oil producers need to upgrade the bitumen. A move in this direction would provide Alberta with a plan to clean its oil overnight. Such a plan would certainly calm its critics and will conserve at the same time our natural gas resources. An enormous amount of pollution will be saved by stopping the production of hydrogen from natural gas. Initially the unit cost of hydrogen will be higher but as the infrastructure expands and develops it would bring it down considerably. (Ch 16).

Under this scenario, no instabilities are present, no stabilizing plants are needed, no tariffs, no carbon taxes. Alberta will be exporting "clean oil" and the new renewable technologies which will be developed along this new field. Under this scenario wind power could become very competitive and grow, without limits and caps that are present in a grid system, thereby contributing a valuable, large scale currency. Wind power could also be used in the synthesis of currencies for transportation. (see chapter on synfuels).

Even the production of hydrogen will not happen in a 100% clean environmental manner. Wind mills need to be anchored to prevent them from toppling over. A 2MW wind mill requires a concrete foundation about 14.5 M (47 ft) in diameter and 12.5 m (40 ft) deep. It takes about 230 m^3 (300 cubic yards) of concrete to support a wind mill[(50)]. Cement plants are powered normally by coal and it is known that the production of cement is one of the most polluting industrial processes. Considering the concrete and their high tower, wind mills are counted to produce 13gCO_2/kWh over their operating life time[(51)]. A wind-farm with 100 windmills, 2MWe each, can produce 9,300 tons of H_2 per year, will consume 83,700 m^3 of water/year (83,700,000 liters, about 1.5 times the daily consumption of the city of Lethbridge) and will save 24,000 tons of CO_2 per year from being released to the atmosphere.

HYDROELECTRIC PLANTS

Hydro plants have been traditionally the best power option. They have a high original investment but they can operate for many years with low operating costs. Due to the original construction of the dam, it takes a lot of energy, and it produces a lot of pollution, it is estimated that hydro power produces 13 g CO_2/kWh[52] of electrical power produced. Unfortunately, we don't have many sites left that can be used for hydro power in Alberta except in the very North end of the province that present a host of new problems.

In conclusion of renewable energies, it was mentioned earlier that R & D, prototyping of power stations and implementation of technologies takes a very long time frame. All the renewable technologies, except hydroelectric plants, are at their early stages of their development and prototyping. It will take many years before they are able to contribute effectively and to compete. For example wind power doubled its installed capacity between 2005 and 2008. Yet it still provides the same 1.5% of the world's energy demand. (0.5% in Canada). The problem is that the world's energy demand increases much faster than the wind power industry can grow.

In Denmark as well as other European countries, after 20 years of experimenting with their political play things, they still have 70% of their power produced by fossil fuels (gas and coal). In addition they have their hydro power[74].

The Canadian Energy Research Institute's (CERI) study concluded that renewables should be able to provide 20% of the total demand. This is possible considering that hydro and bio-fuels are included in this category and they can produce more than 10% of the demand.

9.0 THE CURRENT STATE OF NUCLEAR POWER AND ITS CURRENCIES

Nuclear power is a complex system used to boil water and make steam to drive a turbine. The primary fuel is uranium, a metal that is mined from the ground. The energy density of uranium is 1,000,000 times more than the energy density of hydrocarbons. It is used to produce heat in the power plants, or in industries that need a strong metal for such things as airplane wing junctions, stabilizer fins and steel piercing ammunition.

To appreciate the enormous energy density of uranium, one must consider that each time a single uranium fuel pellet (about 5 grams ea) is residing in the reactor core for about 1 year, it is producing the same amount of energy currency as 807 kg of coal[(53)] or 677 liters of oil or 476 m^3 of natural gas. Now, one must also consider that during this one year of residency in the core, only 1% of the uranium is burned, in this 5 gram pellet. The other 99% uranium is still good uranium fuel but it is contaminated and needs to be reprocessed and cleaned from the contaminants and adjusted before it can be burnt again. It follows then that with reprocessing, the same uranium can go into the reactor core again and again until it is all burned. Using breeder reactors[(67)]and reprocessing not only extends our uranium resources by 90 - 95 times, but also destroys (burns) the very long lived isotopes. The reason that reprocessing has not taken place in North America yet is because of lobby, political regulations and economic considerations only. Most of the technical problems have been resolved, for example in France they now reprocess and recycle their fuel. In Japan and the UK they do the same. Initially, after removing the spent fuel from the reactor, it is very radioactive. But after 25 years of storage the radiation has dropped to only 0.05% of its original value and the spent fuel can then be reprocessed more economically. (see table 2)

When the fuel is not reprocessed, i.e. it goes only one time through the core, the so called spent fuel is radioactive with isotopes, some of which live for thousands of years. This is why the nuclear industry wants to bury it underground, retrievably, in such a way that future generations will be able to retrieve it. The thinking is, that after 300 years buried underground, the radiation of the spent fuel drops to the same level as that of a natural uranium initially mined from the ground. Again, it could at that time be recovered and reprocessed much more economically.

The mention of nuclear power generates several questions: Is nuclear Power safe? Is the spent fuel dangerously radioactive for 250,000 years as anti nuclear activists say or for only 10,000 years as nuclear experts claim? Do nuclear plants release radiation and other harmful radioactive substances to the public? Do nuclear plants cause cancer and leukemia in the public living in the vicinity of a nuclear plant or not? How damaging is the tritium that is released from nuclear plants? Can people steal spent fuel to make a bomb?

The task of answering these questions is hindered by a widespread confusion regarding key facts of science. This confusion has given rise to several fallacies and misconceptions. These myths and misconceptions and how they relate to the above questions are explained here.

Humanity, since the beginning of time, has survived and evolved in a continuous bath of radiation that is called "**background radiation**". This radiation comes from the ground, the buildings, trees, air, the water we drink, the food we eat, from our spouses, children, ourselves from the sun etc. Many people may be astounded to know that in our bodies we have an average of 7000 atoms per second giving out radiation. This continues throughout our lives.

The average background radiation on earth is 2.4 mSv/yr[54], (milli Sievert- Sievert being a unit of radiation absorbed by the body) but it varies with altitude and location. Minimum background radiation is 1 mSv/year and maximum is 790 mSv/year. If radiation within these levels was damaging, one would expect that people who live in locations with very high background radiation, would keep filling the hospitals, suffer from cancers and death at much higher rates than the world average. Well, this does not happen. The rates of deaths and the incidents of cancer are the same regardless if one lives in a low or high level of background radiation area.

People living close to, or are working in a nuclear plant have understood this concept and have learned to evaluate all radiations in terms of their background radiation. The idea is that any radiation received that does not exceed the levels of background radiation should not be alarming. Hence, levels of radiation are gauged and one gets a feeling of the real meaning of numbers that indicate intensity of radiation. It is important to be able to gauge radiation because otherwise we cannot see it, smell it, taste it or detect it with any of our senses. The background levels provide a datum line against which we compare all other levels of radiation.

The regulatory authorities have gone one step further and have set the allowable limit for a worker in a nuclear plant at 1 mSv/yr,[54] (about 40% of average background radiation). This is the equivalent of one abdominal x-ray per year. They also limit the amount of radiation from nuclear station contaminants that can be legally released to the environment. They are defined such that they don't cause a wide localized area with increased background radiation. The nuclear reactor operators have gone even further and they make sure that their releases don't exceed 1/100 th of the regulated limits[55]. (This is 0.4% of background radiation). Table 2.0 provides typical amounts of radiation that we receive from our everyday activities. It also includes radiation doses from medical diagnostics and procedures.

Nuclear plants, like any other industrial plant, will inevitably have some time a valve leak, a pipe break, or some other industrial mishap. A strong building that houses all the radioactive materials is kept inside with lower pressure than atmospheric. This permits the containment of accidental releases. As a result the general public in the proximity of a nuclear reactor gets only 0.009mSv/year from the nuclear plant. Since the background radiation, that is 1000 times stronger, does not cause cancers, then why should this miniscule amount be alarming. Complaining about this amount of radiation, is viewed by experts to be the equivalent of someone throwing a drop of water at people in a swimming pool. Should they be alarmed that they will get wet?

Anti nuclear activists, get the reports of releases from failures or mishaps, in nuclear plants and without analyzing them relative to background radiation levels, they freak out and panic. Similarly, they calculate half lives of isotopes, ignoring the background radiation, and conclude for example that spent fuel lives (remains radioactive) for 250,000 or more years. The experts consider its life time to be that until it drops below background radiation and conclude that we should be concerned for only 10,000 years. Are the experts lying? Or they have more information and can relate to it better than the anti-nuclear activist. Even 10,000 years of life time for the spent fuel is too long. It would be preferable to reprocess it and reduce the radiotoxic lifetime of the final wastes to 350 years, while increasing our resources 90 fold. It is just a matter of time before this will be fact. MIT in 2009 conducted a study and decided that reprocessing will be economical in about 25 years. Table 2.0 is showing that we get a lot more radiation from medical procedures or from air travel than from nuclear power plants.

TABLE 2

RADIATION DOSES RECEIVED FROM/BY

Background radiation - various locations		
Natural radiation from tritium	0.02	mSv/yr
Natural background radiation on earth – minimum	1	mSv/yr
Natural background radiation San Francisco and US Gulf states	1.2	mSv/yr
Natural world background radiation – average	2.4	mSv/yr
Natural background radiation in Western Canada	2.6	mSv/yr
Natural background radiation in Banff, Alberta	2.8	mSv/yr
Natural background radiation Washington DC & Grand Central Stn NYC	5	mSv/yr
Natural background radiation Findland	8	mSv/yr
Natural background radiation Sweden	18	mSv/yr
Natural background radiation Karala Beach India	35	mSv/yr
Natural background radiation Haute Provence France	88	mSv/yr
Natural background radiation Ramsar Iran	700	mSv/yr
Natural background radiation Guarapari Beach Brazil- Earth maximum	790	mSv/yr
Radiation by single or limited events		
Hiking to 12,000 feet	0.0002	mSv
Panorama dental X-ray	0.02	mSv
Standard medical diagnostic procedure	0.04	mSv
Breast X-ray	0.05	mSv
Mandible CT scan	0.07	mSv
Skull X-ray	0.15	mSv
Chest X-ray	0.3	mSv
Abdominal X-ray	1	mSv
Head CT scan	3	mSv
Astronauts during a 12 day flight	5	mSv
Barium fluoroscopy	5	mSv
Body CT scan	10	mSv
10% of evacuees from Chernobyl site following the accident	50	mSv
5% of the closest evacuees from Chernobyl accident following accident	100	mSv
Heart catheterization	450	mSv
Radiation dosage capable of causing sickness	1,000	mSv
Mild acute radiation syndrome	2,500	mSv
Single dose of radiation capable of causing death	4,000	mSv
Radiation therapy localized and fractionated	60,000	mSv

