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Dispatchable Demand

Keep up with the pace of the Energy Transition by flipping the energy supply and demand model on its head

By Derrick Bowen

ClimateTech investors will need to flip the energy supply and demand model on its head to keep up with the pace of the Energy Transition

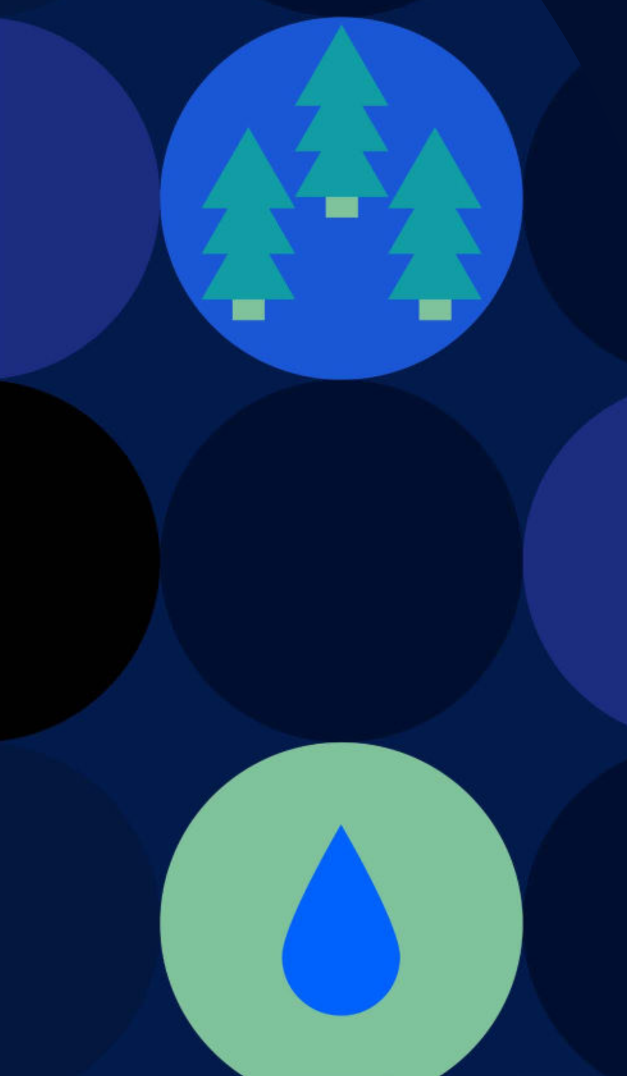
The transition from hydrocarbon-based fuels to clean renewable energy is accelerating due to exogenous forces, such as recently passed legislation in the US and EU and the swelling ESG movement

In 2021, financial firms pledged more than $130 trillion toward the energy transition, and an estimated $472B was invested in renewable energy in 2022. While many investors are committed to supporting the Energy Transition, they face a challenge in finding opportunities that align with their investment goals.

Utility-scale renewable energy projects are capital intensive, take a long time to plan and execute, and have payback periods potentially stretching beyond a decade. Most good opportunities have lower risk and modest rewards, while viable high risk/higher reward opportunities are rare. By flipping the electricity supply and demand equation on its head, a new future business opportunity becomes available to route extra electricity into a powerful new value chain – with specific rules for engaging successfully that are laid out as the Dispatchable Demand Framework.

The industry is moving away from dispatchable generation

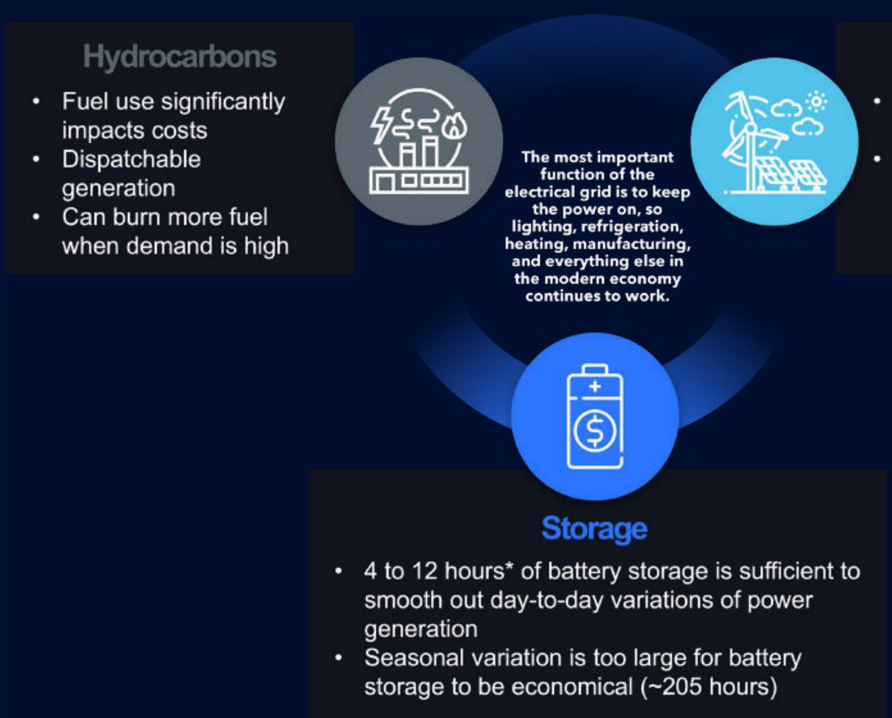
The immediate problem of generating enough clean electricity to meet the needs of our modern economy is being worked on by industry leaders, but as described later, the best options currently available to us will result in large quantities of extra electricity going unused due to curtailment. As curtailment is becoming common for early adopters in California and Germany, we are seeing signals of this, but what is now a local phenomenon will grow to be a global norm as added renewable generation outpaces the local ability to consume, distribute and store that energy.



