



Renewables vs. Hydrocarbons The Energy Reality

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Executive Summary

There are economic and practical realities about renewables that are often ignored.

We believe natural gas will play a central role in meeting global energy needs.

Hydrocarbons are the most economic form of energy we have access to at this time.

Issues related to energy use are vast, challenging and complex.

There is no shortage of information – and misinformation – in the media about energy use, renewables and the need to curtail (or eliminate) the use of hydrocarbons. While it is true that mankind needs to reduce its dependence on hydrocarbons, because of their non-renewable nature, there are many economic and practical realities about renewable forms of energy that are often not considered or simply ignored. We believe these realities will cause the transition to renewables to take much longer and cost significantly more than might be realized.

The objective of this report is to identify the realities about renewables, compare these to other forms of energy on an “apples to apples” basis and forecast how our energy use will change over the coming decades. We take into account the practical advantages and disadvantages of each type of energy source, the economics of producing the energy and include the cost of CO₂ emissions (which we have priced at \$50/tonne) in the financial analysis. From this analysis, we believe that unless there are significant breakthroughs in renewable technologies, hydrocarbons will continue to dominate our energy needs well into the next century.

We believe that natural gas, the lowest-cost and cleanest-burning hydrocarbon, will play a central role in meeting global energy needs and the long-awaited paradigm shift to increased natural gas demand is not that far off.

Economic Realities of Energy

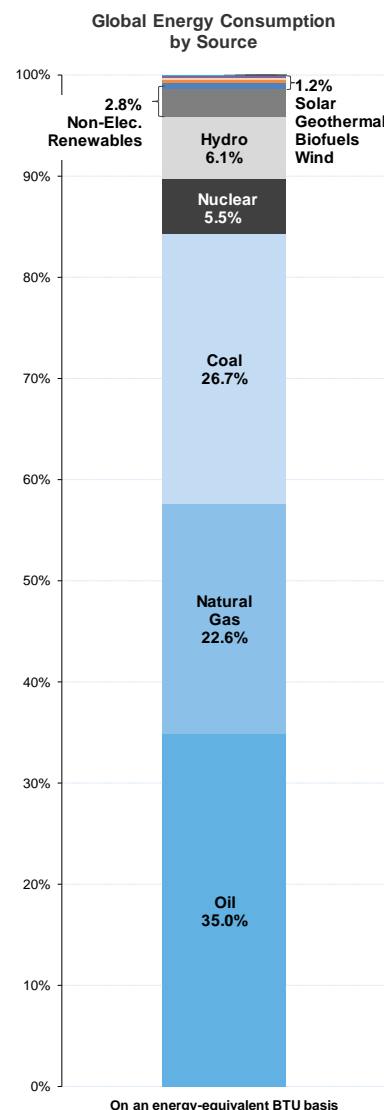
The following accurate statement is often repeated: “we now have the technology to convert to renewable forms of energy.”

However, an equally-accurate statement is: “renewables are too expensive, when compared to hydrocarbons, to implement on a broad basis.” Hydrocarbons are non-renewable, but they are the most economic form of energy we have access to at this time.

Renewables are often considered sustainable sources of energy due to the fact that their energy comes from infinitely-renewable wind, sun, waves or crops. Ironically, many of these renewables are only sustainable if continually subsidized by governments; governments that are often not in the financial position to fund economically-unviable projects. Subsidies are indeed required in many circumstances, but should act only as catalysts that temporarily insulate nascent technologies from market forces until they become self-sustaining.

Nuclear energy currently plays a small role in the global energy picture at only 5.5% of the total; we believe it will continue to play a relatively small role, especially after recent events in Japan. Notwithstanding, at some point in the future, it could play a more meaningful role as hydrocarbons become scarce and if safety concerns can be addressed.

The issues to be addressed in regards to energy use, and the necessary conversion to renewables, are vast, extremely challenging and very complex. While it is true that society needs to reduce consumption of hydrocarbons, it is also true that developing economies want, and require, an ever-increasing amount of energy. These two truths are fundamentally in conflict with each other because the developing economies will use the cheapest form of energy to meet their growing demands: the non-renewable hydrocarbons.



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An Energy-Equivalent Economic Analysis

Natural gas will play a central role in meeting energy demand in the coming decades.

Renewables' role is dependent on society's ability to pay for higher-cost energy.

The end-product of AltaCorp's energy-equivalent, or "apples to apples" economic comparison (including the \$50/tonne cost for CO₂ emitted) can be seen in Figure 1 where we have shown the cost of developing 11 different energy projects on a \$/mmBTU basis. Also shown on the chart is the measure of "\$/boe-energy", which is the cost of developing each type of energy project to receive the equivalent amount of energy in a barrel of light oil. Even with the cost of CO₂ included, hydrocarbons are the most economic form of energy at this time. Renewables can be significantly more expensive, which is an indication of how difficult (that is, costly) the transition to renewables will be.

Note on the chart that the lowest cost form of energy is natural gas. As a result, this fuel will play a central role in meeting energy demand in the coming decades. Renewables' role in the future is dependent on society's willingness, and ability, to pay for this higher-cost form of energy. Figure 1 shows that offshore wind becomes viable at about \$342/boe-energy and solar voltaic become viable at about \$429/boe-energy.

Total Cost of Energy Including CO₂ - Conventional and Renewables

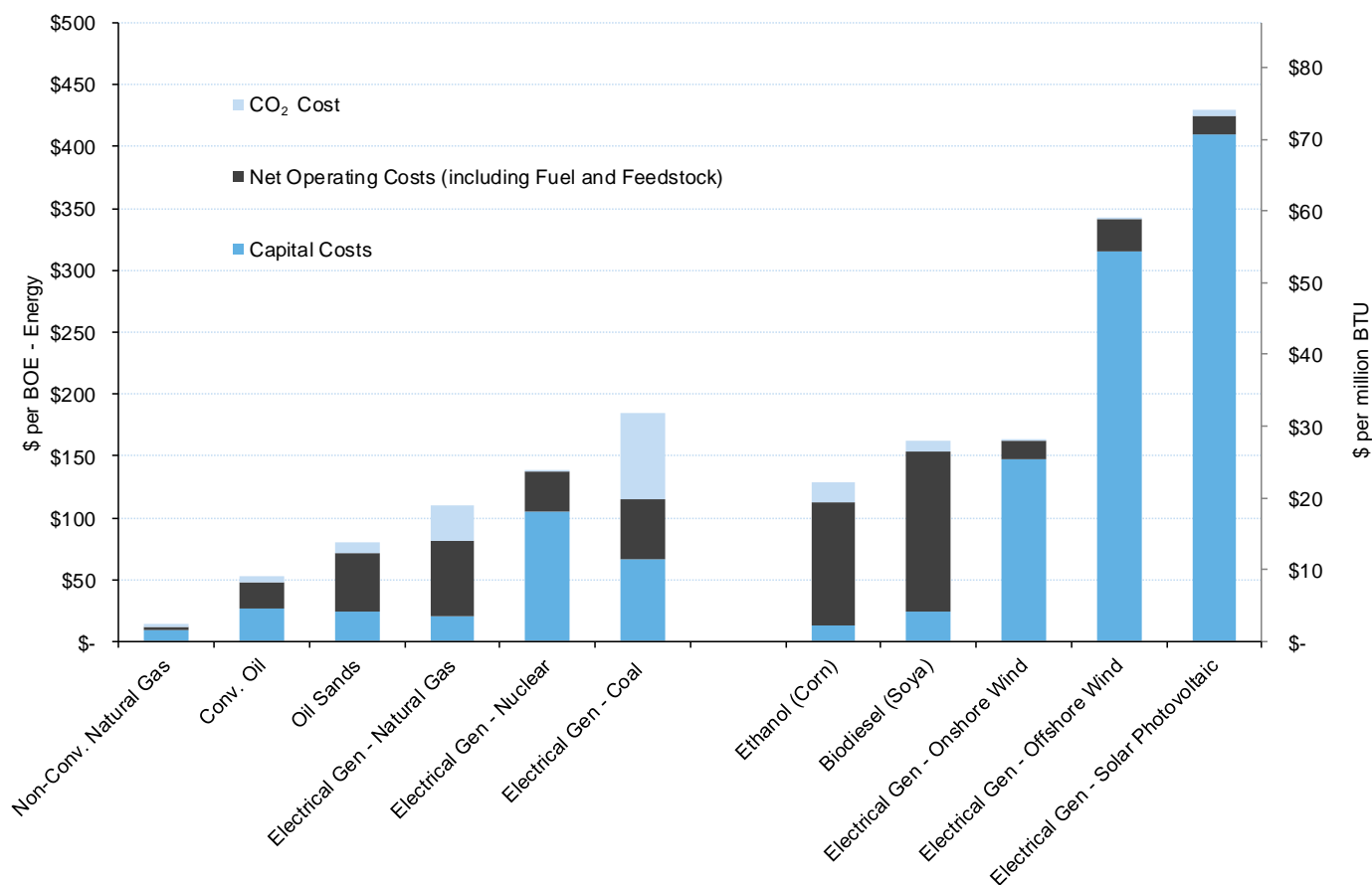


Figure 1. Total Costs for Various Energy Projects, Plus CO₂ Costs at \$50/tonne (using a Corporate Cost of Capital of 10%)

Sources: Please refer to the Sources section of this report.

Note: Oil Sands is an average of mining and SAGD.

Exec Summ Cont'd...



There is a realization that the global society needs to move to renewable sources of energy. This is not in dispute.

Practical Realities of Energy

- Over 84% of global energy now comes from hydrocarbons; replacing these will not be easy.
- Limited arable land (suitable for crops) is available for growing biofuel feedstocks and there are serious ethical issues related to using food crops for fuel in an over-populated and under-fed world.
- Although there are some small applications for the storage of electricity such as electric cars, there are no utility-scale technologies to store energy created by solar and wind.
- Many renewables create electricity, which is impractical in most transportation applications.
- Individuals in developing economies want (or expect) higher standards of living, and higher per capita energy use is central in that objective. Compounding this is the ongoing natural growth in world population.

There is a realization that we – as a global society – need to move to renewable sources of energy. This is not in dispute, because hydrocarbons are a depleting resource. Although we do have the technological capability to implement renewable energy such as wind, solar and biofuels, there are many practical limitations to their eventual replacement of hydrocarbons. For instance, solar power is only generated when the sun shines, wind energy is only generated when the wind blows and there is no practical way to store the electrical energy to balance a broad-based electrical grid. Biofuel production is increasing, but the energy derived from food-based crops could be used to feed millions of people.

To put in context how difficult the transition to renewables will be, we have made the following calculations:

- If all the arable land (land suitable for growing crops) in the U.S. was converted to corn for ethanol production – *leaving no land for growing food* – the total amount of ethanol would only replace 74% of the country's imports of oil.
- To replace the current global oil production of 84.4 million barrels per day with corn ethanol, it would take a corn field the combined size of the United States, China and India. This area is actually greater than the currently-used arable land in the world. If mankind was to convert all of the land now being used for growing crops we would only be able to replace the energy from 54 million bbls/day of oil. This represents only 64% of current global oil production.
- To replace the coal-fired electricity in the United States, it would take solar panels valued at approximately \$4.4 trillion. The limiting factor, moreover, is the inability to store the power generated during sunny periods for use throughout darkness and times of cloud cover. There is no current technology to store this amount of electricity on a practical basis. To put the significance of the storage problem in context, it would take approximately nine billion car batteries (those used in automobiles for starting the engine) costing about \$950 billion to store the solar power. The nine billion batteries represent over 34 times the number of batteries in the roughly 260 million registered vehicles in the U.S.

To replace global oil production with ethanol, it would take a corn field the combined size of the United States, China and India.

The transition to a sustainable-energy world will not be seamless and will require the ongoing use of hydrocarbons.

Converting to renewables will not be an easy task and will take a great deal of commitment on behalf of individuals, governments and industry. We believe the transition to a sustainable-energy world will not be seamless and will require the ongoing use of hydrocarbons well into the next century.

Mankind needs to develop an economic way to store electricity on a utility-scale basis. Until that is done, electricity generating renewables such as wind and solar will be a type of "Unobtainium" in economic and practical terms (see definition on page 80).

High Oil Prices are Here to Stay

- Due to the practical and economic realities, we believe high oil prices are here to stay, which will continue to make Canada's conventional oil and oil sands companies attractive investments.



Natural Gas Will Play a Central Role

Oilfield service companies will benefit from the global trend towards more natural gas use.

- Natural gas is the lowest cost source of energy and it is also the most environmentally-friendly when compared with other hydrocarbons.
- In the move towards increasing use of renewables, natural gas will play a much bigger role than just a “bridge fuel”; we believe it will become the largest source of energy on the planet.
- We expect companies levered to natural gas, especially those with long-term unconventional resources, will see significant share price appreciation as natural gas demand increases.
- Oilfield service companies, which are central to the development of unconventional gas, will be clear winners in this global trend towards more natural gas use.
- Infrastructure companies are also central players in this paradigm shift towards greater natural gas use. In addition to pipeline companies, these will include companies that can provide technologies to allow additional uses of natural gas, technologies such as gas to liquids (GTL), liquefied natural gas (LNG), compressed natural gas (CNG) and electrical generation fired by natural gas.
- Note the increase in natural gas use in our forecasts in Figure 2, this is an increase of almost 80% over current levels.

Ethical Realities of Biofuels

149 million people per year could be fed with the feedstocks now being used for ethanol production in the United States.

Readers will see that we are particularly sceptical about biofuels as a renewable source of energy. The ethical reality around biofuels is the dilemma commonly referred to as the “food for fuel” issue. We calculate that approximately 149 million people per year could be fed with the feedstocks now being used for ethanol production in the United States. This surprisingly-high number might be considered unbelievable by some readers; accordingly, our analysis, calculations and sources are shown in detail on page 53. Given the magnitude of the problem, we suggest reducing the subsidies for biofuels because they are distorting an already over-burdened global food system.

To put this issue in context, if one oil sands plant with a capacity of 100,000 bbls/d was used solely to offset ethanol production in the U.S. and the ethanol-feedstock land was instead used for growing food, 34 million people could be fed every year. This is approximately the population of Canada. Frankly, a better option for the United States would be to reduce energy consumption and use these savings to offset and limit ethanol production. If the country dropped its oil consumption from all sources by only 1% and this reduction was used to offset ethanol production, then the feedstock land could continually feed 64 million people every year.

Mankind needs to develop technologies, such as cellulosic ethanol, that can generate biofuels without further burdening the world’s over-taxed food supply system.

Environmental Realities of Energy

Biodiesel crops use 500 times the amount of water than an oil sands mining project, for the same amount of energy produced.

Environmental impacts need to be considered for all forms of energy use including renewables. All too often, it is an overall simplification of one source of energy being “bad” and another being “good.” For instance, the amount of water used in biofuels is significant; biodiesel crops use over 500 times the amount of water than an oil sands mining project for the same amount of energy produced. Hydroelectricity also has an impact, based on the amount of carbon-absorbing forest that is lost when a valley is flooded for a hydroelectric project.

It is a stretch to claim “electric cars are leading a green revolution,” when half of them will be powered by coal.

A simple example is electric cars, many of which are coming to market with claims of being emissions-free. However, this claim does not take into account where the electricity came from in the first place. Assuming that electric cars are distributed widely throughout the United States, 51.2% of these cars will actually run on coal (the amount of coal-fired electricity, measured on a BTU input basis). It is a stretch to claim “electric cars are leading a green revolution,” when half of them will be powered by coal, the most emissions intensive hydrocarbon. This is a commonly-repeated mistake, where a small subset of the world’s multifaceted and complex energy issues are examined in isolation. The answer may be accurate, when a subset of energy issues are viewed, but in terms of addressing the world’s energy challenges it may be of limited value (at best) or misleading (at worst).

Exec Summ Cont’d...



Hydrocarbon-producing companies are often accused of “greenwashing” (that is, trying to make themselves look environmentally friendly with minimal effort), however some “green” energy producers or supporters might be accused of this as well, by failing to point out all environmental effects. In this report, we deliberately do not apply the word “green” to renewable energy because we feel the reality is much more complex.

Meeting Growing Demand

If global energy demand was to increase by only 1.2% per year, total consumption would grow by almost 60% over current levels by 2050, as shown in Figure 2. This increase represents approximately three times the current total energy use, from all forms, of the United States. The ability of mankind to extract this amount of energy from the earth over the next 40 years will be a monumental – if not impossible – task; a challenge made more difficult by trying to do so with fewer greenhouse gas (GHG) emissions and using more renewables. It is really a one step forward and two steps back situation.

Global energy demand will grow 60% by 2050; this represents approximately three times the current energy use of the U.S.

Relying on non-renewable resources will eventually force mankind to reduce consumption and use renewables, but the transition will be difficult.

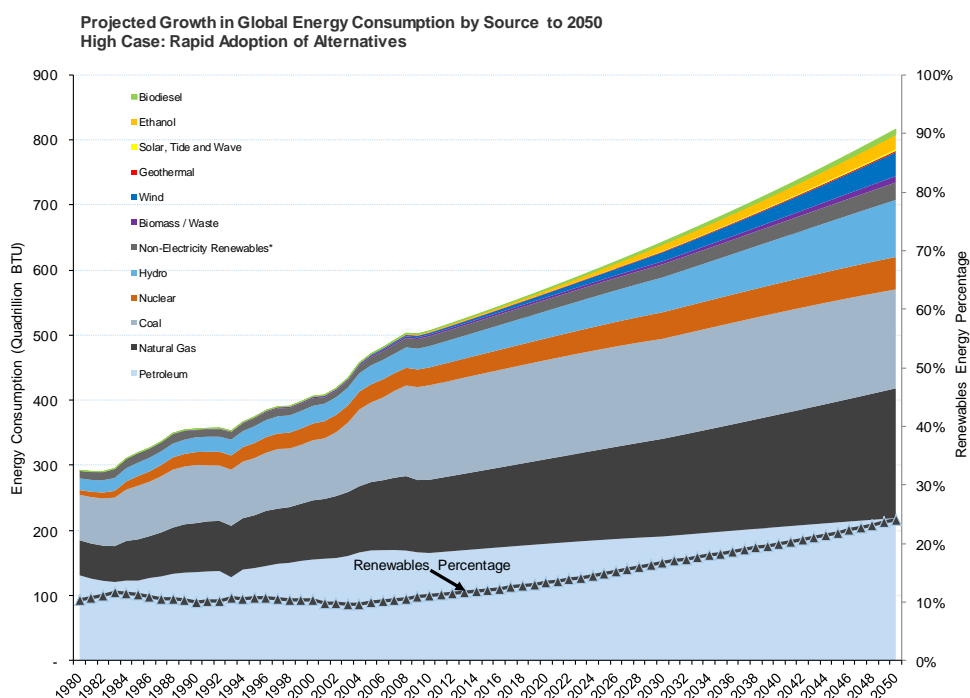


Figure 2. Projected Growth in Global Energy Consumption by Source to 2050
High Case: Rapid Adoption of Renewables

Sources: EIA, Earth Policy Institute, AltaCorp Capital Inc.

Note: Renewables Percentage includes Hydro and all other renewables

* Non-Electricity Renewables are those used for heat generation

Reduced Consumption as a “Source” of Energy

The need to seek advances in energy conservation is self-evident.

Reduction in energy consumption can be a “source” of energy; this is an essential part of our energy future. The need to seek advances in energy conservation is self-evident. Not only is it the most economic, it is also the most environmentally attractive “source” of energy. It is our view that mankind needs to reduce its energy needs by choice, or the choice will be forced upon us.

Exec Summ Cont'd...



Our ongoing use of hydrocarbons is slowly “emptying the tank.”

Individuals will use hydrocarbons until forced to make a transition.

Tragedy of the Hydrocarbons

Mankind has a preference for hydrocarbons, because of their convenience and low cost, but there is a tragedy developing related to our ongoing use of these non-renewable resources. We call this The Tragedy of the Hydrocarbons, which is related to Garrett Hardin’s The Tragedy of the Commons. In the Tragedy of the Hydrocarbons, individuals will choose to consume hydrocarbons because they are the most economic form of energy available and the most convenient. Because of their non-renewable nature, our ongoing use of hydrocarbons is slowly “emptying the tank.” Even the huge natural gas resources now being exploited with new drilling and completion techniques will eventually run out (albeit many years from now).

The tragedy lies in the reality that people will continue to use and deplete the non-renewable hydrocarbons, even though it is not in the best long-term interest of the individual, society, mankind or the planet for this to continue. Relying on a non-renewable resource will eventually force us to reduce consumption and use renewable forms of energy, but the transition will (in the Tragedy of the Hydrocarbons context) be difficult and painful. Mankind could have a relatively seamless transition to renewables but, because hydrocarbons continue to be the most economic and practical forms of energy, individuals will use these until forced to make a transition. A transition forced upon us will not be simple or problem-free. We discuss this tragedy in more detail on page 39.



What Are Our Sources of Energy Now?

Hydrocarbons account for 84% of global energy consumption.

Wind and Solar Power make up only 0.3% of our energy use.

Due to their practical and economic benefits, hydrocarbons will continue to be a critical source of energy for decades to come.

Let's start our analysis by examining the sources – or fuel types – for global energy consumption. We can see that hydrocarbons, at 84%, account for the vast majority of our energy consumption. Hydroelectricity is the most significant renewable energy source at 6% of the global total. Other renewables include solar, wind, ethanol, biomass, biodiesel and geothermal, which collectively make up just 4% of the total.

Global Energy Consumption by Source

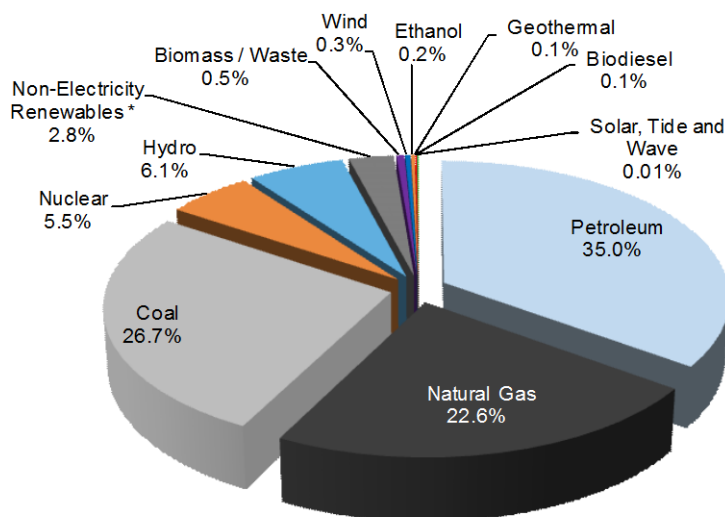


Figure 3. Global Energy Consumption by Source (on an energy-equivalent BTU basis)

Sources: EIA, AltaCorp Capital Inc.

* Non-Electricity Renewables are those used for heat generation

The world needs to convert to renewable forms of energy in the future, but the very large component of hydrocarbons in the current energy mix only begins to indicate the challenge in the conversion. It is not just the sheer volume of hydrocarbons that will make the conversion difficult, it is also their convenience with existing infrastructure, reliability and consistency when compared to renewables. Moreover, hydrocarbons are some of the most economic forms of energy at this time, even with CO₂ costs included. As we will see, natural gas, a hydrocarbon, could well turn out to be the most practical "alternative" with the least environmental burden.

For clarity, in this report we will use the terms alternatives and renewables interchangeably to describe hydro, wind, solar, biofuels, geothermal, biomass, tide and wave energy. We categorize nuclear on its own rather than as a renewable or alternative. Also for clarity, we will use the term hydrocarbon to describe coal, natural gas and petroleum as a group. We will also use the term non-renewable to describe hydrocarbons.

Why do Hydrocarbons Make up Such a Large Component of our Energy Use?

Mankind uses hydrocarbons because, by their very chemical make-up, contain a great deal of energy in their unrefined and natural state; energy that can be readily accessed through simple combustion. Additionally, hydrocarbons can be transported with relative ease by pipeline, rail or truck; in fact, coal and oil can even be carried by hand, if required. These attributes are critical and unique aspects of hydrocarbons when compared to some other forms of energy including nuclear and renewables which have no transportable and naturally-

Mankind uses hydrocarbons because they contain a great deal of energy in their unrefined and natural state.



All forms of energy, including alternatives, require inputs from hydrocarbons.

occurring energy in them. The challenge we now face with hydrocarbons is that they are becoming increasingly difficult and expensive to extract, as compared to several decades ago when conventional oil was easy to find.

It is important to note that all forms of energy including nuclear power plants, hydroelectric projects and all alternative forms of energy require inputs from hydrocarbons in the form of heavy equipment, machinery, electrical power (used in manufacturing components) and materials from petrochemicals. Hydrocarbons themselves are no different; they also require inputs from hydrocarbons to be converted into a useful form. The oil sands of Canada are a good example where natural gas, diesel and coal or natural gas-derived electricity are used to extract the resource. Biofuels such as ethanol and biodiesel also require inputs from hydrocarbons, in the form of fuel, for farm machinery and fertilizer created from natural gas. Energy from the sun through photovoltaic solar panels is free, however, building the solar panels is expensive. There are components within the solar panels made out of glass, plastics, copper and aluminum that require various inputs from hydrocarbons.

We believe that natural gas will grow in its importance in global energy use over the coming decades.

The Future for Natural Gas

There are many new or expanding applications for natural gas.

There is an abundance of unconventional natural gas within Canada and the U.S. which will help the transition away from the more carbon-intensive coal resources. We see natural gas demand increasing over the long term, especially in the following applications:

- **Gas to Liquids (GTL)** – This is the chemical process that converts natural gas to gasoline, jet fuel or diesel. When natural gas prices are low and oil prices high, the economics of these capital intensive projects make sense. In a long-term development plan, Talisman joined forces with Sasol Ltd. to assess a large gas-to-liquids (GTL) facility in Western Canada. This type of facility would provide another option to LNG for accessing offshore markets.
- **Liquefied Natural Gas (LNG)** – LNG is a way that inexpensive and export-limited natural gas could be shipped overseas. This could be a large area of growth for North American natural gas. In mid-March, Encana announced that it was acquiring 30% interest in the proposed Kitimat facility, a natural gas liquefaction and export facility in British Columbia. The Kitimat facility will enable producers to export natural gas to overseas markets, with an associated pipeline. This facility and pipeline have a proposed capacity of 700 mmcf/d of natural gas to come to the market.
- **Power Generation** – Natural gas electrical generation has far lower GHG and other emissions than coal-fired power generation. There are new power generation facilities in both Ontario and Alberta. The Ontario Power Authority is currently operating 6,967 MW of natural gas-fired energy contracts, and the closing of coal-powered plants will create a greater demand on natural gas-fired replacements. With the current concerns around nuclear energy, we see an ongoing increase in natural gas for power generation.
- **Transportation** – Compressed Natural Gas (CNG) can be used as a transportation fuel and is currently being used in vehicles such as buses, trains, pick-up trucks and taxi cabs. It is more common in Asia, South American, Middle East, and Europe as well increasingly for industry uses North American. There are some diesel trains which have been successfully converted to CNG in North America and Peru. The advantages to CNG include less CO₂ emissions than gasoline, diesel or propane. The limitation in broader application is the extended time required in refuelling and the need for heavy duty and expensive fuel tanks.

Hydrocarbons will continue to be a critical source of energy for many decades to come.

Hydrocarbons will continue to be a critical source of energy for many decades to come. The reasons for this are their inherent and readily-usable energy, existing infrastructure, attractive economics and increasing demand for inexpensive fuels in developing economies. We will show what role hydrocarbons have played in the past and how we believe they will be used in the future – along with alternatives – but first, let's review what those alternatives are.



What Can Replace Hydrocarbons?

Renewables

In working towards replacing hydrocarbons, there are many technically-viable renewable energy sources, which are shown in Figure 4 below. We have grouped these into Biofuel Alternatives, Electrical Alternatives, Heat Alternatives and Natural Gas Alternatives. All of these have the ability to replace a portion of hydrocarbon use. For instance, the biofuels – ethanol and biodiesel – can replace gasoline and diesel, respectively. The various electrical alternatives can replace electricity generated from coal, petroleum or natural gas, while the heat alternatives can also replace these same hydrocarbons.

