INTERMITTENT ENERGY RESOURCES FOR ELECTRICITY MARKETS

By
Federico S. Fische
5326 Nebraska Ave. NW – Washington, DC 20015
+1 202.257.2214
fsfische@alternativesustainablenenergy.com

Abstract

When looking into the energy resources for electricity markets we can find two major groups, traditional and alternative resources. From the perspective of the supply, traditional energy provides a continuous electricity source at a fixed cost with a small basket of definitive generation technologies. Alternative resources can fall into two major groups, renewable and none-renewable resources. None-renewable are composed by traditional large hydropower and nuclear energy. These none-renewable resources have, from the supply side, they share the same characteristics than the traditional resources. The renewable resources are characterizing as intermittent and geographical dependent resources, which can affect electricity dispatch, and access, because they may be located in places with no interconnections. In addition, there are some concerns about the intensity of capital needed for renewable energy resources and the fact that conversion and generation technologies are constantly evolving and diversifying, creating a basket of options for a single resource which, for now, makes impossible to move toward fixed costs operations.

Given the characteristics of the renewables, the desire of increasing renewable resource in the supply side of the electricity sector, and the nature of how the electricity markets operate today, the paper explores how accessible is the current design of electricity markets to renewables. The paper challenges the current scheme and propose a new approach, at least from a conceptual perspective, where the nature of the renewable resources and the dynamics associated to the portfolio of available technologies are at the center of the design.
Brief Review of Electricity Market Design

A simplified view of the electricity market value chain can be presented by the following three stages:

Initially, the value chain was hidden behind a monopolistic approach, where the chain was vertically integrated either within government companies or private operators. “The old model was built around the principle of monopoly franchise with regulatory structure that assumed a high degree of vertical integration and a reasonable degree of certainty.”¹ This vertically integrated approach, created a central planning process where the equation of $\text{Supply} = \text{Demand}$ was met with regulation, infrastructure planning and cost/price mechanisms designed to provide certainty, reducing investment risks.²

Changes in the rules of the “oil-game” in the 70s, started by the oil embargo and subsequent coordination scheme by OPEC members, began to question the sustainability of the old model. In addition, while the economies of scale of the sector began to impact operational costs and real prices, the market began to show some system failures, perhaps more evident in developing countries, like

- Slow reaction to respond to changes in demand due to moderate or rapid economic growth, which began to affect system reliability
- Persistent need for subsidies, even with economies of scale in place
- Little capacity to respond to externalities, such as
  - Prices and/or availability of resources
  - The regulatory framework affecting all economic activities, like new standards and environmental rules
  - Demand due to voluntary and involuntary migration resulted from natural disasters and/or conflict.

The diagnostics was that the vertically integrated approach did not longer apply to the reality of the electricity markets. The solution was to restructure the markets to allow competition to deal with the failures of monopolized, or quasi-monopolized, markets. This restructuring, wrongly call by many deregulation, created a new regulatory framework that unbundled and regulated the stratification of the electrical market value chain. The transition toward restructured markets began in the mid-70s in the USA and Europe, reaching almost every country by the end of the 90s.

² In the case of government entities, this would justify certain entitlements in the national budget.
In general, restructuring markets started with a set of initial rules. These rules where design for the purpose of creating a favorable environment for the bidding process that would transform the market. In general, this processes used these initial set of regulations as the baseline for the regulatory framework of the market. Regulation and enforcement provides certainty, reduced investment risks and provides a sense of security. Restructured markets usually ended up providing limited competition, a so call “regulated competition,” rather than free and open competition. Regulated competition sparked the need for players to become avid “adapters,” rather than adopters. Key players not only needed to adapt to the new set of rules, but also began to shape the regulatory framework through lobbying and other initiatives. The electricity market was no difference. This interaction between government and private sector mitigated the perception of capital investment risks and provided consumers and suppliers with a sense of security and certainty. This creates a business culture of “business as usual,” making adaptation to regulation a high priority, and changes in technology a low priority.

Why this adaptation became a corner stone of the electricity market? Let us look the matter of pricing electricity services. In the period leading to restructuring, price became a delicate matter between potential takers and governments. Some governments promised consumers to keep prices on check on their behalf; most of them dropped such pledge after the restructuring process ended. As a result, many restructured markets had higher prices, while preserving or marginally improving system-wide reliability. In many cases, the new distributors found difficult to overcome the challenge of meeting the demands needs. Some countries haven’t seen any major improvements even after decades of ending restructuring process of the electrical market. This haven’t stop the new players to lobby for a more benign regulatory framework for the sector, more control over the market, reduced oversight from government and its agencies, and better leverage on price setting.

