Executive Summary

Over time the governments, regulators and utilities have largely figured out a way to provide reliable and affordable electricity. But now they must also figure out a way to make electricity low-carbon while still maintaining reliability and affordability. This paper lists the main challenges and provides a roadmap for overcoming these challenges.

The most common types of low-carbon electricity generators are powered by nuclear energy, renewable natural gas, water, sunshine or wind. Some jurisdictions like Alberta do not have nuclear, renewable natural gas or large water powered electricity generators however many sunshine or wind powered ("green" thereafter) electricity generators have been built and many are in the works. Even when we have sufficient amount of green generators, we cannot count on them for two reasons: (a) producing enough electricity in every hour of every day, and (b) sudden large swings in electricity production.

There is no sunshine at night and reduced sunshine on cloudy days. And while wind patterns are not as obvious, there is a seasonal or daily pattern at most locations. This means we may run out of electricity in some hours of some days. With climate change, it is possible that the locations that are sunny or windy now may not remain so and we may run out of electricity for many days altogether and not just some hours. Currently coal and natural gas powered generators cover up this hourly or daily shortfall.

Electricity is unique in that it travels at the speed of light which means that its generation and use must be balanced every second. Any imbalance lasting even a few seconds could damage both generators and devices that are using electricity. When green generation increases or decreases rapidly, other generators must respond in the opposite direction within seconds. At present natural gas powered generators provide this real-time response for the most part.

This means to get uninterrupted and reliable electricity, we would have to pay the costs of coal and natural gas powered generators in addition to the green generators. This doubling down doubles the electricity bill, generally speaking. Even more troubling, if natural gas use is prohibited or made prohibitively expensive via carbon tax etc. we would have to turn to even more costly alternatives such as batteries which could quadruple the bill.

Is not there a cheaper way to complement the green generators? Yes there is: all of us working together as one giant generator i.e., Distributed Energy Management (DEM). We use electricity in many ways: fridge, stove, washer, dryer, air conditioner, space heater, TV, microwave oven, toaster, computer, light and perhaps even electric vehicle (EV). What if we could manage our electricity use up or down to match the green generators? Since DEM uses all these existing devices at our home it does not add much costs.

While this idea has been around for some years now, it has not been pursued seriously. The main barrier was lack of technology that could take us from limited demand side management to DEM. With mesh networks, powerful computers, big data, block chain and artificial intelligence, DEM is not science fiction anymore. In fact DEM is already operational in a few places. Not discounting the effort required, we do not have to invent or develop, we just have to adapt and apply DEM to our jurisdiction.

Other notable barrier is some aspects of the legal and regulatory framework. Government, regulator and industry collaboration can make short work of this barrier. This collaboration would be similar to one in Alberta in the 1990s that created the framework which has delivered generally good results. If we could do it then, we can and must do it now. Fortunately Alberta can still call upon folks who created the framework and who can now guide the next generation in creating the framework for the future.

What would it take to have low-carbon, reliable, AND affordable electricity?

Over the last many decades the governments, regulators, and utilities have largely figured out how to provide reliable and affordable electricity. The first challenge to this established order was the advent of the market for electric energy and in some cases electric generation capacity. We would discuss this challenge in detail in a subsequent post. The second and more recent challenge to this established order is the codified or uncodified requirement to reduce or eliminate the emission of green-house gases like the carbon di-oxide. This post lists these challenges and provides a roadmap for how these challenges could be overcome.

1. Reliability challenges of transitioning to low-carbon electricity

Transitioning to low-carbon electricity creates significant reliability challenges. These challenges have been well documented so we will just touch on them at a high-level in this post.

The most common types of low-carbon electricity generators are powered by nuclear energy, renewable natural gas, water, sunshine, or wind. We would focus on sunshine and wind powered generators in this post since they make up a vast majority of what is being developed and built. We plan to cover the challenges facing nuclear, renewable natural gas, and water powered generators in a subsequent post.

1.1. Adequacy (i.e., availability)

As Alberta recently experienced, we cannot count on sunshine or wind. When sunshine or wind is not available we may not be able to produce enough electricity to meet our needs.

a) Short-term

There is no sunshine at night and reduced sunshine on cloudy days. While wind patterns are not as obvious, in most locations there is a seasonal or even a daily pattern. In the short-term this means we may run out of electricity in certain hours on certain days.

b) Long-term

With climate change it is quite possible that the locations that are windy or sunny now may not remain so. This risk has a small probability but very high impact. If the wind or sunshine is reduced for a longer-term such as a season, year, or decade, we may run out of electricity for many days and not just in certain hours.

1.2. Swing (i.e., ramping up or down)

Electricity is unique in that it travels at the speed of light which means that its generation and demand must be balanced every second. Any imbalance lasting even a few seconds would likely damage both generators and many devices that are using electricity. In comparison we likely would not notice an imbalance lasting many minutes to even an hour in natural gas or water services.