In electrical markets, wind and solar look to be the economical choice for mitigating climate change; however, their operating characteristics are different from today's system. With hydrocarbon generation, the cost of energy is dependent on fuel use. There is some capital cost upfront to build generators, but a large amount of the cost comes from the fuel being burned in an engine or turbine. The most expensive "Peaker" generators (or combined cycle gas turbines) are kept on standby, designed to quickly ramp up to dispatch more energy to the grid when electricity demand exceeds forecasts. This gives utilities the ability today to increase supply by burning more fuel when demand is high to meet the projected and actual needs of the electricity market.

The different characteristics of wind, solar and battery storage

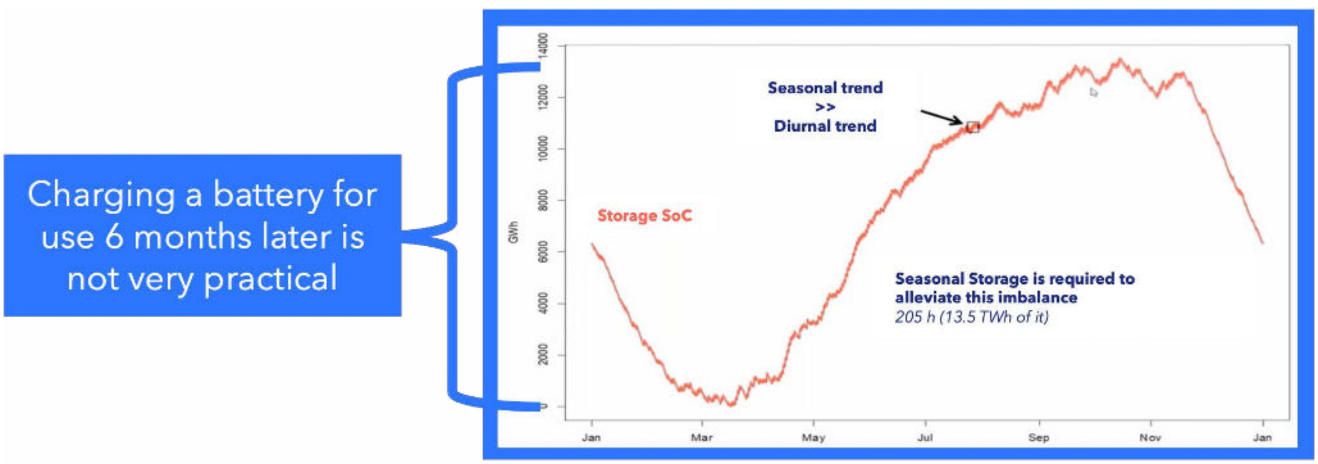
Wind and solar are different. These renewable sources are not dispatchable during times of high demand in the same way as hydrocarbon-based sources. The amount of power generated at any moment is based on environmental conditions (e.g., how sunny or windy it is in the area at that moment). An operator cannot increase output when there is an unexpected surge in demand. On the other hand, no fuel needs to be purchased or consumed to generate electricity. Wind and solar projects have higher upfront capital costs, while their marginal cost is meager.



The most essential function of the electrical grid is to keep the power on, so lighting, refrigeration, heating, manufacturing and everything else in the modern economy continue to work

The most essential function of the electrical grid is to keep the power on, so lighting, refrigeration, heating, manufacturing and everything else in the modern economy continue to work. To get through the day-to-day variations without needing to rely solely on "Peaker" plants, we are deploying battery storage. Most analysis shows that somewhere between four to 12 hours of battery storage (depending on the region) will be sufficient to smooth out the daily variations of environmental conditions. The amount of battery storage needed will depend on existing base loads from non-carbon emitting generation such as hydroelectric, geothermal and nuclear energy.