Renewable Alternatives

Biofuel Alternatives	Electrical Alternatives	Heat Alternatives	Natural Gas Alternatives
<u>Ethanol:</u> Cellulosic Corn (Maize) Sugar Beet Sugar Cane Wheat Other crop-based Ethanol	Biomass (wood waste, peat, other) Concentrated Solar Power Fuel Cells Geothermal Hydroelectric Ocean Thermal Energy Conversion Ocean Wave Energy Offshore Wind Turbines	Biomass (wood waste, peat, other) Concentrated Solar Power Geothermal Thermal Solar	Biogas
<u>Biodiesel:</u> Algae Canola Flax seed Jatropha Palm Oil Soya Sunflower Tallow (Animal Fat) Other crop-based Biodiesel	Onshore Wind Turbines Photovoltaic Solar Tidal Electrical Power Thermal Solar		

Figure 4. Renewable Alternatives

Sources: EIA, Natural Resources Canada, AltaCorp Capital Inc.

In addition to the renewables, there are also hydrocarbon-based options, which can have a lower environmental footprint than traditional hydrocarbon uses. This is achieved through the use of newer technologies such as clean coal or the use of natural gas (the lowest carbon-intensive hydrocarbon) for transportation. Coal to liquids is not an environmentally-friendly alternative, but does provide another way of using the vast amount of global coal resources through the conversion of coal into gasoline and diesel. These options are listed below.

Hydrocarbon-Based Options (Non-Renewables)

Non-Renewable Options

Electrical Generation	Transportation Fuels
Clean Coal Technology	Coal to Liquids Compressed Natural Gas Gas to Liquids

Figure 5. Hydrocarbon-Based Options

Sources: EIA, AltaCorp Capital Inc.

Reduced Energy Consumption

What might have been conspicuous by its absence up to this point is the degree to which the reduction in energy consumption can be a “source” of energy; this is an essential part of our energy future. The need to seek advances in energy conservation is self-evident. Not only is it the most economic, it is also the most environmentally attractive “source” of energy. It is our view that mankind needs to reduce its energy needs by choice, or the choice will be forced upon us.

In the next section, we look at the economics of various sources of energy on an equal energy basis.



Economic Reality – An “Apples to Apples” Comparison

The public discussion regarding energy development and consumption has become increasingly important as environmental issues become forefront and oil prices again rise above \$100/bbl. Because access to inexpensive energy is critical to all economies, the issues under discussion are wide-ranging and include: energy conservation, greenhouse gas emissions, oil supply, alternative sources of energy, non-conventional hydrocarbon recovery, environmental sustainability and national security.

The statement “we need to get off our addiction to hydrocarbons and replace them with alternatives” is true but many questions remain.

One doesn't have to look very hard in the media to find articles regarding energy use and the necessity for mankind to move away from hydrocarbons and towards alternatives. Increasing the use of renewables is necessary (because hydrocarbons are a depleting and non-renewable resource), but how that will be achieved within realistic economic terms and time frames is a question that needs to be asked. Too often it is boiled down to “we need to get off our addiction to hydrocarbons and replace them with alternatives because we have the technological know-how to do so.” That statement is true but many questions remain, such as:

- How much will it cost to make the transition?
- Can we add alternatives faster than we increase our demand for hydrocarbons?
- Are there limits to growth in some alternatives?
- Is the public willing to pay more for clean energy?
- Can cash strapped governments and individuals afford to subsidize the development of new technologies?

Although many will say “we need to be willing to spend more on renewable solutions” our actions are not consistent with this.

We feel it is time for an “apples to apples” comparison of the various energy technologies and the economics of each. Mankind needs to transition to renewable technologies as oil continues to get more expensive as conventional oil gets harder to find. However, our society is still driven by economics and individuals make a majority of their decisions based on price. Although many rational people will say “we need to be willing to spend more on renewable solutions” our actions are not consistent with this. It is our belief that society will indeed spend more for renewable solutions, but only when oil prices rise to the point that alternatives make economic sense. There has been wind-powered electrical generation for over a century, but it only makes up 0.3% of global energy supply. This points out the economic and practical limitations of wind power; we have had the technology for over a century, but it is still not widely-used because it is more expensive than hydrocarbon-based electricity, and it cannot provide base load (consistent) power.

It will always be the consumer that ultimately pays for higher energy prices.

It will always be the consumer that ultimately pays for higher energy prices, even if the government facilitates subsidies. The consumer will pay through higher taxes, utility costs, vehicle prices (for electrical or hybrid cars) or prices at the pump. The majority of consumers will continue to select the lowest-cost options; very few will opt for renewable sources of energy except those that can afford to do so.

Many point out that “we have the technology to develop green energy solutions”, but this rarely takes into account the economic limits. As an example we now have hybrid cars, the technology is developed, the vehicles can be purchased, but are they really commercial? The answer appears to be “no” because sales of hybrid cars are very low even with the government subsidies that are offered. If the fuel savings (provided by the hybrid technology) were significant enough to offset their higher purchase price, these vehicles would be more popular.

Selecting Energy Sources for Comparison

For this “apples to apples” analysis, we will compare several conventional sources of energy such as coal, oil and hydroelectricity, along with various energy alternatives including wind, solar and biofuels. The list is not meant to be fully inclusive given the scope of this report and the vast number of alternatives at various stages of development. However, we have selected 27 sources of energy from both conventional and alternative technologies that represent a cross-section of electricity and liquid fuel energy sources. The following criteria were used to select the energy alternatives used in this report.



1. Commercialized technology exists to leverage the underlying resource. For example, we have not included algae-based biofuels as we feel the technology has not been demonstrated at a sufficient scale to determine its long-term economic viability.
2. The alternative must be a source of energy itself, not just a mode of converting energy from one form to another. For instance, fuel cells are not evaluated here because they are not actually a source of energy; they convert energy from one format to another.
3. Capital and operating expense information is available from public sources with sufficient detail to model the cost behaviour under a number of different assumptions/scenarios.

The BTU – A Common Measure for all Energy

In order to compare a diverse set of energy projects on a level playing field, we have taken the straightforward step of converting the output energy of the underlying resource – be it electricity, oil, natural gas, ethanol, biodiesel or other – into British Thermal Units (BTUs) as a common unit of measure. In this report, the following conversion factors were used:

- Electricity – 1 MWh = 3,412,000 BTU
- Light / Medium Oil – 1 Barrel = 5,800,000 BTU
- Natural Gas – 1 mcf = 1,027,000 BTU
- Ethanol – 1 Barrel = 3,563,00 BTU
- Biodiesel – 1 Barrel = 5,359,000 BTU

As part of evaluating projects on an equal measure, we also consider the project life span (how long it will produce energy) and its capacity factor (what % of the time it produces and at what average rate). This gives the total energy output (measured in BTUs) over the project's life. It is important to note that in our analysis we identified that some projects have much longer lives than others. Hydroelectricity projects have very long lives, but solar panels and wind turbines require replacement and we have assumed 30-year lives for these projects.

Capacity factor can dramatically reduce what the nameplate output is, for instance an average solar panel will only produce 22% of its full capacity given the limited number of hours of sunshine daily and annually. We assume an onshore wind project has a capacity factor of 34% and an offshore project has a capacity factor of 39%. Our analysis assumes energy output using current technology. Over time there will most likely be an increase in output from the various technologies, but we have not attempted to make predictions in this regard.

Capital Costs and Operating Costs

For estimated capital costs for the various projects we have used several sources including: the U.S. Energy Information Administration (EIA), U.S. Department of Agriculture (USDA), company reports and other energy research publications. To address the cost of capital required by investors in any allocation of funds, we assume that the total capital costs include both principal and interest paid over the life of the project at a 10% interest rate, the “corporate cost of capital”. We address cost of capital in more detail in the next section where we evaluate a ‘social cost of capital’ and a zero cost of capital, which may be more appropriate for some projects and taking into account longer-term environmental issues. In addition to capital, we then add annual operating and maintenance costs. The sum of these costs in combination with the total output energy (in BTUs) allows us to examine energy investment on an equal economic and energy basis.

In all cases we look at the costs involved in preparing the source of energy ready for the end-use consumer. For instance, the non-conventional natural gas costs include drilling, production and transportation costs to allow the gas to get to the burner tip. The natural gas electrical generation is quite a bit more expensive than natural gas used for heating/cooking purposes because it includes all the natural gas costs plus the capital, maintenance costs, operating costs and operating efficiency related to an electrical generation plant. Similarly,

In this report, we use British Thermal Units (BTUs) as a common unit of measure.

An average solar panel will produce only 22% of its capacity given the limited amount of daily sunshine.

For capital costs, we have used several sources including the EIA, USDA and company reports.



all the liquid projects including conventional oil, oil sands, ethanol and biodiesel include any production, upgrading and refining costs required to get the product ready to be used in a transportation application.

Here is an example of our methodology for ethanol and wind:

- **Ethanol** – For feedstock like sugarcane, fermentation/distillation technologies are required to convert the sugars to ethanol. Given that these plants use the simplest and least number of technologies, the capital costs tend to be the lowest. For grains like corn and wheat, additional processing steps (and thus additional capital and operating costs) are required to convert the raw grains to sugar. However, unlike sugar-based feedstock, the increased processing also creates usable by-products, in the form of distiller's dried grains and solubles, which are sold as animal feed to improve the overall economics of the process. For cellulosic feedstock like wheat straw, more complex biochemical or thermochemical processing steps are used in order to breakdown the fibres into sugar. These increased processing requirements are reflected in the higher capital requirements for cellulosic projects.
- **Wind** – In wind-powered projects, the turbine is a key technology used to harness the power of wind and convert it into electricity. Equally as important are the forecasting techniques and models used to predict the short-term and longer-term wind resource at a project site. These forecasts are important to determining project economics because although the capital costs are relatively well known, the production, in terms of kWh actually produced, is not. One of the key benefits of wind turbines is the minimal variable costs of operation, however, the upfront costs of implementing a wind power project can be significant.

Economics alone aren't going to answer all questions, nor should they.

Of course economics alone aren't going to answer all questions, nor should they; there are many other factors to consider. For instance, can one form of hydrocarbon energy be simply replaced by an alternative, or are there logistical or practical limitations? What about the long-term environmental effects?



The results of our cost per BTU analysis are shown in Figure 6, for our 27 conventional and renewable energy projects. We have created four groups, the first group (seven on the left) being various oil and natural gas production projects, followed by seven liquid fuel alternatives including ethanol and biodiesel projects. The third group consists of six traditional electrical generation projects including coal, natural gas and nuclear while the last group includes seven electrical renewables including hydro, wind, solar and geothermal (including the biomass, geothermal and solar thermal technologies) which can also be a source of heat, but we have only considered the electrical projects here.

Total Cost of Energy (BTU) - Conventional and Alternative

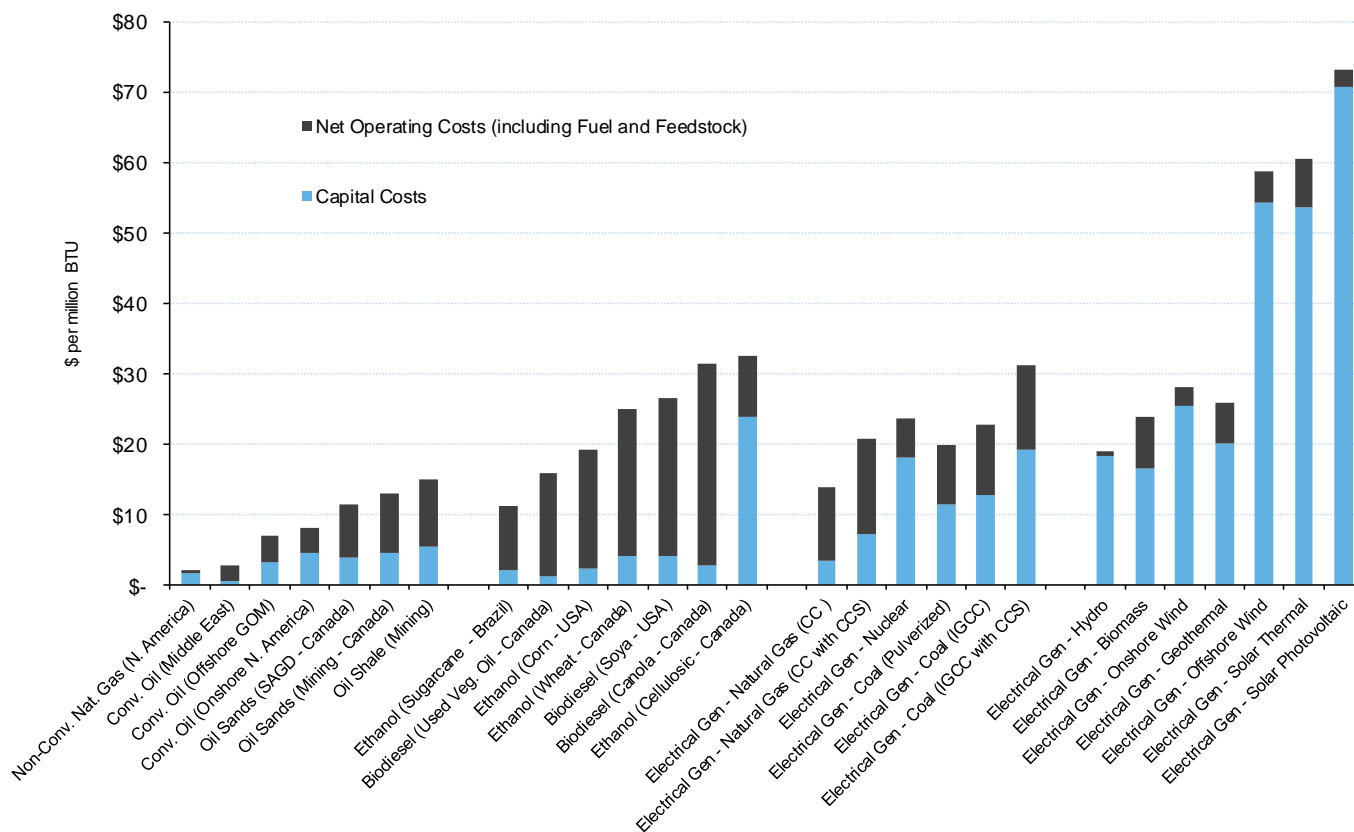


Figure 6. Cost of Energy Comparison (\$/mmBTU) (using a Corporate Cost of Capital of 10%)

Source: Please refer to the Sources section of this report.

Note: CC – Combined Cycle; CCS – Carbon Capture and Sequestration; IGCC – Integrated Gasification Combined Cycle

For the ethanol and biodiesel projects, the operating costs are net of the revenue received for the meal by-products. For instance, the costs of \$27.00/mmBTU for soya-based biodiesel calculated in the model includes the benefit of the sale of the soymeal, which in the model we have calculated as a benefit of \$34.00/mmBTU. If this was not included, the resultant total costs would be misleading at \$61.00/mmBTU.

In addition to capital and operating costs, a central issue at this time are the environmental costs – specifically CO₂ emissions – of various sources of energy. We discuss, and add-in, these costs next.



Environmental Costs – Greenhouse Gas Emissions

Renewables also have GHG emissions associated with their production.

The process of producing, transmitting and consuming all energy sources, both conventional and renewable, has a number of environmental impacts including greenhouse gas (GHG) emissions, primarily CO₂. We consider the amount that is emitted for each energy source, and we show the CO₂ associated with the production of various forms of energy in Figure 7 on the common BTU measure. Renewables also have GHG emissions associated with their production – an often-ignored reality.

CO₂ Environmental Footprint - Conventional and Alternatives

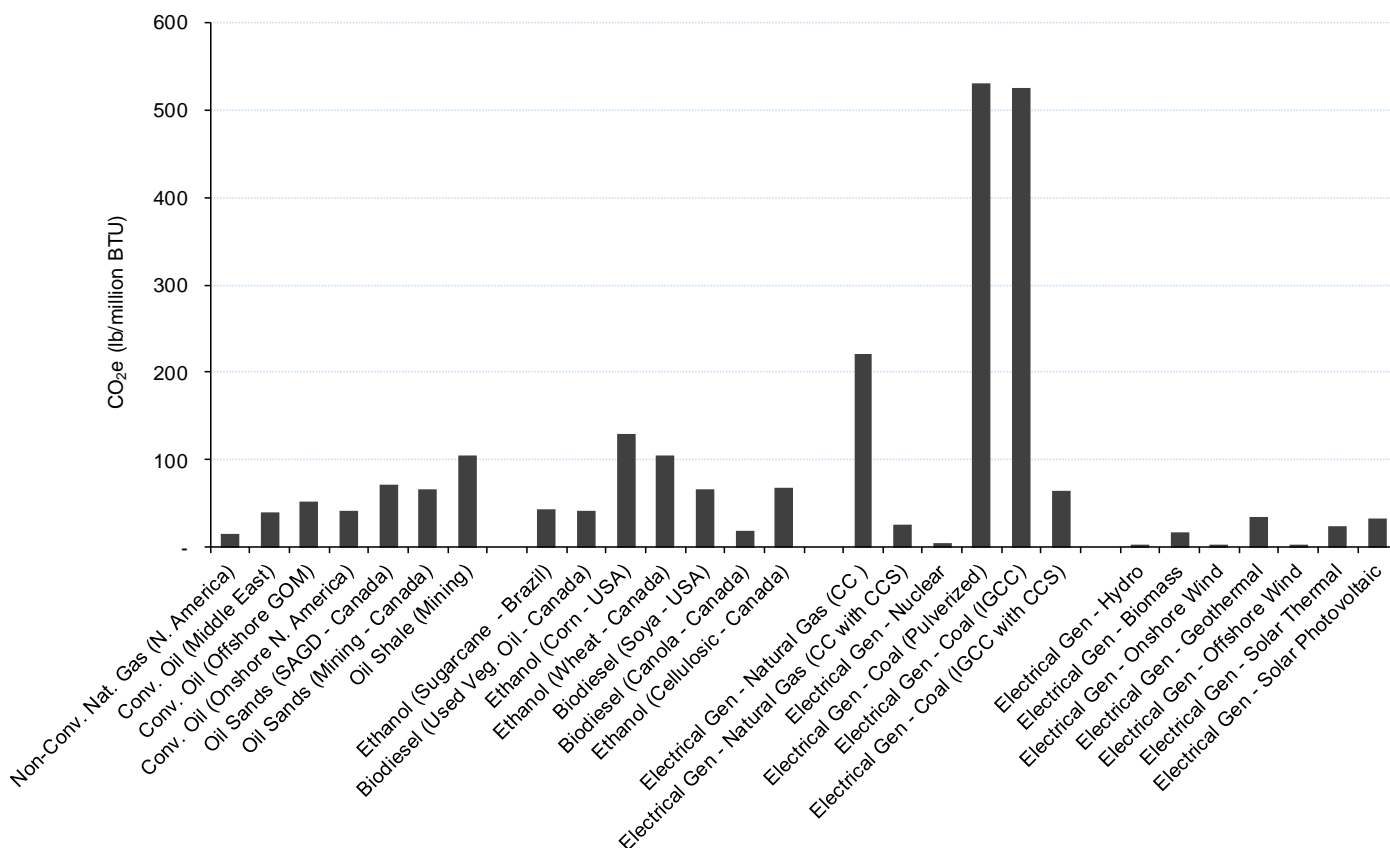


Figure 7. CO₂ Environmental Footprint

Sources: Please refer to the Sources section of this report.

Note: CC – Combined Cycle; CCS – Carbon Capture and Sequestration; IGCC – Integrated Gasification Combined Cycle

Higher CO₂ with Electrical Generation

Emissions are amplified in a natural gas-fired electrical generation plant due to thermodynamic inefficiencies.

As discussed in the previous section, in all of our evaluations, we consider the costs involved in preparing the source of energy ready for the end-use consumer. In the case of non-conventional natural gas, the GHG emissions are very low but if this fuel is used for power generation then the emissions are higher due to the actual combustion of the gas. The emissions are further amplified because of thermodynamic inefficiencies in converting heat to electricity in the plant.



Sources of CO₂ from Various Energy Projects:

Natural gas plants tend to produce about half the CO₂ emissions compared to coal power plants.

With hydroelectricity, the destruction of carbon-absorbing forests has an impact on climate change.

- **Oil** – The process of extracting conventional oil has quite low CO₂ emissions, but the conversion into refined products and the ultimate combustion by the end-user is where most of the emissions occur. Unconventional oil such as the oil sands have greater CO₂ emissions during the extraction process due to the more energy-intensive nature of the resource.
- **Natural Gas** – Natural gas electrical generation plants tend to produce about half the CO₂ emissions compared to coal plants. This makes them an attractive option in the transition towards more environmentally friendly electricity.
- **Biodiesel and Ethanol** – Most of the GHG emissions for biofuels are created during three processes: 1) growing/harvesting the feedstock including the production of fertilizers which is a highly energy-intensive process; 2) producing the biofuel; and 3) transporting the biofuels to market. Most of the CO₂ released during combustion processes was originally sequestered from the atmosphere during the growth of the feedstock. We discuss this offset in the next section.
- **Coal** – Conventional coal-fired electrical plants are large emitters of CO₂ (averaging around 530 lbs/mmBTU in our model). However, continued advancements in technology such as super-critical steam plants will mean more power produced per tonne of coal burned, improving energy efficiency and reducing emissions on a per BTU basis. Other technologies in different stages of research and development, including Carbon Capture and Sequestration (CCS) and hydrogen separation, could become standard in coal-fired plants of the future.
- **Nuclear** – This is one of the cleaner forms of energy from this perspective because a nuclear reaction has no CO₂ emissions. The CO₂ related to this type of power comes during the mining of the uranium ore and the construction of the plant.
- **Hydro** – The process of harnessing the potential energy of water to drive turbines does not create CO₂ emissions. However, the destruction of carbon-absorbing forests, which are carbon sinks, due to the required flooding behind the dam, does have an impact on climate change. There is also CO₂ emitted during construction process.
- **Geothermal** – Although geothermal power plants burn no hydrocarbons, the geothermal fluids contain dissolved gases such as CO₂ and H₂S, in some cases in excess of those produced by conventional power plants. The specific amounts, however, will vary with the resource.
- **Solar Photovoltaic** – Solar PV cells create no CO₂ emissions during their operation, but CO₂ is emitted during their construction, installation and eventual disposal.
- **Solar Thermal** – Similar to Solar PV, the majority of CO₂ emissions for solar thermal plants occur during their construction and dismantling. The levels of CO₂ also vary depending on the specific type of solar thermal technology implemented.
- **Biomass** – The majority of GHG for biomass plants is created during the operation of the plant and some emissions associated with the construction and dismantling of the plants. However, the combustion process of biomass releases a lot of CO₂ that was originally sequestered from the atmosphere during the growth of the biomass feedstock. It is important to note that burning biomass can introduce other emission challenges, especially for particulates, CO and NO_x.
- **Onshore and Offshore Wind** – The main component of GHG emissions for wind farms is the construction process (and to a lesser degree the dismantling process). The main contributor to the construction emissions is the large requirements for steel.



Full Life Cycle GHG Emissions

In recent years, there has been a move towards a Full Life Cycle (FLC) analysis of GHG emissions, which takes into account all emissions in developing and producing a form of energy. This is to consider all aspects of producing the electricity from – one might say – the Earth's perspective. As mentioned above, solar power does not create any GHG emissions when viewed in isolation, but many resources were extracted from the Earth to build, install and make them functional. Another example of FLC analysis is the use of a Well to Wheels (WTW) approach to the carbon intensity of different liquid fuels. For instance, a battery powered car does not create any GHG emissions when looked at in isolation, but when all factors are considered including the construction of the vehicle, the generation of the electricity and the eventual recycling of batteries and disposal of the car, there are a great deal of emissions.

The largest component of CO₂ emissions related to liquid fuels occurs when vehicles burn gasoline, diesel or biofuels.

In the case of CO₂ emissions for fuels, we have compared the CO₂ released during only the upstream production/recovery process in Figure 7. It is important to note that the largest component of CO₂ emissions related to liquid fuels occurs during the combustion phase of the energy cycle (i.e. when vehicles burn gasoline, diesel or biofuels). During combustion, biofuels will have better CO₂ emission performance than conventional fuels because most of the CO₂ released was originally sequestered from the atmosphere during the growth of the feedstock.

If we apply a credit for this sequestered carbon – which is the logical thing to do – the combustion emissions are dramatically reduced. In our research, however, we have observed that the application of the credits for sequestered carbon is not applied uniformly in the literature; in some cases it is applied to feedstock production and in others the downstream combustion. Interestingly, sometimes it is actually applied to both, which is double-counting and for a proper energy analysis; it is important to apply the credit to one or the other, but not both. We believe the GHG credit for sequestered carbon should remain in an analysis of the downstream costs/emissions. Figure 8 helps to illustrate the benefit of the GHG credit for the FLC of biofuel production and end-use consumption. The use of biofuels is far from being “emissions-free.”

The use of biofuels is far from being “emissions-free.”

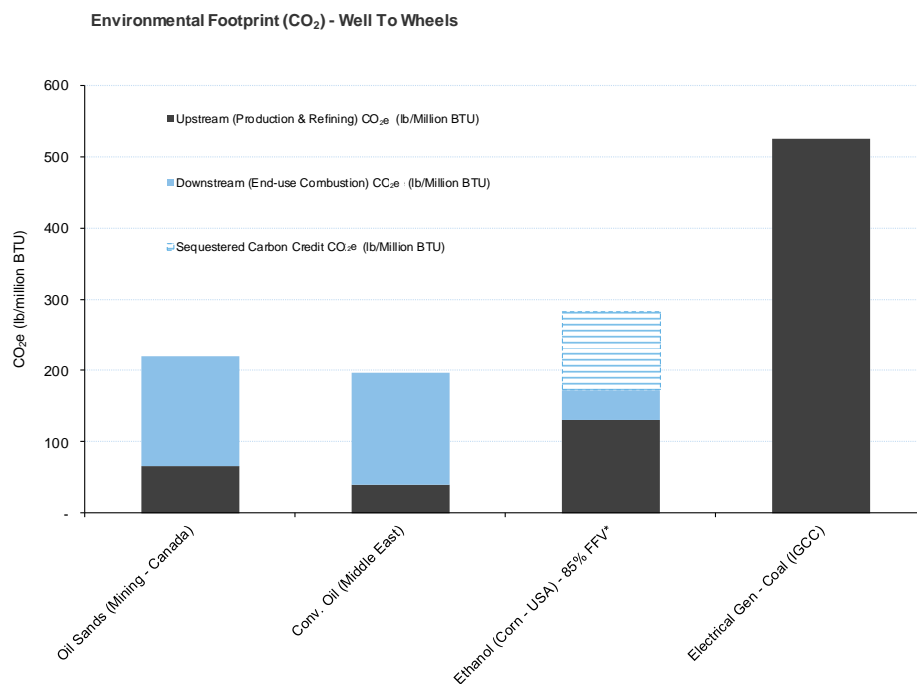


Figure 8. Well to Wheels GHG Emissions Comparison

Sources: Please refer to the Sources section of this report.

* 85% FFV: Flexible Fuel Vehicle burning a blend of 85% ethanol and 15% gasoline fuel

Note: IGCC – Integrated Gasification Combined Cycle



A \$/Barrel-Equivalent Measure

We compute the cost to produce the amount of energy in a barrel of light oil, and use the term “boe-energy”.

Biodiesel is quite a bit more expensive, becoming economic at \$163.00/boe-energy for soya biodiesel in the U.S.

Offshore wind turbines and photovoltaic solar electricity are economic at \$342.00/boe-energy and \$429.00/boe-energy, respectively.

For those more familiar with oil pricing than BTU values, we have compared costs on an oil equivalent basis and added this measure to Figure 9. For clarity, in addition to calculating the cost to produce energy on a BTU basis, we can also compute the cost to produce the amount of energy in a barrel of light oil and we use the nomenclature “boe-energy” to describe this. Having already done the analysis on a \$/BTU basis, the conversion is elementary using the light oil energy equivalent of 1 Barrel = 5,800,000 BTU (or 5.8 mmBTU) to get the \$/boe-energy. For instance, ethanol from corn in the U.S., as calculated in our model, costs \$22.00/mmBTU and to convert that to a \$/boe-energy we simply multiply by the 5.8 mmBTU in a barrel of oil to get \$129.00/boe-energy of ethanol. This is an energy equivalency (which is unrelated to volume) \$129.00 is the amount you would have to pay in capital, operating and maintenance costs to get an equivalent amount of energy in a barrel of oil. Going forward in this report, we will show both the \$/boe-energy and the \$/BTU wherever appropriate and possible.

The significance of the \$/boe-energy measure cannot be overstated. This puts into context the cost of various energy projects in the widely-understood \$/bbl value, and directly indicates at what oil price these technologies become economic on a BTU to BTU basis.