When the sun sets or sunshine is covered up by clouds, snow, or dust etc., electricity production of the solar powered generators drops sharply. Similarly when the wind stops blowing or slows down considerably, electricity production of the wind powered generators drop sharply. This sudden drop in electricity production (i.e., ramping down) must be countered within a matter of seconds to minutes. A similar problem in the other direction arises when the sunshine or wind ramps up sharply.

2. Affordability challenges of transitioning to low-carbon electricity

The cost to incorporate low-carbon electricity generators into the existing electricity systems is material for many reasons. Following explains why electricity bills are going to increase for the next few years.

2.1. Cost of change

Electricity is a capital intensive business primarily because of economies of scale: it is cheaper to build one large generator or pole and wire than many smaller ones. This is why most electricity systems have been planned and built to address the needs for the next five, 10, or in some cases 20 years. The requirement to incorporate low-carbon electricity generators to these existing optimized electricity systems usually leads to some wastage and lower efficiency of the existing electricity system.

2.2. Cost of Capacity Backup

As discussed above, to ensure that we do not run out of electricity on certain days, months or seasons, we must have other types of electricity generators that can replace sunshine and wind powered electricity generators for the whole day or even whole month or season. Coal, natural gas, nuclear or to a lesser extent water powered electricity generators ("controllable generators") can reliably backup sunshine and wind powered electricity generators for days, months, and years. However this means for each sunshine or wind powered electricity generator we must also have a corresponding controllable generator standing by. This essentially means we would have to pay for two electricity generators and not one.

If coal or natural gas powered electricity generators are prohibited by act or regulation, or become uneconomical due to carbon pricing etc. then this backup must be provided by currently even more costly electricity generators such as nuclear or water powered. This would add even more cost to be recovered from the electricity customers.

2.3. Cost of Additional Ancillary Services

Similarly, to counter the ramping down or up of the sunshine or wind powered electricity generators we need a corresponding controllable generator that can ramp up or down at a matching pace. While natural gas (in simple cycle mode) and to some extent water powered electricity generators can ramp up or down at a good pace without prohibitive extra costs, coal, natural gas (in combined cycle mode) or nuclear powered electricity generators have limited ramping rate that comes at material extra cost. Therefore, to counter the ramping down or up of each sunshine or wind powered electricity generator we likely would have to add a corresponding natural gas powered electricity generator. Natural gas electricity generator in simple cycle mode is usually costlier to run than coal, nuclear or natural gas electricity generator in combined cycle mode. This extra cost would have to be paid by the customers.

If natural gas powered electricity generators are prohibited by act or regulation, or become uneconomical due to carbon pricing etc. then this ramping service must be provided by currently even more costly equipment such as battery. This would add even more cost to be recovered from the customers.

3. Reliability and affordability challenges are inter-related

As can be seen from above, current solutions to the reliability challenges of short and long-term reliability: sufficient number and amount of controllable generators that can also ramp up or down at a good pace, add material extra costs and therefore create the affordability challenge. According to various sources, the electricity bill may increase two to five times within the next 10 years.

4. What would be a perfect complement to the low-carbon generators?

While controllable generators that can ramp up or down at a good pace can enable the integration of sunshine or wind powered electricity generators, it comes at a high cost which could be prohibitive for some jurisdictions.

Natural gas powered electricity generators can be made net-zero emitting if their carbon di-oxide emission is captured and then used or stored. However, this usually increases costs by 30% to 100%.

Fast ramping energy storage devices such as a battery can complement low-carbon generators but with the huge caveat that its run-time i.e., hours for which it can "generate" is limited by its size. In comparison coal, natural gas, or nuclear powered electricity generators' run-time is practically unlimited. While many batteries with sufficient run-time can fulfill the same role as the other controllable generators, their combined cost is prohibitive at this time.
This pushes us to look for more solutions. What are the other controllable generators that can ramp up or down at a good pace?

5. All of us as together are the perfect generator!

We use electricity in many ways: furnace fan, fridge, stove, washer, dryer, air conditioner, TV, microwave oven, toaster, computers, lights, and perhaps even electric vehicle (EV). What if we could "ramp" our electricity use up or down to match sunshine or wind powered generators? This Distributed Electricity Management ("DEM" hereafter) would greatly reduce if not eliminate the need for natural gas powered generators or energy storage devices like battery.

5.1. Technology and tools already exist

Many people believe that we are years away from being able to ramp our electricity use. We do not. Many companies in many countries and jurisdictions have demonstrated that the technology and tools already exist and more importantly it all works. (Please reach out to us for real world implementations.)