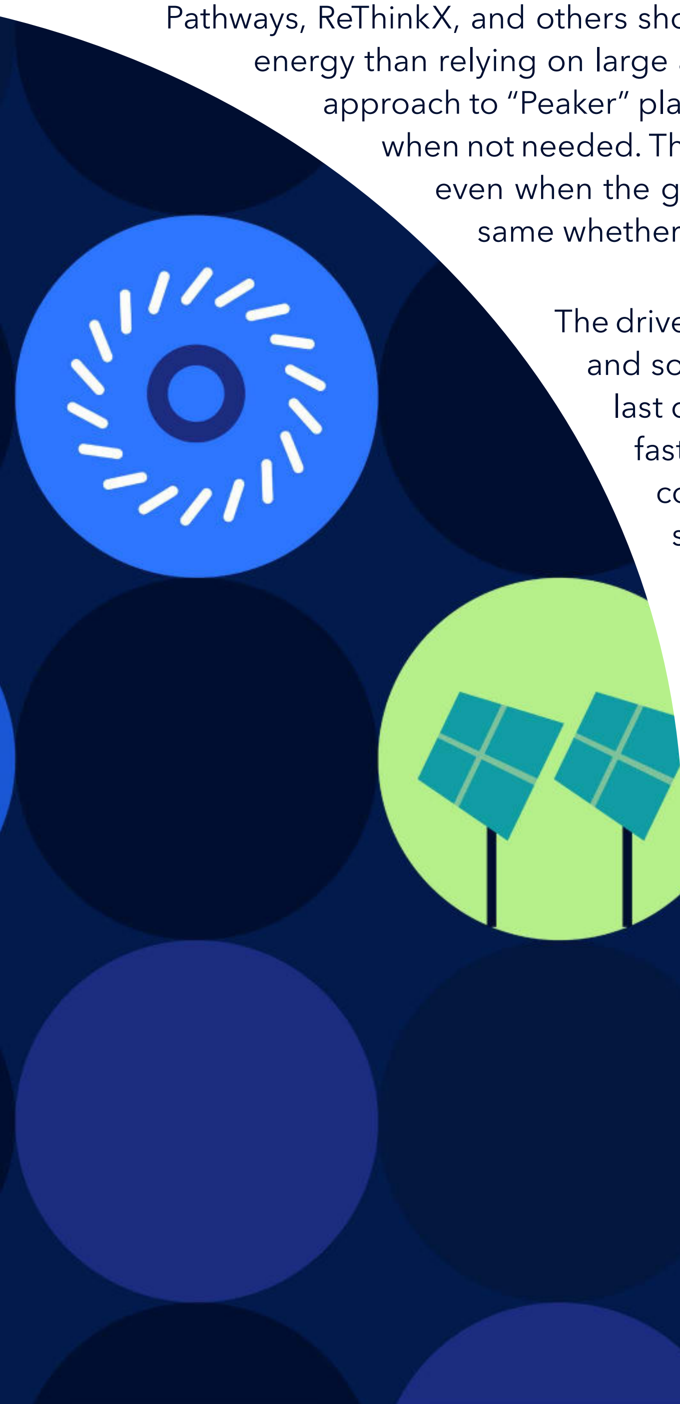
Utility-scale battery storage is being deployed quickly, with large projects already operational in Australia and California. The technology will improve and costs will continue to fall over the next several years, replacing critical grid management functionality that today relies on hydrocarbon-based fuels.



Source: MN Solar Pathways

However, seasonal variation between summer and winter poses a greater problem to fully decarbonizing the power grid. If we were to only match the amount of electricity generated by the grid today, we would need vast quantities of energy storage to save the extra electricity generated during spring and summer until the darker months of the year. It turns out that batteries are not a practical solution for months-long energy storage. As a chemical-based technology, they are too volatile, too expensive, and degrade too quickly for storing high levels of power for that duration. Other forms of storage could potentially alleviate the situation, but those technologies are either nascent, expensive or have limited ability to scale (e.g., pumped water storage).

Overbuild and curtailment solves the problem of energy availability



That's where overbuilding and curtailment come into play. By building renewables with enough daily storage to cover the energy needs of the market during times of the year when it is less windy and sunny, the problem of energy reliability can be resolved. Analysis by MN Solar Pathways, ReThinkX, and others shows this approach results in a much lower average cost of energy than relying on large amounts of battery storage. In many ways, this is a similar approach to "Peaker" plants, as these extra facilities will essentially remain dormant when not needed. The difference is that they will continue to produce electricity even when the grid is at maximum capacity, and the projects will cost the same whether the energy is used or not.