For instance, the ethanol from U.S. corn in Figure 9 becomes economic at energy prices of \$129.00/boe-energy basis. Another example is sugarcane ethanol from Brazil, which is economic at energy prices of \$72.00/boe-energy. Oil from the oil sands is more expensive to extract than conventional light oil and these projects are economic, using this analysis, at energy prices of \$76.00/boe-energy in the case of a SAGD operation and \$84.00/boe-energy in the case of a mining operation. The analysis shows that biodiesel is quite a bit more expensive, being economic at \$163.00/boe-energy for soya biodiesel in the U.S. market and \$185.00/boe-energy for canola biodiesel in the Canadian market. Onshore wind turbines, offshore wind turbines and solar photovoltaic electricity are economic at much higher prices (\$163.00/boe-energy, \$342.00/boe-energy and \$429.00/boe-energy, respectively) than oil projects.



Total Costs of Energy Including CO₂

We add in a CO₂ price of \$50/tonne for all energy sources.

In Figure 6 we did not include costs related to CO₂ in our analysis, but in Figure 9 we add in a price of \$50/tonne for all energy sources. For our analysis of the typical project, we assumed \$50/tonne for CO₂ credits, which is higher than the \$20 - \$25/tonne in historical trading.

Total Cost of Energy Including CO₂ - Conventional and Alternatives

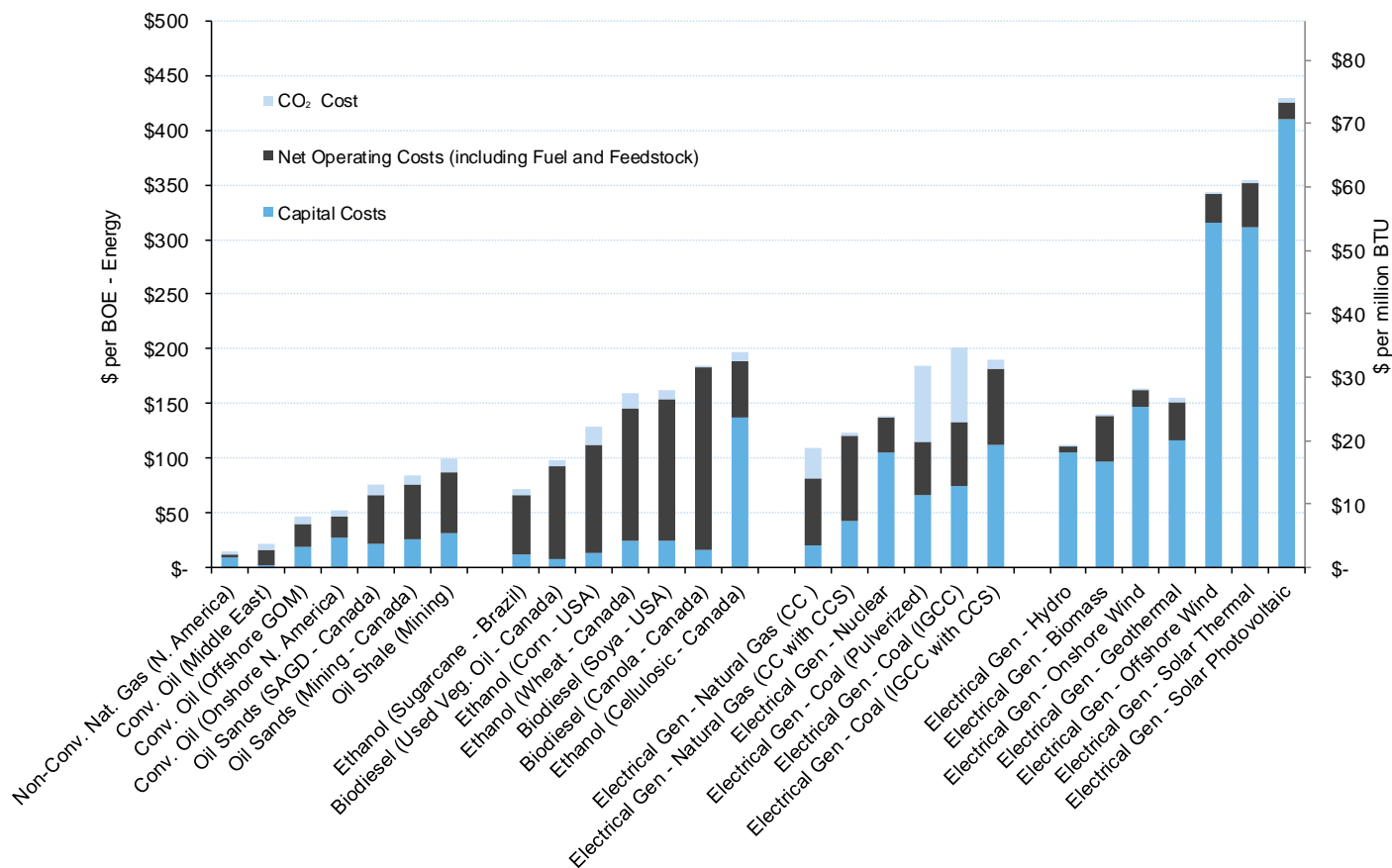


Figure 9. Total Costs for Various Energy Projects, Plus CO₂ Costs at \$50/tonne (using a Corporate Cost of Capital of 10%)

Sources: Please refer to the Sources section of this report

Note: CC – Combined Cycle; CCS – Carbon Capture and Sequestration; IGCC – Integrated Gasification Combined Cycle



Cost of Capital

Cost of capital is in conflict with future generations because it gives lower value to cash received in the future.

Society is driven to maximizing value in today's dollar, forcing us to use the cheapest forms of energy – hydrocarbons.

The higher the cost of capital, the lower the value we assign to the future, clearly a problem with environmental issues.

The capital intensive nature of many large-scale energy projects, particularly alternatives, can lead to a debate about an appropriate cost of capital to apply in the calculation of energy costs. In our analysis, we have assumed a corporate cost of capital of 10%, which is in the range of what many corporations might use in major capital investment decisions. However, as accurately indicated by many in the energy debate, we need to consider future generations' access to reasonably priced energy and to a conserved environment. It is important to note that cost of capital – or expected rate of return by an investor – is fundamentally in conflict with future generations because it, by its nature, gives lower value to cash received in the future.

The higher the cost of capital and the further away in time, the lower the value in today's dollar. For instance, at a cost of capital of 10%, a dollar received in 10 years is worth \$0.35 today and if received in 20 years it is worth only \$0.12 today. The implication here is that it is better to receive the dollar in 10 years rather than in 20 years because it is many times more valuable at the earlier date. The goal in business – in a free market society – is to maximize the net present value (NPV) of assets and the higher the cost of capital, the lower the amount of value that is attributed to future years. This is more than just a way of doing business, it is a fundamental decision-making tool for all individuals.

To take this to the extreme, it would make the most economic sense for an owner of an energy resource to produce all the energy today, not next week or even tomorrow; producing it today will maximize their return on capital, but takes no consideration to future generations. To take the opposite extreme, the owner could produce no energy for 30 years and then produce it all in one day in 2041. In this case the energy would have no value to the owner today, but may be of great value to his or her beneficiaries. However, it would have been better for everyone – at least from the economic point of view – if the owner had produced all the energy today and then reinvested the proceeds over the 30 years. These examples assume that energy prices stay flat.

All of this discussion is to point out the fundamental problem we are facing in our society in that we are driven by maximizing value in today's dollar and this is forcing us to use the cheapest forms of energy. The result is we will use inexpensive hydrocarbons initially, and the more expensive alternatives are being left until they become economically viable or hydrocarbons become too expensive.

Note that the higher the cost of capital, the lower the value we assign to the future, at least in economic terms. Now layer on environmental considerations to this, that is, how do we take into account long-term environmental issues when economics are telling us to focus on the short-term? This is where the short-term economic advantages of hydrocarbons are in conflict with the necessary long-term environmental considerations. If society only looked at things from the cost of capital point of view, everything would be done to maximize value in the present, with little to no consideration of the future. To include environmental and other longer-term issues, a broader perspective is required. To address (but not resolve) this cost of capital problem, we compared the total cost of energy, on an energy-equivalent basis, using three different discount rates:

- **Corporate Cost of Capital** – This is the 10% rate of return we used in Figures 1, 6 and 9 that might be expected by private or corporate investors. This number will range due to the required rate of return for various companies, but 10% is reasonable in the current environment.
- **Social Cost of Capital** – This is the rate of return that would be used by governments and economists to determine the value of investing in social projects like energy.
- **No Cost of Capital** – This approach assumes a zero cost of capital over time and can arguably be used in the analysis of the cost of energy and the related environmental issues.

Of these three values, the use and calculation of a social cost of capital has prompted the most debate. There is no consensus on the best approach to determining a social discount rate, but there is a general agreement that for longer term projects, with intergenerational and environmental effects, lower discount rates should be used so that a significant weight is applied to the costs/benefits incurred by future generations. As an example, the



authors of a Pembina Institute (a Canadian not-for-profit sustainable energy think tank) study titled: *Natural Credit – Estimating the Value of Natural Capital in the Credit River Watershed*, note that “Uncertainty, risk, intergenerational equity and potential irreversibility of policy decisions imply that the social discount rate should be lower than interest rates set by traditional capital markets”. We agree with this assessment and have calculated a social cost of capital, as discussed below.

Calculating a Social Cost of Capital

Some economists have argued that a good approximation of the social cost of capital is the real pre-tax rate of return on riskless private investments. AltaCorp’s estimate of the social cost of capital was developed based on the historical average of Moody’s AAA long-term bond yield of 5.9%. This value was then adjusted to account for taxes and inflation, and then adjusted downwards by a factor of 2% to account for the intergenerational nature of most energy projects based on a review of discount rates used by several countries and international agencies. The resulting cost of capital was determined to be 3.5%. In comparison, governments around the world have used values between 0.5% and 8% as the social cost of capital for long-term projects. For comparison, the Pembina report performed valuations based on both a 2% and 5% discount rate.

We have applied the three costs of capital to the 27 energy projects.

In the next two figures, we show the same 27 energy projects, and applied the three costs of capital. The liquids projects are shown in Figure 10 and the electrical projects are shown in Figure 11.

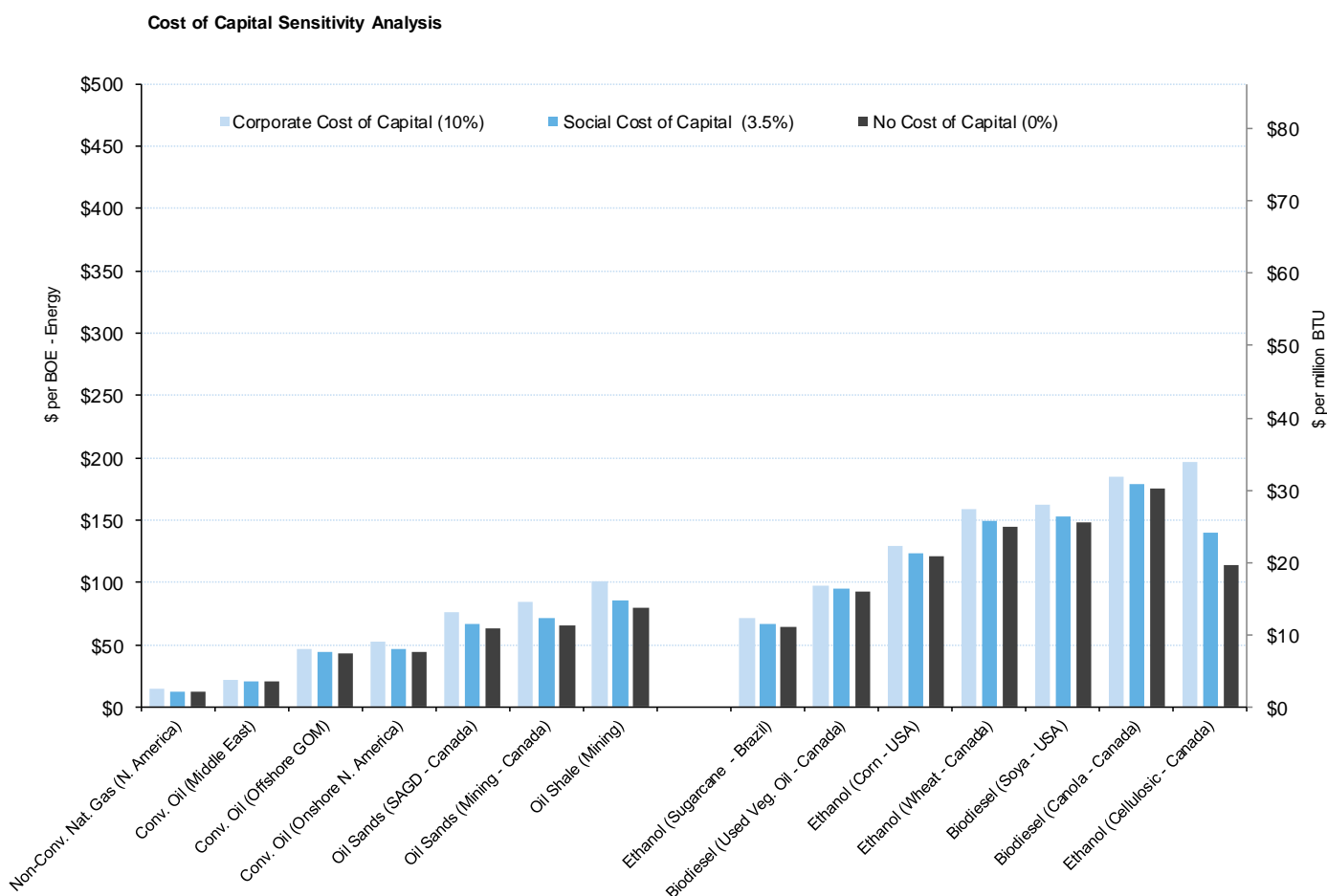


Figure 10. Cost of Capital Sensitivity Analysis

Sources: Please refer to the Sources section of this report.



The best environmental choice would be to develop the cellulosic ethanol rather than the oil shale.

Note that if energy rose to the price of \$145/boe-energy then soya biodiesel at a zero cost of capital would be economic, as shown in Figure 10. However oil shale mining using a 10% corporate cost of capital becomes economic at \$100/boe-energy and will therefore be developed before soya biodiesel (under a subsidy-free economic perspective). In the same chart, cellulosic ethanol at a zero cost of capital becomes economic at \$120/boe-energy. Many would rightly argue that the best environmental choice would be to develop the cellulosic ethanol rather than the oil shale (with its many environmental issues) and the food-based biodiesel (with its ethical issues).

Cost of Capital Sensitivity Analysis

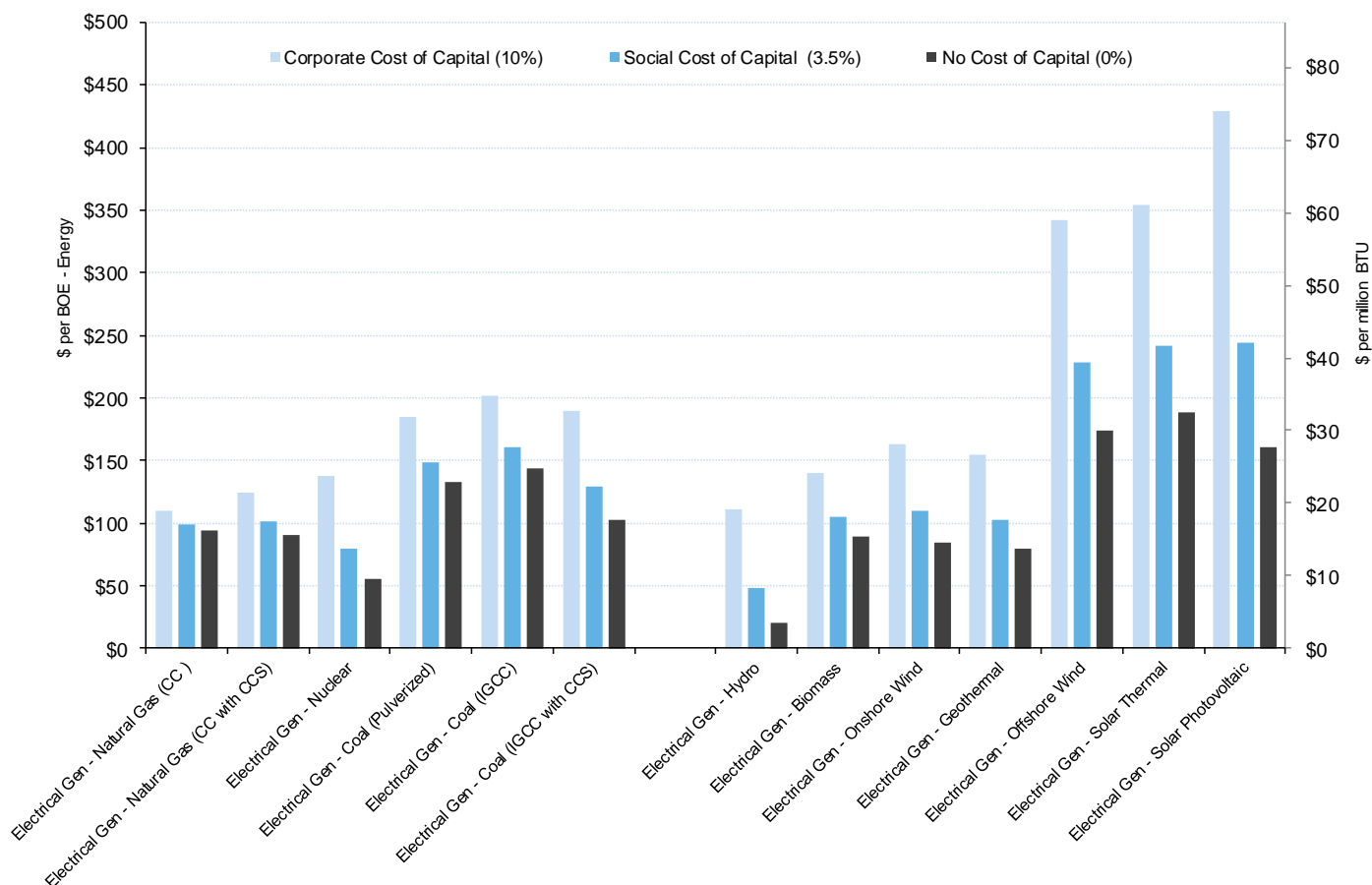


Figure 11. Cost of Capital Sensitivity Analysis

Sources: Please refer to the Sources section of this report.

Note: CC – Combined Cycle; CCS – Carbon Capture and Sequestration; IGCC – Integrated Gasification Combined Cycle



Sensitivity Analysis – What Will Drive Variability in Cost Estimates?

There are many factors that will cause expected costs to vary significantly.

As a quick review, in Figure 9 we compared the cost of energy for a “typical” project under a specific set of assumptions and in Figures 10 and 11 we evaluated the same costs under three different costs of capital. We do not believe that the estimates in those figures are final and indisputable; there are many factors that will cause these results to vary significantly including fuel prices, feedstock costs, carbon credit pricing, capacity factors and heat rates. As a result, there will be a wide range of total costs per BTU (and per boe-energy) when various projects are evaluated; some will have lower costs than our typical project and some will have higher costs. Therefore, to better understand the dynamic behaviour of total energy costs under different scenarios we have performed a sensitivity analysis; the drivers of variability are discussed over the next several pages with the final results shown graphically in Figures 24 and 25.

Capacity Factor

In the case of several renewable resources, the capacity factor is a key driver of the total cost of energy that is produced. The capacity factor is a ratio comparing the average energy produced over a period of time to the energy that could have been produced at continuous full power operation during the same period (the latter often referred to as a nameplate rating). The capacity factors used in our comparison of “typical” electricity generation projects are shown in Figure 12.

Capacity Factor Comparison

Project	Capacity Factor
Electrical Gen - Nuclear	90%
Electrical Gen - Natural Gas (CC)	87%
Electrical Gen - Natural Gas (CC with CCS)	87%
Electrical Gen - Coal (Pulverized)	85%
Electrical Gen - Coal (IGCC)	85%
Electrical Gen - Coal (IGCC with CCS)	85%
Electrical Gen - Geothermal	90%
Electrical Gen - Biomass	83%
Electrical Gen - Hydro	51%
Electrical Gen - Offshore Wind	39%
Electrical Gen - Onshore Wind	34%
Electrical Gen - Solar Thermal	31%
Electrical Gen - Solar Photovoltaic	22%

Figure 12. Average Capacity Factors (Renewables and Conventional)

Sources: EIA, AltaCorp Capital Inc.

Note: CC – Combined Cycle; CCS – Carbon Capture and Sequestration; IGCC – Integrated Gasification Combined Cycle

We can see that most conventional power plants like nuclear, coal and natural gas operate at relatively high capacity factors, indicating that the nameplate capacity of the plant is a relatively accurate indication of the actual amount of energy produced over the economic life of the project. In contrast, the capacity factor for several renewable alternatives is relatively low. For example, our analysis of solar photovoltaic (solar PV) cells is based on a capacity factor of 22%. Therefore, a solar PV cell with a theoretical or nameplate rating of 100 watts will only generate an average of 22 watts of power over its life, in this case because of the limited availability of its underlying resource (sunshine) throughout the day and night.



In Figure 13, we can see that the cost curve for a select group of renewable technologies with lower capacity factors show a dramatic increase in the cost of energy when the capacity factor approaches values of 30% or less.

A dramatic increase in the cost of energy occurs when the capacity factor drops below 30%.

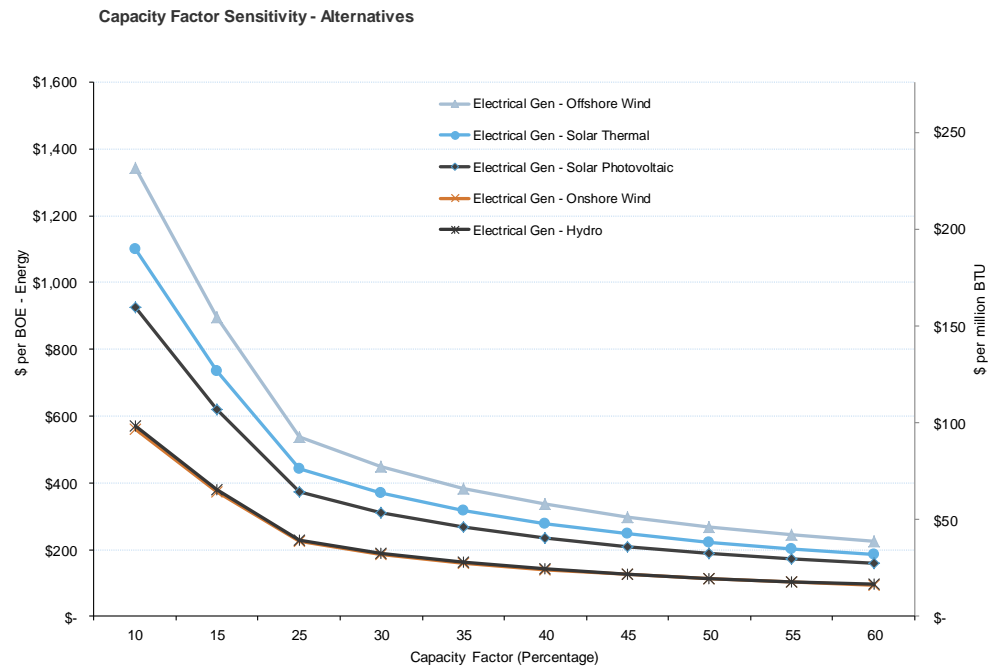


Figure 13. Sensitivity of Energy Costs to Capacity Factor (Alternatives)

Sources: Please refer to the Sources section of this report.



Feedstock Prices

For biofuel projects, the price of the feedstock used to create the ethanol or biodiesel – be it corn, wheat, sugarcane, canola, soya or other – is a fundamental driver of the total cost of energy that is produced. Therefore a feedstock that can be purchased inexpensively should result in cheaper biofuel production costs. Figure 14 plots the price of canola, corn and soya beans over a 10-year period and shows the food crisis peak in 2008 and the run-up towards the current food crisis. These higher costs are what will likely lead to the development of second-generation biofuels using cellulosic technology, which uses lower cost (and non-food) feedstock.

Higher food prices will likely lead to biofuels that use non-food feedstocks.

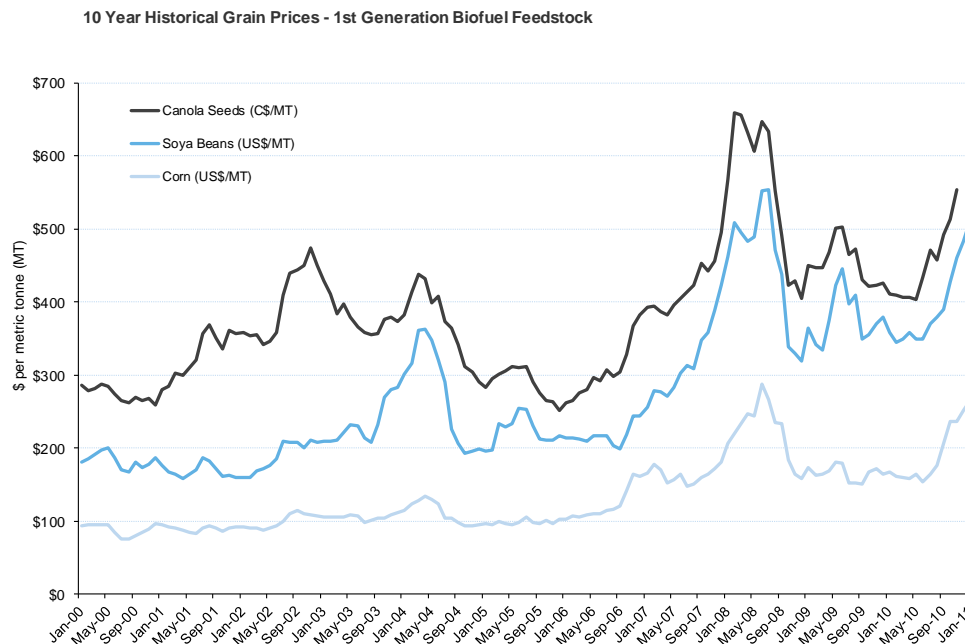


Figure 14. Trends in Feedstock Prices

Sources: Canola Council of Canada, International Monetary Fund, AltaCorp Capital Inc.



In Figures 15, 16 and 17, we compare the cost of feedstock (shown in \$/tonne) used in our model and its impact on the overall cost (shown on a \$/boe-energy and BTU basis). The economic feasibility of these and other biofuels is highly dependent on the revenue generated from the sale of by-products resulting from the seed crushing process (in these cases soya and corn meal). Feedstock price alone is not the only driver of biofuel cost; there is the benefit received from the by-products which is turned into meal for animal feed.

Biofuels are highly dependent on the revenue generated from the sale of by-products.



Figure 15. Feedstock Impact on Total Energy Cost

Sources: Please refer to the Sources section of this report.



In Figures 16 and 17, we illustrate the sensitivities of two biodiesel alternatives: canola and soya. Although the graphs appear similar in shape, it is interesting to note that the underlying economics are different. In the case of canola, roughly twice the amount of oil is extracted per tonne of feedstock, when compared to soya beans. But this is offset by a reduced amount of canola meal to generate additional revenue. Future fluctuations in oil-meal differentials could cause these graphs to be markedly different.

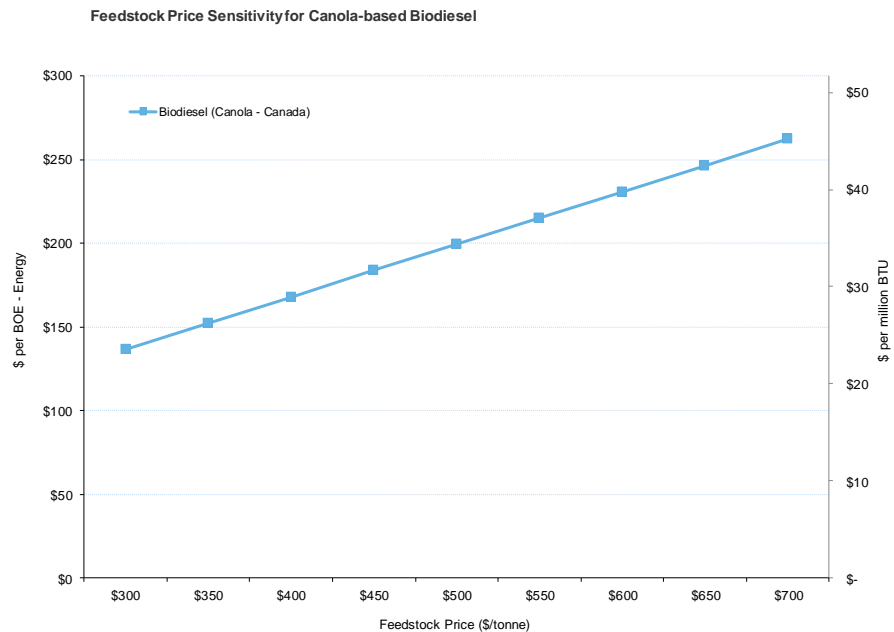


Figure 16. Feedstock Impact on Total Energy Cost

Sources: Please refer to the Sources section of this report.