Some studies on the restructuring process have shown that the economic gains for the society in general were not there. One could argue that the bidding process during the early stages of restructuration were the closest you could get to a true competitive period in these restructured markets. Once the dust was settled, the market found itself in a pseudo free market, with a value chain working like an oligopoly rather than an open and free model.

How much innovation did this new market provided? The results are mixed. In the case of the USA, restructuring the markets resulted in no further modernization of the transmission lines, it dropped to a halt the construction of new generation facilities, and incidents in the last decade or so seems to indicate that the system that is just able, at best, to react to potential failures. In other cases, mostly in developing countries, the first ten to fifteen years after restructuring were spend on provisioning reliability to those already served by the grid, and unable to seriously reduce the number of people with no service or the under served. Furthermore, Supply and Demand gaps are not been closed; levels of subsidies for traditional energy had reached $500 billions by 2010, and many countries suffer of a decaying and inefficient infrastructure. It seems that a pattern of failures began to emerge with similar marks to those seen in the vertically integrated ones, under the old model.

In these two approaches, market design can be based in three pillars: regulation, infrastructure planning and certainty. In the last two hundred years, certainty was based on system where the infrastructure and regulation were design for a resource that was thought unlimited, with only positive benefits, and with a small basket of technologies that evolved mostly to reduce programmed downtime and failure ratios.

For over 200 years the traditional resources, represented by monopolistic systems or quasi-free market value chains had the following characteristics:

- Define the sector’s regulatory framework
- Design and deployed infrastructure to meet the characteristics of the resources, conversion technologies, and distribution needs
- Created its own price mechanisms
- Considered the consumer primarily as a data set, not as a variable in the equation.

In the perspective of traditional energy resources, conversion and generation options are limited and technology changes had stop into a crawl. There has been little need for developing traditional technology characterizations. These technologies have been in place for over a century, all of them are consider mature and commercially available. This has been a key contributor to the certainty factor, the symbol of traditional energy.

In the last decades, renewable energy resources had began to play a role in the electricity markets. Obviously, the ability of these resources to respond to the current market challenges is questioned by the incumbents. Are these sources reliable? What about their availability and dispatch effectiveness? What is their grid price parity? Can they be less capital intensive?

Are these fair questions? Yes. Do they apply to a market design with renewable resources in mind? No. The questions search for signs of “compatibility,” of renewable energies to the current design. Most of the markets and value chains of services and products had evolved to keep with the pace of changes in technology and consumer behavior. What if the current market design is not compatible with the introduction of a diverse and dynamic basket of technologies?

Is there a reason for the electricity market to follow a different path, other than adapt and evolve due to changes in technology? Doubtfully. This evolution may need an overhaul of the market design. Evolution will not happen overnight, and it will require a migration process that involves heavy doses of renewable energy resources if feasible.

Renewable energy technologies are characterized for been a bunch of wide spectrum of alternative conversion and generation options, with different levels of maturity. Technology advancement is creating a new dynamic of innovation in power generation and energy solutions, primarily from renewable resources. Under the current business culture, this is a fluid situation, which translates to the key players as uncertainty. Therefore, electricity markets design should focus on how to adapt or reformulate the existing scheme to the nature of renewable power resources because doing the opposite is an impossibility.

**Intermittent [Renewable] Energy for Electricity Markets**

Renewable energy resources have been characterizes as intermittent resources with lack of storage capacity. Intermittency is presented as a technological problem that will not go away. Storage issues are related to the ability to store energy in a liquid, solid or gaseous form, which is mainly true for wind and solar resources.
While the questions on renewable resources seems to imply that whole the technologies suffer of the same shortcomings, a review of the literature on intermittence seems to indicated that the responses are about the way we can deal with the issue for the case of wind and solar. This ignores the fact that different renewable resources would have different levels of intermittence. Therefore, while it is possible that for certain markets redundancy is the solution for wind power that may not be a reasonable solution for biofuels. Redundancy would create shortages of feedstock for biofuel production.