The drivers for this are both economical and physical. Costs for wind and solar generation have dropped by as much as 64% over the last decade, and they are expected to continue to fall as fast or faster than battery storage. While all three technologies are complex, batteries require more specialized materials and safety systems to prevent self-destructive failures.

Think about it the other way. If we only generated the minimum necessary electricity and then used vast amounts of battery storage, most of that storage capacity would go unused much of the year. Having more wind and solar generation than battery storage makes for a more economical and resilient system overall.

Curtailment is already happening in some regions for early adopters, such as California and Germany. An example is the famous California duck curve, where power prices get very low in the middle of the day (when environmental conditions are optimal) and then peak in the early afternoon as the sun goes down but energy use is still high.

How much extra electricity will be curtailed?

Estimates for the optimized amount to overbuild range between 1.7X to 3X of the current amount of energy generated today, depending on the region. MN Solar Pathways has published its model as a web application that anyone can visit and inspect. That level of overbuilding means that the amount of curtailed electricity could be 70%-200% of the total electricity generated by the grid today.

In 2021, the US grid generated 4,116 terrawatt hours (TWh) of electricity. Using these overbuild estimates would mean 3,200 to 8,000 TWh of extra electricity each year being curtailed once wind and solar reach market saturation in the US (at least 10-15 years in the future). This represents the extra, unused electricity generated by wind and solar when the transmission grid is at maximum capacity and all existing consumer demand is being met.

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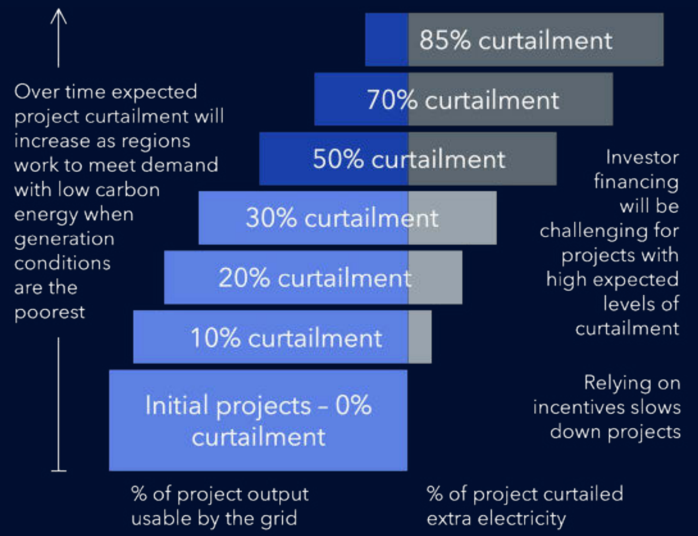
The challenge for renewables developers

Currently, wind and solar generation are being absorbed by the grid without requiring significant changes in operating behavior, as existing hydrocarbon generation can be adjusted to compensate. Once wind and solar market penetration increases to the point where significant curtailment is required regularly, the market dynamics change, creating challenges for renewable developers and utilities.



The need for curtailment at any given time will be signaled by the grid operator in one of two ways: a mandatory signal to reduce generation output, or by reducing short-term prices for load down to or below zero. Because the environmental conditions for wind and solar at any given time are similar across a wide area, projects will be most productive when least profitable.

Today, renewable projects are financed using fixed price offtakers to guarantee profitability for the life of the asset (typically 15 to 30 years) and net metering or feed-in tariff systems. This enables those offtakers to take credit for the renewable energy sent to the grid even if the time of the generation doesn't match the time of the demand. As the market becomes more saturated with wind and solar, the price difference between different times of the day will cause these existing contractual and regulatory systems to be unsustainable and financing the large, upfront capital costs of wind and solar projects will become more challenging. New projects will have very high expected levels of curtailment so as not to overload the grid during very sunny and windy periods, and/or existing projects will begin curtailing much more frequently than initially projected, upsetting their founding ROI projections.

One possibility is for funding for projects at this point to more closely resemble "Peaker" plants, with the entire cost of the build paid for by only a small percentage of the output. Doing so would likely require regulatory and policy incentives to encourage utilities to move away from hydrocarbons for these projects. These factors could have a dampening effect on the pace of the energy transition unless investors and operators can find alternative ways to create value from the extra electricity that the local grid cannot absorb.

Influencing factors for the eventual level of overbuild and curtailment

As we are making predictions about a market that does not yet exist, the anticipated level of overbuild and curtailment anticipated falls across a large range (1.7X to 3X). How much extra electricity will manifest as we approach a net zero carbon electrical grid depends on several factors and will vary from region to region.