Radiation per year by event

Canadian from Chernobyl accident now	0.00028	mSv/yr
Public by proximity to a nuclear reactor	0.009	mSv/yr
Ukranians from Chernobyl now	0.02	mSv/yr
World from nuclear tests in 1958	0.11	mSv/yr
Average radiation for Canadians from medical and dental tests	0.6	mSv/yr
Worker in a nuclear plant	1	mSv/yr
Commercial airline crews	2	mSv/yr
Fresh uranium bundle before placement in reactor core	3	mSv/yr
Limit for Canadian nuclear workers averaged over a 5 year period	20	mSv/yr
Limit for Canadian nuclear workers in any one year	50	mSv/yr
Partially spent fuel 300 years after removal from reactor	530	mSv/yr
US radiology technicians practicing on each other during WW-2	1,000	mSv/yr
Partially spent fuel 100 years after removal from reactor	5,312	mSv/yr
Partially spent fuel 10 years after removal from reactor	34,000	mSv/yr
Partially spent fuel 1 year after removal from reactor	300,000	mSv/yr
Partially spent fuel coming out of the reactor	30,000,000	mSv/yr

With regards to tritium, much has been done to exaggerate the effects of these releases. At 7000 Bq/L (Bequerels per litter, Bequerel a measure of radiation emitted), which is the Canadian limit for tritium in water, a release of this size corresponds to a radiation exposure near the station of a dose of 0.1 mSv. This is 10% of the International Commission on Radiological Protection (ICRP) limit for public exposure and 3% of the average Canadian annual background exposure. In Ontario, they have now lowered the tritium content for drinking water down to the ridiculous level of 20 Bq/L, a policy that appears to appease anti-nuclear hysteria. This effectively makes it illegal to pour Scotch whiskey into Lake Ontario. The radiation that naturally exists in the booze would be above this limit. (56)

Finally, anti-nuclear activists are claiming that nuclear power plants cause cancers, deaths and leukemia, but they have never be able to show the dead bodies, the victims, or the hospitals filled with cancer patients. Percentages of cancer victims or death rates appear to be consistent whether you live close to a nuclear plant or not.

Economic considerations

Uranium exists everywhere in the crust of the earth to a density of 0.04%. In some areas it has been concentrated by the action of water. Some mines in Canada have a concentration of 20%. It is also estimated that the rivers worldwide leach out about 1600 tons/year. In addition uranium, and another similar fuel, thorium, can be extracted from sea water. It is reasonable to expect to find additional uranium mines where underground water has concentrated uranium ore. The known reserves for now are estimated to last for 70 years without reprocessing, at the current cost of uranium. If we were to start reprocessing, the reserves will last for thousands of years. At the same time, we will reduce the time of long lived radioactive wastes to about 350 years, from 10,000 years. If we follow this path, we could achieve a reduction in CO_2 emissions and secure a low cost reliable energy that can be converted to any of the currencies that we now use.

The cost of a nuclear power plant includes a very high capital cost upfront and a very low cost for fuel and for staff to operate it and maintain it. The capital costs upfront represent about 80% of the total cost, and the operating cost for 60 years represents 20% of the total cost of the plant over its life time. In addition, an appropriate refurbishing should be budgeted for the 30th year of operation, about 30% of the original capital cost, inflation adjusted.

The high upfront capital cost for the first reactor in a station represents a can of worms for potential problems. While one plant may prove very profitable another one may not. It all depends on: a) The length and cost of the planning process, b) Solid project management with no changes during the project, c) Rapid execution of construction and use of modularization, d) Low interest rates that can be achieved by loan guarantees and e) Mass production of equipment and construction for multiple units.

Experience has shown that delays due to design changes midway through the project can have devastating consequences. The cost of interest on the borrowed capital adds $3 million/day, for a plant 1000 MWe. Therefore, the stakeholders must ensure that the licensing authority is completely satisfied and that no changes will be introduced after the design has been licensed.

Note that this argument is valid for any very large scale industrial project. The high upfront capital cost does not depend on the technology we use or the type of plant that we construct. It is related to the size of the plant. That is why the new technology of small nuclear reactor units of100MWe with modular construction of power plants is appealing. In this case, mass production techniques can be used, easier licensing procedures expected, more favorable economic model is created, and results in a more efficient grid system if distributed.

With the low anticipated interest rates during the next few years The first 1200MWe nuclear power plant in North America should be expected to cost about $5-8 billion dollars. Second or third units in the same power station could come to as low as $3 billion/1000 MWe. (The United Arab Emirates awarded to South Korea a contract in December 2009 for a multi unit nuclear power station that averaged at $3,500/kW. This is $3.5 billion/1000MWe). The power plant could be selling its power for as low as $0.07 – $0.10/kWh and it would be producing a net income of $350 to $500 million per year after operating costs that could be used to amortize the loan on the capital cost within the first 20 years. After that a nuclear plant becomes a cash cow.

A nuclear plant can provide several energy currencies at the same time. A large amount of heat through low temperature coolant water, high temperature steam, low cost electricity for the grid or for generating other currencies such a hydrogen and synthetic fuels for transportation. (See chapter 11). It can be an effective currency generator that could lead to technical integrations and synergies with other technologies.

Environmental Considerations

Nuclear power average emissions is 66 g CO_2/ kWh.[57] This includes all the CO_2 that is produced in the manufacturing of its equipment and the construction of the station. It also includes all the CO_2 that is produced from mining, and preparing its uranium fuel, and all the CO_2 that is produced from handling radioactive wastes and decommissioning the plant at the end of its life time. The life base for this calculation is 30 years. It could be cut by 1/2 if we consider the 60 year life time that a nuclear plant is expected to live, but it is low enough at 66 g CO_2/kWh.

A 1998 study (Andesta et all) estimated the following CO_2 emissions:

Front end emissions	4.4%
Construction -“-	14.4%
Operations -“-	77.0%
Decommissioning	3.9%

Since the Canadian reactors operate on natural uranium (no enrichment), the Canadian nuclear emissions are about 35 g CO_2/kWh. The ACR (advanced candu reactor) with its low enriched uranium, is estimated to be about 43g CO_2/kWh. These levels of emissions are equivalent to 10% of the emissions from the cleanest hydrocarbon source – natural gas.

The nuclear power technology has some unique areas of concern, with regards to a different type of environmental pollution, due to the radioactive isotopes and contaminants that it generates. If not designed and managed properly it has the potential to cause serious damage. During the 60’s, as the industry was still developing, some serious mistakes took place. Now, as mentioned above, nuclear plants use a containment building capable of containing all forms of radiation, following an accident. This building is maintained in a lower than atmospheric pressure to also control and contain the smaller accidental releases of contaminants. Most of the releases from a nuclear plant are voluntary, controlled and monitored to be within 1/100 of the permissible levels. These levels are defined and monitored by the regulatory authorities who provide a transparent monthly report of all releases to the public. As a result of these improvements, pollutants released from a nuclear plant should not cause any more concern than those from any other industry.

Safety problems and their consequences are always important, but for nuclear power plants they are much more important. Their issues have to be considered by policy makers. Above, it was made clear the case that there are no breaches of safety with the minor and controlled releases of radioactive isotopes. What about the spent fuel that is not reprocessed and recycled and what about the safety of the reprocessing process itself.

As one can see in table 2, (p 39 A) when spent fuel comes out of the reactor it is very radioactive. Within one year this radiation drops to 1/100 th of the original amount and within 10 years it drops to 1/1000th. Yet its radiation levels are still so high, that for about 500 years after removal from the core, it is considered to be **self protected**. This means that people cannot steal it and make a bomb. Even if one gives them enough spent fuel, they will not be able to survive a minute of exposure with it, never mind having enough time to refine it and manufacture a bomb with it. They could do it if they have a $50 million dollar installation in their garage that includes all kinds of materials and specialized equipment. These materials and specialized equipment are closely monitored, need special permission to obtain and any procurement will trigger investigations. Then there are the monitoring systems in airports, borders, roads and satellites that can detect and pinpoint small amount of radiation with values above background level. It has not been appreciated the significance that one does not need a nuclear reactor to make a nuclear weapon. In fact it can be made easier without reactors. A country with large human and financial resources could probably succeed and produce nuclear weapons with or without reactors. Even then, one should consider that Libya, N. Korea, Iran and maybe others, have been trying for years now. Consequently, one wonders, how our world does achieves non proliferation by controlling nuclear power plants for the production of electricity.

In the early 1970’s the US government made a policy which effectively froze all R & D for reprocessing. Their reason was proliferation concerns, so they discouraged all countries from reprocessing. In retrospect, this policy was effective but it only provided a politically convenient short term solution. The key issue here is that the longer you leave the spent fuel without reprocessing, the less “self protected” it becomes, the easier one can work with it and in time, you cannot even detect it, if it is stolen, because its radiation levels drop below those of background levels in 10,000 years. You can better control proliferation by reprocessing spent fuel and burn it in a reactor such that it ceases to exist. The only requirement is to have only internationally operated reprocessing facilities with effective surveillance and controls.

Non proliferation is achieved much easier when the fuel is “self protected” by its own radiation levels. It is also achieved now with a new development, where the fuel is “spiked” and is rendered useless for weapons purposes. At the same time it can be burned in reactors as a useful fuel. If we were to reprocess spent fuel within 30 - 50 years, in an internationally operated facility, under the supervision and control of an international organization, and within the confines of a secured site, the proliferation dangers from the reprocessing of uranium spent fuel will disappear.

Based on the above reasoning, it is only a matter of time before reprocessing becomes common practice. Reprocessing facilities include hot cells, completely isolated from the environment, with monitored and controlled ventilation and discharge systems, very thick lead glass, remote manipulators, vitrification facilities for the wastes etc. Such facilities have been operating for some time, confirming their technical and safety feasibility.

Unlike other reactor designs today, the Canadian reactors have a tremendous technological advantage. They can burn a variety of fuels and also they can be integrated much easier with future reactors. Here will be provided an explanation and a means to appreciate the superiority of the Canadian technology. It is not mentioned here just because it is Canadian. This paper does not contain opinions. It just summarizes scientific/engineering facts.

One important point is that nuclear reactors based on uranium fuel have been a derivative of the original weapons programs. The uranium enrichment process can be used to make weapons. Plutonium created in uranium fuel can be separated from reactor spent fuel, although very difficult, can be used again to make weapons.

There are other nuclear fuels such as thorium that can be an excellent nuclear fuel. It was ignored originally because it’s processing and spent fuel contents do not yield the means, quantities and quality of materials needed for nuclear weapons.

The table below summarizes the relative properties of the two fuels(68,69,71). The key issue is that the Canadian nuclear reactor design can be easily adapted to burn thorium. Oak Ridge Labs in the USA have had an operating a Molten Salt Reactor Experiment (MSRE), that led to the design of Liquid Fluoride Thorium Reactor (LFTR). In November 2009 India announced the design of a Canadian type of reactor using Thorium fuel. The table below compares the (LFTR) with the (LWR), which is the predominant reactor at this time.