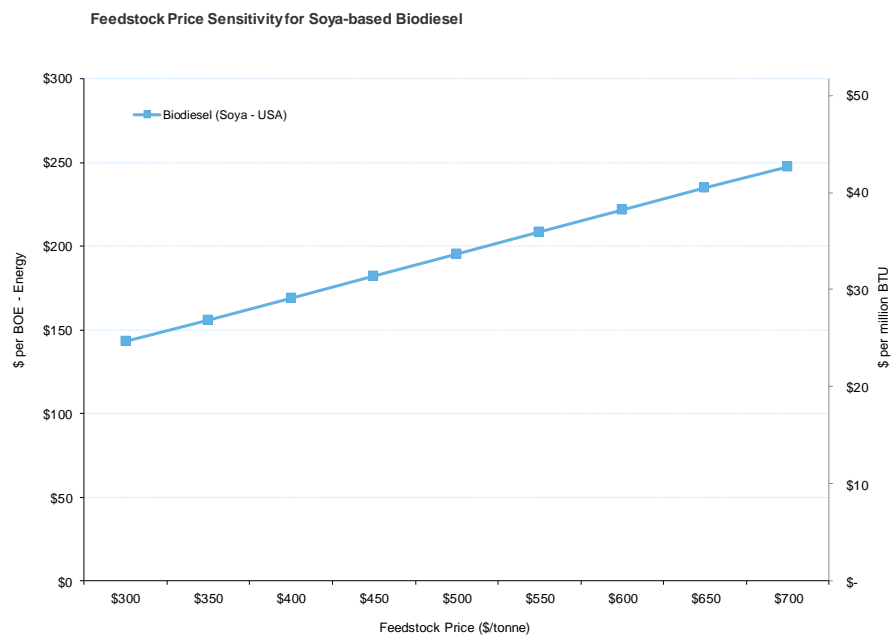


Figure 17. Feedstock Impact on Total Energy Cost

Sources: Please refer to the Sources section of this report.



Heat Rate

Heat rate is the measure of efficiency in hydrocarbon-based electrical generation plants, that is, the efficiency of converting the fuel (in the form of heat) into electricity. The units are BTU per kWh and the lower the number, the more efficient the plant (less heat required for every kWh produced). A heat rate of 3,412 BTU/kWh represents the theoretical no energy-loss conversion of heat into electricity and is therefore the limit of any power plant's conversion efficiency. In Figure 18, we display the heat rate sensitivity for three different types of coal plants and two types of natural gas plants. A majority of coal plants run at heat rates ranging from 9,000 to 12,000 BTU per kWh.

Fuel costs make up a large component of overall costs for natural gas plants.

In Figure 18, we can see that the cost curves of natural gas plants vary more significantly with heat rate than those of coal, resulting in steeper curves. This result is driven by the fact that fuel costs make up a large component of overall costs for natural gas plants. We show the scale starting at the theoretical 3,412 BTU/kWh but stop the lines at the limit of current or possible heat rates. For instance, we stop the line for coal plants at 6,000 BTU/kWh as there are technologies being developed that could in theory push numbers close to that level.

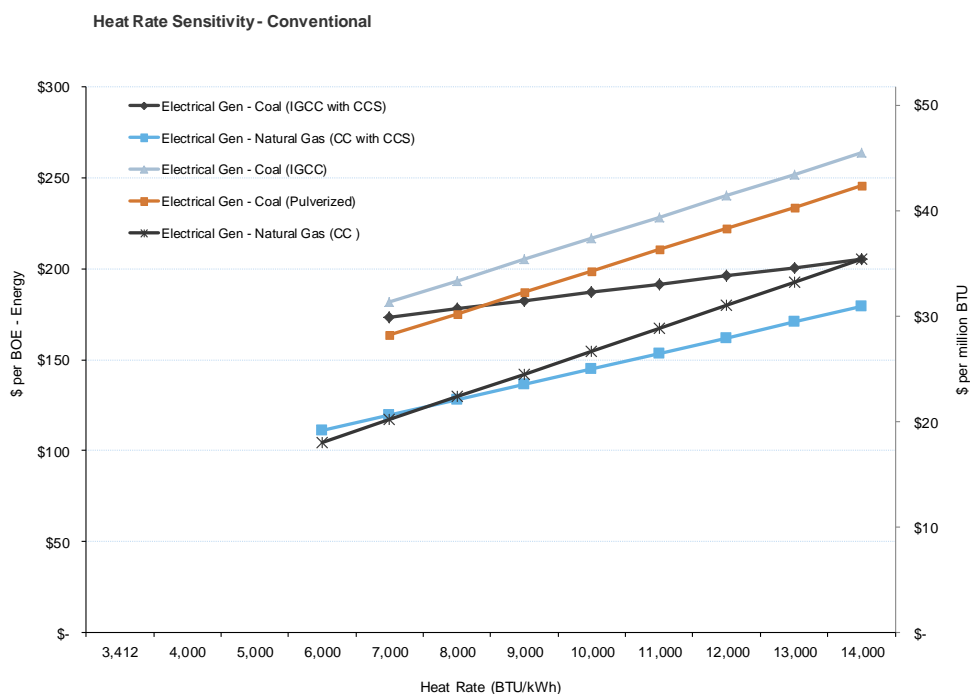


Figure 18. Sensitivity of Operating Costs to Heat Rate

Sources: Please refer to the Sources section of this report.

Note: CC – Combined Cycle; CCS – Carbon Capture and Sequestration; IGCC – Integrated Gasification Combined Cycle

Based on information from the EIA, the following heat rates were used for our typical projects:

- Coal (Pulverized Coal) – 8,800 BTU/kWh
- Coal (IGCC) – 8,700 BTU/kWh
- Coal (IGCC w/ CCS) – 10,700 BTU/kWh
- Natural Gas (Combined Cycle) – 6,430 BTU/kWh
- Natural Gas (Combined Cycle w/ CCS) – 7,525 BTU/kWh



Fuel Prices: Coal, Natural Gas and Uranium

For conventional coal and natural gas-based electricity projects, the price of coal and natural gas has similar effects to the price of feedstock for biofuels. Therefore, a fuel (like coal) that is abundant and can be purchased cheaply has benefits for electricity consumers. In Figures 19 and 20, we examine the sensitivity of the total cost of energy to fluctuations in fuel prices.

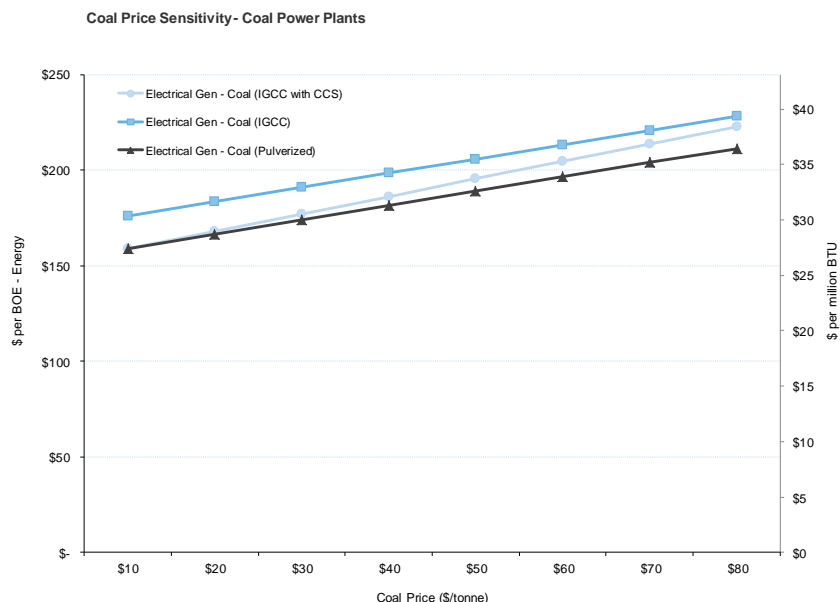


Figure 19. Sensitivity of Energy Costs to Coal Prices

Sources: Please refer to the Sources section of this report.

Note: CC – Combined Cycle; CCS – Carbon Capture and Sequestration; IGCC – Integrated Gasification Combined Cycle

Coal and natural gas are abundant fuel sources which provide low-priced electricity for consumers.

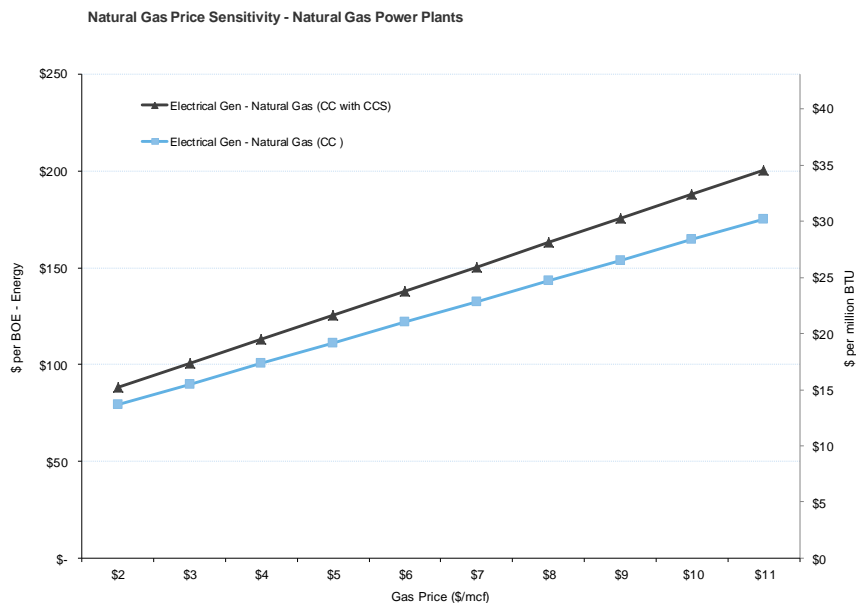


Figure 20. Sensitivity of Energy Costs to Natural Gas Prices

Sources: Please refer to the Sources section of this report.

Note: CC – Combined Cycle; CCS – Carbon Capture and Sequestration; IGCC – Integrated Gasification Combined Cycle



In the case of nuclear, we can see that the total cost of energy is relatively insensitive to fluctuation in the price of the primary fuel.



Figure 21. Sensitivity of Energy Costs to Uranium (plus Enrichment) Prices
Sources: Please refer to the Sources section of this report.



The Cost of CO₂

There will be variability in the amount of CO₂ produced for various projects and assumed price of CO₂ credits. For our analysis of the typical project, we assumed \$50/tonne for CO₂ credits, which is higher than the \$20 - \$25/tonne in historical trading shown in Figure 22.

CO₂ credits are currently trading in the \$20 - \$25 per tonne range.

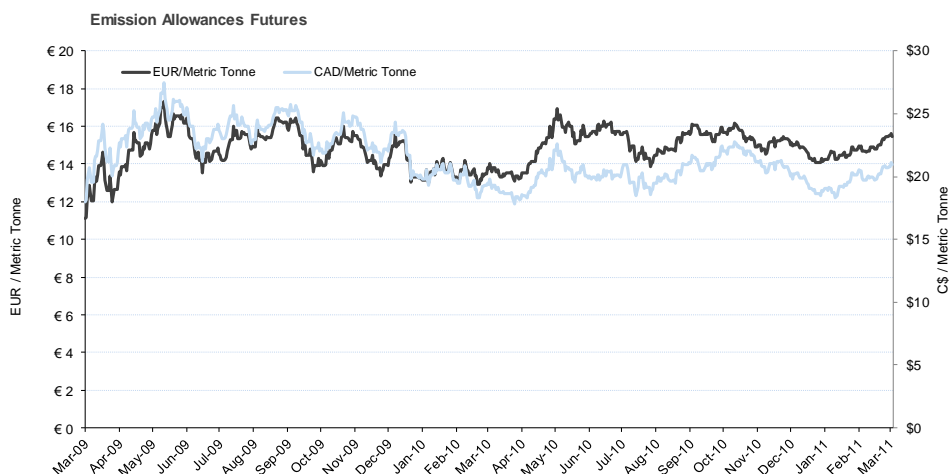


Figure 22. CO₂ Prices

Sources: Bloomberg, AltaCorp Capital Inc.

When we apply the cost of credits to the CO₂ generated from the various projects we get dramatically different curves with the changing price of the credits. Figure 23 shows the results with the value of credits from \$0 to \$150/tonne and, as might be expected, coal shows the steepest slope while solar PV and wind power are essentially flat.

Coal shows the steepest slope while solar PV and wind power are essentially flat.

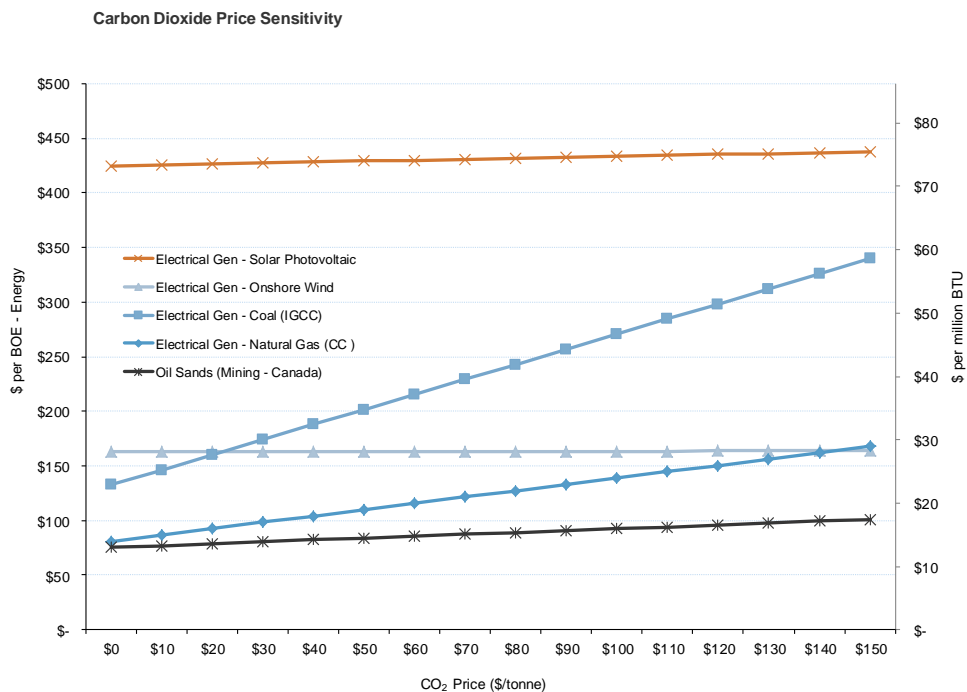


Figure 23. Sensitivity of Energy Costs to CO₂

Sources: Please refer to the Sources section of this report.



Taking into Account Range of Costs – the Range of Results

As pointed out at the beginning of this section, there are many factors that will cause the costs of the energy projects to vary significantly from our “typical” projects (which were done under a specific set of assumptions). There will be a wide range of total costs per boe-energy when various projects are evaluated; some will have lower costs than our typical project and some will have higher costs. This is a result of different quality of resources and a range of operating and capital costs. The major cost drivers, as discussed on pages 23 through 31, include fuel prices, feedstock costs, carbon credit pricing, capacity factors and heat rates.

In the next two figures, we show the possible total cost ranges using a “barbell chart”. The top of each barbell shows the upper end of possible total costs of energy for each project type; the bottom of each barbell shows the lower end of possible costs. The dash on the bar bell represents our typical project. It can be seen that some projects such as wind and solar have a wide range of outcomes where capacity factor plays a very large role. The biofuels also have a wide range of possible costs, largely driven by feedstock prices. In the first of these two charts, Figure 24, we use the corporate cost of capital of 10%.

Cost Ranges for Energy Alternatives (Using the Corporate Cost of Capital of 10%)

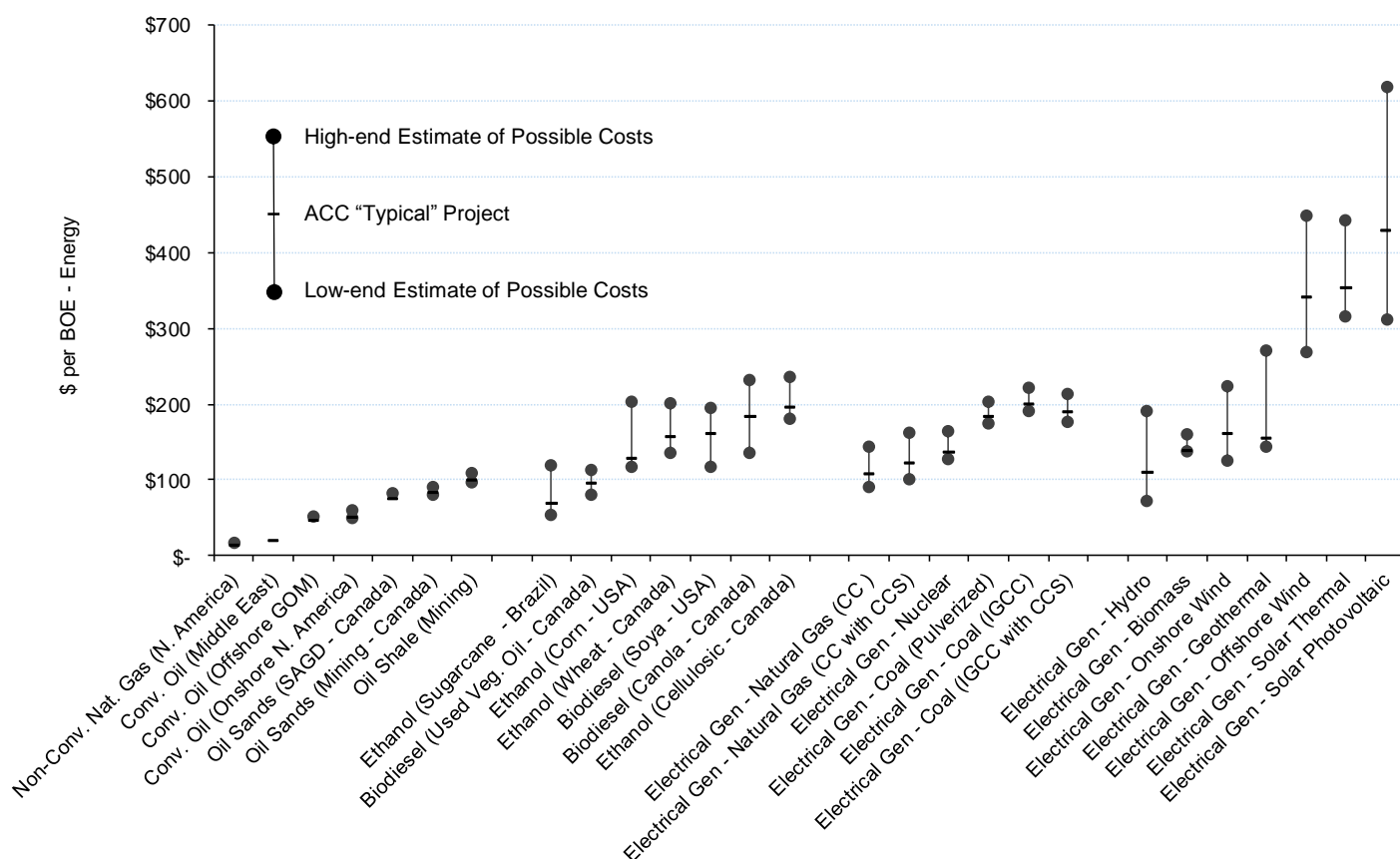


Figure 24. Cost Ranges for Energy Alternatives (using a Corporate Cost of Capital of 10%)

Sources: Please refer to the Sources section of this report.

Note: CC – Combined Cycle; CCS – Carbon Capture and Sequestration; IGCC – Integrated Gasification Combined Cycle



Figure 25 shows the same ranges of total costs but uses the social cost of capital of 3.5%. Although we have attempted to take into account the most significant sources of conventional and alternative forms of energy and their related costs, we may have excluded a particular technology or a material cost consideration known to our readers. We encourage anyone with detailed cost and energy output data on the technologies we have assessed – or any other technology – to contact us and we will gladly integrate your information in our model and share the results.

Cost Ranges for Energy Alternatives (Using the Social Cost of Capital of 3.5%)

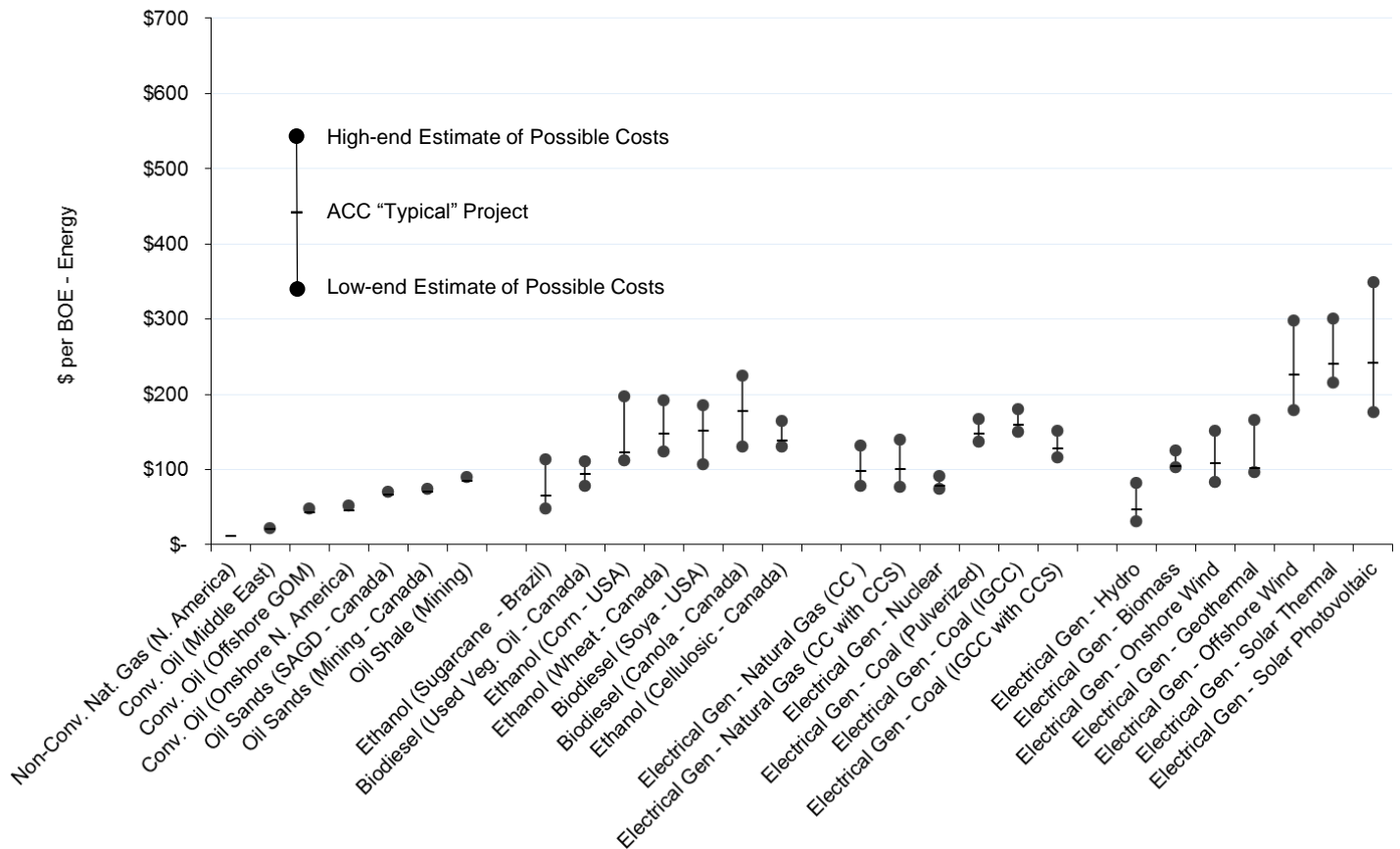


Figure 25. Cost Ranges for Energy Alternatives (using a Social Cost of Capital of 3.5%)

Sources: Please refer to the Sources section of this report.

Note: CC – Combined Cycle; CCS – Carbon Capture and Sequestration; IGCC – Integrated Gasification Combined Cycle



The higher oil prices are, the more expensive alternatives become.

What Happens If Oil Prices Continue to Rise?

It is very important to note that in all of these ranges we do not include what might happen to input costs of the various projects if oil prices rise beyond current levels. We previously indicated that our total cost analysis showed alternatives become economic when oil prices rose to a certain level. For instance, soya-based biodiesel in our typical cost scenario becomes economic when oil reaches approximately \$160/boe-energy at the corporate cost of capital. However, if oil prices were that high, then the fuel required to run the farm machinery to plant and harvest the soya would also be more expensive, which in turn would raise the cost per BTU of energy received from the biodiesel. The higher the oil prices, the more expensive alternatives become, because oil is an input cost for all forms of energy, including oil itself.



Economic Reality – Subsidies Required

From the preceding analysis, it is clear that many renewables are more expensive than conventional sources of energy. Given that individuals will, in almost all cases, opt for the lowest-cost good or service, the more-expensive alternatives will not be the choice of the average consumer, unless their price can be artificially reduced. From the corporate point of view, a company will not invest its capital in lower-return (or economically unviable) projects such as wind or solar unless there is incentive to do so through some sort of subsidy. Although most of the initiatives for alternative energy development come from governments, it will always be the consumer that ultimately pays the price, either directly or indirectly.

With subsidies, it is the consumer that pays, whether through taxes, utility costs or prices at the pump.

In our comparison of energy costs above, we evaluated all the various alternatives without the effect of subsidies in order to understand the true costs of producing the energy. The fact is that subsidies in their many forms are prevalent in energy markets around the world and, to be fair, there are also subsidies for hydrocarbon development. Therefore, a review of subsidies is warranted in any discussion about energy development, and we have identified that subsidies tend to fall into one of four different categories:

- 1) Direct Transfers
- 2) Preferential Tax Treatment
- 3) Feed-In Tariffs
- 4) Government Policies and Regulations

Direct Transfers

Direct transfers usually take the form of rebates, grants or low-interest loans given to energy producers, consumers or intermediaries for the purpose of developing specific energy markets. A table that summarizes various U.S. electricity rebates is shown in Figure 26 and examples of some energy resources include:

- **Solar** – The California Solar Initiative provides rebates to consumers who install solar panels in their homes or businesses.
- **Renewables / Energy Efficiencies** – Programs such as the USDA Rural Energy for America Program Grants. These will cover up to 25% of costs associated with renewable energy or energy efficiency improvement projects.
- **Biofuels** – Governments around the world offer countless production subsidies, crop insurance premium subsidies, loan guarantees and price support payments that go towards farmers, some of whose crops are used to create ethanol and biodiesel.
- **Carbon Capture and Storage** – The Canadian and Alberta governments plan to support three large-scale CCS projects: \$865 million for a Shell Quest CCS demonstration project; \$779 million for the TransAlta Keephills CCS project; and \$63 million for the Alberta Carbon Trunk Line project.

Direct transfers usually take the form of rebates, grants or low-interest loans given to energy producers.

U.S. Electricity Subsidies

Fuel / End-Use	FY 2007 Net Generation (billion KWh)	Alternative Measures of Subsidy and Support	
		FY 2007 Subsidy and Support (\$mm)	Subsidy and Support per Unit of Production (\$/MWh)
Coal	1,946	854	0.44
Refined Coal	72	2,156	29.81
Natural Gas and Petroleum Liquids	919	227	0.25
Nuclear	794	1,267	1.59
Biomass (and biofuels)	40	36	0.89
Geothermal	15	14	0.92
Hydroelectric	258	174	0.67
Solar	1	14	24.34
Wind	31	724	23.37
Landfill Gas	6	8	1.37
Municipal Solid Waste	9	1	0.13
Unallocated Renewables	NM	37	NM
Renewables (subtotal)	360	1,008	2.80
Transmission and Distribution	NM	1,235	NM
Total	4,091	6,747	1.65

Figure 26. U.S. Electricity Rebates

Source: EIA

Notes: Unallocated renewables include projects funded under Clean Renewable Energy Bonds and the Renewable Energy Production Incentive. NM=Not meaningful. Total may not equal sum of components due to independent rounding.



