Six Design Principles for the Power Markets of the Future – A Personal View

By Michael Liebreich
Chairman of the Advisory Board
Bloomberg New Energy Finance

For years, the most common question asked by outsiders of those in the clean energy industry was “when will renewable energy be grid-competitive”. Wind and solar needed subsidies in order to compete, and there was legitimate concern that as the sector scaled these would become unaffordable – as indeed they did in Spain, Italy and a number of other European countries.

In February 2013, however, the world changed. Bloomberg New Energy Finance published research showing that new wind farms in Australia could produce power more cheaply than new coal or gas-fired plants – even unsubsidized and without a carbon price. Since then we have seen the same news story again and again: record-low bids for wind and solar in reverse auctions, below the price of new fossil or nuclear power, increasingly often by a factor of two or more. By 2016 the World Economic Forum pointed out that unsubsidized new renewable power was cheaper than that from fossil fuels in over 30 countries, and by 2025 that will be the case in most countries around the world.

Forget grid competitiveness, this is the era of “base-cost renewables”, in which wind and solar are cheaper than any other source, and are therefore the default choice for new capacity. The more exuberant boosters of renewable energy are jubilant, declaring victory over fossil fuels (and by extension new nuclear, which is proving to be painfully expensive and difficult to deliver). But does that mean they would be happy to see all subsidies and support mechanisms phased out? Not at all!

First, in order to produce power at these low prices, renewable energy projects need access to cheap debt, and that requires guaranteed income for long periods – 15 years or more. Second, wind and solar are variable resources. For all that they can produce cheap power *on average*, they are unable on their own to meet demand when the sun is not shining and the wind is not blowing. Their integration into the power system therefore depends on the presence of other technologies – demand response, power storage, flexible fossil plants or interconnections with neighbouring systems. Someone has to build and run these, and they too must be able to earn their cost of capital.

And so we are approaching a twilight zone in which, while large-scale renewable power itself no longer needs subsidies, it seems to need other technologies to be subsidized or offered protected markets in order to enable its continued growth. Here’s a postcard from this dystopian future: a member of the Vermont House of Representatives is currently sponsoring a bill that requires the Department of Public Service to demand the installation of batteries. The almost inevitable result of designing a network in this way is that its costs will become unaffordable.

Right now, we are careering down a path to more and more regulatory interventions. We are not talking about a broad national energy and resource plan: we are talking about demands for a particular mix of supply, particular technologies to keep the grid stable, particular new technologies to be piloted, particular levels of interconnection, particular programs of investment

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in energy efficiency and particular consumer prices – with guaranteed returns as rewards for compliance and the cost of mistakes borne by users. It might be easier to just nationalise the whole the whole network outright (as the Labour Party is indeed suggesting in the U.K).

All this, of course, provides fertile grounds for pushback from opponents of renewable energy, who have been quietly shifting their focus from grid competitiveness to overall system costs. In the U.K. this takes the form of a campaign to demand mythically precise “integration costs” be identified for renewable energy projects (but not conventional projects) and charged to their owners. One of the first moves of incoming U.S. Secretary of Energy Rick Perry was to launch a 60-day review of “critical issues central to protecting the long-term reliability of the electric grid,” including the extent to which shifting technologies might be destabilizing the way power markets work and the impact of “mandates and tax and subsidy policies”. On the surface this might seem like a reasonable thing to study, but the introduction to the review reveals a strong bias against renewable energy, stating as it does that “base-load power is necessary to a well-functioning electric grid”.

If it means anything, “base-load” means generating capacity that is rarely if ever switched off, indeed which is expensive or impossible to switch off. When coal and existing nuclear power plants were the cheapest sources of power, and before the risk of climate change was well understood, that might have been acceptable. But now, if consumers are to gain the cost and climate benefits from super-cheap renewable power, what is needed is flexible, dispatchable power by way of complement, not inflexible base-load that crowds it out.

So, if the actual or *de facto* nationalization of our power system is the wrong answer, and an atavistic yearning for the simplicity of base-load is the wrong answer, what is the right answer?

Truth be told, no one knows, because no system in the world can yet claim to have answered all the questions. Everywhere I go, from Australia to Germany, New York to California to China, Brussels to Whitehall via Washington DC, there are two simultaneous discussions going on: the first, a technocratic one, about tweaks and modifications to the current regulatory system; the second, an existential one, about the nature of deep re-regulation required to meet the long-term challenge of the energy trilemma: providing cheap, clean, reliable power in the face of new technologies, new types of user behaviour and the all-encompassing need to address climate change.