**Renewable energy technologies characterization**

Renewable energy technologies characterization presents an assessment and description of conversion and generation technologies. The assessment has a static component, by looking at the current state of the technology, and a dynamic component, which looks to the future potential of the technology. There is a study done on the USA case, by the US Department of Energy and the EPRI institute, which assesed biomass, geothermal, photovoltaic, solar thermal, wind and energy storage back in 1997.\(^4\) The document presented the following technology characterization outline:

- System Description
- System application, benefits and impacts
- Technology assumptions and issues
- Performance and cost
- Evolution overview
- Performance and cost discussion
- Land water, and material requirements
- References

When we use technology characterization we have a clear idea of the maturity, benefits and limitation of different renewable resources. Is in this context that we should accept that not all resources are equal. The characterization of each resource and the basket of conversion technologies suitable for them should allow us to limit the issue of intermittency to just two major resources: sun and wind.

**Intermittency of renewable energy technologies**

We could measure intermittency facto as either/or the availability of electricity and the dispatch effectiveness, measured as the reaction time to changes in demand. Characterization of renewable energy technologies show that not all technologies are equal.

In a business culture of looking for the fastest turn-around, the next big thing and the single solution, which should be the mother of all solutions. We forget the fact that to migrate to an electricity market where renewables are predominant we would need to transition from the current model to a new one. The maturity of many of the technologies should allow us to build a transition that will mitigate the matter of intermittency with an acceptable level of redundancy, based on system design not on the characterization of the generation resources.

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The migration should take advantage of existing low intermittency resources, like biomass, biofuels, modern hydro and geothermal for the short term, and transition toward the inclusion of those high intermittency resources, like wind and solar.

Following the technology characterization, we know that biomass, biofuels, modern hydro and geothermal sources have similar availability and dispatch capacity than traditional resources, like nuclear and fossil fuels. In fact, most of these resources are process with similar technologies that are use for fossil fuels. That is why today we can see coal plants co-firing with biomass pellets and biofuels, power generators using bunker or diesel can run on mixed fuels, or see these fossil fuels totally displaced by methane from municipal waste, or biofuels from yellow grease and waste streams of agroindustry processes.

As discussed above, certainty is one of the three pillars for market design. In this first phase, Certainty for consumers will continue to be that supply will be there when needed. On the other hand, technology choices today, allows consumers to self-generate power from renewable resources, which not only mitigates intermittency, but also creates certainty for the consumer.

Certainty for investors and operators becomes a question of technology choice and risk factor. Under the current model, a small portfolio of traditional technologies reduced the perceived risk, making the investment problem a simple one. Today there are many ways to measure risk when one deals with multi-technology portfolio. In addition, an increasing number of operators are finding that mixed portfolios are becoming more beneficial for their bottom-line. So as long as regulators, investors and operators would continue to do business as usual, changes in technology will be a high-risk venture. Therefore, making the current market design, not the technology characterization of renewable resources the source of uncertainty for the future.

Within this first phase, we would also find increasing number of distributed generation. In the past, on-site self-generation or shared mini-grids were a natural response to the shortcomings of the old electricity model. Some systems required the distributed resources to resolve “end of the line” load and reliability issues, and it were an acceptable solution for isolated regions or communities. Today, clean production initiatives and efficiency are stronger drivers for industry and consumers to look into generating power. The spread of self-generation opportunities, especially using renewable resources, is becoming an alternative to a “redundancy” strategy for some electricity markets.

The first modification to the current design starts on how to adapt when we leave fossil fuels and switch to those low intermittency renewable resources. During this phase, some technologies will phase-out, other will remain, while new will be phased-in. Let’s be clear, certainty in the market place has little to do with a technology choice during this phase of the migration, but mostly on the ability of the business culture to adapt to change, rather than the potential of system failures.

As the first phase evolves, intermittency challenges from sun and wind resources will be meet with advances in storage solutions, distributed generation strategies, smart grid solutions and the increase role of consumers as part of the distribution and generation pool of the electricity market. These changes would keep pushing further

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5 True only when environmental and sustainability factors are set aside.
modification in the model; regulators would need to expand their horizons and all the players would need to be more creative on infrastructure design.

**Levelized Cost Analysis**

There is a consensus, reflected in the reports of the International Energy Agency and other organization, that renewable energy is more capital intensive than fossil fuel energy. This is supported by the use of total system levelized cost analysis for electricity generating technologies. The Information Energy Agencies, Department of Energy, specifies that “levelized costs represent the present value of the total cost of building and operating a generating plant over its financial life, converted to equal annual payments and amortized over expected annual generation from an assumed duty cycle.”