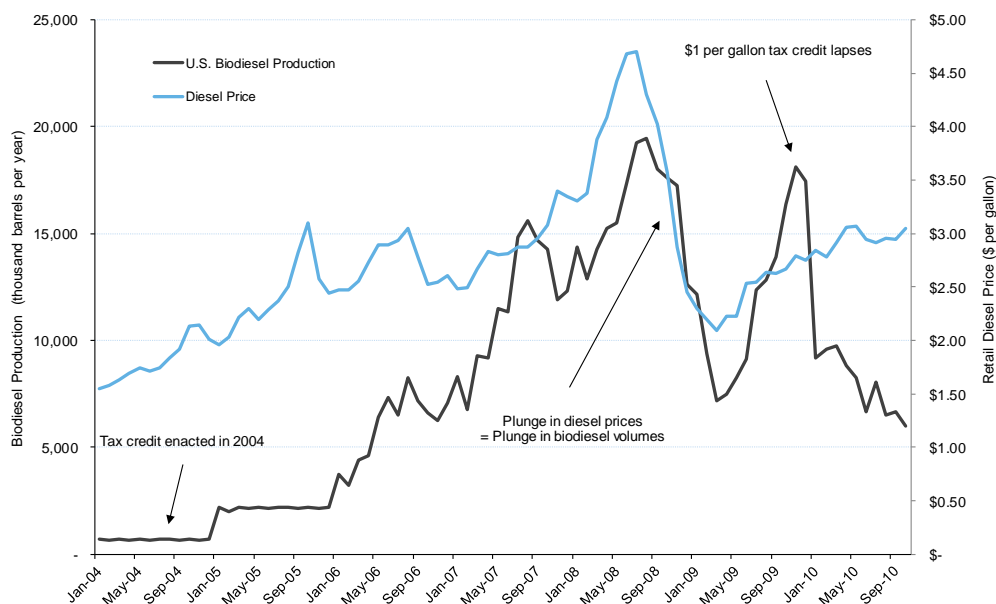
Preferential Tax Treatment

Preferential tax treatments include tax credits, exemptions or accelerated depreciation allowances that are provided to energy producers to provide incentives for continued development of specific energy markets. Some examples include:

- **Solar** – Under the U.S. Energy Policy Act of 2005, residential purchases of solar PV systems can take 30% of the cost of the system off their taxes.
- **Wind** – The Modified Accelerated Capital-Recovery system of taxation in the U.S. has special allowances for the accelerated depreciation of certain technologies such as large wind projects.
- **Clean Coal** – In an effort to develop clean coal technologies including Integrated Gasification Combined Cycle (IGCC) projects, the U.S. government has instituted tax credits for these technologies.
- **Ethanol** – The U.S. Volumetric Ethanol Excise Tax Credit (VEETC) of \$0.45 per gallon is paid to refiners to blend ethanol into gasoline and the Small Producers Tax Credit of \$0.10 per gallon is provided to companies producing less than 60 million gallons per year.
- **Biodiesel** – The U.S. government enacted a tax credit for biodiesel in 2004, which led to an increase in the production of the fuel, but the credit lapsed at the end of 2009 and volumes dropped dramatically as show in Figure 27. In December of 2010 the U.S. House of Representatives voted to reinstate the incentive, which will most likely lead to an increase in volumes during 2011.
- **Oil Sands** – The Canadian government currently has a provision in the tax act that allows certain oil sands capital expenditures to be written off more quickly using an accelerated capital cost allowance which has the effect of reducing near term taxes payable. This provision is being phased out over the next three years.

Preferential tax treatments include tax credits, exemptions or accelerated depreciation allowances.

U.S. Biodiesel Production History - Links to Prices and Subsidies



The tax credit lapsed at the end of 2009 and biodiesel volumes dropped dramatically.

Figure 27. Biodiesel Production Reliant on High Diesel Prices and Subsidies
Sources: EIA, Bloomberg, National Biodiesel Board, AltaCorp Capital Inc.



Feed-In Tariffs

A feed-in tariff is a premium price that utilities are legally obligated to pay for certain types of energy.

An alternative to direct transfers and tax incentives, which have a negative impact on government balance sheets, is the application of feed-in tariffs. A feed-in tariff is a premium price, set by government legislation, that utilities are legally obligated to pay for certain types of energy (in addition to providing guaranteed grid access). The end result of feed-in tariffs is that the incremental cost of energy due to premium prices and new grid connections is passed onto all energy rate payers. Therefore, the financial burden migrates from “Joe the Taxpayer” to “Joe the Ratepayer.” Some examples of feed-in tariffs include:

- **Solar** – In Ontario, the renewable energy feed-in tariff program provides guaranteed prices under long-term contracts for energy generated from renewable sources. In the case of solar PV projects, this premium pricing can be as high as \$802/MWh whereas average monthly prices for consumers run at a fraction of that, in the range of \$30/MWh to \$60/MWh.
- **Wind** – In Denmark, the country’s large penetration of wind power has been driven, in part, by significant feed-in tariffs for wind power in the form of Public Service Obligations that appear on consumers’ electricity bills. This tends to stabilize the revenue received by wind turbine operators in the range of €67 to €81/MWh, which is significantly more than spot market prices in the range of €33 to €57/MWh.

Government Policies, Regulations and Royalties

In some cases, subsidies can take the form of government mandates or regulations designed to encourage the use of specific types of energies.

Mandatory blended percentages of ethanol / biodiesel are designed to encourage consumption of biofuels.

- **Biofuels** – Around the world, mandatory blended percentages of ethanol/biodiesel are designed to encourage consumption of biofuels. In the U.S., some ethanol producers view these regulations as critical to continued growth in biofuel production/consumption, referring to current standards as a “Blend Wall” (virtual limit to biofuel production that could not be surpassed without further government intervention).
- **Renewables** – In the EU’s directive on renewable energy, it sets a target of a 20% share of energy from renewable sources by 2020.
- **Oil Sands** – To encourage development of the oil sands, a more-expensive hydrocarbon resource than conventional oil, the Alberta government initially had in place a very low 1% royalty on gross revenues before the return of invested capital and 25% of net revenue after return of capital. This was revised to a sliding scale scheme based on oil prices, which came into effect in 2009, where the royalty now varies from 1 to 9% before return of capital and from 25% to 40% thereafter.

Tougher Decisions in Leaner Economics Times?

The cost of subsidizing the various segments of the energy sector can take a huge toll on either government balance sheets or individuals through higher energy costs. No matter what form of subsidy, it is always the consumer that will pay, whether through higher taxes, higher utility costs or higher prices at the pump. During tougher economic times there has been a shift away from many forms of subsidies and in some extreme cases, retroactive reversals. Some prominent examples include:

During tougher economic times there has been a shift away from many forms of subsidies.

- In 2000, the Renewable Energy Sources Act (EEG) introduced in Germany had feed-in tariffs over €500/MWh paid for several years. In 2010, the government announced significant reductions in these tariffs on a go-forward basis.
- The Spanish government has announced retroactive cuts of up to 45% in the feed-in tariffs for solar PV projects and has also announced cuts to wind power subsidies of 35% by 2012.
- The Ontario Power Authority is proposing to cut the rate paid to ground-mounted solar systems by 27% to \$585/MWh for new contracts.



In many cases alternatives are not sustainable without government support.

Maybe alternatives are a type of “Unobtainium” in practical and economic terms.

It would be better for society if fewer jobs were created for every dollar invested.

Should the government subsidize the less efficient company to create more jobs?

Sustainable Energy – Under What Economic Conditions?

Alternative energy is often referred to as sustainable energy, which refers to the fact that we can continuously grow biofuel crops, there are unlimited amounts of sun for solar power and we won't run out of wind for wind turbines. Ironically, it has been shown in many cases that alternatives are not sustainable without government support. How truly sustainable are alternatives if they cannot survive without government subsidies? How can governments sustain subsidies in the face of increasing indebtedness? Maybe alternatives are a type of “Unobtainium” in practical and economic terms.

A Comment on “Green Jobs”

This phrase, which refers to new jobs created by the development of alternatives, is usually used in a positive light, but given the subsidies required for the development of renewable technologies, these “green jobs” are really based on businesses that might not survive without government support. Although the development of renewable industries is necessary, it needs to be done in a truly sustainable way and create jobs that will be there for the long term, not just for the duration of a government subsidy. Job creation only helps society if the jobs provide a net economic benefit.

It has been pointed out that renewable energy projects, like solar and wind, create more jobs for every dollar invested than hydrocarbon projects. This is not surprising; from our analysis of the economics of these projects, it would actually be expected. This is because for every BTU of solar and wind energy produced, significantly more money needs to be invested – including labour costs. Although more jobs might be created with renewable energy for every dollar invested, it would in fact be better if *fewer* jobs were produced for every dollar invested. The logic here is: if total costs (including labour) were reduced on a BTU basis then the projects would be more economically-viable and the businesses behind them might become truly sustainable.

To clarify this somewhat counter-intuitive argument, consider two companies competing in the same business sector and producing the same product (BTUs in this case, but could be any product). One employs 10 people and the other five, but they both produce the same amount of product, have the same financial resources and pay their employees similarly. With everything else being equal, which one will be more successful, grow more rapidly and continue to add jobs? Obviously the lower-cost company, the one with fewer employees per product produced; the BTUs would be produced for lower cost. Should the government subsidize the less efficient company to create more jobs? That seems doubtful.

Some might point out that oil sands projects and certain other hydrocarbon operations do receive subsidies too, but these rarely involve cash payments from consumers or governments. It is usually in the form of lower royalties over a limited period and there is no direct movement of cash out of government coffers or consumers wallets.



Tragedy of the Hydrocarbons

In this report, we introduce the concept of the Tragedy of the Hydrocarbons, which is a dilemma related to Garrett Hardin's *The Tragedy of the Commons*. In the Tragedy of the Hydrocarbons, as we describe it, individuals will choose to consume hydrocarbons because they are the most economic and practical form of energy available. The tragedy lies with the reality that it is not in the best long-term interest of the individual, society, mankind or the planet for this to continue. This is because hydrocarbon resources are limited; as we continue to consume them, we continue to "empty the tank". We could have a relatively seamless transition to alternatives but, because hydrocarbons continue to be the cheapest form of energy, we will use these until forced to make a transition. A transition forced upon us will not be simple or problem-free.

Garrett Hardin's *Tragedy of the Commons* is well described on Wikipedia:

Central to Hardin's article is an example (first sketched in an 1833 pamphlet by W. F. Lloyd) of a hypothetical and simplified situation based on medieval land tenure in Europe, of herders sharing a common parcel of land, on which they are each entitled to let their cows graze. In Hardin's example, it is in each herder's interest to put the next (and succeeding) cows he acquires onto the land, even if the quality of the common is temporarily or permanently damaged for all as a result, through over grazing. The herder receives all of the benefits from an additional cow, while the damage to the common is shared by the entire group. If all herders make this individually rational economic decision, the common will be depleted or even destroyed to the detriment of all.

The Tragedy of the Hydrocarbons is similar in many ways to the *Tragedy of the Commons*, including:

- The "group" in this tragedy is the billions of humans on the planet and the "commons" are the hydrocarbons that are available to most of mankind. We can equate the grasses on Hardin's commons to hydrocarbons; both are a source of energy and a shared resource. The grasses on Hardin's commons are the source of energy for the cows (and ultimately the herders); in the Tragedy of the Hydrocarbons the hydrocarbons are the source of energy for the global society.
- Hydrocarbons provide one of the most economic forms of energy available, and therefore, will be consumed preferentially before more expensive alternative forms of energy.
- The consumption of hydrocarbons can increase the quality of life for an individual through low-cost transportation, food, goods and services. The individual receives the full benefit of the use of energy, but shares damage to the commons with billions of others. The damage to the commons in this tragedy is the reduction of global oil reserves. That is, increasing consumption will reduce the amount available for others, including future generations.
- Conversely, consider an individual who chooses to use a more-expensive and completely-renewable form of energy, say wind and solar. Although commendable, this person bears the full burden of higher energy costs and practical limitations of these forms of energy. The benefits this individual provides to society – less pollution and the preservation of resources – are shared with billions of other individuals. The net result is the individual pays a large cost for a wise choice, but gains essentially no personal benefit (when spread over billions of others) from his/her efforts. Think of the resentment and frustration this wise person might feel when left on the side of the road with depleted batteries in their expensive solar-powered car while multiple gas guzzling SUVs drive past.
- This is the tragedy: individuals will make the choice to use the cheaper non-renewable hydrocarbons because it is best for them at this moment. It would be better for society if this was not the case, but this is how individuals will act under the circumstances.
- To reiterate what was stated earlier, mankind will have to dramatically change its collective thinking to avoid this tragedy and adopt the use of alternatives before we are forced to change under more challenging circumstances.

Society will use hydrocarbons until we are forced to make a transition.

The individual receives the full benefit of the use of hydrocarbons, but shares damage to the "commons" with billions of others.

Mankind will have to dramatically change its collective thinking to avoid this tragedy.



Practical Reality – An Integrated System View

Integrated means taking into account all significant practical factors that enter into the choice of an energy source.

Society will need access to all forms of energy as global demand continues to grow.

Wind power is a highly variable and unpredictable source of energy.

Most people have come to expect low-variability and high-certainty energy.

In addition to understanding the economic realities, we believe that to objectively compare and contrast alternate energy sources, an integrated approach to comparing the costs and benefits of each is required, rather than examining one or two criteria in isolation. In this context, integrated means taking into account all significant practical factors that enter into the choice of an energy source. These include variability, certainty, versatility, storability, transmission system integration, environmental, and socio-economic factors.

All too often, the notion of a “balanced” approach to comparing energy sources is to ignore economic costs and practical realities, and consider only CO₂ emissions, which are often used as a form of trump card. While we believe that evaluating pollution is necessary, it should not be done in isolation nor should we focus exclusively on CO₂ emissions. What about water use, as an example? Biofuels actually use far more water per BTU produced than oil sands projects. Our goal in using a broader perspective is to illustrate that there is not a clear “winner” – nor should there be – in the energy debate and that every conventional or renewable form of energy brings with it a number of advantages and disadvantages. Society will need access to all forms of energy as global demand continues to grow.

Resource Variability and Certainty

Variability is a measure of extent to which the availability of the primary resource (be it oil, gas, wind, sunlight or moving water) varies over time, which can negatively impact the reliable output of an energy system. Certainty is a measure of the predictability of variations (magnitude and timing) of the primary resource. In order to forecast the energy supply and plan for the safe and reliable operation of electrical grids and other critical energy systems, a higher level of certainty for the underlying energy source is desirable.

In most of the developed world, people have come to expect and demand low-variability and high-certainty energy but many alternatives do not provide either. We discuss a few renewables from this perspective:

- **Wind** – A wind turbine generates power in direct correlation to the amount of wind at the site which can fluctuate from one minute to the next – at some times producing at its maximum potential and at other points, no electricity at all. This results in a highly variable source of energy, which also has very little predictability. Despite the development of advanced wind modelling techniques, significant differences between forecasts and actual production levels can occur. For example, on February 26, 2008 in Texas, wind generation of 2,000 MW dropped to 360 MW, an event that occurred hours sooner and at a rate faster than forecasted. This unexpected drop resulted in emergency demand-response measures, forcing several industrial and commercial customers to curtail their electricity consumption.
- **Solar** – Solar panels’ power generation will vary depending on cloud cover during the day. There is greater predictability when solar will produce no electricity (at night) and this can be counted on for electrical grid management. Similar to wind power, the amount of energy collected from the sun cannot be controlled by plant operators and solar energy is not demand responsive. If there are peaks or spikes in demand, the solar power cannot be relied upon requiring other forms of power generation to step in.
- **Hydro** – Water flow from rivers can vary on an hourly basis, but the ability of dams to “store” water energy helps smooth the availability of hydro power. Therefore, the resulting variability of the underlying resource tends only to be seasonal in nature. Certainty is very high with hydro and facility operators have the ability to control this, unlike solar or wind. Even in “dry” years, the lack of water can be forecast with relative accuracy, allowing grid operators to adjust the energy supply mix.
- **Biofuels** – With improved farming techniques, many countries have been able to produce consistent levels of biofuels and in many instances increase production due to increased crop yields. However, unlike conventional oil projects, production levels remain sensitive to variations in the weather and



Oil sands have shown themselves to be vulnerable to unscheduled maintenance and shut-downs due to fire.

its effect on crops. The variability in the production of biofuels is tied to the seasons for growing and harvesting the underlying feedstock, such as corn and sugarcane, and this variability is highly predictable. The development of cellulosic technologies will enhance the diversity of feedstock to produce biofuels and will help to smooth the availability of biofuel inputs. Biofuels are storable which increases their certainty.

- **Unconventional Oil** – The oil sands have low variability with most projects having the ability to maintain or increase production levels over their very long lifetimes. However, these facilities have shown themselves to be vulnerable to unscheduled maintenance and shut-downs due to fire or other emergencies. Like biofuels, oil is storable so this makes the resource more certain.

Resource Versatility / Useful By-Products

Versatility and useful by-products is an assessment of the resource to satisfy demands of different energy uses and other applications.

- **Natural Gas** – In addition to heating and electrical generation purposes, natural gas is used for making plastics (polyethylene). For transportation purposes, it is a source of propane and can be compressed (CNG) or converted to liquids in a GTL process and used in conventional reciprocating engines.
- **Oil** – Oil generated from the conventional and unconventional sources, is used for more than just a combustible fuel source, but also serves as the primary ingredient in plastics, fabrics and other materials. As a comparison, alternatives often replace only the combustible component of oil, but may not provide any useful by-products.
- **Coal** – Coal is used as a thermal energy source, for electricity generation, but is also used to create coke, a primary input to manufacture steel. Coal has significant limitations as a transportation fuel.
- **Biofuels** – Ethanol and biodiesel have the potential to be used as the primary ingredient in fuel, plastics, fabrics and other materials. However, this versatility is dependent on the larger-scale development of bio-refineries to create end-use products from the feedstock.
- **Solar PV and Wind Power** – These energy sources can only be used to generate electricity; no other side products are created.

Solar and Wind Power can only be used for electricity; no other side products are created.

Storability and Transport

Storability is a measure of the ability of the resource to be stored for a considerable period of time without loss or degradation in its usability. The ability to store energy is particularly useful when there are fluctuations in energy consumption.

- **Oil** – Crude oil can be stored for long periods of time without loss or degradation in its usability. One of the greatest benefits of oil is that it is relatively stable and can be transported by pipeline, ship, truck and rail. As an indication on how transportable it is, it could even be carried in a pail, if required.
- **Coal** – Coal is probably the most storable form of energy, but not as easy to transport as oil and biofuels. For this reason, coal electrical plants are usually built where the coal exists and the power is then transmitted to the end-user.
- **Biofuels** – Similar to crude oil, biofuels have a good measure of storability. However, potential corrosion challenges and the fact that ethanol absorbs water mean that biofuels tend to be shipped by truck, rail and ship as opposed to pipelines. This has cost implications for countries that might otherwise have the potential to be biofuel exporters.
- **Natural Gas** – Natural gas can be stored in underground facilities such as depleted oil and gas reservoirs, aquifers or salt caverns. The benefit of these storage facilities is that they improve the security of gas supply and increase price stability when there are seasonal fluctuations in demand.

Coal is the most storable form of energy, but not as easy to transport.



Electricity needs to be used the moment it is generated.

This is a much more limiting form of storage than for oil or biofuel as it depends on geology of the area, whereas oil storage tanks can be built almost anywhere.

- **Electricity (Conventional & Renewable)** – One of the greatest challenges faced by grid operators and electricity producers is the lack of practical and widely available utility-scale solutions to store electricity (other than the “stored” water behind a hydro dam). When electricity is produced it needs to be used the moment it is generated. Significant progress and cost reductions in electricity storage technologies could be the solution to address the intermittent nature of many alternative electricity resources. These developments would also reduce the need to build excess capacity in electrical grids to ensure adequate supply during spikes or peaks in consumption.

Electrical Transmission and Infrastructure

Electrical transmission and infrastructure is a consideration of the construction, installation and maintenance costs for expanding and adjusting an energy system’s infrastructure in order to collect and distribute energy from the primary resource. Transmission from where the electricity is generated to where it is used is a cost issue due to the capital required to build transmission lines and the power losses incurred during delivery. Many renewable energy resources, including wind and solar power, will face geographic restrictions as to where they can be built and operated in the most economical manner. The resulting energy will then need to be transported to large population centres. This point can be illustrated graphically by examining the availability of several resources in the United States as shown in Figures 28, 29 and 30.

The S.W. United States is best suited for solar power.

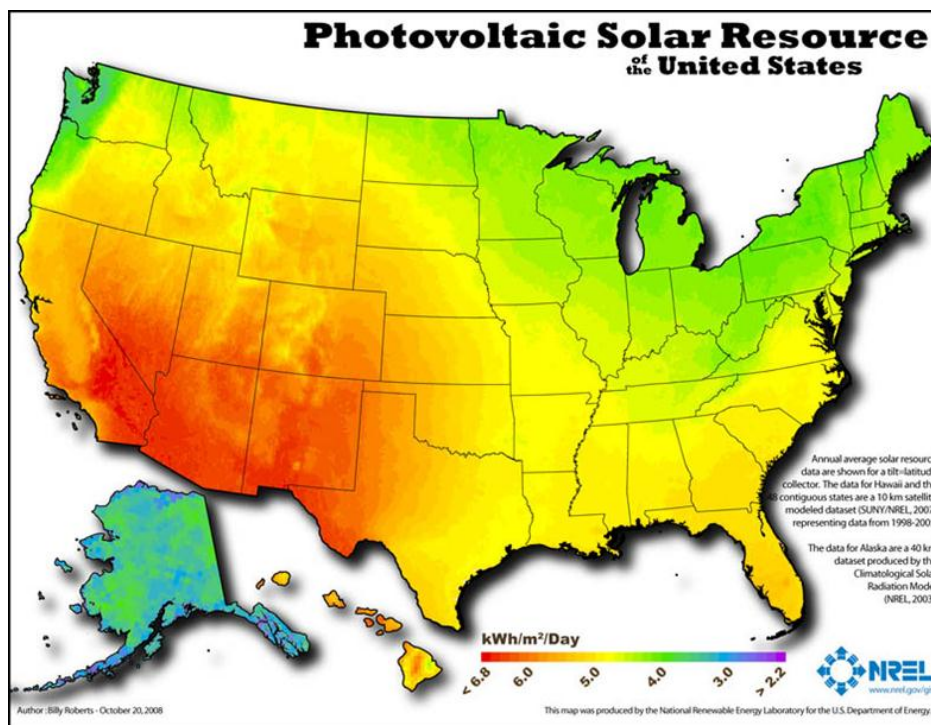


Figure 28. U.S. Solar PV Resource

Sources: National Renewable Energy Laboratory (NREL)



The best geothermal areas of the United States are located in the West.

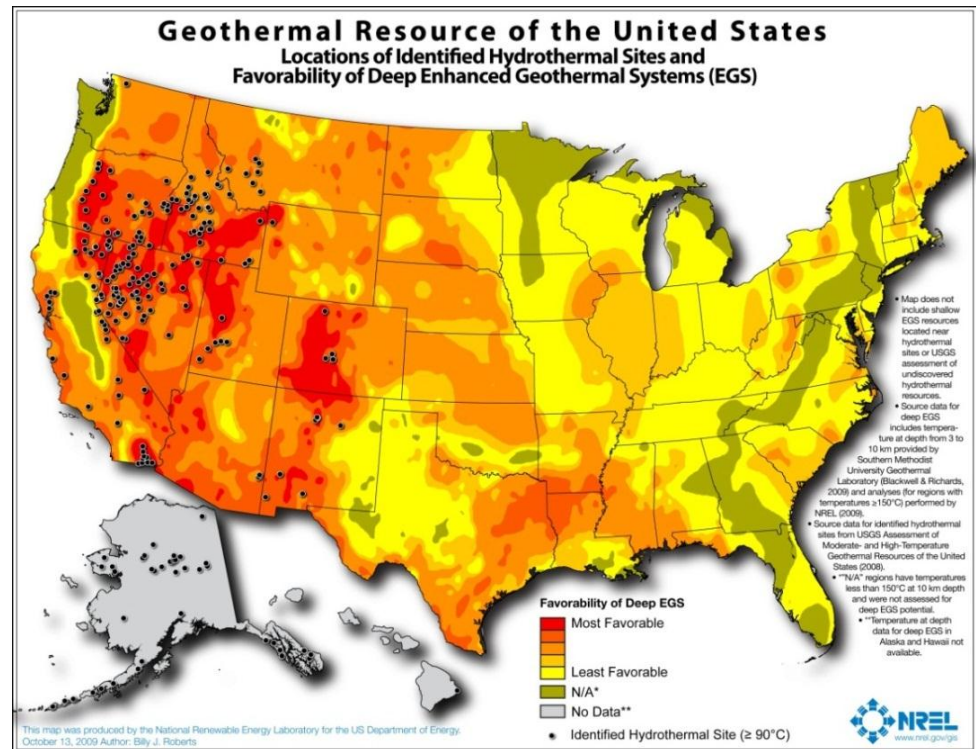


Figure 29. U.S. Geothermal Resource

Sources: NREL

The central United States has the most potential for onshore wind power.

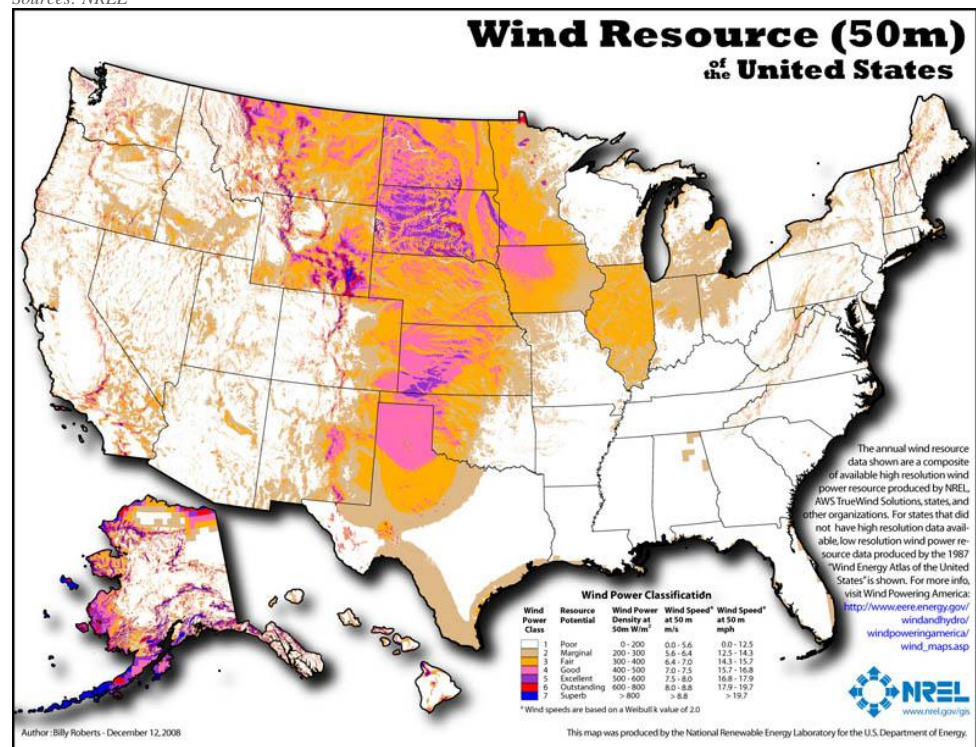


Figure 30. U.S. Wind Resource

Sources: NREL



Batteries – the “Gas Tank” for Electrical Transportation

There are significant limitations to the use of electricity for the purpose of transportation.

Storage of electricity is problematic for transportation purposes when compared with oil-based fuels such as diesel and gasoline because it is not easy to store. Batteries are required, which are heavy, expensive, consume non-renewable resources, and require disposal at the end of their life, take a long time to recharge and have limited capacity. Traditional hydrocarbon fuels can be contained, transported and transferred from one location to another with minimal difficulty and there is an established infrastructure of refuelling stations throughout the world. There are significant limitations to the use of electricity for the purpose of transportation because of this storage problem.

To put this in context, think of a gas tank in a car, which is technologically very simple, can be manufactured for a reasonable cost and is very light. To stress the simplicity of storing gasoline, diesel, or biofuels, they could even be placed in a pail and used directly from this container (but admittedly not very safely). This tank can be filled with an amount of fuel that can transport an average North American car for 600 to 800 kilometres and can then be refilled in a matter of minutes to travel that distance again.