5.2. Challenges experienced in the past can now be overcome

Almost all governments, regulators and utilities have dabbled in demand side management (DSM) over the years. There is a tendency to equate DEM with previous DSM implementations and conclude that:

5.2.1. But we do this already

Some argue that electricity use has been managed for many years such as by allowing the electric utility to control the air conditioner but such management cannot replace the generators. While this may have been somewhat true before powerful computers, big data,

mesh networks, block chain and artificial intelligence, it certainly is not true anymore. With advanced metering, data acquisition, protections, controls, market operations and billing etc. through Advanced Metering Infrastructure (AMI), Supervisory Control and Data Acquisition (SCADA) and Advanced Distribution Management System (ADMS) etc., DEM can replace the generators.

5.2.2. But it is not allowed

Some point to the legal or regulatory framework that does not explicitly allow the required DEM. While unfortunately this is somewhat the case in some jurisdictions, much could still have been done under the current framework particularly by the government or independent agencies and regulated electric utilities. The framework was created a few decades ago in a very different environment so it is not a surprise that some revisions are urgently required. In a way it could work out well – the agencies and utilities can get started on what can be done now and at the same time work with the government or regulator to get the right framework in place as soon as possible.

5.2.3. But it is not profitable

As one would expect quite a few enterprises have attempted to get the advanced DEM started particularly in the last decade or so but none has really taken off. A major reason is that the "market size" and therefore profitability has been limited due to the factors noted above. Once legal and regulatory barriers are removed, the electricity industry is now well poised to take advantage of the technology and tools to profitably deliver DEM at the scale required to replace the generators.

6. How can we make this happen?

We challenge the governments, regulators, and industry to focus their energy on "how can we best do this" instead of on proving that "this cannot work". We strongly believe that if there is a will we can minimize the costs and achieve an acceptable distribution of costs and revenues.

6.1. Think long-term

As we explained above, the cost of change is real and material. Just as the requirement to reduce carbon emission led to waste and inefficiency in the existing optimized electricity system, any sudden or perhaps even gradual change will also likely lead to extra costs. Rather than react to current problems, such as by rushing to build natural gas powered electricity generators whose cost will have to be paid for many years, we should try to find a solution that minimizes costs over the next 10 or more years. Only the governments through its policy, acts and regulations, and the regulator through its decisions, rules and orders can provide the necessary certainty and guidance to the industry.

6.2. Do not rule anything out

There is a tendency to favor what has worked in the past or what we are comfortable with. Another tendency is to look for a silver bullet or two. While we are a big fan of keeping it simple, we believe that in a complex adaptive system one should continuously consider every option and maintain a dynamic portfolio based on these options. As the environment changes, the characteristics of each option and its relative merit will change.

6.3. Enable

While unlike most we do not unconditionally consider the market approach supreme, the market generally performs better than governments or regulators in a dynamic environment that is in front of us. We recommend that government or regulator set the framework, structure and rules of the game and then let the market or economic forces deliver.

6.4. Empower

As with any big change management, enablement alone is not sufficient. The government would have to empower the regulator, regulator the agencies, agency the industry and so on. In particular the government should empower the regulator by providing clear goals and accepted or unaccepted outcomes and then stay out of regulation. And in the same way the regulator should empower the generators, transmitters, distributors, retailers and electricity use managers etc. by providing the incentives and then staying out of the business.

While we are not a fan of government supporting a particular technology or solution, the government perhaps has to sweeten the deal but only for solutions that create a net benefit and are the most economic to kick start or expedite the transition as opposed to solutions that are a net cost. This support is required because we are smaller in (opportunity) size compared to some provinces and many states, have a complex structure, costlier transmission and lack larger water or nuclear powered generators. We are a bit behind and we are competing with other jurisdictions to attract the capital and businesses that have the technology, know how, resources and a proven track record. Mechanisms such as a targeted temporary tax holiday or reduction are a great way to create win-win. These can attract DEM businesses free of cost in the near term and then create incremental tax revenue once these businesses become sustainably profitable.

7. It is in everyone's best interest to get this right

COVID, wars, immigration, supply chain disruptions, inflation, and slowing economic growth and in particular wage growth have created an affordability challenge for most jurisdictions. The electricity industry is widely expected to play its part by keeping the electricity bill as low as possible. If the electricity industry fails to satisfy the government, regulator or customers then it risks exposing itself to reactionary changes to framework and regulations that are usually not good for anyone. Rather than protecting what it has, which perhaps is a lost cause anyway, the electricity industry should become an active and responsible partner of the government to create a roadmap that acceptably balances the interests of all stakeholder in particular of the customers which are also the voters.

Rather than each party working in isolation, government, regulator and entire electricity industry including the energy use management businesses should work very closely together with purpose and urgency that is perhaps overdue. This would not be unlike the effort in 1990s that gave us the current framework in Alberta which generally served us well up to say about 2020. If we could do it then we can and must to do it now.