Having a consistent base load of electricity from hydroelectric, nuclear, natural gas paired with carbon capture, geothermal, and other sources will reduce the need for overbuilding, pushing a region toward the lower end of that estimated range.

Increased electrification (to reduce carbon emissions from transportation, heating, manufacturing, etc.) will increase the demand for electricity above current levels. Wind and Solar ($32-$44/MWh) are cheaper and easier to build than hydroelectric ($64/MWh), nuclear ($71-$189/MWh), or geothermal ($37/MWh) generation, so this new demand would be expected to also increase the amount of extra electricity produced during peak conditions. (Source: eia.gov)

Theoretically, high levels of transmission capacity between regions would help offset the different environmental conditions and reduce the overall need for overbuilding and curtailment to achieve reliability. However, building high-voltage power lines requires large capital projects that have traditionally been difficult to complete. These projects are expensive, cut through large areas of land that are otherwise undisturbed, and need to cross regional, state, and/or national boundaries, which increases geopolitical challenges and introduces delays and unanticipated expenses.

There's recently been legislation to try to increase the success rate of these infrastructure projects, hopefully enabling increases to our current level of transmission capacity. We desperately need more high-voltage transmission, and over time many projects will be planned and completed. There will be pressure and incentives to build enough transmission capacity to meet the base needs of the grid to ensure demand is met reliably. However, it is difficult to imagine any incentives for investing in expanding the grid beyond peak demand, meaning curtailment – when generation is higher than demand and higher than the grid's ability to safely operate – will continue to be a factor in our future. When it comes to innovative energy ideas, this localized limitation of grid transmission capacity will be a crucial constraint to possible ways to create value from extra electricity.

Reframing extra electricity as a $3 trillion market opportunity

Consider what happens if we flip the idea of dispatchability on its head, applying it to demand instead of supply. A new value chain appears – creating opportunities for energy-dependent workloads to make use of the extra electricity if they can fit some very specific requirements. A different business model than exists today will be required to be successful.

If we use a conservative average of four to six cents per kilowatt hour of value for the 3,000 to 8,000 TWh of extra electricity expected, that presents a total addressable market opportunity of $120B to $450B each year in the US, and an almost $3 trillion market worldwide. (Calculated using data from the EIA and OurWorldInData.org)

This presents a high risk/high reward opportunity for a different class of investors. Being able to create value from that energy successfully will require a specialized business model which utilizes dispatchable demand to ramp up production when extra electricity is available and decentralized production to spread out the energy demand when grid transmission is over capacity.

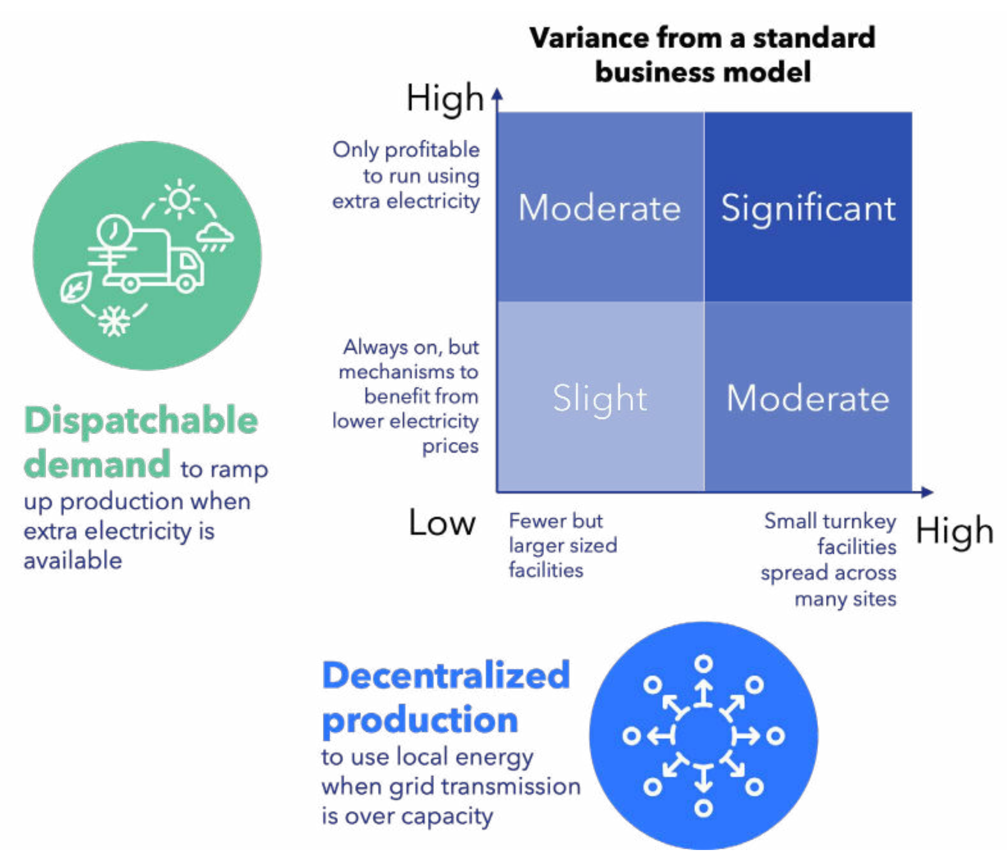
Consider what happens if we flip the idea of dispatchability on its head, applying it to demand instead of supply.

