Opportunities and perils of natural gas usage on the road to renewables

Ben Harack

•

Kyle Laskowski

August 2011

Table of Contents

What is Vision of Earth?

Vision of Earth is a volunteer group comprised of university students and graduates from a variety of fields. We have taken on the task of using our technical skills to deeply investigate various issues that face our society today.

We attempt to write about these subjects in a manner that is understandable and accessible for the general public. We tend to focus on complex and controversial issues that demand patience and knowledge to understand.

All of our publications are accessible through our website www.visionofearth.org.

The Goal

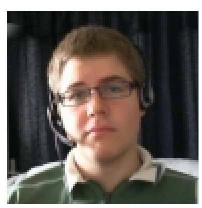
Since its creation, the overarching theme of Vision of Earth has been efforts towards the positive development of our society. We firmly believe that improvements in human quality of life can come about by making well-informed decisions today.

The Vision of Earth Project attempts to take the knowledge that humanity has collected and connect it with the practical challenges that face our society

Authors

Ben Harack
A graduate of the University of Regina in computer science, mathematics, physics, and psychology, Ben has dedicated his volunteer time for the last several years to studying the challenges faced by human societies. This volunteer work has led him to the edges of his academic disciplines and beyond.

ben.harack@visionofearth.org



Kyle Laskowski
A graduate from the University of Regina's Honours Physics program, Kyle has long held a deep interest in large-scale energy systems. Pursuing this interest has led him towards study of the political, economic, and social realities of societies and how they relate to the application of technical solutions.

kyle.laskowski@visionofearth.org

While the title of this publication is the *Renewable Energy Review*, today we are going to talk about natural gas - a distinctly non-renewable energy resource. Why are we doing this? The reason is simple: *It has become increasingly clear to us that natural gas is going to play a major role in global energy systems for several decades to come.*

Today, the transition away from fossil fuels towards renewable energy resources is already underway. However, all of the best authorities on the subject agree that this process will not be completed overnight. A wholly renewable energy grid, even in just the developed nations, will take at least a few decades to build.

Here we will discuss the particular properties of natural gas that make it the fuel of choice to interim generation during these key periods of transition towards renewable sources. We will attempt to give our readers an understanding of the broad issues surrounding the accelerating use of natural gas in our world.

What is natural gas?

Natural gas is a gaseous fossil fuel, extracted from deposits in the earth using techniques somewhat similar to those used to recover oil. Natural gas primarily consists of methane, one of the simplest hydrocarbons.

Since the natural gas wells are often remote, there can be vast distances between the point of extraction and where the gas will be stored or used. Continent-spanning networks of pipelines carry the gaseous fuel on these journeys.

Undesired constituents of raw natural gas such as sulphur, water vapour, and carbon dioxide must be removed prior to usage to produce a high quality combustible fuel.

Non-renewable extraction

Natural gas can often be found along side other fossil fuels. Thus many natural gas wells exist near oil shale and coal beds. As with all resource exploration, new techniques have been developed over the years to find and develop deeper, smaller, and more remote reservoirs.

The story of the history of natural gas exploitation is much the same as that of other fossil fuels and resources. It was initially found along with other desirable products such as coal. It proved to be a cheap and plentiful source of energy in its own right. Development sped up over the years as many uses were found for natural gas in areas such as fertilizers, electricity, and home heating.

Just like all other nonrenewable natural resources that humanity has tapped into, natural gas has become harder to find and harder to access over time. We have depleted many of the easiest to access reservoirs and are now searching farther afield to meet our growing demand.

Natural gas extraction is a major discussion point today. The advent of hydro fracturing or 'fracking' has led to rapid growth in both the extraction industry and its environmental effects. Debates are currently raging around the world as to the safety of this technique. We will look at the fracking debate in more detail later in this piece.

Renewable sources of natural gas?

Curious what we literally mean by 'renewable'? Check out our piece about what renewable really means.

Renewable sources of combustible gases exist. These gases are not identical to natural gas, but they share many of the same primary properties. As an example, biogas is composed of methane, hydrogen, and carbon monoxide. Biogas can be produced from a variety of sources, refined, then used in a manner almost identical to natural gas.

How can we make biogas? Almost any system that decomposes (in the absence of oxygen) produces a form of biogas. Thus, there are a variety of potential renewable sources we might tap into. Systems have been set up to harness biogas from animal waste, landfills, and waste water treatment plants to name a few. Cleaning these biogases up to natural gas purity can be a challenging and costly technological effort.