In the spirit of spurring discussion about this sort of deep re-regulation, I submit the following six principles. They take as their starting point my keynote at our Future of Energy Summit in New York last month. If these principles are smart, it is because of the extraordinary team at BNEF, in particular those who helped prepare my New York keynote; if they are stupid, it is entirely my fault.

1. From Dark Spread and Spark Spread to Firm Spread

First of all, we need to stop talking about “the wholesale power market”, and design the future around multiple power markets. Electricity is a commodity, but there are multiple ways of supplying it (or of eliminating demand for it) with different characteristics: different grades of reliability, different speeds of response, different abilities to ramp down as well as up, different levels of carbon intensity, in different locations, and so on. The key to cheap, resilient, clean energy lies in the ability to put together the perfect portfolio of different types of power.

Most current developed-world power systems have liquid spot and forward markets for bulk power, a good market in power purchase agreements or other long-term contracts for renewable energy, and a range of markets for ancillary services such as frequency response or power reserves of varying degrees of sophistication. But few have real transparency in relation to locational prices, and none differentiate adequately between variable and dispatchable power.

This latter is probably the single most important area for innovation. Base-cost variable renewable power may be the cheapest source of supply, but it can only meet some proportion of demand, and it depends on the presence of other market players to pick up the slack. Which is OK. Think of the telecoms sector in the 1990s: discounted long-distance providers suddenly appeared, eating into the business of traditional phone companies; they couldn't handle local calls, but that wasn't the point – they simply ignored that market. Similarly, discount stores supply bulk groceries at cheap prices; it is not their problem that you can't find foie gras or taramasalata on their shelves. In both cases, consumers learned that by splitting their purchases, they could meet the entirety of their needs at a lower cost.

In the same way, what the power system requires is clearly-defined, separate markets for variable power and dispatchable power. Each must deliver price discovery across as much of the forward curve as possible – from a few minutes ahead at the short end, all the way up to 15 years and beyond at the long end. The delta between the variable and firm price is then the "Firm Spread" – *the true value of dispatchability at key locations in that particular market* – which should be as important for investment decisions as Spark Spread and Dark Spread are in making dispatch decisions.

Firm Spread will be very low in any market that has not yet saturated in terms of variable renewables, in other words where there is a lot of existing flexibility at little or no incremental cost. That is why it has flown for so long under the radar. However, Firm Spread will rise rapidly in markets that are saturating, where there is so much solar and wind that the spot price for variable power is crashing to near-zero or even sub-zero at sunny/windy times, and where restricted operating hours drive the cost of flexible generators up. It can be expected to drop again over time, as technology innovation makes firming cheaper and the premium for firm power is reduced.

It is Firm Spread that is the motor needed to drive innovation in technologies with the potential to turn cheap variable power into affordable dispatchable power. At present, we have only an approximation for it: short-term wholesale markets for bulk power with good price discovery, an over-the-counter market for longer-term power purchase agreements (PPAs), and a raft of assumptions and pre-conceived notions in between. That's why we see law-makers promoting this or that technology, not because they are foolish or captive to one sector or another, but because there are no good data on Firm Spreads – data that the complexity of the power system decrees cannot be calculated and that only the market can reveal, in the same way that only reverse auctions could reveal the real cost of renewable power.

The Holy Grail, to which we must aspire, would be sufficiently good market data on Firm Spreads, a sufficiently robust forward curve, that shrewd investment in firming technologies can be made without government guarantees or even PPAs.

Fanciful? In the short term, certainly. But think ahead, to 2030 and beyond, when many renewable energy projects will be off their PPA periods and trading in the merchant market; when demand will be increasing because of electrification of transportation and heat, and the volume of demand response capacity will be unrecognisable (see below, section 6). Is it really impossible to imagine spot and forward markets for firm and variable power delivering a clear signal for the value of dispatchability?

2. Towards a demand-led system

One reason why power markets are so damn complex is that supply has to meet demand, everywhere in the system, at every moment. The second key design principle of the power market of the future is that responsibility for matching supply and demand must be, to the greatest extent possible, placed on power retailers. It is they who best know their customers – not generators, not transmission or distribution system operators, and certainly not regulators or policy-makers.

Any approach that matches supply to a centrally-produced demand forecast will over-procure and result in excessive power prices.