A new value chain appears.

Dispatchable demand and decentralized production

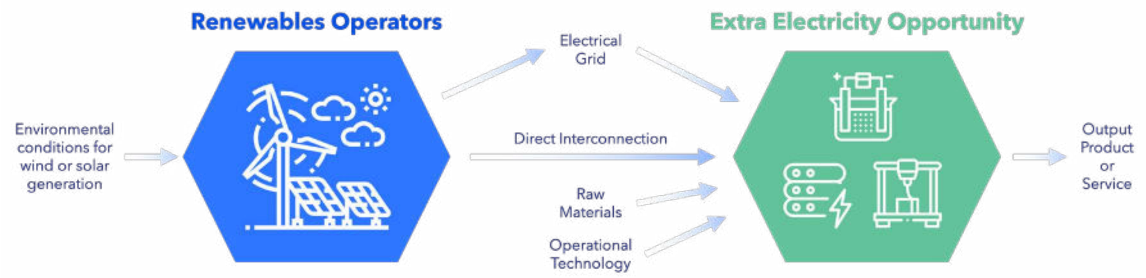
The main constraints that differentiate this new value chain are the need to vary production based on the availability of extra electricity (requiring dispatchable demand) and the enormous cost and effort to increase the transmission capability of the grid (requiring decentralized production). These constraints may manifest more or less strongly over time as technologies for using the extra electricity mature, and as the generation mix of the electricity grid changes to remove increasingly difficult to replace sources of carbon emissions.

The more strongly these constraints manifest, the more significant adaptations will be needed by entrepreneurs to be able to profitably make use of extra electricity that would otherwise be curtailed. Use cases that consume large amounts of electricity and could be made modular and decentralized are better positioned to take advantage of curtailment where and when it occurs. However, this will come with added complexity from factoring these atypical adaptations into the business model in addition to all the other considerations required to get an innovative new venture off the ground. As an investor, a use case is more promising if it will only require low to medium capabilities in at least one of the factors, as that will reduce variance from a standard business model.



Operators and entrepreneurs must partner for value realization

To use this extra electricity, renewable operators and entrepreneurs looking to capitalize on this extra electricity must partner closely for value realization. Through collaboration, each side will be better able to avoid the pitfalls that could erode value. Investors will play a crucial role in encouraging cooperation by providing the legal and financial framework for sharing resources. Modeling the system interactions will be helpful for analyzing the structure of ventures looking to create value from electricity that would otherwise be curtailed, as well as for investigating which components may be tailored for either dispatchable demand or decentralized production.



Starting at the left side of the above diagram, environmental conditions for wind and solar dictate when higher or lower levels of electricity will be generated. Operators will either export to the electrical grid or they could have direct interconnection to nearby entrepreneurs able to use the extra electricity when the grid has reached maximum capacity. Entrepreneurs will receive electricity from the grid when renewable generation is low. When the renewable projects they are connected to have extra electricity, they will then use operational technology to transform raw materials into a product or service they can sell on the market. The use case may be slightly dispatchable (relying on lower energy prices when extra energy is available to average out the cost of electricity to break even) or highly dispatchable (only operating during times of extra electricity) depending on the specifics of the opportunity. That calculus could change over time based on the relative costs of energy and supplies.

While this model considers operators and entrepreneurs as separate entities, they could also be different groups within the same organization. For example, the renewable operator could launch their own internal value capture venture, or they could be sister companies that each belong to the same private equity firm as part of a shared portfolio. Alternatively, the value capture initiative could be a program put in place by the utility provider, who is already well-placed with assets and infrastructure to connect to the renewable projects. This would involve creating non-regulated businesses within their organizational structure to seek increased revenue. For each of these different organizational structures, the basic principles of dispatchable demand remain the same.

Key pitfalls to avoid when using this extra electricity

The goal for renewable operators will be to partner in a way that will not add more operational costs than the value created by utilizing the extra electricity. That means the business venture will need to be carefully tailored for the specific renewable project. In order to be accepted for direct interconnection, entrepreneurs will need to prove to the renewable operators that they have thoroughly considered their business model and how they will create value. Otherwise, the churn of partners for these renewable operators could stress the system and cause problems. Importantly, if the entrepreneurial enterprise is not well-designed, such that the energy needs of the entrepreneurs get out of sync with the availability of extra electricity (by having urgent demand at low supply times), this could amplify the stresses on the renewable projects rather than creating extra value.