A COMPARISON OF NUCLEAR FUELS

Reactor type		**LWR**	**LFTR**
Reactor electricity producing capacity	(in MWe)	1000	1000
Type of fuel used		U	Th
Amount of ore needs to be mined for one year fuel	(in Tons)	800	200
Amount of natural fuel we get after refining	(in Tons)	250	1
Amount of fuel we get after enrichment	(in Tons)	35	not needed
Amount of time we have to wait before reprocessing	(in years)	25	0
Amount of time to care for un-reprocessed spent fuel	(in years)	10,000	0
Plutonium present in the spent fuel	(in grams)	1,000,000	100
Amount of time to care for reprocessed spent fuel	(in years)	350	10 yrs 83%
			300 yrs 17%

Note in the comparison above that for the same output of 1,000 MWe the thorium burning reactor core is much smaller, although thorium has about the same energy density as uranium. The LFTR has the ability to burn all of its fuel without the need to remove it and reprocess it. A simple chemical process achieves this while the plant is operating. The leftover radioactive wastes remain radiotoxic for a much shorter time, and the weapons making material quantities are small and too diluted to make weapons.

In summary, contrary to popular fears, nuclear technology can safely provide an abundance of low cost electrical power, reliably and for hundreds of years and in harmony with our environment. Yes, there will always be lots of technical problems. But also, this technology provides a lot of options and realistic technical solutions. Above all, there is a tremendous potential for a non polluting production for almost all of the energy currencies that we need. The problems of nuclear power are no longer technical or environmental but rather political and financial whenever a project is a prototype not properly controlled by a solid management. The most important problem nuclear power faces is public misconception and wrong perception.

10.0 THE CURRENT STATE OF HYDROGEN CURRENCY

We all know that the seawater contains a vast amount of hydrogen. The problem is that hydrogen is combined with oxygen to form the water molecules. In order to separate hydrogen from oxygen we must input some energy which will come from the conversion of a primary fuel. When we burn back the hydrogen currency, we actually re-produce the water and get out some of the energy we put into it, about 70%.

The theoretical energy required to separate hydrogen from oxygen is 39 kWh of electricity per kg of hydrogen produced at a temperature of 25 C and 1 atmosphere pressure. In practice however we use 53.4kWh/kg[79,80] of hydrogen produced. As the temperature of the water increases it needs less and less electricity to separate. At 3000 C 50% of the water separates by itself from the heat energy input. The water used is 9 liters of water for every 1 kg of hydrogen produced. This is much lower than the amount of water consumed in the steam reform method which is 19.8 liters of H_2O/kg of H_2 produced. With electrolysis we produce also 8 kg O_2/kg H_2.

Hydrogen can be produced by pure electrolysis using renewable energies such as wind power. It can also be produced more efficiently and likely at a lower cost, by electrical power plants that can provide heat and electricity to produce hydrogen through a process called "high temperature electrolysis". Using conventional electrolysis, we can get one metric ton of H_2 with an electrical energy input of 53,400 kWh[58,79]. The more we raise the temperature of the water the less amount of electrical energy is required.

At present 95% of the hydrogen needed is produced by the steam methane reforming method that strips hydrogen out of natural gas at a cost of $2.70/kg. This produces and releases to the atmosphere a very large amount of CO_2. Pound for pound hydrogen contains about three times the energy density of natural gas (143 MJ/kg[59]), and when consumed its only emissions are pure water. (also some negligible amount of NOx).

Sandia National Labs in the USA have developed a process to add solar heat to a system called Counter Rotating Ring Receiver Reactor Recuperator (CR5)[60] that converts water into hydrogen. This process however is still in an experimental stage and needs at least 10 more years for developing this small volume production process.

Economic considerations

Electrolysis can produce 1 kg of hydrogen at a cost of \$2 to \$6, depending on the primary fuel consumed. High temperature electrolysis can bring down that cost between \$1.50 and \$3.50 per kg[11]. Simplified wind mills can also produce hydrogen through electrolysis probably with the same subsidies and tax breaks they get today.

Hydrogen is a very light gas. In order to fill the gas tank for a car, it must be compressed, if the car is expected to have a range of about 500 km/tank. This means that the hydrogen pressure will need to be about 10,000 psi. This was successfully tried in California in 2008-2009 with the prototyping of hydrogen cars and fill up stations[61]. Handling of hydrogen was similar to propane gas but higher pressure tanks and piping systems were used. Finally, hydrogen has a tendency to settle in the surface imperfections and form hydrides. These hydrides contribute to the propagation of the imperfections and cause cracking. Therefore, a non metallic coat liner must be covering all internal surfaces of vessels and circuits that contain hydrogen.

Locating a hydrogen production facility will need to include the electricity transmission losses in a grid system (in Alberta 6%[62]), and availability of hot water. Ideally, locating a hydrogen production facility in the proximity of a small nuclear plant will make possible to use of some of the hot cooling water. Locating small nuclear plants along the pipeline that carries the bitumen to the USA can open up energy corridors where several communities can participate.

Environmental Considerations

Hydrogen burns very cleanly with almost no pollution. The area of environmental interest is not in the burning of the hydrogen currency itself. It is in the process that we used to produce the hydrogen in the first place. The current practice of using steam reforming of methane, produces a lot of CO_2 . But with electrolysis, whether it is high temperature or low temperature, the pollution level depends on the primary fuel consumed to produce the electricity currency. One can roughly estimate the amount of CO_2 produced by multiplying grams of CO_2/kWh by 130%. For example if the primary energy fuel was:

coal it would be	1000x130%= 1300 gCO_2/kWh	
diesel it would be	778x130%= 1011 gCO_2/kWh	
steam reform of natural gas	664x130%= 863 gCO_2kWh	this is the process used now
natural gas	443x130%= 575 gCO_2/kWh	
nuclear	35x130% = 45 gCO_2/kWh	
wind power without backup	11x130% = 14 gCO_2/kWh	

In conclusion, if a hydrogen currency was used extensively for our transportation it could stop increasing the CO_2 in our atmosphere, provided we stop consuming fossil fuels as primary energy for its production. This means that we should target to producing it only by hydro, wind, solar or nuclear power. The major disadvantages of hydrogen as a transportation fuel, is that it needs much higher pressure for storage than natural gas. Also, before the hydrogen era begins we will need to change our infrastructures for both the production and the distribution of our new transportation currency. The consumption infrastructure will also need to be changed and include either fuel cells or engines capable to burn hydrogen.

The synfuels described in the next chapter, provide us with a synthetic fuel that is easier to handle, it can be burned in our current car engines and it takes a lot of hydrogen to make it. Furthermore, the burning of clean synfuel does not cause a net pollution. At the same time all our energy infrastructures for transporting and consuming the fuel can remain the same.

Looking into the future hydrogen produced by splitting the water using radiation energy has not been developed so far, but “Radiolysis” in combination with high temperature electrolysis has some potential. A nuclear plant could be producing on the one end electricity and heat currencies and from the other end simultaneously producing hydrogen as a byproduct. The shield cooling of the Candu reactor absorbs a lot of gamma radiation. With a design focused in hydrogen production it could be made to split water, collect and separate hydrogen and oxygen.

A 2MWe wind mill with a 30% availability, will be producing on an annual basis 4,900,000 kWh. This means that it can produce 93 tones of hydrogen per year while It consumes 837 m^3 of water per year (873,000 liters). The oxygen may also be collected and used in coal fired plants to improve combustion which in turn can improve the efficiency of the CCS process.

11.0 CURRENT STATE OF SYNFUELS AND THE POSSIBILITY OF CO_2 RECYCLING

The hydrocarbon based energy currencies that we have been using are made from carbon atoms (C) and hydrogen atoms (H_2). Both carbon and hydrogen are abundant elements on the earth. If we could have free carbon and free hydrogen it would not be very difficult to synthesize all the hydrocarbons that we use today without pollution: synfuels such as diesel, gasoline, jet-fuel, and industrial products for $1/gallon. (n) represents number of CH_2 molecules in the chain.

$$\mathbf{nC+nH_2=(CH_2)_n}$$

The problem is that we don't have abundant free hydrogen. Almost all of it exists either in the water or in hydrocarbons. Synthetic fuels called "Synfuels" have been produced for some time now using hydrocarbon based processes such as the Fisher-Tropsch reaction with feed-stocks of water and coal, or water and coke or water and asphaltenes.
Asphaltene being coke with higher hydrogen content which accumulate in the oil sands as a by-product of bitumen upgrading.

$$\mathbf{2C+H_2O+1/2\ O_2=CH_2+CO_2}$$

Also, the hydrocarbon based process that produces the needed hydrogen is by using the water-gas shift reaction with feed-stocks of water and natural gas.

$$\mathbf{CO+H_2O=H_2+CO_2}$$

All the processes used for producing the synfuel currencies themselves emit a large amount of CO_2. It should be accepted by now, that as long as the required hydrogen is produced from fossil sources, rather than water, synfuel production will also produce an extensive amount of CO_2. We must also add here that we will also emit CO_2 when we burn these synfuel currencies.

A modified process[63] has been developed to produce "clean synfuels", that receives feed-stock of CO_2 and H_2O (water) and then produces synthetic hydrocarbons and oxygen. It does not produce/release CO_2 during the production of the synfuel currency because H_2 is produced by splitting water. However, when we burn the synfuel (diesel, gasoline or Jet-fuel) we produce the same amount of CO_2 as the burning of our conventional hydrocarbons.

For those that understand chemical formulas This is: “Synfuel by CO_2 Capture + H_2 from Water Splitting, called “Clean Synfuel”.

$$\mathbf{CO_2+H_2O+Energy=CH_2+3/2O_2}$$

This is achieved by using the reverse water shift reaction $H_2+CO_2=CO+H_2O$, the Fisher-Tropsch reaction $CO+2H_2=CH_2+H_2O$, and water splitting process $H_2O+Energy=H_2+1/2O_2$.

The production of clean synthetic energy currencies for transportation fuels (diesel, gasoline or jet fuel) was originally intended to have the captured CO_2 , from CCS process, sequestered in the liquid fuels, thereby qualify for carbon credits. It was proposed to the US Navy however, to produce transportation fuel currencies by filtering CO_2 out of the atmosphere and by splitting water to free hydrogen. The required energy for the splitting of the water would be provided by their on board nuclear reactors. Such development would open the door to the possibility of producing clean synfuels and then recycling the CO_2 to and from the atmosphere, instead of continuously adding to it.

In other words, we could remove CO_2 from the atmosphere and use it to make a synfuel energy currency. Then when we burn this fuel we will be returning the CO_2 back to the atmosphere to be filtered and collected again to make a new synthetic fuel, and so on, thus recycling CO_2.