Natural gas prices have historically been quite low. This has hampered the development of renewable gas sources in the past. Today we live in an age of somewhat uncertain natural gas prices and a cultural shift towards green technologies. Biogas is currently seeing accelerated development in many areas of the world as the price of natural gas climbs higher. Additionally, biogas utilization has the advantageous side effect of converting a potent greenhouse gas (methane) into much less potent ones (water and carbon dioxide), and generating usable power in the process.

It would be wise for our society to economically encourage the maturing of various biogas technologies so that a cost effective alternative exists in the near future when natural gas supplies will be falling further behind demand. As demand continues to grow, and extraction becomes more difficult, prices are definitely going to climb. A major question facing our society will be whether we will choose to be ready to make a smooth transition to a renewable fuel gas or a suitable substitute such as electricity produced from renewable sources.

Why is it so important?

Natural gas is used to heat millions of buildings in North America alone. About half of US households get their heating energy from natural gas[1]. In Canada the number is around 56% of all households[2].

The world's supply of ammonia fertilizer is heavily reliant on natural gas for its low cost production. This fertilizer is primarily produced through the Haber-Bosch process which process utilizes about 3-5% of world natural gas production and is responsible for feeding approximately 40% of the human population[3]. Therefore, a cheap and abundant natural gas supply is a cornerstone of humanity's food production system.

In short, it is clear that natural gas is currently responsible for keeping large portions of humanity fed and warm.

Natural gas is also seeing increasing use in the area of electricity production.

[1] NaturalGas.org: Residential Uses. Accessed June 17th, 2011.

[2] The ways we heat our homes. Statistics Canada. Accessed June 23rd, 2011.

[3] "We can thus conclude that the Haber-Bosch synthesis now provides the very means of survival for about 40% of humanity." Nitrogen and Food Production: Proteins for Human Diets. Vaclav Smil. University of Manitoba. Accessed June 18th, 2011.

We will now discuss in some detail why natural gas has been so popular recently for new power plants.

Interim power source

While transitioning to a larger share of renewable, clean power sources, we will likely be using natural gas more heavily than ever before. Why is this so?

For those so inclined, a previous issue of the Renewable Energy Review was written about all of the important properties of power system technologies. This is a highly recommended read for anyone interested in attaining a solid understanding of electric power systems in general.

A proven technology

Natural gas turbines are an existing and proven power production technology. They have been adapted to a variety of scales, from small district heat and power systems to multi-megawatt turbines capable of providing a large portion of the grid power.

Low Cost

When compared to other sources of power, natural gas turbines tend to have the lowest setup cost. A turbine can also be purchased and installed in a matter of months, making natural gas one of the fastest power systems to set up.

The majority of the cost of natural gas power comes from the cost of the gas itself. This makes the cost of power highly dependent on the daily, monthly, or yearly price of natural gas. Many power companies will own and operate natural gas storage facilities so that they can avoid some of this price uncertainty.

Cost-effectiveness is not true everywhere. The costs of transporting natural gas long-distances can be very substantial. Natural gas is quite expensive in California for instance. We discuss the particular situation in California in much more detail later in this piece.

The cost effectiveness of natural gas power has another major limitation. The turbines that can respond quickly to demand (which we discuss in the next section) are inefficient compared to their slower-responding brethren. This means that their cost of operation can be very high for a given amount of power. This typically means that natural gas peaking power generation cannot compete very well in terms of cost against established hydroelectric power if it exists locally.

Dispatchable power

Natural gas power can be implemented in such a manner that it can be ‘turned on’ in a relatively short amount of time. Thus natural gas power is regarded as being ‘dispatchable’. In another piece we go into a lot of detail about why dispatchable power sources are so important and the many niches that need to be filled in a functioning grid.

In short, natural gas power is there when you need it.

However, as we mentioned earlier, the natural gas turbines that can turn on and off the fastest are the ones that are the least efficient. That is, they produce less electricity from burning the same amount of natural gas as their slower-responding cousins. Turbine designs thus face an inevitable trade-off between responsiveness and the price per unit of energy produced.