Now compare this with a battery-operated car where the cost of construction of the battery is very high and current technology allows these vehicles to travel only 100 to 200 kilometres on one charge and take several hours to recharge.

The Myth of “Emissions Free” Electric Cars

Approximately 51% of electric cars will actually run on coal.

Electric cars are not, and never will be, “emissions free.” Assuming that electric cars are distributed widely throughout the United States, 51.2% of these cars will actually run on coal (the amount of coal-fired electricity, measured on a BTU input basis). Similarly, 44% of global electrical power is generated from coal, so assuming widespread use of electric cars approximately 44% of them will be running on coal-generated electricity. The technology of electric cars is actually allowing cars to run on coal. It is a stretch to claim “electric cars are leading a green revolution” when half of them will be powered by coal, the most emissions-intensive hydrocarbon.

The fact that electric cars will not be consuming gasoline is only beneficial if the electricity is being sourced by nuclear, wind, solar or hydro. If the electricity is being generated by coal, the planet is worse off than if a conventional automobile were used.



Socio-Economic Impact

Many of the debates about using different energy alternatives derive from socio-economic impacts. The impacts can be difficult to quantify for comparison purposes but are important none-the-less, and are categorized below:

Sustainability/Renewability

Sustainability is a measure of the ability to reliably develop resources to meet the needs of humanity in the short term and for future generations.

- **Biofuels** – The sustainability of certain first generation biofuels is questionable if volumes were to increase to more significant percentages of global production levels, given the constraints of available arable land.
- **Biomass** – Energy systems based on biomass feedstocks are only as renewable as the policies which guide the harvesting of feedstocks, particularly those feedstocks that do not grow quickly.
- **Coal** – Although not a renewable resource, the significant level of coal reserves in many countries is a primary driver for its use in electricity generation. For example, according to the ERCB, Alberta has established reserves of 33.4 billion tonnes, which represents over 1,000 years of supply at current Alberta production levels.

The significant level of coal reserves in many countries is a primary driver for its use in electricity generation.

Energy Security

Energy security is a measure of the ability of a country to provide a secure and stable energy system that isn't dependant on resources imported from other countries or regions of the world.

- **Oil** – The dominance of global oil production by OPEC member nations and other state-controlled oil companies, are reasons that energy security and independence dominates many discussions of energy development. The current events in Libya highlight this concern.
- **Coal** – The fact that significant coal reserves exist in over 70 countries reduces the chance for OPEC-type control.
- **Natural Gas** – The better geopolitical distribution of natural gas reserves, particularly shale gas, positions this resource as a short and medium-term option to reducing many countries' dependence on imported crude oil.
- **Wind / Solar** – The relatively universal nature of wind and solar resource means that it can serve to meet the energy security needs of many countries. It is important to note that the quality of the wind resource will vary dramatically within each country.

The fact that large coal reserves exist in over 70 countries eliminates the chance for OPEC-type control.

Expertise and Jobs

Expertise and jobs are the measure of a country's ability to provide jobs to its citizens and develop expertise from the development of a primary resource. An evaluation of energy resources also needs to consider if a country possesses the requisite knowledge, skill set and general know-how to leverage the full potential of a particular energy resource. Even with the scientific know how in place, countries need to determine if they have the sufficient resources (people and capital) to undertake efficient development.



Environmental Impacts – Water Use

Water usage is the measure of the amount of water used in the energy process across all parts of an energy system. Water plays a critical role in many conventional and alternative energies, and is used for several purposes including: 1) the production of a fuel/feedstock; 2) the generation of electricity via steam; and 3) the transfer of heat via a wet cooling process.

Hydrocarbon sources of energy use up to 20 barrels of water per boe-energy.

Biofuels use thousands of barrels of water per boe-energy.

- **Oil and Natural Gas** – Water is used as an input for drilling and fracturing processes, and can reduce the quantities of groundwater and/or surface water available for other purposes. Additionally, water is produced as an output from exploration and development wells and can be saline or contain other contaminants, which can impact the quality of groundwater and surface water.
- **Oil Sands** – The mining and in-situ processes for oil sands require significant amounts of water for the separation of the bitumen from the sand reservoir. In mining projects, the associated tailings ponds can impact the quality of ground and surface water.
- **Biodiesel and Ethanol** – Water is used in the processes of growing the feedstock crops; the water footprint of biofuels is particularly large when the cropland requires irrigation.
- **Coal and Nuclear** – The mining process for coal and uranium can produce significant amounts of water; the resulting tailings can impact the quality of groundwater and surface water. The electrical generation process also requires significant amounts of water as part of a cooling process.
- **Hydro** – The magnitude of hydropower production varies directly with the amount of water available, therefore larger reservoirs can displace more hydrocarbons. Unfortunately, these large reservoirs can lose large quantities of water due to evaporation.
- **Biomass and Geothermal** – Both of these electrical generation processes require water in cooling processes. Biomass electrical plants can also require additional water if irrigation is required for the biomass feedstock.
- **Solar Thermal** – Solar thermal plants require water in order to convert solar energy into steam used to generate electricity.

Figure 31 shows the results of our research, with surprisingly-high volumes of water use for the biofuels related to production of feedstock crops – note that the scale in the figure is logarithmic. The various hydrocarbon sources of energy use up to 20 barrels of water per boe-energy while the biofuels use thousands of barrels of water per boe-energy. Even hydroelectricity is higher than the hydrocarbon sources, due to evaporation from the lakes behind the dams.

In this analysis, we include all uses of water including non-potable, and give no credit for recycling.

In this analysis we do not include any component of recycling in any of the energy sources. For instance the oil sands can use up to 18 barrels per boe-energy, but this does not include the effect of the 75 to 90% recycling of water at the plants, which would reduce the water requirements to 1.8 to 4.5 barrels per boe-energy. Also, in-situ projects mostly use non-potable water, but we do not give any credit for this either. Similarly, how is the evaporation of water from a hydro project treated? The water will return to the earth through rainfall, but it is removed from the particular watershed where the dam was built.

Clearly, this is a very complex subject and there are many issues related to water that need to be addressed. These include what should be considered a “use”, what uses are a concern for human consumption, what are the environmental impacts and where might water be preserved or recycled.



Environmental Footprint (H₂O) - Conventional and Alternatives

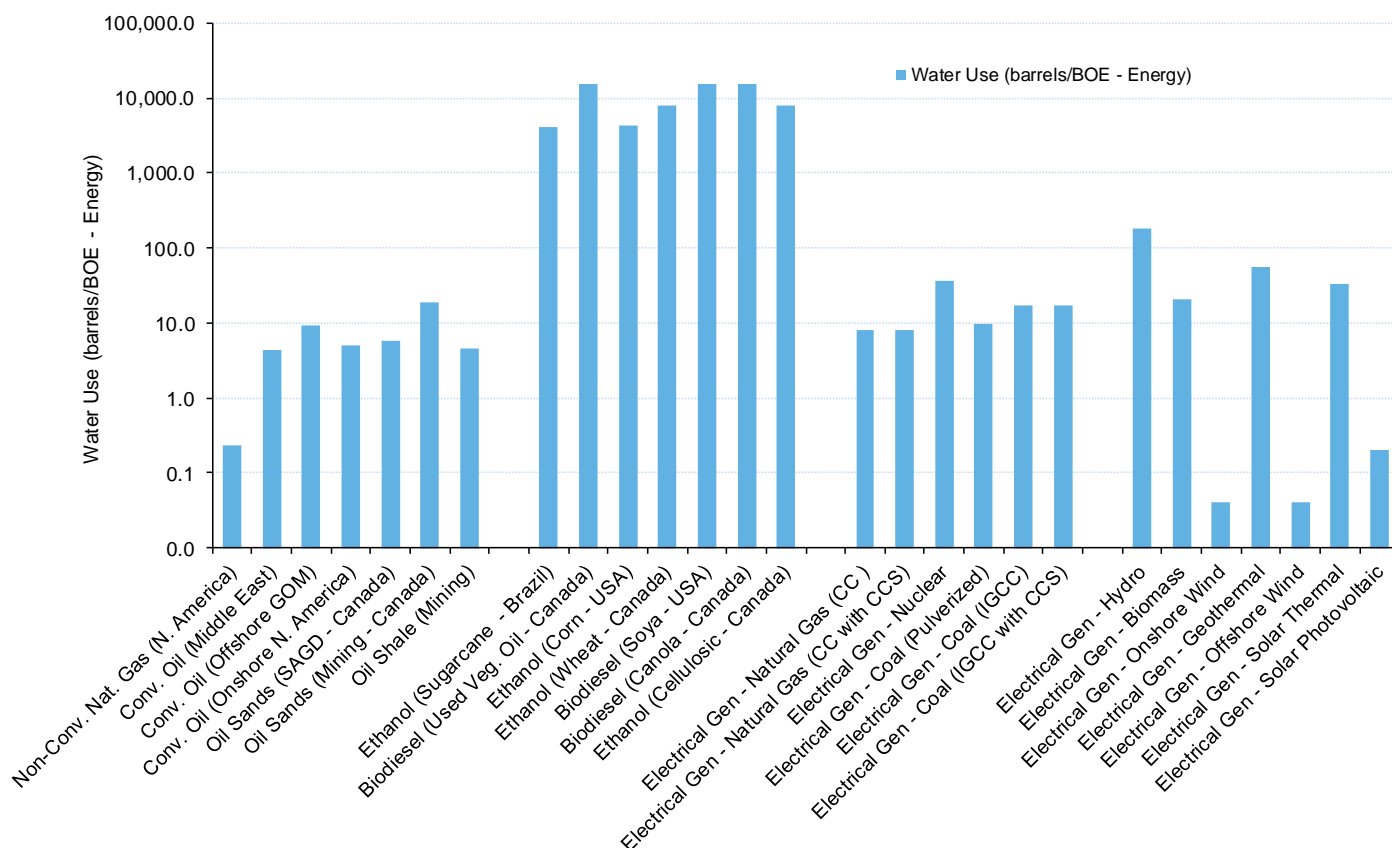


Figure 31. Comparison Water and H₂O Use – Logarithmic Scale

Sources: Please refer to the Sources section of this report.

Note: CC – Combined Cycle; CCS – Carbon Capture and Sequestration; IGCC – Integrated Gasification Combined Cycle

The majority of water use associated with biofuels comes from the rainfall and irrigation water used to grow the feedstock. The industrial process of converting the same feedstock into biofuels is very small by comparison. For example, the conversion process for corn-based ethanol usually requires about 3 barrels of water per barrel of ethanol (net of recycling).

To validate the magnitude of water required for biofuels that we gathered from several sources, we can convert agricultural water use, commonly measured in acre-feet, to barrels of water to better contrast it to the volumes of output energy.

- 1 acre-foot of water is the volumetric equivalent of 12 inches of rain and irrigation over one acre of land. This is equivalent to 7,759 barrels of water.
- 1 acre of corn can be used to produce roughly 9.4 barrels of ethanol or 5.8 barrels of boe-energy.

Therefore, each foot of rain and irrigation required to grow corn, for conversion into ethanol, results in a water use ratio of roughly 1,337 barrels of water per barrel of oil equivalent energy. Although water requirements for corn-based ethanol are high, it is important to note that the water requirements for some alternative



biofuels, such as soya-based biodiesel, can be even higher because more water is required to grow the underlying feedstock.

Some will argue that rainfall, as it occurs naturally, shouldn't be counted as a contributor to water use for biofuels. Others will counter with the view that the majority of that rainfall is necessary for the process of growing feedstock and that same rainfall, if not diverted for agricultural purposes, would in large part replenish natural water aquifers, rivers and lakes.

Figure 31 illustrates that water is a necessary ingredient in the production of most conventional and alternative sources of energy. The water may be used in different ways and take different forms (fresh vs. saline, new vs. recycled), which can make comparisons of usage challenging, but it is clear that without water most forms of energy that power our modern society could simply not be produced.

Integrated System View - Summary

An integrated system approach to analyzing energy resources provides a sound context from which to compare conventional and alternative energy sources. This broad perspective sheds a light on two problematic characteristics of the energy debate:

1. Despite what many would argue, there is *not* a clear “winner” (or “loser” for that matter) in the energy debate and that each form of energy has distinct advantages and disadvantages.
2. Many energy systems' problems, such as the need to reduce energy costs and environmental impacts, are not associated with a specific resource but instead are shared by many. Attempts by different industries to vilify each other can be described as “the pot calling the kettle black”.

We believe that to address these problems we need to refocus the energy debate towards shared solutions. The development of new water recycling technologies can just as easily reduce the fresh water required for synthetic crude from a mining oil sands project in Alberta as ethanol from a plant in Iowa. Advancements in combined cycle heat engines can improve efficiencies in a coal power plant in the same manner as a geothermal equivalent. Conventional and alternative energy technologies located at the same site could reduce the need for additional infrastructure, lowering energy costs for everyone.

We need to refocus the energy debate towards shared solutions.



Practical Reality – What Would it Take to Replace Hydrocarbons?

Global Liquid Consumption to be Replaced

Figure 32 shows where liquids (predominately crude-oil derived products) are used on a global scale, which shows the predominance of transportation. The reason we show this is to indicate how important liquids are when considering what alternatives might be usable as a replacement. In the transportation sector, we can see that oil is the dominant source of energy. In fact, transportation accounts for more than 50% of the global consumption of liquids.

Transportation accounts for more than 50% of the global consumption of liquids.

Global Liquids Consumption by End-Use

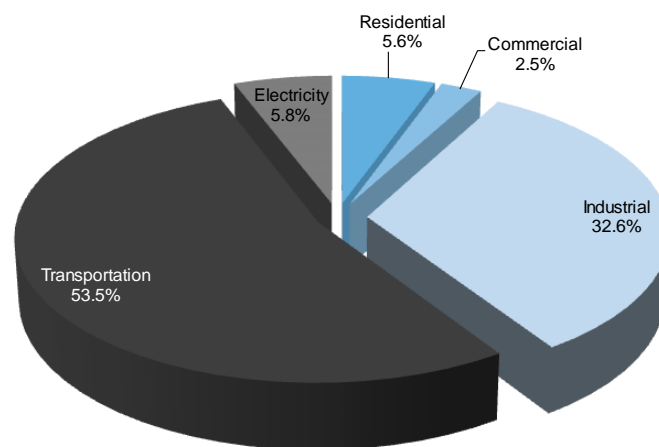


Figure 32. Global Liquids Consumption by End-Use
Sources: EIA, AltaCorp Capital Inc.



Global Transportation Energy Use from all Sources

Global transportation energy use includes all forms of transportation such as rail, air, car, and shipping. In Figure 33 note how important petroleum (oil) is, at almost 94%; this is due to the simplicity of handling and the existing infrastructure. To point out the obvious, gasoline and diesel are much easier to handle and essentially all automobiles can easily stop at a gas station to refuel.

In the transportation sector, oil is the dominant source of energy at 93.8%.

Global Energy Consumption for Transportation by Fuel Type

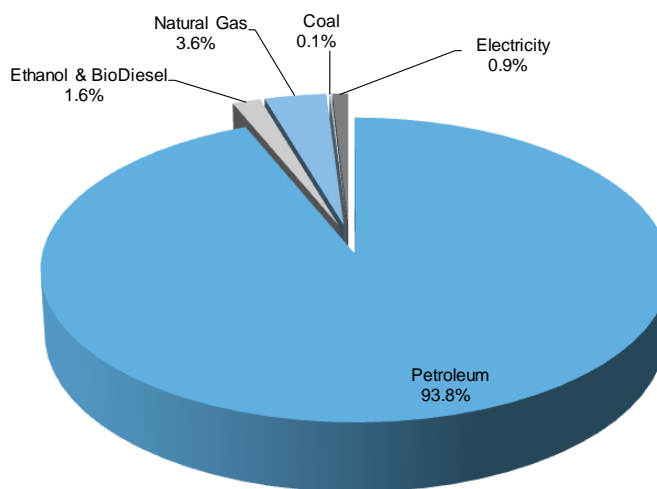


Figure 33. Global Energy Consumption of Transportation by Fuel Type
Sources: EIA, AltaCorp Capital Inc.

Biofuels to Replace Crude Oil?

It would take a corn field the size of the United States, China and India to replace current global oil production with corn ethanol.



To better understand the limitations of transitioning to renewable energy, we have analyzed a few scenarios where a conventional energy source is replaced with renewable alternatives. There will always be limitations with alternatives' ability to replace very large volumes of hydrocarbons. To put the magnitude of the problem in context, here are some comparisons:

- To replace 84.4 million bbls/day of global oil production with corn ethanol, it would take a corn field the size of the United States, China and India – combined.
 - Note that this area is actually greater than the currently-used arable land in the world. If mankind was to convert all of the land now being used for growing crops we would only be able to replace 54 million bbls/day of oil. This represents only 64% of current global oil production.
- If all the arable land in the U.S. was converted to corn for ethanol production – *leaving no land for growing food* – the total amount of ethanol would only replace 74% of the country's imports.
- To replace the United States' oil imports with ethanol, it would require corn fields covering 25% of the country. This represents about 1.4 times the amount of arable land available to do so.

This analysis is done on an energy equivalency basis and does not take into account the fact that ethanol doesn't provide many of the petrochemicals that crude oil does.



Countries with more arable land – such as the United States, India, Russia, China, Brazil, Australia and Canada – have the potential to be more dominant players in the worldwide production of biofuels. Other regions, like Europe, are constrained by a smaller amount of arable land and will likely explore other renewable energy sources. This conclusion is supported by our analysis of global ethanol and biodiesel production, shown in Figure 34, where ethanol production in the U.S. and Brazil accounts for approximately three-quarters of global biofuels production. This is consistent with both countries being in the top five countries in terms of total arable land (India, Russia and China are the others).

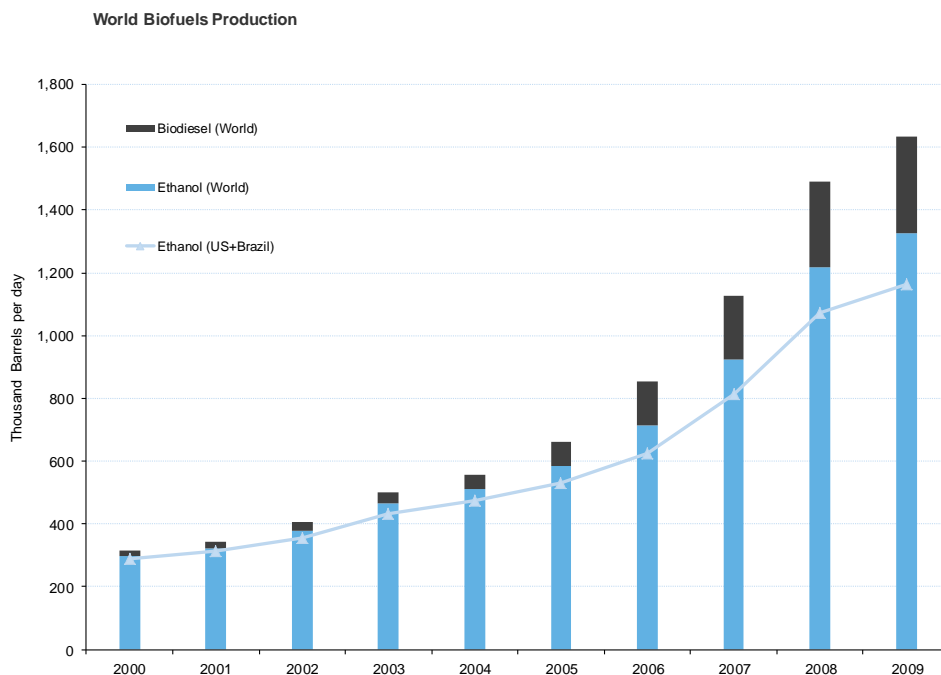


Figure 34. U.S. and Brazil are Dominating the Biofuels Scene

Source: EIA, AltaCorp Capital Inc.

Note that meal by-products are a key part of what make biofuels economic. That is, the material that is left over after the fuel has been produced can be used as feed for livestock and has a dollar value which offsets the cost of buying the feedstock in the first place. However, if biofuel production ramps up dramatically, to the point where supply exceeds demand, then the value of the meal drops and along with it the economics of the projects.



Other Sources of Ethanol – Switchgrass and Cellulosic

The moral debate associated with food based ethanol is not an issue with cellulosic.

Switchgrass is a perennial plant that does not need to be replanted every year (meaning potential cost savings for farmers of this crop) but still takes up arable land – land that could be used for food crops. It is often argued that switchgrass can be grown on more marginal lands that aren't suitable for food production, but yields will be lower. The corresponding factor is that a more conservative estimate of switchgrass yields is warranted in this case because they will be grown in those marginal areas where the soil conditions and amount of rainfall aren't as conducive to growing crops as prime arable land.

Cellulosic technology is not commercially viable, but there is a great deal of research going into this process to make it economically attractive. This technology creates ethanol using non-food feedstocks such as wood, wheat straw, corn stalks and biomass waste. However, the process involves more expensive processes that involve either a biochemical or thermochemical conversion to breakdown the feedstocks. There are good reasons to research this technology as it has many advantages including:

- *Cheaper Feedstock* – The feedstock is normally a waste product, making it inexpensive.
- *More Diverse Feedstock* – Various technologies are designed to take advantage of different feedstocks, depending on what is available in the area.
- *No Competition for Food* – The feedstocks are usually parts of plants that are not edible, or other non-food waste. The moral debate associated with food based ethanol is not an issue with cellulosic.



The Ethics of Biofuels

This is the “food for fuel” issue. The pivotal question in this debate is “should food crops, or land otherwise dedicated to food crops, be used for the production of transportation fuels?” The answer for many is a definitive “no”, especially when the world is facing another food crisis. Using food crops for fuel will only further increase the price of corn, wheat and other biofuel feedstocks, and push more low-income families into poverty. Given the magnitude of the problem, we suggest limiting the use of biofuels because they are taxing an already over-burdened global food system.

149 million people could be fed with the corn used to create ethanol in the U.S.

How significant is the amount of food-based feedstocks used for ethanol production in the United States? Our analysis has shown surprising results: 149 million people could be fed for a year with the amount of corn that is annually used to create ethanol in the U.S. That is not a mistake or a misprint, 149,000,000 people globally could be sustained every year with the 38.7 million tonnes of corn annually grown in the U.S. to produce ethanol for blending with gasoline through government incentives and mandates. We suggested the adjective “surprising” but the strongest words about this issue have been used by Jean Ziegler, Chair of the United Nations Human Rights Council’s Advisory Committee who stated:

“So it is a crime against humanity – it’s a crime against humanity to convert agricultural productive soil into soil...which will be burned into biofuels”

Jean Ziegler, October 26, 2007

Food for Fuel – the Math

We can put the scale of U.S. corn production for ethanol into perspective by examining the caloric equivalent of the corn and comparing that to the number of Calories required for sustaining an individual. Our methodology is outlined in the following steps and these calculations are also summarized in Figure 35, including the sources of data.

Step 1 – How much U.S. produced corn is used for Ethanol production?

- According to the USDA in 2009, the U.S. produced 13,110 million bushels of corn, of which 4,568 million bushels was used for ethanol. This amount of corn by weight is 115.1 billion kilograms.

Step 2 – How many Calories in this Corn?

- According to the Food and Agriculture Organization of the United Nations (FAO), the global corn used for food in 2007 averaged 3,020 Calories per kilogram (we used this conservative number instead of the USDA’s own Nutrient Database where 1 kilogram of corn contains approximately 3,650 Calories).
- Therefore, the 4,568 million bushels of corn used for ethanol has a caloric equivalent of 350 trillion Calories.

Step 3 – How Much Food Corn Could be Grown in Place of Industrial (Ethanol) Corn?

- In the interest of keeping a conservative estimate of people that could be fed, we have assumed that yields of food-based corn are one-third of that of the industrial corn. This is based on a review of global corn yields published by the FAO, where corn yields in most countries range between one-half to one-third of the U.S. industrial corn.
- Therefore, the food corn grown in place of industrial (ethanol) corn would have a caloric equivalent of 117 trillion Calories.

Step 4 – What is the Recommended Caloric Intake of an Average Person?

- According the USDA, the estimated caloric needs for people vary by age, gender and physical activity, and range from 1,000 to 3,200 Calories per Day. We have selected an average of 2,000 Calories per day based on this data.

The corn used for ethanol in the U.S. has a caloric equivalent of 350 trillion Calories.

We have assumed that yields of food-based corn are one-third of that of the industrial corn.



- To account for the difference between food production and consumption (due to spoilage & waste), we increased this amount by 8% (double the global estimated waste for corn (maize) published by the FAO).
- Therefore, the average person should consume 788,400 Calories per year.

Step 5 – How Many People Could be Fed With This Corn?

- To calculate this number we simply divided the Calories in the corn by the caloric requirements of our average person with the result being 149 million people.

If a 100,000 bbls/d oil sands mining project were brought on stream to replace corn ethanol production, the feedstock land could feed 34 million people.

U.S. Corn Production and Caloric Equivalent

Step	Calculation	Total	Source(s)
1	U.S. Corn Production Used for Fuel Ethanol	4,568 Million Bushels / Year	USDA Quick Stats and Feed Grains Databases
2	Caloric Equivalent of U.S. Corn = 4,568 million bushels x 56 lbs/bushel x 0.45 kg/lb x 3020 Calories/kg	350 Trillion Calories / Year	FAO Food Balance Sheets Database; USDA National Nutrient Database for Standard Reference Database
3	Caloric Equivalent of U.S. Corn (Food Corn Replacement) = 350 Trillion Calories (per year) x 1/3	117 Trillion Calories	FAO Crop Production Database
4	Caloric Requirements per Person = 2000 Calories per capita/day x 108% (spoilage/waste) x 365 days/year	788,400 Calories per Capita / Year	FAO Commodity Balances Database; USDA Dietary Guidelines 2010 Policy Document
5	Number of People that Could be Fed = 117 Trillion Calories ÷ 788,400 Calories per capita	149 Million People	

Figure 35. U.S. Corn Production and Caloric Equivalent

To put this in context, we did the following calculation. If a 100,000 bbls/d oil sands mining project were brought on stream for the sole purpose of replacing ethanol production, the corn otherwise used for this fuel could feed 34 million people on an ongoing basis. Even though many in the U.S. do not want Canada's "dirty oil", we suggest it may be a contribution to humanity if it were used to displace ethanol production.

If the U.S. dropped its oil consumption by only 1% and this was used to offset ethanol, the feedstock land could feed 64 million people.

Frankly, a better option for the United States might be to reduce energy consumption and use these savings to limit ethanol production. If the country dropped its oil consumption from all sources by only 1% and this reduction was used to offset ethanol production, the feedstock land could feed 64 million people every year and continually.

Practical Reality – Replacing U.S. Coal-Fired Electricity

Coal currently produces 51% of the United States' electrical generation.

Coal is not a good environmental choice but does provide inexpensive base load power.

Coal currently produces 51% of the United States' electrical generation as shown in the chart below, which is seven percentage points higher than global electrical generation of 44%. It is important to note that this percentage is based on the amount of energy input, in BTUs, to generate the electricity, rather than energy output. On this basis, the effect is that coal is a higher percentage than it would be if it was measured on an output basis, since coal-fired electricity is less efficient than other forms of electrical generation. If we were to look at electrical generation on an output basis, we would see that coal provides about 45% of the U.S.'s electricity. However, we use the input measure to be consistent with the shared BTU metric used in this report for comparing various forms of energy.

United States Electrical Generation by Source

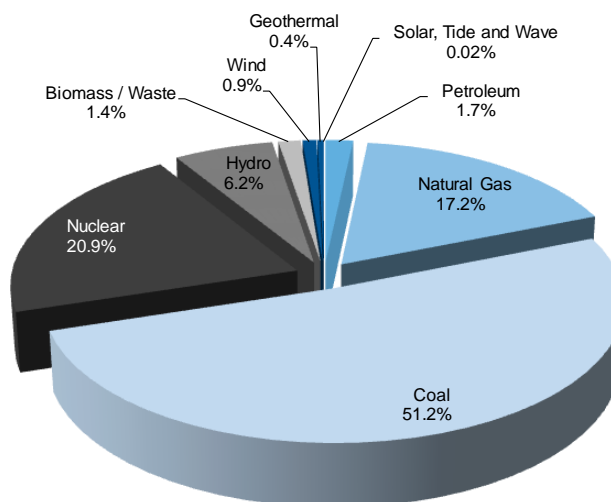


Figure 36. United States Electrical Generation by Source

Sources: EIA 2010 International Energy Outlook, AltaCorp Capital Inc.