Environmental Consideration

The Clean Synfuel process can be very significant from both the environmental and the energy strategy points of view. It fills a void in the production and consumption of energy fuel currencies for transportation purposes without additional release of CO_2 to our environment. The CO_2 that is released from cars, trains, ships and airplanes when the fuel is burnt, could be captured and made into new transportation fuel again, thereby recycling the same amount of CO_2. This process could almost eliminate any increased release of CO_2 to the atmosphere from transportation fuels without causing drastic changes in our current energy infrastructure.

Economic Considerations

Using the Oxyfuel coal plant and the Fisher-Tropsch Process, augmented with externally provided O_2 and H_2 produced by water splitting, using nuclear power, it was estimated that the cost of clean synfuel would be about $3/gallon [63] (2007 $) without any credit given for the carbon capture. With credits for carbon capture the cost is reduced to about $2/gallon[63] (2007 $). This could be comparable with, our current practices for producing the fuel currencies of diesel, gasoline and jet fuel from fossils. Alberta based oil companies could collect carbon credits by removing CO_2 from the atmosphere and exporting the clean synfuels to the consumers that will pay carbon penalties when they burn them. (NOTE: The difference between 2007 and 2010 with regards to the cost of nuclear energy will be examined in Chapter 16).

The most significant economic benefit would be that society will not have to change the existing engines in our cars or the energy fuel distribution infrastructure.

In conclusion, producing synthetic hydrocarbon fuel currencies can help with our continuously increasing dependence on transportation fuel currencies. With the clean synfuel process described above, if the hydrogen is produced from water using wind and nuclear power, a clean and smooth bridge will have been established to a hydrogen economy, if and when technical solutions are developed for the problems in hydrogen handling and in improving the performance of solar power. Meanwhile, we can produce all the required fuel energy currencies that we now use in harmony with our environment and without massive CO_2 emissions. All of this could be achieved with comparable costs to today's practices. (see Ch. 16).

An added bonus to this approach is that we can use the front end of the carbon capture and storage process (CCS) now being developed in Alberta, to supply the initial CO_2 for the synfuel production process. With our wind mills starting to produce the hydrogen Alberta oil will become recognized as the most environmentally clean oil overnight. As time progresses small nuclear plants can assist the wind power with the production of hydrogen and also with electricity as needed by the retirement of aging coal fired plants. The oil companies will have sufficient time to adapt in stages and convert their production processes for our energy currencies. This means retiring aging assets and facilities and replacing them with new technologies instead of refurbishing the old ones.

12.0 EXTRAPOLATING EACH ENERGY TECHNOLOGY INTO THE FUTURE

Earlier it was mentioned that it takes an enormous amount of effort, R & D, manpower and investment to develop and implement a new energy policy. Even after the technical development, it takes a very long time before prototypes are built and tested, designs modified and retested until finally the new technology gets a foothold.

Each energy technology has advantages and limitations for further growth. In this chapter we will examine each of the technologies for its ability and adaptability to grow at the rate desired to provide the energy currencies required. Furthermore, the likely areas where new developments will be made for each technology are examined.

a. **COAL**: This industry is large and it can be mobilized to fill unexpected energy shortcomings. Currently, the coal industry provides over 50% of the world's primary power requirements, mainly for electricity currency and industrial heating.

   A future development in this arena is the CCS process that captures and sequesters the CO_2. If this process can be perfected to capture all of the CO_2, as opposed to capturing only 85%, and sequestration is made in solids or liquids, coal can reverse the trend and remain as a good dominant primary fuel. Coal cannot be used to produce transportation currencies without the generation of CO_2. Using coal to power trains and ships would be a step backward increasing pollution to the atmosphere, since scrubbers and CCS cannot be used in mobile installations.

b. **OIL**: This industry will continue with the production of industrial currencies used for the production of some 5000 products. It does not need any new technologies to do this, as the plastics and other products sequester the hydrocarbons in solids and liquids, hence limit their potential to produce CO_2. This industry is also capable of producing for decades most of the needed transportation currencies.

   Future developments for this energy are the perfection of clean synfuels manufacture and CCS. While the CCS will provide the oil industry with a temporary relief from environmental problems, the clean synfuels will provide it with indefinite longevity and a smooth transition into an industry that is environmentally friendly.

c. **NATURAL GAS:** This industry can be mobilized quickly and can fulfill unexpected requirements. It can produce all the energy currencies that we use plus industrial products and fertilizers. The problem with gas is availability, as we look into the future, and the pollution that it creates at about half the rates of coal.

A future development in this primary fuel is the making of clean synfuels which can provide an infinite longevity to this primary fuel resource – natural gas.

d. **GEOTHERMAL:** This is a perfect small scale energy source. Due to geological limitations and uncertainty of performance, it cannot be counted on to mobilize and produce a significant amount of our energy currencies on a large scale basis.

A future development in this energy is in the diagnostic methodologies to identify underground enclosures and perhaps in deep underground long horizontal drilling.

e. **WIND POWER:** Wind power has had a spectacular growth. In the last 5 years, it has doubled its capacity. The problem is that it is not suitable for the production of electrical currency for the grid, due to the well known instabilities. The area where it can be most competitive is in the production of the hydrogen energy currency. As mentioned earlier, by even doubling its installed capacity, it has not been able to increase its market share due to the fact that the world increase in demand is so much larger than the ability of this industry to grow. Using a simpler windmill strictly for the production of hydrogen, wind power would be able to grow much faster.

During the last 25 years, Denmark has gained a great reputation as a Country with environmentally clean power. This reputation was based on the 19% built capacity of wind power and the modification of its coal fired power plants for higher efficiency and with integration with bio-fuels from waste, to decrease its overall emissions of CO_2. Based on this reputation Denmark was selected to host the 2009 world's conference on environment in Copenhagen. It was mentioned earlier that this 19% capacity is balanced by the Nordic grid of all the Scandinavian countries rather than Denmark alone. But there is another point to be made in looking ahead.

Wind mill owners earn a significant portion of their income from government tax breaks and direct subsidies. Last year after the inauguration of the “Horns Rev 2” offshore wind farm the Danish government removed any more financial support for renewable energy. They stated that renewable technology must compete under strict market conditions. It will be very interesting to see if any investors will come forward with new projects that will depend on an intermittent and unstable output for returns[75,78] on their investment.

Future development in this energy will likely be in the application of wind power for the production of hydrogen and clean synfuels. This will require much simpler wind mills with no caps and no limits for potential growth to capacity.

f. **SOLAR POWER:** This is a perfect niche power source for remote applications. It cannot be mobilized to participate with other energy technologies and as it exists today, it is not able to meet large scale demand.

Future development areas are unlimited. The incidence of sun light is 10 times higher than what the current panels can convert to electricity, so further developments in improving conversion efficiencies are substantial. Also different technologies could reduce the capital cost of this energy in the future.

g. **BIOFUELS:** This industry has been the most successful of the renewable technologies. It has captured the highest percentage of the renewables in terms of output power (except for hydro power). It can be used effectively as peak power or base power for the electricity currency. However, it cannot grow to become a large scale producer due to the limitations in availability of wastes to convert and burn. Crops for energy currency are a questionable area as it affects negatively our food chain and require hydrocarbon inputs along with significant amount of water.

Future developments in this industry are to find niche applications where it can be competitive and to develop the photosynthetic microorganisms & bacteria processes for clean production of energy currencies.

h. **NUCLEAR POWER:** Nuclear power has unlimited potential to provide the energy for all the energy currencies. At this moment, it has limited capacity to grow as it is still coming out of the Chernobyl doldrums. Within the decade however, it could be mobilized at a faster rate. The time required to bring a plant on power is still 6-8 years. Major efforts will be required to streamline the licensing procedures and to minimize project construction time and capital costs.

   Future developments for the next ten years include the “spiking” of the spent fuel technology to make it useless for weapons manufacturing. Also the design, development, and prototyping of small reactors will provide a good alternative to the currently built large scale reactors, as a means for bringing to power large number of small low cost reactors that are faster and easier to build, license and finance. Other developments will include the reprocessing and recycling of spent fuel along with the development of Thorium powered small and large GEN IV reactors.

   A major area for industrial development is to test and possibly perfect the process of producing hydrogen involving “radiolysis of water”. If successful, it could drop the price of hydrogen significantly.

i. **HYDRO POWER:** This has been the best performer. This technology is very mature and there are not many more sites where a new dam could be built. As a result, hydro power cannot be expected to increase its market share by much more.

   Future developments will be limited, since this technology is performing at close to optimum now. The economics and logistics of exploiting northern Alberta sites will be an area of interest.

13.0 SUMMARY OF PRIMARY FUELS AND ENERGY CURRENCIES

In previous chapters, every form of energy, primary fuel and every form of energy currency that we produce has been described. In this chapter, a synoptic summary is provided that enables the reader to compare the various primary fuels and energy currencies with regard to their energy density, availability in the future, cost/kWh, and amount of CO_2 that they emit to the atmosphere.

13.1 Energy considerations

Table 3: FUEL ENERGY DENSITY AND AVAILABILITY

Fuel or currency	density MJ/kg	Available for -- years
Coal primary fuel	24.0	147
Jet fuel currency	42.8	*
Diesel currency	46.2	*
Crude oil primary fuel	46.3	100
Gasoline currency	46.4	*
Natural gas primary fuel	53.6	60
Methane currency	55.6	*
Hydrogen currency	143.0	*
Uranium primary fuel once through	3,873,600.0	70
Uranium primary fuel with reprocessing	368,000,000.0	6,300

- *Energy Currencies will be produced in the duration that primary fuels are available. Past this time, they will have to be synthesized indefinitely, as described in Ch. 11.
- Hydrogen currency will always be synthesized from whatever energy is available.
- Whenever the energy density of a currency is greater than that of the primary fuel consumed during a conversion process, the mass of the currency is smaller than the original mass of the primary fuel. That is where the loss has occurred.
- Thorium has the same characteristics for comparison as Uranium.

In table 3, one can appreciate that hydrogen gas has almost three times the energy of natural gas, and that crude oil and its currencies have almost two times the energy of coal. One can also appreciate the tremendous increase in the energy density provided by uranium regardless of whether it is reprocessed or not. Note also, that if and when Thorium is used as a fuel in nuclear plants, its energy density will be about the same as that of uranium and its supply will be for an indefinite period.

13.2 Economic considerations

Table 4 summarizes the cost/kWh of electricity produced by the various power plants. It summarizes the elemental costs of the various plants a) with and without the cost of CCS in fossil fuels and biomass b) with and without including the needed cost for backup power plants to stabilize wind power when it is connected to the grid, and c) old built nuclear power plants operating today and new built ones. (see also Ch. 16).