Natural gas power plants are designed to fill particular roles in the power grid. There is a lot of flexibility with regards to what those roles can be at the design stage. However, once a plant is built and operating, it is essentially locked into its role. This is why natural gas power plants need to be designed carefully, keeping in mind the nature of power that they are expected to provide.

Less C02 emission than coal

Power production using natural gas produces 45% lower carbon emissions than coal per unit energy. This is because coal is almost pure carbon while natural gas contains a lot of hydrogen in addition to carbon. Both of these elements combine with the oxygen in the air to produce energy as they burn.

These lower C02 emissions are an important reason why natural gas has been an attractive choice in the developed nations as the evidence of climate change continues to mount. Readers interested in the climate change debate may be interested in the climate change section of our deliberate societal change publication.

Cogeneration / waste heat

Since natural gas power is thermal in nature, it produces a lot of waste heat. This waste heat cannot be effectively used for more electricity production, but it can be economically used for heating buildings and running industrial processes. This use of 'waste heat' for productive purposes is known as cogeneration, and it is possible with all thermal power plants including coal, nuclear, solar thermal, biomass, biogas, and geothermal.

Storage

It is very hard to store electricity. This is such a difficult and important problem that we devoted an entire issue of the renewable energy review to looking at why energy storage is useful.

Natural gas can be stored rather easily in certain geological formations (including those from which natural gas was first extracted). It can then be piped out and used when it is needed. This is a form of energy storage.

Natural gas can be extracted throughout the year and stockpiled for use during times of great energy need. This is currently the case during the winter in North America for example. During this time, natural gas is burned much faster than it is extracted.

Synergy with renewable power sources

One of the key weaknesses of renewable energy is the highly variable nature of wind and solar energy production. For more information, see our renewable energy review issue on the variability and dispatchability of renewable energy sources.

Some of this variability is relatively predictable such as daily tides, daily / weekly wind forecasts, monthly river flow estimates, or annual direct sunlight. Each resource has its own level of predictability.

Similarly, different forms of electricity demand (such as heating, lighting, or industrial usage) can be somewhat unpredictable on different time scales. Uncertainty both in supply and demand of power is currently met primarily using dispatchable power sources, such as natural gas turbines.

The flexibility of some natural gas power plant designs allows them to fill in when renewable energy sources are producing low amounts of power. A popular version of this is the idea of leveraging dammed hydro to use wind power.

Additionally, natural gas can be used in conjunction with heat-based green power systems like biogas, biomass, or solar thermal. Solar thermal can provide the heat to run a power plant during times of steady sunshine. When the sun is hidden by clouds, or at night, natural gas heating can kick in to keep the power production smooth and steady. These 'solar-gas' power plants may soon be widespread in the sunniest regions of the globe.

The fuel supplies for biomass/biogas can be somewhat uncertain. If natural gas can affordably fill in the gaps in their supply, then biomass/biogas power plants will be possible in many more locations than they are currently. This increased reliability would certainly also help with the acquisition of venture capital for these renewable projects.

We are fortunate that natural gas power has a healthy mix of the advantages of coal power and strong synergy with renewable power sources.

Better than coal, but...

Better than coal isn't saying much. Of all major electricity production systems in existence, coal is the most damaging to humans and ecosystems. For a more complete picture of this subject, see our piece about just how bad coal really is.

We will now begin to look at some of the major downsides of our societal shift towards natural gas.

In the next section we will attempt to spell out a number of adverse effects that we think should be considered when a natural gas power plant is being proposed. It is important to note that many of these are systemic rather than local concerns. A single natural gas power plant in one place might not pose that much of a problem either locally or regionally. However, a national or international shift towards natural gas as a fuel for electric power generation will create a number of major problems and exacerbate others.

Volatile prices

Before dealing with some of the other effects of our increased natural gas usage, we will first discuss the volatility of natural gas prices. A variety of factors contribute to the instability of natural gas prices. One of the more obvious ones is **weather**. A cold snap across North America could increase demand immensely in only a few days.

Pipelines are another important concern. If a region begins to demand more than the capacity of the pipelines into that region, then the price can skyrocket. A rather telling example is that of California in the last dozen years or so. In 1999, California produced about 50% of its electricity using natural gas. In 2009, it produced 60%![4] Now, take a glance at these natural gas prices in California over the last couple decades. You can see the cost of a standard unit of natural gas (1000 cubic feet) go from between $2 and $3 in the late 1990's to $6 to $8 in 2004-2008.