If the entrepreneurial enterprise is not well-designed, this could amplify the stresses on the renewable projects rather than creating extra value

Three categories for value creation

Three categories for use cases have emerged based on the characteristics and requirements of dispatchable demand and decentralized production. Within each category, opportunities vary on how important dispatchability and decentralization will be to the cost and capital structure of ventures looking to create value.

The first category is the extraction of natural resources with high energy needs and low human intervention. This includes opportunities such as the desalination of water, generating green hydrogen via electrolysis, and processing or recycling glass and aluminum. These are all cases where the raw materials can be supplied in bulk or via pipeline, as needed, and then the process can run whenever the energy is available. Processing could stop and restart with highly automated systems managing everything. Also, being decentralized rather than all in one central facility is feasible as long as the renewable assets are located near the necessary sources of supply. Care would need to be taken to ensure that ample supplies are available on hand during times with high levels of extra electricity.

The second category is manufacturing – where energy costs are higher than materials, inventory storage costs are low, and processes are automatable. An example of this category is high-temperature 3-D printing, such as using high-energy lasers to build products out of titanium or aluminum dust. Another possibility is printed ceramics, where clay is shaped ahead of time and then fired in a kiln to finish the process. Traditional manufacturing processes with high energy needs could also be a possibility, but economies of scale may make these less amenable to decentralization.

The third category is information services with high energy use requirements, such as running high complexity models that require a lot of processing and where the customer is flexible with when results are returned. Bitcoin mining is a current example, but the future of that use case is uncertain. Other possible scenarios include running medical protein/drug models, digital twin simulations, geo-seismic processing, or similar workloads. Another opportunity in this category could be for cloud providers to locate data centers near wind and solar farms and then introduce variable pricing for executing cloud workloads depending on the amount of extra electricity that is available. This unique offering would encourage customers to be greener with their data processing, help them save money, and could be eligible for ESG credits.

Extraction of natural resources with high energy needs and low human intervention

- Desalination of water
- Green hydrogen via electrolysis
- Recycling of Glass/Aluminum/etc.

MED -> HIGH DESPATCHABLE | **LOW -> HIGH DECENTRALIZED**

Manufacturing where energy cost is higher than materials cost, inventory storage cost is low, and processes are automatable

- High temperature 3-D printing
- Ceramics

MED -> HIGH DESPATCHABLE | **LOW -> HIGH DECENTRALIZED**

Information services with high energy use requirements

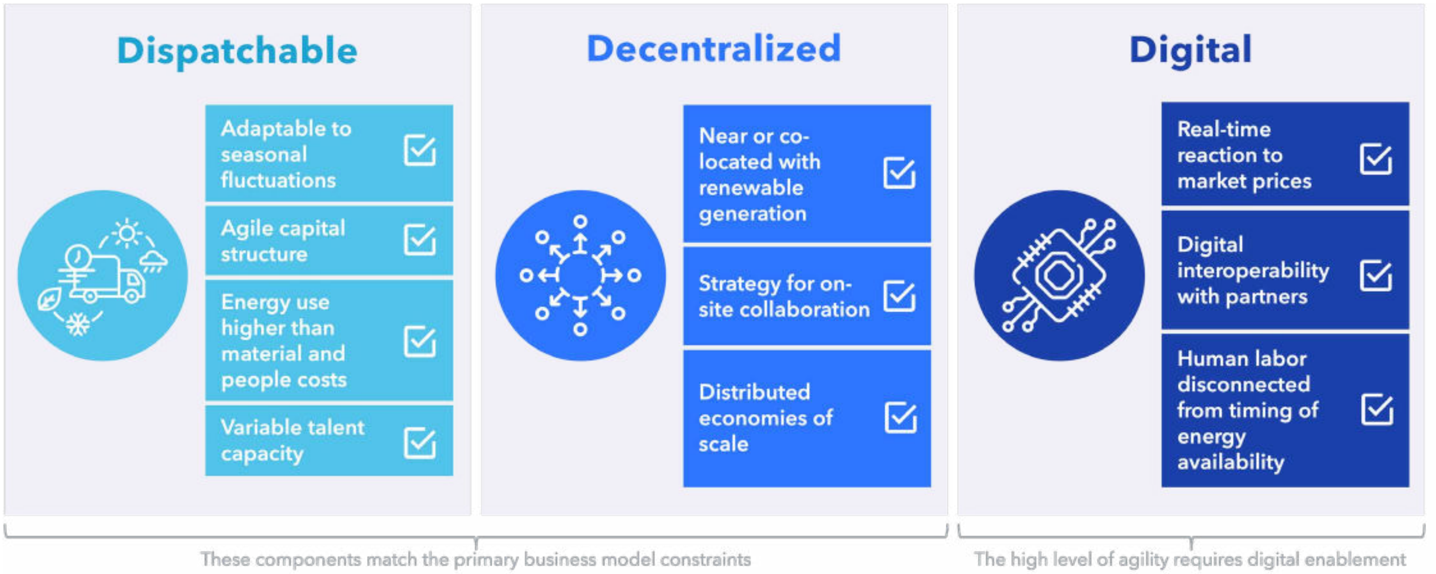
- Compute heavy analysis(Protein folding, Geo-seismic, etc.)
- Running of simulations
- Time shifting of cloud resources