Table 4: COST OF PRODUCING OUR ELECTRICITY CURRENCY

Primary Fuel or Currency used	**Cost in $/kWh**	
Hydro old plants	0.060	Old plants today
Natural gas without CCS	0.060	"
Nuclear- existing plants	0.060	"
Coal without CCS but with scrubbers	0.060	"
Hydro plants build today	0.080	New plants today
Natural gas with CCS build today	0.120	"
Wind power onshore without backup costs	0.130	"
Nuclear plants new build conservative estimate	0.130	"
Wind DC power producing H_2	0.130	"
Coal power plant with CCS costs	0.140	"
Biomass without CCS	0.190	"
Wind power offshore without backup costs	0.195	"
Wind power onshore with back up costs	0.227	"
Biomass with CCS	0.250	"
Wind power offshore with backup	0.340	"
Solar power PV panels	0.800	"

Notes:1) As the price of oil increases, the cost/kWh will increase proportionately.
2) Addition of CCS can be expected to increase the costs/kWh by 100%
3) Backup costs of gas fired plants for wind power in grid will add at least 75%
4) New nuclear plants costs seem to have gone up but no reference exists

It is interesting to note in table 4 that

- The consumers will face at least a doubling in the cost of their electrical bills to cover the cost of environmental improvements to our energy infrastructure. Policy makers have to ensure that an improvement is actually taking place and that the extra costs are justifiable and reflect the actual benefits to our environment.
- Hydro power is still the most competitive. Given that hydro is not a heavy polluter, the policy makers should ensure that every possible location that favors hydro power is exploited.
- The cost of CCS more than doubles the current cost of electrical currency produced by fossil burning power plants (coal and natural gas), including cost of extra energy.
- Onshore wind power costs, that include the necessary costs for the backup power station, at 22.7 cents/kWh, are more expensive(almost double) than nuclear power, even if nuclear is penalized with unconfirmed costs and penalties at 13 cents/kWh.
- Wind power used to produce H_2 is very competitive at 13 cents/kWh which includes the 30% inefficiency in the production process of hydrogen.
- Nuclear plants at 13 cents/kWh vs. 6 cents/kWh for the old plants, are penalized by current cost estimates that have not been confirmed in N. America yet.
- The cost of natural gas cannot remain constant over the next 60 years, nuclear power, even if it is penalized by unconfirmed estimates, provides the second best choice, next to hydro power, for future power stations.
- Many economists conduct what they call "Levelized cost" estimates for energy schemes and then they list their assumptions. Usually their assumptions negate the term "levelized". A true levelized analysis must include among others the cost of extraction of primary fuel and its conversion process to the currency consumed. It must also include the capital and operating costs of backup power plants and the necessary environmental facilities such as CCS, to give a complete and accurate picture of the levelized costs.

13.3 Environmental Considerations

Table 5: PRODUCTION AND NET RELEASES OF CO2 TO THE ATMOSPHERE

Primary fuel or currency	**Net emissions to atmosphere grams CO2/kWh[64]**	
Coal without scrubbers	1,050	
Coal with scrubbers	960	
Diesel oil	778	
Producing gas by the steam reform method	763	used at the oil sands
Wind power in grid backed up by coal fired plants	753	
Natural gas	443	see note 1
Wind power in grid backed up by gas fired plants	313	
Coal fired plant with CCS	157	
Coal fired plant with CCS and Scrubbers	144	
Nuclear power plants world average	66	
Solar power PV Panels with no back up	40	
Nuclear power in Canada without enrichment	35	
Geothermal power	32	
Bio-fuels	16	
Wind power producing H_2	11	

- Note 1 : This does not include the tons of CO_2 that come out of gas wells directly. It includes only CO_2 released to the environment while burning gas for electricity.

- Note also that small automobiles burn gasoline and produce 89 g CO_2/km when driven. Larger private cars produce 500g CO_2/km. We are going to start using electric cars to stop the releases of CO_2. Look above to decide which power plant should produce the electrical currency to recharge our cars ? Then ensure that this particular type of power plant industry can have its capacity scaled up to meet the enormous demand for electrical energy currency for transportation. Furthermore look at which process can produce a desired energy currency with the minimum amount of pollution released? If our cars go electrical how we are going to power our other transport needs, such as trucks, trains, ships and airplanes. The deciding factor regarding the desired benefits is “what primary fuel do we consume for each of our currencies”.

13.4 Options for obtaining our currencies

Based on the tables above, one can derive some possible options for obtaining the energy currencies that we use. One thing that should be obvious by now is that we cannot stop or reduce significantly our CO_2 emissions as long as we continue to derive our energy currencies from primary fossil fuels. This leaves a limited number of options available for obtaining our energy currencies for transport, for electricity and for industrial products such as plastics.

Transportation Energy Currencies

For our transportation currencies we have two options. **One is large nuclear power plants** that feed large quantities of electricity into the grid lines that charge the electric cars. **The second is wind power** as the primary source for the production of hydrogen or for synthesizing our fuel currency for transportation- fuels that recycle CO_2 called Clean Synfuels. Such a scheme could be assisted by nuclear power using large or preferably small units with more manageable economics as needed.

The first option takes care of electrical private cars but does nothing for providing the currency needed for large transports such as trucks, freighters, trains and airplanes. The second option **clean synfuels** however takes care of all our transport needs without changing our engines and energy infrastructure. Since clean synfuels are recycling CO_2, we also can satisfy our environmental requirements.

Redirected wind power, assisted by nuclear power, can provide the energy to produce hydrogen which initially, can be used to produce “clean crude oil” from the oil sands. As oil company facilities age, hydrogen with CO_2 captured by the CCS process can be used to produce “synfuels”. In time clean hydrogen used with CO_2 filtered from the atmosphere will be able to produce “clean synfuels” that recycle CO_2. This approach can reliably secure our future transportation fuels, at a low cost and without changing our fuel distribution system and car engines.

Electrical Energy Currencies

Hydro plants and nuclear plants could be used to replace the aging fossil fired power plants for base loads. Bio-fuels and hydro plants could be used for base loads as well as peak loads. In this area, there doesn't seem to be another choice available if we are serious about controlling CO_2 emissions.

This approach will not inhibit our growth rate and can take us a long way past the transition period until if and when a breakthrough comes from other technologies such as solar, fusion, etc. _The currently planned grid system will be able to accommodate either a distributed, a concentrated, or both systems for supplying electricity.

Industrial Feedstock Currencies

The current practice of extracting our industrial feedstock currencies from existing hydrocarbons in the ground, (bitumen) seems economically acceptable and environmentally sustainable. The cost is low, the emissions of CO_2 are low if the hydrocarbon feedstock is sequestered in solids and liquids. There seems to be abundant available hydrocarbons for this purpose and either a good recycling processes or synfuels could extend the usefulness indefinitely. The key issue is to upgrade the bitumen with hydrogen produced through a clean process. Since we will have secured our supply for hydrogen, carbon can also be extracted from the CO_2 sequestration sites or from coal mines.

The writing of this paper started with the intent to provide a work book of energy options for policy makers. However, it ends up describing a very narrow set of options. This could have be predictable when one considers the three dimensional restrictions of energy demand, financial limitations and environmental limitations. Now we seem to need to focus to almost a single path which is CLEAN HYDROGEN PRODUCTION. From that point on we have options as to how we use this hydrogen. In the foreseeable future this option will have a lasting influence on our lives regardless of future developments.

14.0 LOOKING AHEAD

Earlier in this booklet, it was mentioned that our energy infrastructure is so large and so complex that any new idea will take 20 to 30 years after implementation to obtain a significant market share. During this time, a lot of resources will be consumed including not only materials and money but also human resources to design, test, build and evaluate the prototypes.

Based on the above, an energy policy must have a long time frame and provide future Canadians with options rather than painting them into a corner where they may be forced to reduce their standard of living. The Government must ensure that its policies benefit the future generations and not just provide a short term advantage to one or two current market players.

It is obvious that " Oil Sands" will drive the economies of Alberta and perhaps of Canada over the next decades. The technologies that will "clean" the oil sands will provide Alberta not only with exports of "clean oil" but also with the exports of the technologies themselves, thereby contributing to the industrial diversification that we seek. In contrast, the allocating of $2 billion dollars by the Government to the CCS process will only eliminate 85% of the CO_2 produced from electricity producing coal fired plants, if and when CCS proves to be technically and economically feasible.

The problems at the oil sands are three, a) the amount of pollution released from the SAGD or from the surface mining processes to extract the bitumen, b) the amount of CO_2 released by stripping the hydrogen from natural gas, and c) the extensive use of the cleanest form of hydrocarbons, i.e. natural gas, in extracting and upgrading the bitumen.

a) None of the $2 billion allocated money is going to clean the oil sands extraction such as SAGD.

b) None of the allocated money is going to clean the process that produces hydrogen for upgrading the bitumen.
c) None of the allocated money is going to conserve our natural gas resources.

Coal power plants produce 5000 tons of CO_2 per year for every MW of electricity produced. Employing CCS will cause 4,250 tons/MWyear to be sequestered and 750 tons/MWyear to be released to the atmosphere. This is not sustainable for two reasons: a) we cannot continue to indefinitely pump into the atmosphere 750 tons/yr of CO_2 for every MW of electricity we produce, and b) we cannot pump underground massive amounts of CO_2 (about 46 million tons/yr from our electricity producing power plants) indefinitely. Consequently, CCS is in reality a temporary relief measure, rather than a sustainable long term solution.

Cleaning the oil sands and conserving natural gas, in an environmentally acceptable way, can only be achieved by the use of hydro, nuclear and wind power technologies. Last June, the Canadian Nuclear Society (CNS) organized their annual conference in Calgary(65). The Alberta Branch of the CNS organized a Western Focus Seminar to which small nuclear reactor designers from all over the world were invited and where they presented their designs. PTAC, the Petroleum Technology Alliance Canada, has forged ahead evaluating the small reactors as a way to clean the oil sands, and their conclusions are favorable and impressive(66). This option now needs some supportive Government policies, encouragement and input.

Small nuclear reactors present several useful advantages over large ones. They can have a standardized design that will drastically reduce their cost and make them easier and faster to license. They can be set up in a relatively shorter time. Financially and technically they are easier to manage, and with mass production techniques, ten small modular reactors, 100MWe each, can end up costing less than one large reactor of 1000 MWe. In this scenario, using small modular reactors, the earlier built units will be operating and thus will be able to finance the later built reactors, thereby reducing the overall amount of money required to be borrowed upfront. While small reactors will not be available until 2025 they could present advantages in mass production.

For the short term, large reactors can be used to power the extraction at the oil sands in a clean and acceptable manner (powering the SAGD and the strip mining processes). Any spare power can be used by the grid. When the small nuclear reactors become available, they will likely be individually owned by the oil companies for use in their operations and could perhaps distribute some excess production of electricity to the Alberta grid. The market demand will be there. Government policy should encourage the construction of large reactors now to fill the void until we can acquire, adapt or develop the small reactor technology and can have Canadian based companies participate with equipment building, engineering and construction.

The use of small reactors and the refocus of wind mills will clean the oil sands production process while conserving natural gas resources. If the wind industry cannot mobilize fast enough to meet the demand, additional small multitask reactors can be mobilized to serve triple duties: 1) to produce electricity for the grid 2) to produce hydrogen when electricity is not needed by the grid and 3) to produce hot water for heating buildings or for hot houses from their cooling water. Meanwhile, bio-fuels and hydro power can be dedicated for peak loads in the grid when needed.