This is a rather spectacular change in price for a major commodity. Demand was going up and the pipelines did not have the capacity to match. It is important to note that the California example is not a small incident. California has a population of about 37 million people and is the 8th largest economy in the world.[5] What happened to California can also certainly happen to other regions with limited local resources and a constrained ability to import.

The high volatility of natural gas prices in Canada is also startling. Canada produces far more natural gas than it consumes. In Canada, the most major issue is its extensive connections to other markets. Much of this natural gas is exported to the United States for their heating and electricity needs. A relatively small change in demand in the United States is likely to mean a relatively large change in the amount of natural gas that Canada can export. Thus demand volatility is driven to a great extent by the price volatility in the much larger market of the United States.

---

[4] US Energy Information Administration. California State Electricity Profile 2009. Accessed June 19th, 2011.

[5] MSNBC. Sorry Arnold, California isn't sixth any more. Accessed June 19th, 2011.

Staying warm

We mentioned earlier that natural gas is already used very heavily for heating buildings. Extensive infrastructure already exists to deliver it directly to most of these buildings. If natural gas prices are pushed high(er) by electricity production, then it may hasten the end of the usefulness of this infrastructure. We must be aware that this is a definite effect of greater use. Greater demand of a resource with a constrained supply leads to an increase in price of the resource.

North America is currently importing some liquefied natural gas from overseas to serve current demand on this continent.[6] The price is likely to go up quite a bit if demand continues to increase quickly. Home heating will become more expensive. The brunt of this cost increase will be felt by the people who live in the coldest climatic zones of North America. Similar problems exist in some other regions of the world such as Europe.

As natural gas becomes more and more expensive, using it to heat buildings becomes less and less economical. This can create an additional burden on those regions that are heavily reliant on it for heating. Transitioning to a different form of heating is expected to be quite costly. This transition will likely be extremely expensive as well as disruptive to the economy. Unless another cheap gaseous fuel can be produced in spectacular quantities, there will have to be substantial new infrastructure to handle the form(s) of heating energy intended to replace natural gas.

Even if there is simply a transition towards electric heating, there will be very substantial costs. Most cold regions of North America utilize a lot of natural gas heating currently, so their electric grid connections are not currently designed to handle the tremendous additional electrical load needed to heat homes in addition to powering them. Upgrading power transmission infrastructure tends to be very expensive. Also, this transition would increase demand for electricity immensely. This is a non-trivial problem in its own right, and an extremely expensive one at that.

We are consuming the natural gas that is easily recoverable. Burning even more

[6] The natural gas in North America : USA, Canada, Mexico. Thomas Chaize. Accessed June 19th, 2011.

of it to produce electricity will hasten the end of cheap natural gas. We as a society may want to think long and hard about what we plan to do about heating our homes a few decades from now.

Compound effects

Because natural gas is a such a popular form/source of energy, increases in its price will cause compounding effects on the prices of other vital goods and services. For example, the prices of natural gas and electricity are correlated. When natural gas prices spike, people consider using electricity for heating instead. However, since much electricity is derived from natural gas (more in some regions than in others), then the cost of this heating substitute goes up as well.

We see similar effects in the world economy when one of the world's other major energy sources increases substantially in price, oil. Because the world transportation infrastructure is so highly dependent on oil, increases in the price of oil drive up the cost of everything that relies on our cheap globalized economy. Not only does the price of shipping plastic goods from Southeast Asia increase, but the cost of raw materials used to produce those goods increases as well. Therefore, an increase in the price of one important form of energy can have an alarmingly inflationary effect on prices in general.

In Canada, very large amounts of natural gas are used to heat bitumen in the Alberta oil sands project. A rise in natural gas price would cause an increase in the cost of oil produced through this method. This could lead to a rise in oil prices in North America that will lead to a corresponding rise in fuel prices.

If the price of natural gas were to rise sharply the price of your electricity, your home heating, your car fuel, and your food would increase as well. These are likely outcomes if our society continues to rely more and more heavily on natural gas in the coming decades.

Geopolitical concerns

Many areas of the world do not have substantial domestic natural gas resources. Some of these, such as the United States and Europe, do not extract nearly enough natural gas to meet their domestic needs. These places need to import substantial amounts to meet their demand. Due to this effect, a number of nations and regions are gaining increased geopolitical influence through their control of natural gas exports.