A power retailer can secure power in a variety of ways: building local or remote generation, buying it on the markets, signing long-term PPAs, aggregating it from customers or other consumers, investing in demand response capacity or storage, and so on. It is the retailer's job to make sure that it secures enough to meet the demand of its customers at all times and locations. To do this at the lowest possible cost, it will want to combine a proportion of cheap variable power with more expensive flexible power; how it does so will be a core skill, in the same way that buying is a core skill in every other customer-facing industry in the history of business.

The retailer will also have to ensure that it has options on enough spare capacity to meet unexpected demand spikes. If it is caught short, the retailer must purchase power on the spot market (or be prepared to meet the costs of such a purchase by another market participant). It is one of the key jobs of the regulator to stress-test the retailer's plans and balance sheet, to ensure it can meet demand in all reasonable scenarios. In one sense this is a capacity market, but it is a capacity market linked directly to each retailer's ability to meet demand, and with the retailer driven to innovate in order to reduce its costs.

The main job of power generators is to meet the volume and conditions of the contracts into which they enter, whether in the form of PPAs, forward or spot market transactions. If they cannot, then they must be liable for any resulting costs – individually, not in aggregate. The regulator must ensure they are planning and operating professionally, in the same way as the aviation regulator does for airlines.

As for transmission and distribution grid operators, even if it is they that actually step in to procure power in the event of a spike in demand or shortfall in supply, the costs must end up with the guilty retailer or generator respectively. They must also procure those ancillary services required to address stability problems resulting from the aggregate choices of retailers and generators, or associated with the engineering of the transmission or distribution grid; unless these interventions are obviously driven by one particular supply or demand technology, their costs should be passed on to retailers pro-rata to volume.

All this should result in an efficient, demand-led system. Power retailers, focused on meeting the needs of their customers, will be buying from a range of suppliers; the regulator will be ensuring that supply, transmission and distribution are reliable, and costs to the greatest extent possible will be borne by the relevant end-customers (who must of course be able to switch retailers).

Such a system should address two of the three challenges of the energy trilemma: delivering cheap and reliable power. But that power may not be sufficiently clean to meet climate goals.

3. Cleaning up

The system as described so far will certainly create demand for some basic level of variable renewable energy, given that it is now cheaper than fossil power in an increasing number of markets and there is always some flexibility to integrate it at very low marginal cost – perhaps up to 20% to 40% of demand, depending on geography. Left to its own devices, however, the penetration of variable renewable energy will then stagnate; if you don't want this to happen, another intervention will be required. And that intervention needs to take the form of pushing fossil capacity out of the market, not further support for clean energy.

Let's do a thought experiment on a market with no subsidies, in which penetration of renewable energy is currently low but renewable energy has become very cheap – India, perhaps, or Jordan, Argentina, France as its nuclear power stations shuts, or Florida. Initially cheap renewable energy flies off the shelves, because utilities (or corporates, if they are allowed to self-generate) see it as a way of reducing their cost of supply. After a while, however, supply at sunny and windy times starts to catch up with demand or even overtake it. Spot prices at those times crash to zero. Now it is difficult to find an off-taker for a PPA: after all, who wants to sign a long-term purchase agreement for a commodity whose price is generally near zero?

At this point you would have a kind of détente between cheap, clean variable renewable power, which is selling into those parts of the market which it can easily access, and fossil plants that are meeting the rest of the demand. As cheap renewable energy has cannibalized their hours of operation, these fossil plants will find that their costs have risen, and they will be selling at a higher price, assuming that is allowed by the regulator (if not, they will be losing money and shut down, leading to increased risk of blackouts, and we are back to de facto or actual nationalization).

Over time, the accessible market for cheap variable renewables will still grow, but only modestly, as costs continue to drop and more cheap demand response is added to the system, most likely in the form of electric vehicle batteries. However, the majority of power demand will be inaccessible to variable renewable energy, until such time as renewable-power-plus-storage is cheaper than a fossil fuel peaking plant. Even with rapidly-falling battery costs, this crossover is unlikely to be the case for many years, perhaps decades – particularly in the U.S, where natural gas costs look like staying low.

And here is the crucial point: *you can't break this détente by applying more renewable energy subsidies*. Reducing the cost of variable power still further might help nibble into the edges of the slice of demand being met by fossil fuels, but it won't open up the bulk of that demand to sources of variable supply. For that to happen, you will have to do one of three things: subsidize technologies that help turn variable supply into firm supply; create protected markets for them; or restrict the supply of high-carbon firm power, allowing the Firm Spread to widen to the point where it spurs *massively distributed innovation* in firming technologies and business models. It should not be hard to figure out which option will result in lower power prices.