Some synergies can also take place by using the small nuclear plant's cooling water to create a high temperature hydrolysis. This provides a much higher yield of hydrogen for the same amount of electricity consumed versus that coming from the wind mills or the reactors with normal hydrolysis. All the above can take place with negligible pollution releases. The supply of water will need to be addressed and if problems are present establish a large pipeline. As Alberta population grows at some point we will have to address this issue.

Synergies can be used in several areas. For example, in Alberta we have existing pipelines that carry bitumen to the USA and passing through several Alberta communities. By locating in these communities a wind farm or a small nuclear reactor, an upgrading station for the bitumen can be set up practically in any community. In this fashion we could maximize the upgrading of bitumen at home, not only in an environmentally friendly manner but also with distributed facilities in all of Alberta such that we can avoid the concentration of everything in the Ft McMurray area. Such a scheme would also reduce costs to the oil industry, while increasing employment and diversification in several communities in Alberta.

Other synergies can take place by electrolyzing (splitting) waste water instead of pure mountain water to make hydrogen. We can also use hot water discharges from small nuclear plants to improve the efficiency of electrolysis or for district heating.

By 2030 - 2040 we could be producing clean oil sands products for export and also could have developed during this transition period other items with export potential such as: simplified wind turbines producing electricity to split water and producing hydrogen, clean synfuels recycling CO_2 from the atmosphere, industrial hydrocarbon based currencies for plastics and other products from the oil sands, CCS technology and equipment, and possibly nuclear power systems, if we play our cards right.

To achieve these goals, it is very important right now to have a strong Government resolve and policy to clean the oil sands. This will automatically imply developments in large and small reactors and wind power. As a consequence, it will be then necessary for the Government to evaluate its options with regards to acquiring the needed technology for large nuclear reactors initially and small ones when available. For large reactors simply encourage proposals from existing vendors. Bruce power has offered to finance, build and operate them. For the small ones, there are the following options:

a. Buy it from one of the various countries which are developing small reactors now.
b. Cooperate with one of the developing countries to jointly prototype their reactor in Alberta for oil sands applications.
c. Develop in Alberta a small, made in Canada reactor prototype.

Options b. and c. provide some great benefits for Canada, as the Atomic Energy of Canada (AECL) is for sale at this time. An expression of interest in a specific project for a specific market could help avoid another Avro Arrow incident. Saskatchewan and Alberta may want to tap into the wealth of AECL's technically expert staff and form a private company, as shown in chapter 15.

If option (a) is adopted and we decide to buy small reactors from foreign developers, we need to be aware that we will be depending on imports at a time when world demand for nuclear power will be increasing very quickly in an industry that does not have the capacity for drastic expansion. The deliveries will be slow and the prices will be getting higher.

Many people tend to view AECL as an albatross around the taxpayers neck. The questions requiring an answer here is whether Alberta really needs nuclear power and whether AECL has the staff capable of providing the technical expertise needed to build in the west a large prototype unit such as the ACR, or to produce a small, safe and economically competitive nuclear reactor (about 2020) to meet the needs of the oil sands and the electricity grids in the West. Chapter 15 provides some insight.

15.0 A SPECIAL CASE FOR ALBERTA

Out of all the provinces in Canada, Alberta is the only province that has entered the hydrogen era some 20 or so years ago. Most Albertans don't realize that right now at the oil sands we produce and consume more than 6.0 million kg of hydrogen per day. This is what it takes to convert the bitumen into synthetic crude oil. The plans are to double the oil sands production, which means the amount of hydrogen that Alberta's industries will consume will also be doubling. The production of ammonia fertilizer also uses an extensive amount of hydrogen. As a result Alberta has become by default the hydrogen capital of North America and likely of the world. Saskatchewan with its oil sands, is positioning to enter the same situation as their bitumen will need the same amount of hydrogen to convert it into crude oil. All these mean that a significant market for hydrogen exists here right now, ahead of the other countries. By all indications this market will be experiencing a significant growth in the years ahead.

As mentioned earlier we have two different ways to produce hydrogen: a) from fossil fuels (stripping it from natural gas) and b) from water (by electrolysis and heat). Right now our oil companies are producing it by stripping it from natural gas. A process that produces also a lot of $CO_{2,}$ for which the world is condemning us and call Alberta oil "dirty with a high CO_2 footprint".

Lets examine where the two methods of producing hydrogen (from fossil or water), lead us in the future.

a) Hydrogen produced from natural gas
   - We do nothing to reduce our CO_2 footprint and our oil is called dirty
   - Risk of our markets being reduced due to environmental pressures
   - We will be depleting a cleaner and useful resource of natural gas
   - The natural gas will end long before the oil sands' bitumen, hence a new way will need to be found to produce hydrogen. This will likely be from splitting water, which means adoption of option (b) but delayed by a few decades.

b) Hydrogen produced by splitting water
   - Immediately we can claim that there is a plan to clean our oil
   - Our markets are no longer in risk of reduction
   - We develop complementary technology with CCS to make synfuels
   - We develop technologies to make clean synfuels by recycling CO_2
   - We perfect the process for hydrogen production from waste water
   - Instead of a dead end we open the possibility for Alberta producing clean hydrocarbons for hundreds of years.
   - Develop an option for Ammonia fertilizer production

The advantage that Alberta has is the high demand for consumption of hydrogen that does not exist anywhere else. This demand provides a continuously increasing market which can be used to finance the development, prototyping, testing and mass production for all of these technologies that lead to clean synfuels. Instead of heading for a dead end as in option (a), we secure humanity for hundreds of years with transportation fuels for current engine cars, without having CO_2 accumulated in our atmosphere.

The disadvantage is that for the short term the hydrogen production from water will cost a little more per kg. (see ch. 16) This is clearly a conflict between the long term collective interest and the short term interest of some. The Government could tax CO_2 emissions and also divert its current subsidies provided for the wind mills, to feed in the electricity grid, and use them to subsidize the difference in cost for the production of hydrogen from the same wind mills. Such an action will provide a good start, however, windmills will not be able to build fast enough to meet all the demand. That is where nuclear reactors, large or small, will be needed to provide the additional energy. On the long term increasing wind mill and nuclear installations will also be able to provide the energy needed for synfuels using CO_2 from CCS to start with, and then progressing to "clean synfuels" from recycling the CO_2.

So far we have established that nuclear power is not really as bad as it has been perceived in the past. It has become clear that this technology provides a great potential for improvements. We have also established that Alberta will end up using a lot of simpler wind mills and a lot of nuclear power in the not too distant future, due to the lack of other choices. The only remaining question to be answered is if this demand can be met domestically in Canada or not. Since energy related technologies and projects take a long time, perhaps now it is a good time to answer some pertinent questions. A substantial infrastructure should be at the planning stages shortly.

The author of this paper has spent a lifetime in the nuclear industry in Canada, the USA an Asia. On the technical side, as a design engineer, construction manager, consultant, and lastly as an equipment manufacturer before his retirement. On the commercial side as a businessman and owner of successful consulting and manufacturing companies. The author has been offered employment positions with the AECL on a few occasions, but has turned them all down because of the bureaucratic/academic culture that prevails in this company. Business oriented people would find it preferable to work with AECL as an outsider.

Based on his experience, he believes that since the beginning of its existence, AECL has been used by the Federal bureaucracies more for political than for commercial gains. Due to excessive political interference AECL has not had the commercial success that its superior technology deserves. This averages to providing only one commercial reactor every 2 years over the time of its existence.

While the AECL management has been inhibited by the Federal bureaucracies, its technical capabilities have flourished. Between 1987 and 2002, AECL built three new reactors in Korea and two reactors in China. AECL was responsible for the planning, the supervision of the construction, and procurement of Canadian manufactured equipment. All five reactors were completed on budget and on schedule. In fact, a couple of the reactors were completed below budget and ahead of schedule. The Darlington reactors, which experienced significant cost overruns, were an Ontario Hydro managed project, and AECL was one of the suppliers. This is important to clarify as many people question AECL's capabilities.

The comfortable bureaucratic/academic environment of AECL made some scientific excellence possible and this reflected in the technology of the Candu reactors. An untrained individual will have difficulty seeing and understanding it. For example, it is not appreciated that the Canadian technology can extend the resources of our earth twofold that is 200% longer. It is not common knowledge that the Canadian reactors can burn the spent fuel from other reactors, and that the Candu reactors can burn a variety and combinations of fuels other than only uranium, as shown at the end of Chapter 9. This AECL bureaucratic and academic environment has provided us with the technology that can best be integrated with the future reactors.

More recently, the technical capability of AECL has been questioned. If AECL could not build the two small MAPLE reactors for isotope production, how can it be trusted to produce another reactor large or small. The technical doubt of AECL's technical capability, at this particular stage, may effectively kill its chances for a successful sale. This would certainly cause far reaching consequences for Canada's future industrial capabilities.

The two MAPLE reactors were built by AECL, commissioned and operated successfully for a short period of time, before they were shut down permanently. The reason given is that they did not meet the specified redundancy for one of its safety systems.

The permanent shutting down doesn't make much sense, since a new spare safety system could have been added to meet the redundancy criterion. The "Hanaro" reactor was built in South Korea from the same AECL design as the MAPLE reactors, and it is identical in most ways. This reactor has been operating quite safely since 1995.

This inconsistency has raised questions that the motives for a permanent shutdown of the reactors may be due to a different reason. The curiosity is focused on the fact that MAPLE reactors burn uranium that is enriched a little higher than that of normal fuel. Some governments frown on this, even if the enrichment level is far from a weapons grade level. Since there seem to be no legitimate technical reasons, one then can only speculate why these two Maple reactors were shut down permanently.

At this stage, the most important thing for Canada is to keep at home AECL and its control of Candu technologies, not because it is Canadian, but because it can best be integrated with next generation of reactors for the ultimate utilization of humanity's natural resources. AECL's management will definitely need overhaul: however, the technical expertise of its staff should not be underestimated when it comes to designing, building and prototyping a new large unit such as the ACR or a standardized, small, competitive nuclear reactor for mass production.

Alberta and Saskatchewan have been contributing to the paying for AECL's upkeep all these years and have very little to show for it except for university size experimental reactors. A good opportunity is presenting itself now whereby the two provinces can help Canada and also help themselves. All it will take is a forward looking attitude, good negotiating skills and a good business plan.