Note: Percentages based on energy inputs on a BTU Basis. On a kWh output basis, coal would represent approximately 45% and natural gas would represent approximately 23%.

Coal is not a good environmental choice for electrical power generation as it has higher CO₂, SO₂ and NO_x emissions when compared to other forms of generation. However, there are good reasons why coal makes up such a large percentage of generation; it is plentiful and inexpensive, the technology is simple and can provide excellent base load capacity – a critical element of a stable power grid.

It will be impossible to convert all coal generation capacity to solar and wind in the next fifty years.

It will be impossible to convert all coal generation capacity to solar and wind in the next fifty years. Electrical consumers require reliable and on-demand power, which cannot be provided by wind and solar. Even in those areas where wind and solar farms will be installed, back-up power generation needs to be available for times when the wind is not blowing and the sun is not shining. Although there are other options such as nuclear and natural gas-fired electricity that could replace some coal production, the complete phase-out of coal is a long way off.

There are good environmental reasons to reduce coal-fired electrical generation with the amount of CO₂ that is put into the atmosphere. To put into context the amount of CO₂ that is emitted by U.S. coal, it is about 50 times the amount of CO₂ emitted by the oil sands as shown in Figure 37.



The amount of CO₂ that is emitted by U.S. coal is about 50 times the amount of CO₂ emitted by the oil sands.

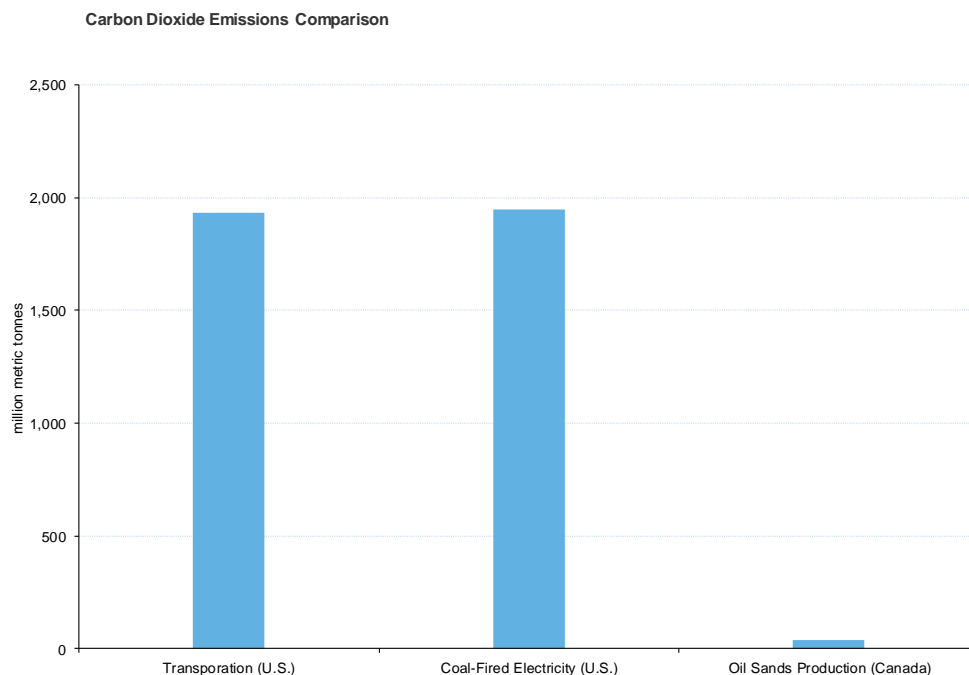


Figure 37. Carbon Dioxide Comparisons
Sources: EIA, CAPP, AltaCorp Capital Inc.

To replace the coal-fired electricity in the United States, it would take solar panels valued at \$4.4 trillion.

Converting from Coal Power to Solar?

If a technology can be developed to store large amounts of electricity generated from solar and wind power, this conversion might be possible. There are, however, many substantial hurdles at this time to the storage of electricity on a massive utility scale required in developed economies. There are smaller applications, such as electric cars, where batteries can play a role but reality is that essentially all large scale solar and wind electrical energy must be consumed the instant it is produced.

To show how significant the challenge of converting coal-fired electrical power to solar we provide the following comparisons:

- To replace the coal-fired electricity in the United States, it would take solar panels valued at \$4.4 trillion. Note that this power needs to be used when it is generated, or be stored in batteries for when it is required. The practical limitation to solar power is that we have no control on when it is produced.
- In addition to the solar panels themselves, batteries would be required to store power for use during darkness and periods of cloud cover. This is not a trivial exercise; it would take approximately nine billion car batteries (those used in typical cars for starting the engine), costing about \$950 billion. Nine billion batteries represents approximately 34 times the number of batteries currently in use (there are about 260 million registered vehicles in the United States). It is actually not realistic that car batteries be used for storing this amount of electricity, this comparison is only to show the magnitude of the problem of replacing coal with alternatives. With current battery technology it is impossible to store meaningful amounts of solar powered electricity.

With current battery technology it is impossible to store utility-scale amounts of solar power.



Converting from Coal to Wind?

A similar challenge exists if trying to replace coal-fired electrical power with wind power. To put this in context we provide the following comparisons:

To replace the coal-fired electricity in the United States, it would take 580 million residential-sized wind turbines.

- To replace the coal-fired electricity in the United States, it would take 580 million residential-sized wind turbines (1000 watt units), which would cost approximately \$2.7 trillion.
- Instead of residential-sized wind turbines, it would take 390,000 large wind turbines (1.5 MW units), which would cost approximately \$1.4 trillion. Note that these are at current prices, and if there was a dramatic increase in the demand for wind turbines (without a corresponding drop in construction costs per unit), the prices would increase, so the actual costs would be much higher.
- Similar to solar power, some of the electricity generated from wind turbines would have to be stored in batteries for use during periods of calm or low wind-velocity periods. Again, to use the car battery as a measure it would take 7.5 billion of these batteries, which would cost almost \$800 billion. This cost excludes any other infrastructure related to these batteries, including inverters which modify the DC (direct current) from the batteries to AC (alternating current) for general household use.

Converting from Coal to Oil Sands?

The U.S. would actually improve its environmental footprint if it imported more oil sands crude and used this crude to offset coal-fired electrical generation.

Although to some this may sound ironic or illogical, there would actually be a reduction in CO₂ emissions per BTU produced if coal-fired electrical plants were shut down and power plants fuelled by synthetic oil from oil sands were built in their stead. Although there is a great deal of criticism of the oil sands as “dirty oil”, it is less carbon-intensive than coal. It has been suggested that the United States should not import “dirty oil” from Canada, but the U.S. would actually improve its environmental footprint if it imported *more* oil sands crude and used this crude to offset coal-fired electrical generation. This, of course, will not happen because of the higher cost of oil when compared to coal.

Converting Coal to Natural Gas Power?

This is probably the most realistic option for the United States. Natural gas is plentiful with new extraction technologies, therefore it is inexpensive and has much lower CO₂ emissions than both coal and oil. With the lower natural gas prices it makes more sense than ever to move away from “dirty coal.”



Practical Reality – Replacing Global Coal-Fired Electricity

Our society is accustomed to readily available power – this will make the conversion to solar and wind very difficult.

Over 98% of electrical generation – including hydro, nuclear, biomass, coal, natural gas and petroleum – is made up of sources that can provide base load power. This points to how we use electricity; we expect it at all times and we don't even question that it will be there when demanded. This attribute is what makes the use of solar, wind and other renewables problematic. Our society has become accustomed to this readily available power and will make the conversion to solar and wind very difficult. We will always need this base load and on demand power, and therefore, renewables will play a smaller role for many years until we develop smart grid technologies.

Global Electrical Generation by Source

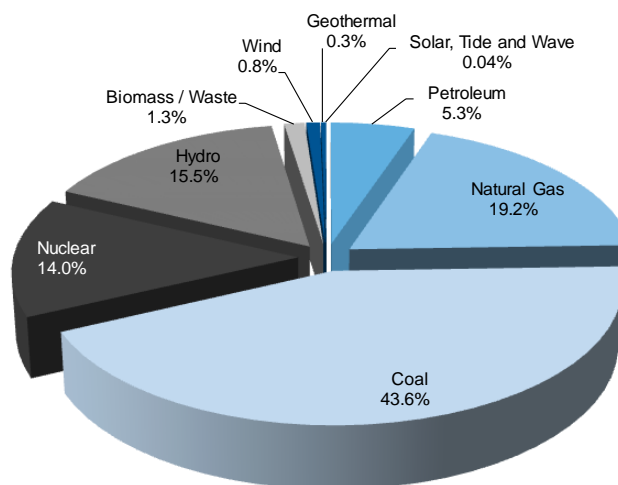


Figure 38. Global Electrical Generation by Source

Sources: EIA 2010 International Energy Outlook, Earth Policy Institute, AltaCorp Capital Inc.

Note: Percentages based on energy inputs on a BTU Basis

We need base load power, and therefore, renewables will play a smaller role for many years.

The amount of electricity that is generated globally from coal is 84.5 quadrillion BTUs every year. The coal generation in the U.S. represents 25% of this, at 20.8 quadrillion BTUs. The problems related to system integration, generation consistency, and electrical storage are even more complex, especially in developing economies where coal will be the cheapest source of electricity. To put this into context, 84.5 quadrillion BTU is equivalent to the energy in 40 million bbls/d of oil production, which represents almost half of the current global oil production.



Scenarios for Energy Growth and Conversion to Alternatives

Global consumption in energy has grown by a surprisingly-high 72% to over 500 quadrillion BTU in 2009 from 292 quadrillion BTU in 1980.

Mankind currently uses the equivalent of 230 million barrels per day of energy from all sources.

Biodiesel, ethanol, solar and wind are essentially imperceptible in the figure.

Note how significant the growth of coal is, largely due to a dramatic increase in the number of coal-fired electrical plants in China.

For this analysis, we continue to use the BTU as a common measure in which all forms of energy can be compared, whether the energy comes from hydrocarbons, hydroelectricity, alternatives/renewables or nuclear. The BTU measure also allows us to directly compare the sources, regardless if the energy comes in the form of heat or electricity. The chart below shows the increase in global consumption in energy over the last 30 years, which has grown by a surprisingly-high 72% to over 500 quadrillion BTU in 2009 from 292 quadrillion BTU in 1980.

Although the term 'quadrillion BTU', or in the shortened form, 'quad', is not an everyday term, it is useful in that it allows total energy use to be shown from all energy sources on an equal basis and on a global scale. To put one quad in context, it is equivalent to approximately 170 million barrels of oil. With mankind currently burning through approximately 500 quads a year in energy, this translates to about 230 million barrels per day of oil equivalent, or 2.7 times current oil consumption of approximately 84 million barrels per day. Global society has a great deal of work ahead to convert to renewables with total renewable energy (including hydroelectricity) consumption steady at approximately 10% over the last 30 years. Note that six percentage points of this 10% is hydroelectricity, which means that non-hydroelectric renewables represent only 4% of total energy consumption. Biodiesel, ethanol, solar and wind are essentially imperceptible in Figure 39, but they will increase on both an absolute and a percentage basis. This will occur out of necessity, at some point, as hydrocarbons become too expensive and/or scarce, but earlier adoption will happen through government and personal initiatives.

Observe on this chart how significant the growth of coal is, largely due to a dramatic increase in the number of coal-fired electrical plants in China over the time period. For the economic reasons discussed previously, coal is an attractive source of energy (setting aside, temporarily, the environmental concerns), especially for a developing economy such as China's, where a great deal of this inexpensive resource exists.

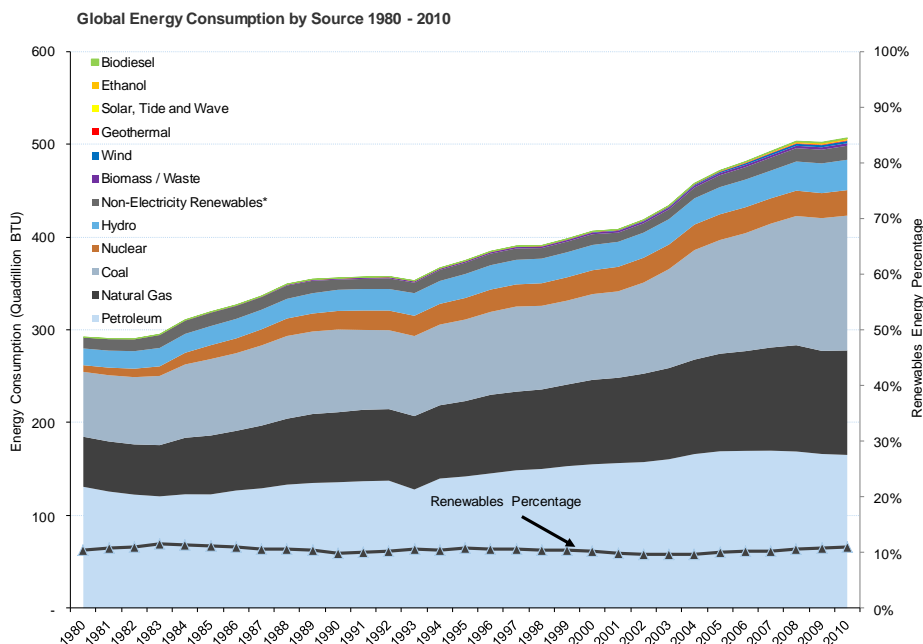


Figure 39. Global Energy Consumption by Source 1980 – 2010

Sources: EIA, Earth Policy Institute, AltaCorp Capital Inc.

Note: Renewables Percentage includes Hydro and all other renewables

* Non-Electricity Renewables are those used for heat generation



The increase in global demand over the next 40 years represents approximately three times the current energy use of the United States.

The task of converting to alternatives is a classic case of one step forward and two steps back.

Wind, ethanol and biodiesel have exhibited the greatest growth recently and this will continue.

Growth in Alternatives to 2050 – the Short Term

The next two Figures, 40 and 41, show the increase in global energy consumption to 2050 with an assumed increase of 1.2% per year. Under this growth rate, energy consumption grows by almost 60% to over 816 quadrillion BTUs from approximately 502 quads in 2009. Although, this rate of growth is not unreasonable (being in the range of other publically-available forecasts) the resulting absolute increase in consumption of 300 quads can arguably be described as “troubling.” Troubling in the sense that 314 quadrillion represents approximately *three times* the current energy use of the United States. The ability of mankind to extract this amount of energy from the earth over the next 40 years will be a monumental – if not impossible – task.

One of the main reasons we will have a hard time replacing hydrocarbons with alternatives is because our demand for energy is growing so dramatically. The task of converting to alternatives is a classic case of one step forward and two steps back. It will be very difficult to meet increased energy demand while at the same time trying to convert to alternatives.

Figure 40 shows our base case, with a moderate adoption of alternatives and where renewables outpace overall energy consumption with an increase to 20% of total energy consumption in 2050 from 11% in 2009. The absolute amount of renewable energy increases to 161 quadrillion BTUs in 2050 from 55 quadrillion in 2009, which represents a 193% increase in renewable energy. In this case we use differing growth rates depending on the type of renewable energy:

- **Hydro (2.0%)** – The largest component of renewable energy will continue to remain so over the medium term, growing at a steady rate 2.0%, which is still large given its current contribution to global energy production.
- **Biomass/Waste, Non-Electricity Renewables (2.6%)** – We anticipate biomass/waste and non-electricity renewables will grow at or near the overall renewable growth predicted by the EIA at 2.6%.
- **Geothermal (2.6% until 2030, then 3.0% until 2050)** – We anticipate that improved development techniques will lead to a bump in geothermal development in the medium term.
- **Wind, Ethanol and Biodiesel (8.0% until 2030, then 4.0% until 2050)** – These renewable technologies have exhibited the greatest growth recently and this will continue in the short term. As the relative size of these renewable energies grow, however, the increase in market size as a year-over-year percentage will start to diminish. Additionally, these technologies will begin to face a variety of constraints (and opposition) as they achieve larger sizes, including arable land constraints and ethical issues for ethanol/biodiesel, and infrastructure limitations for wind, solar, tide and wave.
- **Solar, Tide, Wave (8.0% until 2030, then 6.0% until 2050)** – Similar to wind, ethanol and biodiesel, these renewables have shown significant growth, but the year-over-year percentage will start to diminish over time. They also will begin to face a variety of constraints (and opposition) as they achieve larger sizes, including infrastructure limitations.

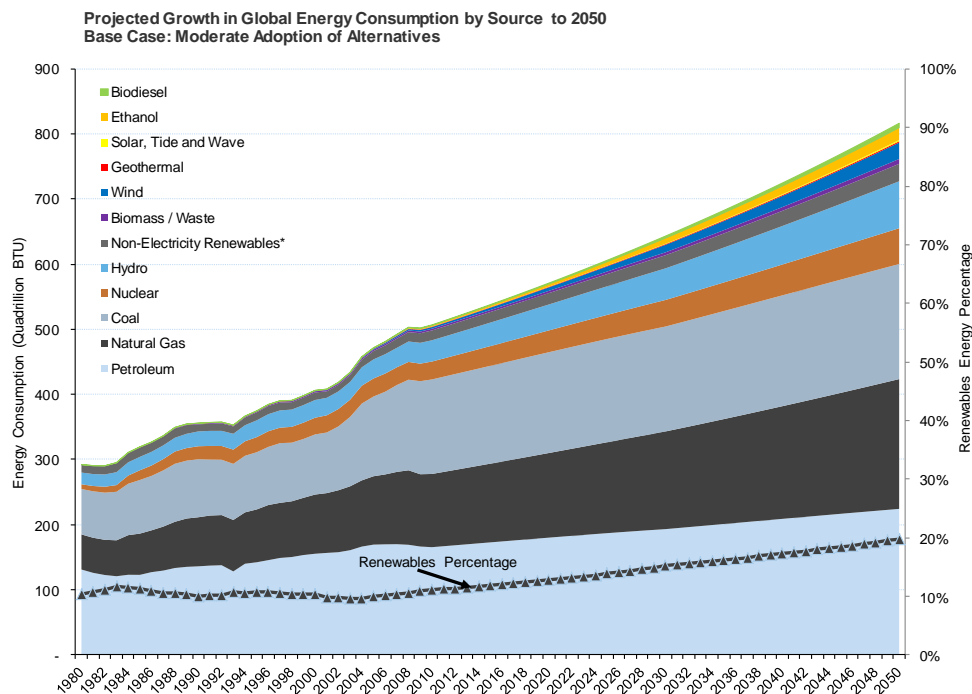


Figure 40. Projected Growth in Global Energy Consumption by Source to 2050

Base Case: Moderate Adoption of Alternatives

Sources: EIA, Earth Policy Institute, AltaCorp Capital Inc.

Note: Renewables Percentage includes Hydro and all other renewables

* Non-Electricity Renewables are those used for heat generation

Figure 41 shows a more-aggressive adoption of renewables in our high case where renewables outpace overall energy consumption with an increase to 24% of total energy consumption in 2050 from the 11% in 2009. The absolute amount of renewable energy increases to 196 quadrillion BTUs in 2050 from 55 quadrillion in 2009, which represents a 256% increase. In this case, we assume some modified growth rates versus our base case depending on the type of renewable energy:

- **Hydro (2.5%)** – With larger financial commitments by governments, the largest component of renewable energy could experience stronger growth at 2.5% per annum.
- **Biomass/Waste (2.6% until 2030, then 4.0% until 2050)** – We anticipate with continued developed in new technologies, and associated cost reductions, the growth in biomass/waste could accelerate to 4% by 2030 and continuing through 2050.
- **Non-Electricity Renewables (3.0%)** – We anticipate that non-electricity renewables would see stronger growth under an aggressive adoption of renewables, keeping in mind that at its current size, the relative growth as a year-over-year percentage would be smaller than other renewables.
- **Geothermal (3.0%)** – With additional financial support under an aggressive adoption scenario, geothermal development could pick up in the shorter term. We anticipate this growth will be limited by the up-front capital and exploration risks associated with drilling and evaluating potential geothermal sites prior to their development.
- **Wind (9.0% until 2030, then 5.0% until 2050)** – As one of the most economically competitive of the renewable alternatives, wind would continue to see strong growth under an aggressive adoption scenario, with limits occurring in markets where it achieves higher penetration rates. In these cases wind would be limited to a 20% market share as we don't anticipate utility scale electricity storage being viable in this time frame.

With additional financial support, geothermal development could pick up in the shorter term.

Wind would continue to see strong growth.



- **Solar, Tide and Wave (9.0% until 2030, then 6.0% until 2050)** – Solar, tide and wave have the greatest potential for large percentage growth over the long term due to their relative size and with continued innovation and financial support under the rapid adoption scenario.
- **Ethanol/Biodiesel (9.0% until 2030, then 4.0% until 2050)** – In the short/medium term, there is the potential for strong growth for biofuels, especially as next generation technologies become more cost competitive and can start to produce at commercial volumes.

Even in this scenario, there is still a significant amount of hydrocarbons required to meet full energy demand. A large portion of this demand is simply driven by population growth and driven further by an increase in energy use per individual.

In the rapid adoption scenario, the absolute amount of renewable energy increases 256% in 2050 over 2009.

Even in this scenario, there are still a significant amount of hydrocarbons required to meet full energy demand.

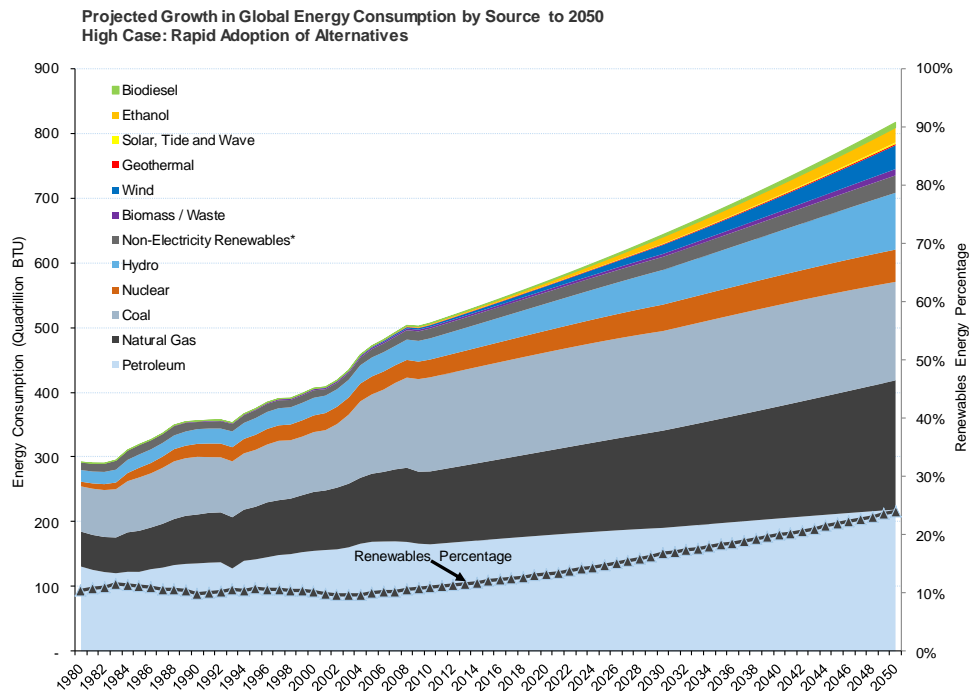


Figure 41. Projected Growth in Global Energy Consumption by Source to 2050

High Case: Rapid Adoption of Alternatives

Sources: EIA, Earth Policy Institute, AltaCorp Capital Inc.

Note: Renewables Percentage includes Hydro and all other renewables

* Non-Electricity Renewables are those used for heat generation



The increase represents over nine times the amount of energy currently consumed in the United States.

The development of multiple energy sources need to be undertaken in combination with conservation.

Growth in wind power would continue, but diminish on a percentage basis as the relative size of wind power increases.

Solar, tide and wave power would see some of the highest growth rates of all renewables.

Growth in Alternatives to 2100 – the Long Term

If we assume that growth in energy consumption continues at 1.2%, the total demand in 2100 will grow by over 195% to 1,482 quadrillion BTUs from approximately 502 quadrillion in 2009. The absolute increase of 980 quadrillion BTUs over this time period represents over *nine times* the amount of energy currently consumed in the United States. Little analysis is required to determine that this amount of energy generation is not possible using current technologies; few would argue it could be achieved. Much is required:

- Drop in consumption? Without question
- Increase in alternatives? Absolutely
- Increase in natural gas production? No doubt
- More hydroelectricity? As much as possible

All sources of energy are required to meet growing demand; no single energy source can represent a “saviour” for the ever-increasing demand for energy. The development of multiple energy sources, including unconventional hydrocarbons and renewable energy sources, needs to be undertaken in combination with programs to curb the global appetite for energy.

Moreover, the “elephant in the room” (the obvious issue that is not being acknowledged) is that there is a limit to the number of people the Earth can support. Current global population is rapidly approaching 7 billion individuals and could reach 10 billion in the next 40 to 60 years. Population growth is an unresolvable problem, at least a problem that will not be resolved through government or personal intervention. The only resolution will be through naturally-occurring events such as famine, disease or natural disasters. Having shared that rather bleak observation, we resume our analysis.

Figure 42 shows our base case, with a moderate adoption rate of alternatives where renewables outpace overall energy consumption with an increase to 32% of total energy consumption in 2100 from 11% in 2009. The absolute amount of renewables increases to 468 quadrillion BTUs in 2100 from 55 quads in 2009, which represents a 751% increase in renewable energy. In this case we assume differing growth rates for the period from 2050-2100 depending on the type of renewable energy, acknowledging that predictions over this longer-term time frame will be increasingly unreliable and depend on a large number of factors which are difficult to predict:

- **Hydro (1.0% 2050-2100)** – Over time, the number of large water sources that could be developed for hydro power will become limited, and growth, although still large on an absolute basis, will fall on a year-over-year-percentage.
- **Biomass/Waste, Non-Electricity Renewables (2.6% 2050-2100)** – We anticipate that biomass/waste and non-electricity renewables could continue to grow at a reasonable rate over the longer-term.
- **Geothermal (3.0% 2050-2100)** – Growth over the long-term would continue to be strong, although still mitigated by exploratory risks that would constrain the amount of capital allocated towards geothermal vs. other alternatives.
- **Wind (3.0% 2050-2100)** – With a large global resource base, growth in wind power would continue, but diminish on a percentage basis as the relative size of wind power increases and the market matures (keeping in mind that the highest quality wind power sites will likely be developed in the first half of the century).
- **Solar, Tide and Wave (6.0% 2050-2100)** – Towards the latter half of the century, given technological advancements and cost reductions, solar, tide and wave power would see some of the highest growth rates of all renewables.
- **Ethanol and Biodiesel (3.0% 2050-2100)** – Arable land constraints will cut-off the development of most first generation biofuels by this time, allowing next generation technologies (e.g. cellulosic, algae-based fuels) to take over as the drivers of growth in biofuel production.



Renewables outpace overall energy consumption with an increase to 32% of total energy consumption in 2100 from 11% in 2009.