North America

The United States currently imports natural gas from a number of places including Canada, South America, and the Middle East. North American supply is increasing (thanks mainly to fracking, discussed below), but it is not expected to meet the rapidly growing domestic demand. It is expected that overseas imports will increase to around 11% of all natural gas consumed in North America by the year 2020.[7]

Europe

Another important geopolitical situation is that of Europe. About one quarter of Europe's natural gas comes from Russia.[8] On Jan 1st, 2009, Russia cut off shipments to Europe. Note that this date is during the European winter, so temperatures were quite cold across the region. Thus gas demand was quite high and inflexible - people don't like being cold! This move set off a series of intense negotiations and technological scrambles as Europe desperately tried to make ends meet. This situation highlighted the tremendous bargaining power that Russia now wields over the EU in particular.[9] [10]

Interestingly, many predictions state that European reliance on Russian natural gas will continue for at least a decade. European domestic production is expected to fall while demand continues to rise. It is also worth noting that Europe draws a tremendous amount of natural gas out of Northern African countries like Algeria. The future of natural gas in Europe appears to one of high prices driven by demand that far outstrips domestic production. It is expected that their supply will rely heavily upon overseas trading as well as Northern Africa, the Middle East, and Russia.

---

[7] Natural Resources Canada. Canadian Natural Gas: Review of 2007-2008 & Outlook to 2020. Accessed June 21st, 2011.

[8] The Oil Drum. The European Gas Market. Accessed June 21st, 2011.

[9] USA Today. Cutoff highlights Europe's reliance on Russian natural gas. David Lynch. Jan 8th, 2009. Accessed June 21st, 2011.

[10] MSNBC: Europeans shiver as Russia cuts gas shipments. Jan 7th, 2009. Accessed June 21st, 2011.

Hard to replace

If we are going to invest spectacular amounts of money in heating, industrial, and electric power infrastructure, we definitely want to use it as long as we can. It seems reasonable to assume that some of the natural gas infrastructure that exists today will outlive the era of affordable natural gas. In a few decades time, natural gas will no longer be a cost-effective solution for all of the things we currently use it for.

What will we replace it with? Ideally we would have a fuel that is very similar so that we could use much of the existing infrastructure. Biogas is certainly a candidate for this job, but it is very unclear how much biogas we are capable of producing, and how cost-effectively it can be done. On a planetary scale, if we are limited to current technologies then it does not seem possible for biogas to literally pick up where natural gas leaves off. We consume too much natural gas to feasibly replace it with any similar gaseous fuels that we can make today.

Monopoly corporations

The middle steps of the natural gas system (refinement and distribution for example) are controlled by a few corporations. In most locations, natural gas pipelines are a natural monopoly. That is, it is infeasible for there to be multiple players on the market. The costs of building and maintaining a pipeline network are simply too high for redundant infrastructure to be feasible in most places. Only in densely populated or highly industrialized areas is there genuine competition among pipeline networks.

This centralization of power can be problematic. The energy industry is often very carefully regulated to ensure that natural monopolies cannot overly misuse their power. However, the push for deregulation has in some cases been successful. Deregulated energy markets are the prime cause of some major problems such as the California energy crises of 2000-2001. In these situations, corporations exploited the weak regulation to make enormous amounts of extra money off the society that they were supposedly serving. In a practical sense, it is very clear that the California crisis cause enormous damage to the Californian economy and inconvenienced tens of millions of people.

Dangers of Production

Natural gas kills more people per unit energy than wind, solar, and nuclear, but far fewer than coal and oil.[11] These statistics include workers and civilians who die in accidents as well as members of the general public who die from pollution. While the claim 'better than coal' can still be made, it can be sobering to think that our energy system choices have a fairly predictable effect on the number of deaths that our energy system as a whole will cause.

Fracking

Much of the recent increase in natural gas production can be attributed to the exploitation of new drilling and extraction techniques. Primary amongst this new set of technologies is hydro-fracturing, or 'fracking'.

Natural gas in the ground is often found to be bound up in disconnected, non-porous rock formations. Some of these pockets are quite large but most are small. Natural gas drilling has traditionally targeted and extracted from these large, economically attractive reserves. Hydro-fracturing is used to connect these small pockets and increase the amount of natural gas that can be extracted from a single site.