What the federal Government appears to have done is first cripple AECL's reputation and hence its value. Then put it up for sale, consequently, crippling its ability to survive. This provides a silver lining for shrewd investors. What AECL and Canada need right now is:

a) Remove the Chalk River National Laboratories (CRNL) from AECL control and convert them into a national lab like Oakridge, or Idaho Labs in the USA. AECL could pay this CRNL lab for services rendered.
b) Provide AECL with one or two projects to get them earning their upkeep. Such projects could come from Alberta, Saskatchewan, Ontario and /or Bruce Power.
c) Provide AECL with a high power management team independent from any bureaucracies and hire an external HR company to do it.
d) Make AECL an IPO and make its shares available to any interested province and to the Canadian public.
e) Remove the nuclear regulator (CNSC) from under the control of Energy Mines and Resources to cut the bureaucratic links with the past and to help it streamline its licensing procedures to serve a rapidly expanding market.

If the Federal Government is prepared to go ahead with this plan then Alberta, Ontario and Saskatchewan together with Bruce Power have the ability to boost the value of the IPO shares of AECL by intervening and negotiating with the Federal Government convenient terms for 2-3 initial projects. Alberta can also negotiate for a western office to develop the small reactor technology that will revolutionize the oil sands as well as provide future power for utility grid systems around the world.

If these two Prairie Provinces want to become the perfect investors for future generations, now is the most opportune time to invest in a diversification process, for which all future Canadians will be very thankful. The local hydrogen market will provide most of the financing needed to support a private nuclear company in the west.

16.0 A BRIEF BUSINESS PICTURE

This paper should be seeing as the first step in a series of initiatives. These can be described as a scientific plan, followed by a business plan, and then by a political plan, to make things happen, and a financial/governance plan, to make sure that what is put in place is sustainable and well managed. It ultimately should lead to Alberta's and Canada's prosperity.

Up to this point we have examined all the technologies associated with primary energies and the currencies that we can get out of them, thereby providing data based on which a scientific plan can be formulated. There also have been included some costs involving individual technologies. In this chapter significant points with special business meaning will be summarized that hopefully will also assist in the formulation of a business plan.

16.1 HYDROGEN PRODUCTION BY WIND MILLS

If the scientific plan calls for gradually reducing the production of hydrogen by steam reform and have wind mills begin producing hydrogen. The question will be what is the cost difference of these two methods?

a) The needed hydrogen at this stage is produced by steam reform of natural gas. Not only it consumes a lot of gas but also it costs of \$2.70/kg of hydrogen. As the price of gas increases this cost of \$2.70/kg of H_2 will also be increasing.

b) A current 2MWe wind mill sells wind power at \$0.13/kWh. At 30% efficiency it produces 4,900,000 kWh per year and earns annually \$637,000 gross.

c) It needs 53.4 kWh to produce 1 kg of hydrogen. Hence it can produce 93 tons/year of H_2 at a cost of \$6.8/kg H^2, to maintain the same income as when it provides its power to the grid. This results to a higher cost difference for electrolysis produced hydrogen by \$4.1/kg $H^{2.}$. This difference appears to be very expensive. It is, but here in Alberta we have special cases to consider.

d) Consider the carbon credits that electrolysis earns from a 2 MWe wind mill with 30% availability producing 93 tons H_2/year and saving emissions of 233 tones of CO_2/yr that would be emitted from the steam reform method, (CO_2mass =2.51 times the mass of hydrogen produced by steam reform). At \$110/ton of CO_2 credit (which is the cost of CCS) it will produce a carbon credit of \$0.27/kg of $H_{2.}$

e) Consider that tax credits and direct subsidies, provided by the government to the wind industry, amount to 43%[81] of the cost of its output. Hence the total amount of subsidies becomes \$7/kg H_2 x 0.43 = \$3.01/kg H_2. Carbon credits and subsidies reduce the cost difference to \$0.82/kg H_2 .

f) Now consider the committed cost to consumers for the \$2 billion grid system designed to facilitate wind power and the conclusion is that switching the wind mills from the grid to produce hydrogen will cost less or nothing more to the government.

g) Subsidies for wind power can be suspended after 10 years of operation, as is the case now. After the capital cost is paid wind farms will be very profitable.

h) The availability of the oil sands will outlast the availability of natural gas. As a result at some future point we will have to do exactly the same thing but in a less controlled pace.

i) The water consumption by the electrolysis is 9 liters of water per kg of H_2 produced. This is much lower than the 19.3 litters of water/kg H_2 consumed with the steam reform method.

j) The oxygen produced from the electrolysis of water can be used to improve the performance of the CCS process. Hence O_2 could have a commercial value.

k) There will be needed 23,550 wind mills, 2 MWe each, to meet today's demand for hydrogen. This demand will keep increasing and new wind turbines will be needed as well to replace the wind turbines after about 20 years of operation. This presents a significant market size to justify a profitable domestic industry that produces simple wind turbines for the production of hydrogen.

16.2 HYDROGEN PRODUCTION BY NUCLEAR POWER

a) Large nuclear reactors 1200MWe can produce 28.8 million kWh/day. At \$0.06/kWh it earns \$588 million/year, at \$0.13/kWh it earns \$1.27 billion/year. If all the power is used for room temperature electrolysis it produces 183,000 tons H_2/y at \$3.20/kg.

b) If the discharged hot cooling water is used for “warm” temperature electrolysis the hydrogen production rate can be increased to about 237,000 tons H_2/year at a cost of \$2.47/kg H_2. (at \$0.06/kWh)

c) Small nuclear reactors of 100 MWe, designed for discharge temperature electrolysis (WARM) would be able to produce 20,000 tons H_2/year at \$2.44/kg H_2 (\$0.06/kWh). If the reactor is designed for high temperature electrolysis it would be expected to produce about 25,500 tons H_2/year at\$1.92/kg H_2 (\$0.06/kWh). This means it can produce in a day roughly what a 2MWe wind mill produces in a year.

d) Both large and small nuclear reactors can always be connected to the electric grid and provide emergency or base load electrical power.

e) The cost of nuclear power \$/kWh depends entirely on the capital cost of a nuclear plant. This is because 80% of the cost/kWh, over a 60 year lifetime, of a nuclear power station is defined by the upfront capital cost of the reactor.

f) No new reactor has been built in North America over the last 20 years. Consequently we can have only estimates for its capital cost. Old build reactors now sell power for as low as \$0.05.kWh and they still make a good profit. Of course they have paid their loans for capital costs.

g) A large 1200 MWe nuclear plant saves 1,757 tones of CO_2 per day that would have been released by the steam reform method. This is about 600,000 tons CO_2/year.

h) A small 100 MWe nuclear plant saves 64,000 tons of CO_2 per year that would have been released by the steam reform method. As the price of natural gas increases there would not even need carbon credits to provide a better option for H_2 production.

i) Table 4 on page 67 has increased the estimated cost from a new nuclear power plant to \$0.13/kWh instead of \$0.06/kWh that we have now. This is a conservative estimate until we have actual data on the capital cost of nuclear plants.

j) The key cost of a nuclear power station is its capital cost. But some economists comparing the cost of a nuclear plant to coal or gas are missing a crucial piece of information. The gas and coal fired power plants operate at much higher temperatures to achieve their high efficiencies. As a result their equipment wear out faster. Hence, a gas fired plant has a lifetime of about 20 years and a coal fired plant a life time of about 25 years. In contrast nuclear reactors have a life span of 60 years (with refurbishing) and even then some utilities get permission to expand their capacity and extend their life time. As a result the life time of a nuclear plant should be calculated at 60 years and have added the refurbishing costs (Inflation adjusted). It should then be compared to three gas fired plants and 2.5 coal fired plants capital cost plus fuel and O & M (inflation adjusted).

k) Another important information is that a prototype nuclear unit costs a lot more that the second or third unit in the same power station. It absorbs the cost of licensing, it absorbs the costs for all the environmental and site evaluations, it absorbs the costs of the learning curve for the engineers, manufacturers and construction people, and it usually absorbs the cost of the cooling system. As a result a first large nuclear plant (1200 MWe each unit) now would be expected to cost between $5 and $8 billion depending on the management capability. The following units however should be expected to be between $3 and $3.5 billion. South Korea won a contract in December 2009 from the UAE for a 4 reactor power station for $3.5 billion per 1000 MWe reactor.

l) Finally, but not lastly, The quality of project management, the speed of construction, the type of contracts let, and the interest on the loan, contribute more to the cost/kWh than the equipment, the engineering, the fuel or the operation and maintenance costs for a nuclear plant.

m) A successful nuclear project needs attention on the following:

(i) Do not lump engineering costs in the equipment purchased – separate them and make transparent all costs.

(ii) Do not award a contract on a “cost plus” basis. Award them on a fixed profit basis + costs + performance bonus.

(iii) Do not start construction before the licensing authority has approved the site and the design and is in the process of issuing a license.

(iv) If there are going to be more than one unit in the same station order all the equipment at once and stagger their deliveries for when they are needed.

n) Small reactors are easier to license, to complete environmental assessment, to build and to finance. They produce hydrogen much more efficiently, and have a favorable economic profile. The upfront loan for capital costs is much lower. By the time the third unit starts construction the first unit will be operating, providing loan guarantee and assist with the financing. The equipment and the construction are designed to resemble a mass production process that has a lower cost for learning curve.

o) Small nuclear reactors can be built along the path of the pipeline that carries the bitumen to the USA. There the reactors can produce the hydrogen needed and upgrade in situ the bitumen into crude oil. Later the same reactors can be provided with CO_2 from the CCS process and produce synfuels for export. And finally the same reactors can produce the clean synfuels for export or domestic consumption.

p) Having the crude oil, a bitumen pipeline and the grid travelling close to each other and going through several Alberta communities, achieves three economic goals with tremendous social implications for Albertans. First It will generate several productive and prosperous communities along “the energy corridor”. Second, It will make it much easier to realize distributed production of electrical energy in the grid, and third, It will reduce the industrial concentration that takes place exclusively in the north end of the Province where the costs are higher for the communities and for the oil companies.

16.3 OTHER USEFULL POINTS

a) The world seems conditioned to the idea that the cost of our energy will increase from the $0.06/kWh that we pay now for wholesale prices. In Europe it has reached up to 4 times higher. The Ontario Power Authority is prepared to pay up to $0.80/kWh for solar power and $0.13 to $0.19/kWh for wind power. We cannot deny that the time for decisions is approaching fast. It seems that we will be better off if we make our decisions long before we have to. In this manner we facilitate evolution rather than wait to make decisions under the duress of revolution.

b) Alberta will get the benefit of avoiding the change of the engines for cars, trucks, trains, ships and planes by going the extra mile to perfect the production of clean synfuels.

c) The source quoted in the Chapter explaining the synfuels was written in 2007. At that time the capital cost forecast for nuclear plants was half of what it is today, but the life time was based on only 30 years. These differences may be producing some error in the estimated cost for producing clean synfuels. If we double the cost and also double the lifetime we end close to the Korean / UAE contract estimate.

d) Since the energy changes take a long time to materialize, inflation has to be included when estimating. This type of long term estimating tend to favor nuclear power since, as we said before, 80% of its life time cost is the capital cost upfront.

e) This makes nuclear power immune to inflation in a similar fashion as a hydro dam or wind mill..

f) Using wind power to start producing H_2, would contribute a lot to reducing the negative perception about oil sands and position Alberta as a strong supporter to reduce CO_2.