In the case of USA, the levelized cost analysis for technologies seems to suggest that in five years levelized capital cost for off-shore wind and solar would remain the highest of new generating technologies. Interesting enough, traditional and advance coal facilities are projected to have similar levelized costs per MW/Hour than advanced combined cycle, geothermal and biomass and wind. Bottom line, by 2016 renewable energy technologies would be as capital intensive as coal technologies, which are, and would keep been if all remains as today, responsible for over 65% of the electricity generation in the USA.

By the end of 2010, it was reported that traditional fuels had received $500 billions in generation and consumption subsidies. While for renewable resources has been only $50 billions. Let us assume for a moment that the USA keeps a similar ratio than the world, when providing incentives to traditional and renewable energy. In that case, since the levelized cost analysis above includes tax credits and other financial incentives, one could argue that most of renewable energy technologies are becoming less capital intensive than coal technologies in the USA.

What the IER report also does is to demystify the idea that the capital requirements for renewable energy technologies makes cost recovery impossible, or may be reached beyond the life of the project, which in turn means high risk investments. The fact is that today is impossible to build an old fashion coal or bunker generation facility. Compare the cost of 25+ year old, fully depreciated, facilities with new ones is a backward looking approach. The IRE studies shows that in comparison, the cost of investing in a diverse basket of renewable energy projects is not different than the cost of investing in advance coal facilities.

The next graphic shows the levelized cost of new electricity generation technologies, projected to 2016 as presented in the IER report.  

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6 Levelized Cost of New Electricity Generating Technologies, Institute for Energy Research (2010)
Levelized cost analysis should play a larger role in the re-design of the electricity market. It is central to infrastructure planning, at least from the generation perspective, and combined with the proper financial tools, becomes an input for investment analysis.

**Summary**

Today, some of the challenges to bring renewables, or at least low carbon technologies, into the electricity market is not much different than coal in the late 1800s. In order to become a reliable source of energy in the current massive grid, renewables need to build a supporting structure that allow harnessing, processing and delivering resource for power generation. Renewables are highly dependable on location, i.e. best predominant winds, solar concentration per hour, wave characteristics and farmland. This is a drastic contrast to coal found at a mine, or liquid fossil fuels found in oil fields.  

The result of 200 years of traditional energy resulted in limited options of conversion and generation options technologies. These technologies have been in place for over a century, all of them are consider mature and commercially available. This has been a key contributor to the certainty factor that is the symbol of traditional energy. Renewable energy technologies are a wide spectrum of alternative conversion and generation options with different levels of maturity. The combination of new materials, research and technological advancements across

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all the sciences creates a dynamic of innovation in power generation and energy solutions from renewable resources. Electricity markets design should focus on how to adapt or reformulate the existing scheme to the nature of renewable power resources because doing the opposite is an impossibility.

The argument against advancing with renewables based on uncertainty and technology choice is only true under the current model. The existing model cannot deal with different levels of intermittency, distributed energy and technology diversity. Nevertheless, with relatively small changes, there is a basket of renewable energy technologies that can make electricity available and be dispatch efficient today, meeting the performance of the traditional ones.

Furthermore, most of the service and manufacturing industries deal with the impact of changes in the technology mix. The business models that tried to remain untouched by these changes either fail or needed to adapt. The challenge for the electricity market is not different, but perhaps more complex. What is unique in this market is the push for a democratization process, where we all produce and consume. This is a contrast to the simplify view of the electricity market value chain presented above. The new model should resemble more the following graph:

A market design where renewable energy plays a predominant role, will require the same three pillars the existing one: regulation, infrastructure planning and certainty. It will need to

- Define the sector’s regulatory framework
- Design and deployed infrastructure to meet the characteristics of the resources, conversion technologies, and distribution needs.
- Considered the consumer primarily as a variable in the equation, especially because under the new model it produces electricity, either by self-generation or by increased energy efficiency.
- Created its own price mechanisms

The power market is in the verge of facing the end of limited technology options. The combination of new materials, research and technological advancements across all the sciences creates a dynamic of innovation. The cycle of innovation is advancing at much faster than the one traditional energy emerged. Most likely, the current dynamic affecting renewable energy combine with the speed of innovation, would create a permanent stage of flux. This fluidized situation should be considered a key new characteristic for designing electrical markets. This new design should include environmental and social cost-benefit considerations throughout the entire life cycle of the energy sector. Financiers and investors would need to take experiences and lessons learned from other sectors, to create analysis and financial/investment products that will suit this reality. Regulators would need to create a flexible framework that can quickly adapt in response to changes in technology and the marketplace. At the end, the new mode should find developers and utilities been more successful when creating a portfolio of resources and technologies, rather than buying into a single type of energy resource.
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