There are a number of different ways of restricting the supply of high-carbon firm power, and the right approach will vary between different political economies: a carbon price here, a carbon tax there, carbon intensity standards or forced closures of dirty plants. Nevertheless, it must be stated clearly that if there is no political will to use *any* of these approaches, the toolbox will be pretty much empty and the penetration of variable renewables, no matter how cheap they are, will more or less stall in that 20-40% zone.

4. Let's get physical

Let's assume we now we have a system that delivers price transparency, clears supply and demand, and pushes dirty capacity off the system. However, there also needs to be a physical delivery system to exactly match the contracts created in the power markets. The regulatory regime of the future must include a mechanism by which this physical delivery system – otherwise known as the transmission and distribution grids – is paid for and made investable.

The best way to do this is for individual retailers to pay for the transmission and distribution capacity they use to deliver power, end-to-end, from generator to customer, including losses. As things stand, most power systems rely on approximations: costs are smeared in a non-transparent way across power users, and retailers are largely exempt from worrying about such issues as transmission or distribution bottlenecks. This has to change. There has to be a clear incentive to procure power locally and to use transmission links that are not congested. It's not enough to vary the cost of power by node, or location, using arcane least-cost dispatch calculations: a retailer that can meet demand locally, all things being equal, must have lower costs and be able offer keener prices than one that procures its power remotely, or via a congested transmission link.

To achieve this, all power contracts need to be priced to reflect supply and delivery points, and settlement needs to include reservation and payment for transmission capacities from end to end. The market needs to be able to deal with capacity that is not used, for instance in the case of a projected demand spike that never shows up, by releasing reserved power generation and transmission capacity for resale. If this all sounds complex, it is. However, it is pretty close to the system operated by many gas pipelines, only with more players and closer to real time. Luckily this is exactly the sort of challenge for which the blockchain and smart contracts appear to have been designed.

Exact allocation of transmission and distribution costs will drive retailers to build an efficient supply portfolio, exactly as you would want. However, it does also mean that new generation capacity will effectively have to meet the full cost of any additional connection it requires to reach the grid, which may starve remote areas of investment. That would be a political issue, not a market failure, and could be resolved if necessary by creating a connection fund into which remote projects could bid.

5. International affairs – interconnect, but verify

As variable renewable energy penetrates ever more deeply into power systems, the value of interconnection with neighbouring systems will increase exponentially. With political currents making the merger of markets across borders look unlikely, there needs to be a push for new interconnection capacity and a global certificate of origin system, in order to enable frictionless cross-border power trading.

Technological trends and asset life cycles mean that by 2040, perhaps as much as three quarters of all power demand may be available for some form of demand response aggregation. However, much of it will be short term – seconds and minutes, not days, weeks or months. Meanwhile storage, whether behind the meter or grid-connected, will certainly help smoothing out peaks of supply and demand, but storage costs money. The bottom line is that the wider the connected area, the less investment will be needed, and the lower the power costs will be for a given level of reliability and emissions.

To preserve the principle of demand-led markets, it must be the power retailers who procure imports (except perhaps in emergencies), with two conditions. First, importing retailers must pay to use interconnections, in exactly the same way as they pay for domestic transmission capacity (see above, section 4). Otherwise they will be getting a free ride vis-à-vis a competitor who has worked hard to procure power locally, or to aggregate it from customers.

Second, any imported power must be accompanied by a certificate of origin, proving that it complies with any carbon limits (see above, section 3). In the case of a carbon price or tax, imported power that has not paid the same amount in its country of origin would need to pay a top-up. In the case of a carbon intensity system, imported power would count towards the calculation of the retailer's average intensity. A system relying on a plant closure schedule would only allow the import of clean power. Without such restrictions, power retailers would be able to gain an unfair advantage by importing cheap dirty power.

A system that allocates interconnection costs to individual power retailers, and registers the carbon intensity of every unit of imported power, might sound very complex – at present, markets use a number of work-arounds to avoid having to do (and check) these sort of detailed calculations. However, this is another example of exactly the sort of challenge that lends itself to blockchain-based smart contracts.

6. Data ubiquity

The first five principles – liquid power markets, demand-led supply, mechanisms to drive carbon reductions, payments for transmission and a framework for imported power – can only be delivered in a fully digital system. The sixth and final principle for any future power sector regulatory regime must be to enable the creation, aggregation, storage, analysis, sharing and protection of data on a scale unthinkable today.