17.0 CONCLUDING COMENT

Formulating an energy policy is not easy. It is not enough to have solid board room working knowledge or sufficient political knowledge. It also takes a good understanding of all the energy technologies as they relate to technical, economic and environmental issues and all the interrelationships and connections between them. Only then one can cut through the fog of marketing interests of the various influential market players and compare energy options, integrate them and optimize them effectively.

Advisory Boards to the Government must have technical-economic and also environmental-economic expertise to help clarify complex concepts and situations. They will then be able to see the complete picture and the merits of all energy options when examining proposals. They must start from the stage of the “primary fuel extraction”, through all the conversion processes of producing “energy currencies”, and finally to the energy currency transport and consumption. The decisions and policies made will take a long time to be implemented. If such policies are not made accurately, it will certainly take a long time to correct.

It must be recognized that policy makers will not be around to witness the results of their policies. They will get the satisfaction of setting the ground rules and pathway leading to their final implementation.

Any new scheme must be compatible with the production of hydrogen currency without the production of CO_2. This means hydro, wind power and nuclear power. The hydrogen currency is not suitable right now as a transportation fuel because it requires a drastic change in our energy infrastructure (different engines, gas stations etc.) It will be helpful however now in producing a clean crude oil from the oil sands and later on a clean synfuel. Currently there is no known way to produce hydrogen cleanly using fossil fuels. Perhaps in the future, biotechnology may come up with some break through. Hence if we are serious about reducing CO_2 emissions, the options outlined seem to be the only ones with which to proceed in this transition without breaking the bank.

Regardless of the path that we chose, for the next 40 years we will need to conserve and optimize energy use. We have all ready developed a very large void in what we call sustainable energy. We don't see it because we waste gas resources to patch up this issue. On careful examination one can see the increasing void in our long term energy sustainability. We already have decided that our energy bills will drastically increase during our life time.

This paper has focused on CO_2 because rightly or wrongly, this is the current concern of several people. This issue has not been settled yet, however; should it prove otherwise the path that emerges from this paper will not need to be altered. This is because as hydrocarbons are depleting this will be the preferred path. Any other path will likely result in our great grand children to wonder how come we ignored the technical and economic experts and based our decisions instead on popular beliefs, dogmatic and misinformed concepts, influential market players or highly vocal minorities. The only comfort is that we will not be around to hear them cursing us.

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GLOSSARY

AESO	Alberta Electrical System Operator
AECL	The Atomic Energy of Canada Ltd
EEE Trinity	The combined effect of Energy, Economy and Environment
CCS	Carbon Capture and Storage
CANDU	Canadian Deuterium Uranium Reactor. The Canadian Technology
LFTR	Liquid Fluoride Thorium Reactor–a reactor that is cooled by its Salt/Thorium fuel
SAGD	Steam Assisted Gravity Drain – a method for extracting bitumen
PTAC	Petroleum Technology Alliance Canada
CNS	Canadian Nuclear Society
MJ/kg	Mega Jules (energy) per unit (weight), indicating Energy Density
GHG	Green House Gases – Gases in our atmosphere that could trap heat
gCO_2/kWh	Grams of CO_2 produced per kilowatt for one hour – a unit of energy production
$/kWh	Cost per kilowatt provided for one hour
kWe	kilowatt of electrical energy – usually 1/3 of the output of electric power plants
kWth	kilowatt of thermal energy - usually 2/3 of the output of electric power plants
mSv/yr	Millisevers per year- the amount of radiation absorbed annually
mSv	The amount of radiation absorbed in a single dose
Bq/L	Bequerrels per litter- radiation emitted by radioactive elements
Tons/MWy	Tones of a pollutant produced from one megawatt for one year of operation

REFERENCES

1) Canadian Energy Research Institute. World Energy, 2007
2) Jim Collinson. Presentation at the McIntyre Collegium, Oct. 2008
3) Alberta Science Teachers Conference Proceedings. C. Voutsinos Aug. 19/2009
4) Wikipedia. Hydrocarbon data.
5) Brighton thermodynamic cycle www.sussex.ac.uk/tfmrc/documents/gas_turbine_engine_internal_air_systems_sussex.pdf
6) Alberta Energy. Oil sands data
7) Rankine thermodynamic cycle. http://en.wikipedia.org/wiki/Rankine_cycle
8) Hydrogen production:
   High pressure electrolysis: http://www.fz-juelich.de/scientific-report-2001/docs/patente/26_11600.pdf
   High Temperature electrolysis: http://www.hi2h2.com/
9) Statoil, Annual and Sustainability Report, 2008
10) Power plant CO_2 production: http://www.eia.doe.gov/cneaf/electricity/page/CO2_report/co2report.html
11) C. Voutsinos: How to get the most out of Alberta Tar Sands. 2006 publication
12) The Globe and Mail, Dec. 2, 2009
13) How stuff works. 2006/08/25
14) Energy density of coal. http://en.wikipedia.org/wiki/Coal#Energy_density
15) Wikipedia, energy density of coal
16) B.P., Annual report 2007
17) Coal prices: http://www.ea.doc/coal/.gov/cneaf/coal/page/coalnews/coalmar.html
18) Ippsa Costcomp 5 (1),(Compatibility Mode), 2008
19) Aeso reports Power Plant Performance 2008
20) CCS : http://www.altenergystocks.com/archives/2007/08/carbon_capture_and_storage_by_the_numbers.html
21) US DOE, Radiation emissions from coal fired power plants, 2008 report
22) http://en.wikipedia.org/wiki/coal_gasification#By.pfroducts
23) Hubbert. Peak oil, 1970
24) Energy density of hydrocarbons: http://en.wikipedia.org/wiki/Gasoline#Energy_content
25) World Street Journal. Price of crude oil, November 20, 2009

26) Canada emits 1.9%. http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions.html
27) CO2 produced by burning diesel: http://unstats.un.org/unsd/snaama/selectionbasicFast.asp
28) Nat. Gas.CO2 emissions: http://www.naturalgas.org/environment/naturalgas.asp#greenhouse
29) Energy density of Gas: http://en.wikipedia.org/wiki/naturalgas#Energy_content
30) Price of Gas: http://www.advfn.com/p.php?pid=commodities&awd=74&kwc=gas&gclid=CMmVycDWkZ8CFR
31) CO_2emissions- gas power plants: www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html#electric
32) Solar constant: http://wikipedia.org/wiki/Sunlight#Solkar_constant
33) Authors calculations of solar variations with altitude
34) Ontario Power Authority, Ontario Unveils North Americas First feed-In Tariff, 3/12/2009
35) CO_2 Emissions from Solar Power. Asakura Keiichiro, Collins, Patrik, Nomura, K ioji at all
36) BioRafinex. biosphere@telus.net
37) Kurt Clein University of Lethbridge. Paper on farmed bio-fuels
38) Jatropha & Camalina, US Navy & commercial airlines bio-fuels, research report 2009
39) http://en.wikipedia.org/wiki/Anaerobic_digestion
40) http://www.popsci.com/technology/article/2009-12/two-major-geothermal-projects-terminated-amid-quake-risk-question
41) CO_2 from geothermal: http://www.everydayadvocate.com/air_geo.htm
42) Wind power limitations: http://www.earthtronics.com/pdf2/CTO-Presentation .pdf
43) Aeso website performance of power plants: http://aeso.ca/ets_web/ip/Market/Reports/CSD_ItalSReport_Serviet
44) Der Spieggel June 2009
45) Laughton, M.A. 2002, Renewables and the UK Electricity Grid Supply Infrastructure, Platts Power in Europe/// UK Energy Research Center, 2006. The costs and Impacts of Intermittency.
46) WNN, World Nuclear News, Sept 28/09
47) WNN, Italy returns to nuclear family, August/09
48) WNN, Belgium postpones nuclear phase out, Oct 13/2009
49) WNN, U-turn for nuclear opponents, Feb. 23/2009
50) Concrete needed by windmills http://www.concretecentre.com/main.asp?page=1145
51) http://epa.gov/climatechange/emissions/co2_human.html
52) http://www.newscientist.com/article/dn7046
53) The Power of Nuclear Energy, aecl pellet data, July 20
54) Canadian Nuclear FAQ

55) Radiation emissions from nuclear plants, CNSC Report August 2009
56) Google group, the Canadian Nuclear Society, discussions
57) CO2 emissions from nuclear power: http://web.mit.edu/nuclearpower/
58) http://en.wikipedia.org/wiki/Electrrolysis_of_water
59) http://en.wikipedia.org/wiki/Hydrogen_conomy
60) Implementing the H_2 Economy, R. Uhring, K. Shultz, L. Bogart. The Bent of Tau beta Pi 19
61) Motortrend.com, December 2008
62) Average Loses In Transmission Lines, aeso report 2009
63) Synthesis of hydrocarbon fuels using renewable and nuclear energy, paper 174100 by K.Shultz, S.Bogart, R.Nceti. ST-HH2 embedded Tropical meeting, Boston MA, USA June 24-28, 2007, ANS meeting.
64) CO_2 emissions from hydrocarbons Wikipedia
65) Canadian Nuclear Society website
66) The Petroleum Technology Alliance Canada, PTAC, website
67) FBR's the Pros and Cons, Macmillan Press, 1980 – 20
68) Thorium Reactors – Green Nuke, www.ccnr.org/aecl_plute_Source.html#W4.6
69) Thorium, Wired Magazine, January 2010 issue
70) Capture of CO_2 from Air, K. Lachner, P. Grimes & H, Ziock, Proceedings of the 24 Int'l
71) Thorium and Candu, Utube, Oil sands Extraction-LFTR in Alberta
72) Geothermal, http://geothermal.inef.gov.
73) Future Developments, Genetic Engineering & Biotechnology News Dec.1, 2009 (vol29,No 21)
74) Cost of Producing Power, PB Power for the Royal Academy of Engineers. http://www.raeng.org.uk/news/publications/list/reports/Cost_Generation_Commentary.pdf
75) Wind Energy the case of Denmark, CEPOS Center for Politiske Studies, Sept. 2009
76) Deffeyes Keneth: Hubert's Peak, The impending world oil shortage- Princeton U. 2003
77) Coal & Energy Price Report, 2009
78) Friends of the earth Europe: www.foeeurope.org/dinosaur/four/Denmark.html
79) S. Locke Bogart, Comparison of Investments and Related Requirements for Selected Hydrogen Vehicle System Pathways. Journal of Fusion Energy Vol 21, Nos, ¾, Dec. 2002
80) Kroposki et. All, Technical report: Electrolysis, NREL/TP-581-40605, Sept. 2006
81) Lazard, Levelized Cost of Energy Analysis- Version 3.0
82) Overpaying for Green Power, Ronald Bailey, Jan. 26,2010, Free Minds and Free Markets, reason.com