Hydro-fracturing is the pumping of water, sand, and a variety of chemical agents at high pressure into a natural gas site. The rock formations shatter and pockets connect, allowing for the natural gas to flow more easily. The natural gas can then be extracted more economically and for a longer time. Sometimes this is done at new sites, and sometimes at natural gas extraction points that were previously abandoned as uneconomic due to the geological properties of the remaining reserves. With hydro-fracturing, new and old reserves alike can produce large quantities of natural gas in addition to the gas that could be extracted conventionally..

So, hydro-fracturing sounds awesome!

Not quite, there are a number of major concerns about its use.

[11] Lifetime deaths per TWH from energy sources. NextBigFuture. Accessed June 23rd, 2011.

Concerns

A number of communities and citizens in areas near hydro-fracturing sites have complained that the process is contaminating their land, streams, rivers, and aquifers. It is claimed that this contamination consists both of hydro-fracturing chemicals, as well as natural gas itself.

Legally, it has been claimed that whether or not contamination is occurring is a moot point in the United States. The Safe Drinking Water Act of 2005 contains a loophole, sometimes called the "Halliburton Loophole" which stripped the EPA of its authority to regulate hydraulic fracturing. The regulatory battle over fracking bears many similarities to the current regulatory battle over coal fly ash in the United States. These regulatory wars could be summarized as follows:

> *Relatively weak regulation of the byproducts of fossil fuel extraction, refinement, and usage is creating a situation in which long-term harm is being done to both human and ecosystem health. Some of the more obvious problems are contaminated water and air as well as giant quantities of fly ash. On the economic end of things, this lack of strong regulation acts as an effective subsidy for these industries since they do not have to pay for the full 'costs' of their activities. These costs will continue to be paid in human lives, health bills, and ecosystem destruction now and into the future.*

Here we will try to focus on the relevant physical concerns and not the broader governmental and regulatory issues that have prevented effective regulation of fracking. We plan to discuss this subject in much more detail in a future publication.

The process of contamination

Natural gas and the chemicals used in fracking are contaminants for drinking water. However, this has been particularly difficult to prove (in the case of the fracking chemicals) because drilling companies claim that their mix of chemicals is proprietary knowledge, therefore they refuse to divulge the list and proportions of chemicals used. Despite this, studies have been conducted on contaminated water, looking for distinctly man-made pollutants. This process has been aided by some court cases which have forced drilling companies to reveal some information about what chemicals they use in their formulas.

Drilling companies also claim that it is impossible for these chemicals to migrate from the deep reservoirs where they tap natural gas into the near-surface aquifers used for drinking water. Despite there being some practical merit to these claims, there are some good reasons to believe that contamination is possible. Conventional drilling does not generally shatter large quantities of rock and rupture the barriers between sealed underground formations. Hydrofracturing however does both, so it is reasonable to expect that the dangers of groundwater contamination are much higher than with conventional techniques.

Natural gas reserves are generally far below the fresh water aquifers used for drinking water supplies. Hydro-fracturing can affect these aquifers in at least two ways:

1. The fracturing process can create routes by which natural gas can migrate upward through other rock formations into the aquifer.
2. As with all natural gas wells, poor cement work can sometimes allow natural gas to migrate back up the original well shaft. Even if the drillers produce the first and only connection between these deeper gas-bearing formations and near-surface aquifers, this connection can form a migration path for natural gas to enter the aquifers.

Conclusion

A perceptive reader will have noticed that one of the underlying themes of this piece has been cautioning against over-investment in natural gas infrastructure. Shifting a large proportion of our energy demands onto natural gas is not a long-term solution and it is likely to cause a number of major problems. Instead, we should make wise use of our natural gas resource in transitioning towards long-term energy solutions. With intelligent use of the natural gas that remains, we should be able to transition relatively painlessly into a renewable energy future.

Natural gas can be a useful platform that will help us build the next generation of energy infrastructure. A wholly renewable energy grid is the only true long-term solution, and that is where we must aim with our policy decisions.

If we fail to take note of these burgeoning problems with regards to our increasing reliance on natural gas, we will be driving our society towards a painful and costly period of rapid and intense adjustment that will destabilize almost every aspect of our lives. It is our firm belief that these concerns should lead our societies to begin actively planning for the end of the age of natural gas and how to gracefully incorporate it into our transition towards renewable energy sources.