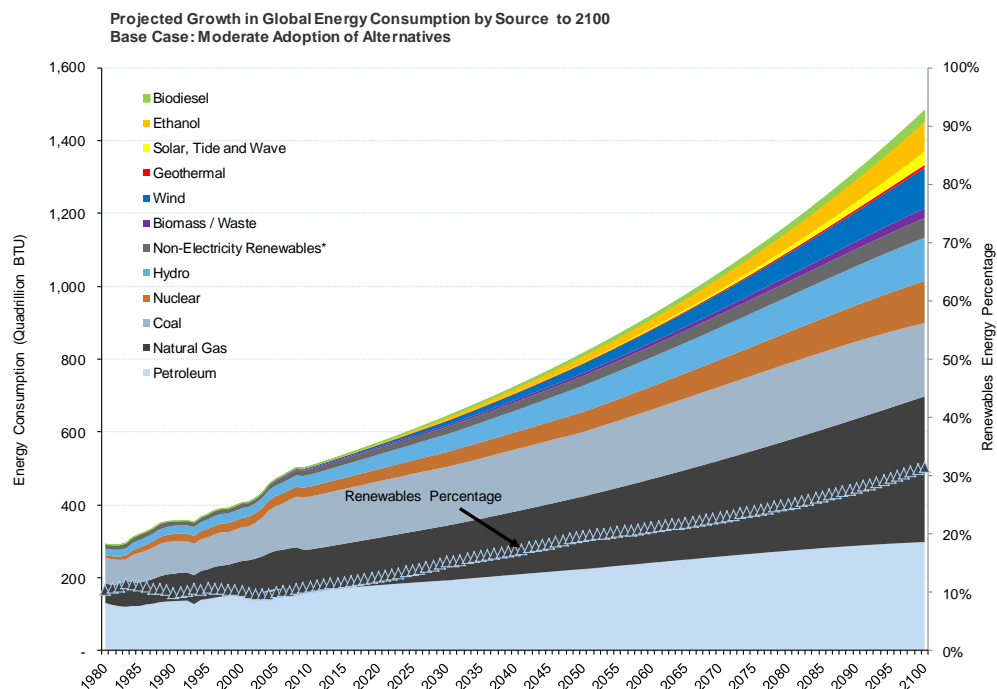


Figure 42. Projected Growth in Global Energy Consumption by Source to 2100
Base Case: Moderate Adoption of Alternatives

Sources: EIA, Earth Policy Institute, AltaCorp Research & Analysis

Note: Renewables Percentage includes Hydro and all other renewables

* Non-Electricity Renewables are those used for heat generation

Figure 43 shows our high case with a more-aggressive adoption rate of renewables where they outpace overall energy consumption with an increase to 47% of total energy consumption in 2100 from 11% in 2009. The absolute amount of renewable energy increases to 701 quadrillion BTUs in 2050 from 55 quadrillion in 2009, which represents an 1,175% increase. In this case we assume some modified growth rates versus our base case depending on the type of renewable energy:

- **Hydro (1.0% 2050-2100)** – We believe that the limited availability of large-scale hydro will mean little or no change in an aggressive adoption scenario.
- **Biomass/Waste, Non-Electricity Renewables (4.0% 2050-2100)** – These renewable resources, with such a large potential resource base, could experience larger growth rates over the latter half of the century given sufficient financial support.
- **Geothermal (3.0% 2050-2100)** – We don't anticipate significant changes in growth under an aggressive adoption scenario, although this could change significantly with the development of improved exploration and development techniques.
- **Wind (3.0% 2050-2100)** – This is the same the year-over-year percentage for 2050-2100 as the base case, but this rapid adoption scenario benefits from the higher adoption rates prior to 2050.
- **Solar, Tide and Wave (6.0% 2050-2100)** – As in the base case, we see the potential for large growth for solar, tide and wave after 2050. Similar to our wind predictions, though, the year-over-year percentage growth is unaltered, but the absolute growth on a year-over-year BTU basis will be larger than under our base case predictions. Note that even though solar, tide and wave has the highest adoption rates they still end up being one of the smallest contributors to global energy in



The next generation of biofuels would drive even higher growth rates.

Ethanol and biodiesel would equate to 104 million barrels of oil equivalent per day in 2100.

The absolute amount of renewable energy increases by 1,175% in 2100 over 2009.

Note the significant drop in coal use and the dramatic increase in natural gas consumption.

2100. This is partially due to these technologies starting at a current base of only 0.04%, so even rapid adoption will have limited compounding results over the century.

- **Ethanol and Biodiesel (4.0% 2050-2100)** – With additional financial support, improved development techniques and a broader acceptance of biofuels, the next generation of biofuels would drive even higher growth rates, beginning to displace more significant amounts of crude-based fuels. In the year 2100, under the high adoption scenario, this would equate to 220 quads of energy or 104 million barrels of oil equivalent per day.

Note on this chart the drop in coal and oil (petroleum) demand later in the century, which is what we, as a global society, want to see so that GHG emissions can be reduced. Also note the ever-growing component of natural gas, which is also good for the world because of its less carbon-intensive nature when compared to oil or coal.

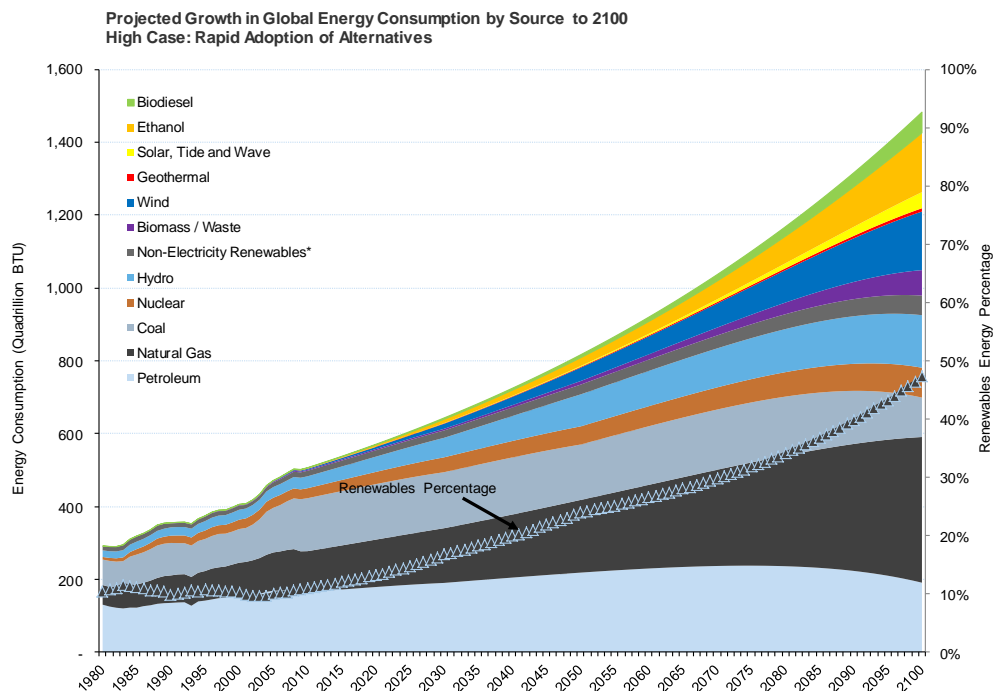


Figure 43. Projected Growth in Global Energy Consumption by Source to 2100
High Case: Rapid Adoption of Alternatives

Sources: EIA, AltaCorp Capital Inc.

Note: Renewables Percentage includes Hydro and all other renewables

* Non-Electricity Renewables are those used for heat generation.

Reducing Greenhouse Gas Emissions – Can we do it?

No.

Our long term analysis does not bode well for mankind's ability to reduce GHG emissions.

That answer may seem flippant, defeatist and/or dismissive, but our long term analysis does not bode well for mankind's ability to reduce GHG emissions. To meet the growing demand for energy on the planet, we will not only need alternatives, but we will also require an ever-increasing amount of hydrocarbon-based, and CO₂-emitting, energy. Anyone who believes we will meet our global climate change targets would require fundamentally different (and, in our view, unrealistic) assumptions than what we have used here. We believe GHG targets currently being discussed are both unrealistic and unachievable. We are not saying that



There are an estimated 1.5 billion people in the world without electricity and about 2.5 billion people without modern cooking or heating fuels.

developed economies shouldn't reduce their energy and hydrocarbon consumption – we must – but that will not resolve the greater issue of a growing global population and increasing per capita energy use.

As the most significant energy consumer in the developed world, the United States' per capita energy consumption has been relatively stable since the 1980s, as shown in the chart below. However, overall consumption from the country has increased with growing population. Figure 44 also shows the per capita energy consumption in China has increased by 3.6 times since 1980 and the growth in population has added 345 million people during the same time period for a total increase in demand of 67 quadrillion BTUs over the time period, or 67% the current amount of energy consumed in the United States. In 2010, the IEA reported that China had surpassed the U.S. as the largest global consumer of energy.

The expected increase in demand from China and other developing countries is significant. Note that there are an estimated 1.5 billion people in the world without electricity and about 2.5 billion people without modern cooking or heating fuels. These individuals want and/or expect to improve their standards of living; meeting these expectations is inextricably linked to increasing global energy consumption.

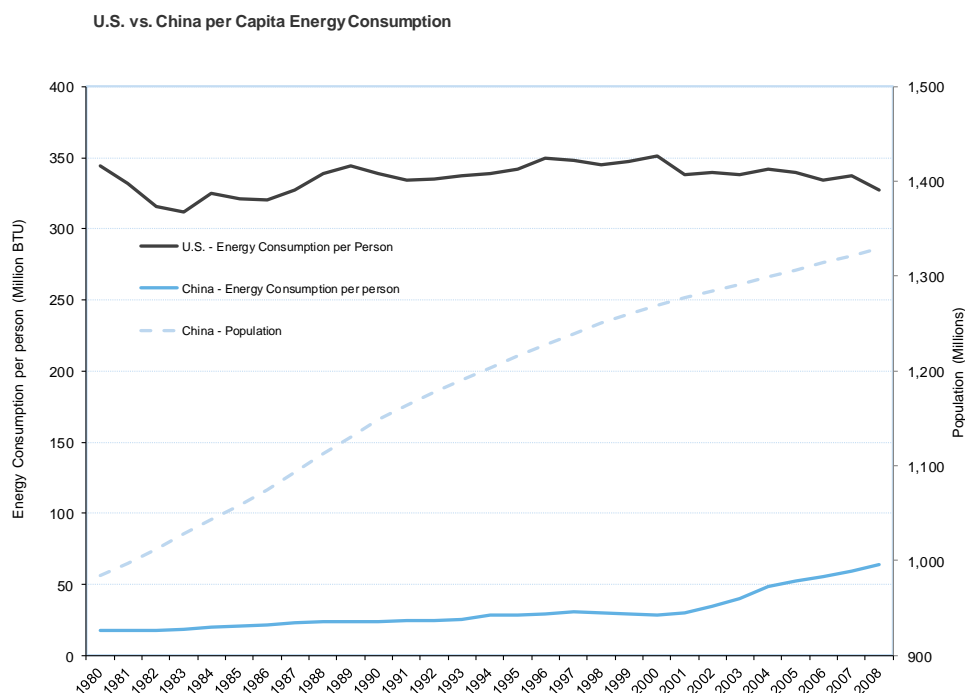


Figure 44. U.S. vs. China Energy Consumption

Sources: EIA, AltaCorp Capital Inc.



The Critical Role of Oil & Gas in a Long-Term Energy Strategy

Renewable energy will become more important as hydrocarbons become more expensive to extract.

Hydrocarbons – especially natural gas – will continue to be central in meeting global energy demand.

We believe that companies leveraged to oil and natural gas continue to offer an attractive long-term investment opportunity. This is particularly the case for companies with long-life reserves and resources such as the oil sands of Canada and non-conventional natural gas. Also, service and infrastructure companies will benefit from this ongoing demand for hydrocarbons. Our comparison of hydrocarbons to several alternatives reveals that the oil sands, conventional oil and natural gas will continue to be developed long into the future and play a critical role in a North American sustainable energy strategy. Renewable energy – harnessing the power of energy sources like the wind and sun – also play an essential role and will become more important as hydrocarbons become more expensive to extract. On many practical and economic measures, however, hydrocarbons are still the best source of energy we have access to at this time.

The diverse nature of the different energy sources also means that from an integrated system perspective it is essential to have a good mix – or portfolio – of energy sources. Each alternative energy source has some inherent limitations, which will place restrictions on their implementation, and hydrocarbons – especially natural gas – will continue to be central in meeting our energy demands.



Suggestions / Recommendations

Improvements or changes could be made in the public debate about energy.

Using an energy-equivalent measure, like the BTU, makes the task manageable and realistic.

There is value to society in having a diverse set of energy sources, distributed geographically.

The development of a new generation of water recycling technologies would be a benefit to both hydrocarbon and biofuel companies.

Most economic activity on our planet is driven by the expenditure of energy. Energy is an essential part of all humans' daily lives, even to those who currently don't have access to electricity or hydrocarbons. Through researching this report we have seen several areas where improvements or changes could be made in the public debate about energy and the move towards renewables. Hopefully these suggestions and recommendations might assist in allowing a more realistic assessment of the global energy circumstance.

Consistency – We Suggest Energy Equivalency

We believe that the debate around energy can be done in a common language; that is, comparing energy sources on an equal – or the “apples to apples” – basis. A consistent methodology is required to properly compare and contrast the various sources of energy. On a global scale, comparing all forms of energy is a huge and complex undertaking, however, using an energy-equivalent measure, like the BTU, makes the task manageable and realistic. An energy equivalency measure will allow consumers, researchers and governments to make informed decisions when evaluating energy projects and energy use.

Refocusing the Energy Debate

Society needs to use our knowledge about the relative strengths and weaknesses of different energy sources to identify the appropriate locations, funding structures (government, industry or private investment) and incentives to develop each energy resource in the most efficient manner. Some examples of this refocused thinking might include:

- **Funding Partnerships** – Technologies that can be developed with returns attractive to industry and private investment, based on a corporate cost of capital, should be funded predominantly by those groups. This would allow more capital-intensive projects that can provide value at a social cost of capital, which would be funded by governments. To achieve this allocation of funding, formal partnerships between government, industry and private investment firms are required.
- **Cost Effective Resource Development** – We believe that every type of energy resource has the potential to be developed in a cost effective manner, but not everywhere in the world. The quality of an energy resource can vary dramatically by country and within different regions in a country. For example, it is clear that in Brazil the development of sugarcane-based ethanol is an efficient and cost effective means to develop liquid fuels. This may not hold true for this feedstock (or others, such as corn) in other areas of the world.
- **Diversity and Distributed Energy Generation** – There is value to society in having a diverse set of energy sources, distributed geographically. The different characteristics of each energy source allow for the creation of reliable and adaptable energy systems when they are used in combinations that can consist of complementary energy sources such as wind and solar, or renewable and conventional.
- **Cooperative Development of Resources and Environmental Technologies** – Companies should be encouraged to cooperate through joint ventures to develop resources and environmental protection technologies including:
 - **Water Recycling** – Conventional hydrocarbon fuel and biofuel companies face challenges with respect to fresh water usage, so the development of a new generation of water recycling technologies would be a benefit to both.
 - **Carbon Capture and Storage** – We believe that there is long-term potential for captured carbon to be viewed as an asset/revenue instead of an expense/liability with the continued development of carbon trading markets, enhanced oil recovery techniques and algae-based biofuels. Perhaps all energy producers (including biofuel companies) could jointly explore techniques for capturing and storing carbon as well as marketing the solutions.



Subsidies – Productive Over the Long Term

Our review of existing subsidy structures leads us to the following recommendations about how subsidy programs should be structured to be productive over the long term:

Subsidies should be given based on cost reductions.

- *Innovation Based Incentives* – Tax incentives or rebates that are awarded generically based on energy source lack the impetus for companies to innovate. As an example, subsidies for solar PV technology are often granted to practically every manufacturer, regardless of their economic efficiency. Subsidies often do not reward innovation because they tend to be higher for higher cost energy solutions (i.e. effectively rewarding them for being high cost). This was the case for oil sands developers where higher capital costs resulted in more royalty reductions. Over time as costs get reduced, the subsidies disappear (i.e. effectively penalizing them for now being lower cost). Subsidies should be given based on cost reductions; for example, the faster you reduce costs the more subsidies / tax credits you receive. Eventually, yes, all subsidies should disappear but the reward / behaviour mechanism needs to be considered.
- *Funding for Research and Development* – More funding for R&D directed at producing lower cost energy sources using conventional alternatives is required (e.g. advances in technology for electrical generation would mean more kWh produced by burning the same tonne of coal or cubic foot of gas and also reduce GHG per BTU.)
- *Subsidies to Create Wider Use of Natural Gas* – These subsidies could encourage the development of new uses for natural gas including GTL, CNG and LNG.
- *Subsidies and Taxes to Reduce Consumption* – This may be one of the cheaper forms of “alternative energy” which could reduce consumption and provide an income stream.
- *Subsidy Balance* – Subsidy programs need to balance energy consumption, in the form of end-use efficiency improvements, and energy production, in the form of energy production improvements.
- *Energy Generic Subsidies* – These subsidies would move towards being based on specific environmental objectives for all fuel types; incentives need to be designed to reward innovation, as well as cost and pollution reductions, regardless of energy type.
- *Subsidy Reduction Over Time* – Subsidy programs need to include mandated reductions over time to ensure that only business models with the potential of long-term profitability would be encouraged to seek subsidies in the first place. This would be similar to hydrocarbon-based subsidies like the oil sands where there is a lower royalty rate initially, but then increase after the operators have recovered their invested capital.
- *Subsidy Aggregation* – Subsidy programs need to be evaluated on an aggregate basis and not implemented in isolation. For example, corn-based ethanol subsidies can be significant when viewed on an aggregate basis. Let’s examine a barrel of ethanol produced by a small ethanol producer:
 - Farmers: \$0.28 cents/bushel of Corn (2002 Farm Act – Direct Payment)
 - Small Ethanol Producer: \$0.10/gallon (Small Producer Tax Credit)
 - Refinery / Ethanol Blender: \$0.45/gallon (VEETC)
 - When these individual subsidies are aggregated, the total ethanol subsidy equates to roughly \$28/barrel of ethanol (or \$46/boe-energy)

Subsidy programs need to include mandated reductions, evaluated on an aggregate basis and not implemented in isolation.



Groups or Individuals Involved in the Energy Debate

There are many groups involved in the energy debate and we have some thoughts / suggestions / recommendations to these groups.

Renewable and Hydrocarbon Energy Producers

There is a clear divide between developers of alternative energy and those involved in conventional hydrocarbon energy production. We believe that increased collaboration between these companies has benefits for all, such as:

Partnerships could promote the sharing of resource evaluation techniques.

- **Sources of Capital and Growth** – Companies in the utility and energy sectors are well capitalized and could serve as reliable sources of funding for alternative energy companies through partnerships and other joint ventures. This funding could be more reliable than government grants, rebates and tax credits, but would likely be driven more by economic feasibility. If shown to be economically viable, the technology and potential resources represented by alternative energy companies could serve as a growth platform for conventional utility and energy companies.
- **Co-Location and Cost Sharing** – Companies in the alternative and conventional energy sectors have the opportunity to share costs by leveraging shared infrastructure and through joint lobbying efforts to governments.
- **Improved Resource Evaluations and Legislation** – Partnerships between conventional and alternative energy components could promote the sharing of resource evaluation techniques. This cooperation would be valuable because legislation associated with the evaluation and publication of reserve and resource data, currently the domain of conventional energy projects, needs to be expanded to include renewable energy sources.

Environmentalists

We respect Suzuki's willingness to engage with industry.

- Environmentalists should follow David Suzuki's lead by being willing to work with industry; as he said to Jim Prentice during a discussion filmed on Haida Gwaii and aired on CBC television in 2010:
 "...it is very easy to be self-righteous when you're fighting: 'we're right and they're wrong, they're bastards and you know' and it's a big shift for a lot of environmental groups and people – including me – to say look, we've got to engage in dialogue. We're not going to make it by ourselves. It's a very difficult thing when you've grown up fighting, to suddenly say 'We've got to reach across'".

We respect Suzuki's willingness to engage with industry and suggest all environmentalists to take this honourable stance, which will allow everyone to get down to work on improving our complex and challenging environmental circumstance.

Some unrealistic forecasts show mankind completely free of hydrocarbons and nuclear energy in just a few decades.

- Some environmentalists forecast how the global society can become completely free of hydrocarbons and nuclear energy in just a few decades. Although this would be an excellent outcome for mankind, we view these forecasts as not being based in reality; they ignore the practical and economic realities about alternative energy. Conversely, if anyone believes *our* assumptions to be unrealistic, we fully encourage input and feedback on our analysis.

Energy Producers

Cooperation between environmental groups and industry must be done.

- Cooperation between environmental groups and industry, in our view, must be done. We suggest that the lead is taken in this effort by environmental groups, because they would be viewed as non-conflicted. This also gives environmentalists, the opportunity to make significant impacts on the industry from the "trenches".



- Fund alternative energy investments and companies, those that have the potential of becoming economically sustainable or those that have a technology that could be integrated with conventional energy operations.
- Donate to reputable environmental causes; especially those who are willing to enter into dialogue with industry.
- Work with government, industry groups and environmentalists to come up with a Canadian Energy Strategy.

Media

- Reduce or eliminate misleading articles that use terms such as:
 - “this leads us to energy independence”
 - “we have the technology now to eliminate our use of hydrocarbons”
- When discussing the benefits of a technology, also address economics and negatives. For instance, cellulosic ethanol can sound like a great solution to replace or offset hydrocarbon use, until the economics are discussed.
- Publish balanced articles that take into account all aspects of various forms of energy.

Individuals

- Reduce personal energy consumption.
- When you buy products that are marketed or considered as “green”, make sure you understand the full life cycle environmental considerations. For instance, if you are buying an electric car ask “where is the electricity coming from?” If the answer is coal, then your electric car is likely making the CO₂ emissions problem worse, not better.
- Donate to reputable environmental causes; especially those who are willing enter into dialogue with industry.

Governments

- When setting subsidies, be clear on the potential long-term viability of the renewable technologies being developed.
- Governments have the capacity to fund broader studies to understand full life cycle economics of various sources of energy sources. A comprehensive and ongoing study would provide the proper basis for making value-added policy decisions.



Conclusion

These realities need to be addressed so that the transition to renewables can be done as easily as possible.

It will be very difficult to meet increased energy demand while at the same time trying to convert to alternatives.

Renewable energy sources are required to create a sustainable energy infrastructure, and we do need to phase out hydrocarbons.

Non-renewable energy resources – hydrocarbons – are the most economic and practical forms of energy available to mankind. Is this sustainable and the most environmentally-friendly solution? No. Do we need to move towards renewable energy sources? Most definitely. We need to move away from consuming hydrocarbons, but there are many realities about renewables that are often ignored. These realities need to be addressed so that the transition to renewables can be done as easily as possible. We believe that the transition to renewables will take much longer and cost significantly more than might be realized.

One of the main reasons replacing hydrocarbons with alternatives will be difficult is because our demand for energy is growing so dramatically. In addition to the continued growth in population, there is an increase in energy demand that goes along with one's desire to increase his/her quality of life. The task of converting to alternatives is a classic case of one step forward and two steps back. It will be very difficult to meet increased energy demand while at the same time trying to convert to alternatives. In our base case adoption of alternatives, we view that by 2050 we see renewable alternatives increasing to 20%, and even with our high case we only see renewables usage increasing to 24% of total energy consumption.

It is going to take open discussions with the public, government and industry to move away from the cost effectiveness of non-renewable energy sources, establish the best method of defining / managing alternatives as well as the positive / negative outputs. An economic reality of energy is that as usage continues to increase, the most cost efficient form is preferable. Another economic reality is that it is expensive to develop sustainable, consistent energy sources on a scale large enough for the masses. The practical realities of energy include the realistic full cycle effects on the environment and society as a whole.

Renewable energy sources are required to create a sustainable energy infrastructure, and we do need to phase out hydrocarbons because of their non-renewable nature. Renewable sources of energy need research and development to help increase their efficiency, and to reduce their environmental footprint. To increase the validity and effectiveness of renewable energy resources, government, industry and individuals are going to have to step up to fund the high cost of these projects.



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Glossary of Terms

Term	Description
Alternatives	In this report we will use the terms alternatives and renewables interchangeably to describe hydro, wind, solar, biofuels, geothermal, biomass, tide and wave energy. Note that we do not categorize nuclear as a renewable or alternative, however, it will play an important role in meeting future energy demand.
Arable land	Land available for cultivation.
Biodiesel	A vegetable oil or animal fat-based diesel fuel usually obtained by reacting the oils/fat with alcohol.
Biofuel	Fuels which are produced from biomass materials; includes bioethanol and biodiesel.
BOE-energy	Barrel of oil equivalent energy – a measure of energy equivalent to that contained in 1 barrel of light/medium crude oil, which is approximately 5.8 million BTU.
BTU	British Thermal Unit – a measure of the amount of heat energy required to raise the temperature of one pound of water by one degree Fahrenheit.
Capacity Factor	Capacity Factor – a ratio comparing the average energy produced over a period of time to the energy that could have been produced at continuous full power operation during the same period
CCS	Carbon Capture and Storage – a series of approaches to capturing carbon dioxide and storing it to prevent it from entering the atmosphere.
Cellulosic	An ethanol biofuel that is produced from wood, grasses, or the non-edible parts of plants.
CH ₄	Methane – a combustible hydrocarbon, but also a GHG if released into the atmosphere with approximately 25 times the global warming potential of Carbon Dioxide.
CO ₂	Carbon Dioxide
Combined Cycle	CC – a combination of engines that convert heat or thermal energy into mechanical energy. The purpose of combining engines is to improve overall energy efficiency by taking waste heat from one engine as an input to other engines.
Compressed Natural Gas	CNG – is a natural gas under pressure, which serves as a substitute for gasoline or diesel fuels. CNG is considered to be an environmentally 'clean' alternative.
Corporate Cost of Capital	This is the 10% rate of return we used that might be expected by private or corporate investors. This number will range due to the required rate of return for various companies, but 10% is reasonable in the current environment.
Discount Rate	An interest rate for calculating present values in discounted cash flow analysis.
EIA	United States Energy Information Administration – a statistical agency of the U.S. Department of Energy (DOE). It provides policy-independent data, forecasts, and analyses.
Ethanol	An alcohol obtained from the fermentation of sugars and starches or by chemical synthesis (a.k.a. ethyl alcohol)
FFV	Flex Fuel Vehicle
Feedstock	The starting (raw) materials (e.g. grains, oils, etc.) used to create biofuels / manufacture a product
Fission	The process of splitting a large atom into two or more smaller ones.
FAO	Food and Agriculture Organization of the United Nations



Full Life Cycle GHG	Taking into account the emissions related to extraction, transport, refining and final combustion by the end-user.
Gas to Liquids	GTL – is the process of converting natural gas to gasoline or diesel.
GHG	Greenhouse Gases – three of the most often discussed greenhouse gases in energy research are: Carbon Dioxide (CO ₂), Methane (CH ₄) and Nitrous Oxide (N ₂ O)
GW	Gigawatt
GWh	Gigawatt hour
Hydrocarbons	A class organic compounds that contain both hydrogen and carbon. Within the context of this report hydrocarbons generally refers to a subset of those compounds used as an energy source (Oil, Natural Gas and Coal).
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle – a power generation technology which allows for reduced emissions and improved fuel efficiency of coal plants. Sometimes referred to as a “clean coal technology”.
IEA	International Energy Agency
Maize	Used in scientific, agricultural and formal usage; known as more broadly as corn.
mcf	A measure equivalent to one thousand cubic feet.
mmBTU	One Million British Thermal Units
MW	Megawatt
MWh	Megawatt hour
N ₂ O	Nitrous Oxide - A GHG with approximately 300 times the global warming potential of Carbon Dioxide.
NO _x	Oxides of nitrogen
Non-renewables	Synonymous with Hydrocarbons
NREL	National Renewable Energy Laboratory. This is a U.S. federal laboratory dedicated to renewable energy and energy efficiency research and development.
NPV	Net Present Value – the sum of the present value of a series of individual cash flows.
OPEC	Organization of the Petroleum Exporting Countries
Pulverized Coal	A fine powdered form of coal (a.k.a. powdered coal)
PV	Photovoltaic – A process of generating power by converting solar energy into electricity using semiconductors.
Quadrillion	One thousand million million or 10 ¹⁵ . A quadrillion BTU is approximately equivalent to the energy in 170 million barrels of oil.
Renewables	In this report we will use the terms alternatives and renewables interchangeably to describe hydro, wind, solar, biofuels, geothermal, biomass, tide and wave energy. Note that we do not categorize nuclear as a renewable or alternative, however, it will play a role in meeting future energy demand.
SAGD	Steam Assisted Gravity Drainage – a process to produce bitumen without mining. The upper of two horizontal wells injects steam into the producing zone, creating a high-temperature steam chamber in the formation. The heat melts the thick bitumen which allows gravity to assist it to flow freely to the second horizontal well below.



Silicon	A non-metal with semiconducting properties, used in the production of solar cells and solar photovoltaic
SO ₂	Sulphur Dioxide
Social Cost of Capital	This is the rate of return that would be used by governments and economists to determine the value of investing in social projects like energy. In this report we use a 3.5% rate.
Solar PV	Solar Photovoltaic – converting solar radiation into electricity using semiconductors
U-235	Uranium-235 – an isotope of uranium that can sustain a fission chain reaction.
Unobtainium	From Wikipedia: Since the late 1950s, aerospace engineers have used the term “unobtainium” when referring to unusual or costly materials, or when theoretically considering a material perfect for their needs in all respects, except that it does not exist.
USDA	United States Department of Agriculture – an agency of the U.S. government responsible for developing and executing policy on <u>farming, agriculture, and food</u> .
VEETC	The U.S Volumetric Ethanol Excise Tax Credit (U.S.)
WTW	Well to Wheels. A life cycle assessment technique for oil and natural gas energy.
Yield	In this report yield refers to ‘crop yield’ which a measure of the agricultural production or output per unit area of land



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