Every asset will be sensor-equipped, software controlled and in communication with other assets. The bulk of decisions will be taken by bots and algorithms distributed within the network, the rest by cloud-based big data analytics. Machine learning will be everywhere, and human intervention will have been banished to the design level. We had better get this right!

The first and most basic need will be for massive bandwidth, far beyond that provided by the current creaking mix of 3G and 4G systems. The energy sector is not alone in needing this, of course: the media loves a story about driverless cars, drone deliveries, mobility as a service, smart buildings, precision agriculture, virtual assistants, subway connectivity, digital medicine, zero-inventory supply chains, virtual reality meetings and a thousand other wonderful innovations. However, these all require massive, always on, latency-free bandwidth – which is simply not available in many rural areas, even in the developed world, and in cities would be quickly overwhelmed if these technologies really do take off.

Assuming the bandwidth issue is solved, the power system of the future will need data protocols governing the efficient sharing of all sorts of information, not just throughout its own value chain and the rest of the energy sector, but also with related industries such as transport, telecoms and finance, as well as client industries. In order to optimize the deployment of demand response capacity, each unit of demand should be accompanied by data on how urgently it is needed: dialysis, uninterruptable; dishwasher, 30 minutes leeway; freezer, one week. We should be planning for itemised billing by appliance too: it won't add much in the way of costs to the next generation of appliances, and would drive a huge wave of demand-side innovation.

With or without adequate planning, this vision is already arriving and frankly unstoppable, for the simple reason that it delivers better services at lower costs – chiefly by enabling far better asset utilisation. Inadequately planned, however, it brings huge risk: our energy, transport, finance, communications, manufacturing, food, water and agricultural systems are rapidly becoming so entangled that a failure in one could cause cascading failure of all. If we are going to put all our eggs in the digital basket, we need to get much better at watching the basket. In particular, we need to get better at guarding it against cyber-risk, as the WannaCry ransomware attack this month so clearly demonstrated, and ensure that privacy protection is designed in from the ground up.

Two final thoughts on the digital convergence of energy, infrastructure and services. First, the current division of labour between electricity, telecommunications, transport, safety and financial regulators will look increasingly clumsy in coming years. A crypto-currency-paid, peer-to-peer electric car sharing network that earns ancillary service revenues from the grid, might need oversight from five different regulators. Is it a bank? Is it a power market participant? Is it a car rental company? A taxi? A bus? Is it possible to regulate half of a smart contract as a power market sale and half as a financial transaction?

And finally, it is quite extraordinary the extent to which big telecoms and software players have been absent from the debate about the future of energy and transportation. They could be among the biggest beneficiaries of the future described here, yet they appear disconnected, perhaps even unaware of the speed and profundity of systemic change. It is vital that they be brought into the regulatory design process as quickly as possible.

So there you go – that's my best shot at six key principles for the regulatory regime of the future.

I know that it leaves many questions unanswered. How do you reduce barriers to entry for those wanting to become retailers, generators, operators of transmission assets or aggregators? How do you create incentives for energy efficiency in a world of zero-marginal-cost power? How do you integrate baseload clean energy such as CHP (combined heat and power) and new nuclear power –assuming it ever becomes affordable? What fiscal and other policies would best support power market investment? What pre-conditions need to be in place in geographical areas where there are still no liquid power markets of any sort, or where there are vertically integrated monopolies, or where skills and capabilities are low?

Even in advanced markets, does this all need to be rolled out right now? Absolutely not – in most cases the current system can still be made to work for a few more years with a few tweaks. But if you want to break through to very deep penetrations of variable renewable power, and if you want to do so in a way that preserves resilience and affordability, then I would venture that these six principles merit consideration. Only if you know where you want to be in 10 or even 20 years' time can you move strategically towards that goal, step-by-step, rather than reactively.

My main purpose in writing this was to spur discussion. I know that there are greater experts out there than me on any individual power market; I really look forward to engaging with you, as does the BNEF team.

I also wanted to give the renewable energy community some new ideas and vocabulary with which to push back against those who would use its variability as an attempt to stop it in its tracks. Because the biggest tragedy of all would be if the benefits of cheap renewable power, now that it is so much more than grid-competitive, could not be passed on to consumers around the world.

This opinion piece has been published in tandem with an insight from BNEF's Head of Analysis, Albert Cheung, on power market design.

About us

Contact details

sales.bnef@bloomberg.net

Michael Liebreich	Chairman of Advisory Board
Angus McCrone	Chief Editor

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