LOW -> HIGH DESPATCHABLE | **MED -> HIGH DECENTRALIZED**

This is not an exhaustive list. There will be even more unique and exciting opportunities that emerge over time. Understanding and applying the core constraints around dispatchable demand and decentralized production will help businesses evaluate these potential opportunities and plan a business model with the highest chance of success.

The dispatchable demand framework helps evaluate if an opportunity is viable

The dispatchable demand framework has three pillars to help assess if a business opportunity is viable. Business models should match the level of capabilities needed with the current and expected state of the energy market and be ready to adapt as energy costs and market conditions change. The framework does not guarantee all opportunities are a sure bet, but it helps entrepreneurs and investors think though some of the challenges with deploying those use cases right now that aren't being considered fully and realize what would be required to make them viable with low-cost extra electricity.



1

Dispatchable

Dispatchable businesses will need to adapt to both daily and seasonal fluctuations. Daily fluctuations will primarily be handled with short duration storage and automated operational technology, which will be discussed under the digital pillar. But there are very different considerations for adapting to the seasonal variation of renewable electricity generation.

Entrepreneurs will need to have processes that can adapt based on seasonal fluctuations. This is similar to how retail functions. During the holidays, stores ramp up the number of staff members and configure their space to move products quickly. When demand is lower, they reduce the number of contract workers in response.

Extra electricity entrepreneurs will face an even more significant disparity between the high and low seasons. Use cases where dispatchability is a low or medium consideration for profitability will be able to simply average the cost of energy across seasons, especially if times of high production roughly match environmental conditions for high wind and solar production.

During the off-season, use cases where profitability requires a high degree of dispatchability will need the ability to go into low-power mode and sip electricity from the grid to keep core systems safe, in the most extreme case just listening for the signal to ramp up again. Tolerance for low or high temperatures may need to be considered. Capital cost structures will need to balance lower cash flows during intermittent times of the year, followed by rushes to keep up with high production.

Illustrative Configuration #1

Offshore wind farm with shared transmission lines

Desalination plant near interconnection point between tie lines and grid

Pipeline for fresh water produced

When considering the level that dispatchability plays into profitability of the opportunity, look to see how much energy use is a driving cost factor compared to material or people costs. In cases where the material and people costs are relatively higher than energy costs, it is unlikely to make sense to force those factors to adjust based on the availability of extra electricity. Alternatively, products or services that require high energy use to produce but then can be stored or transported at a low cost are well-suited for a dispatchable demand model. Products where the customer needs are less time-sensitive will also be more attractive, as that will allow for a buffer to wait until conditions are right for extra electricity.

Talent systems with mature onboarding, training and knowledge management capabilities will be needed to deal with the flux of people during different seasons. Contracts with suppliers and customers should allow for varying amounts of time and volume between deliveries. The goal is to get low-cost economies of scale despite the sizeable seasonal variability.

Illustrative Configuration #1

	Considerations	Unknowns
Dispatchable (High)	50% of cost of desalination is energy. Varying production levels to match extra electricity could reduce costs considerably Clean water demand growing, able to store for later use, but limited upside revenue potential for water Processing should require minimal human interaction	How to vary throughput to match forecasted extra electricity? How well can the technology vary output without similar increase of personnel?
Decentralized (Low/medium)	Sea water supply unconstrained, output also effectively unconstrained due to pipeline Offshore wind generation site output likely to be large, could support smaller number of larger facilities Limited locations suitable for this opportunity, proactively look to establish MOUs	Where will markets for fresh water emerge that support the cost of capital? Will there be enough opportunities to support R&D investment?
Digital	Desalination process start/stop highly automate-able Develop digital integration with generators for start/stop events	How to structure workers with seasonally variable contracts? Gig economy tie in?

The goal is to get low-cost economies of scale despite the sizeable seasonal variability

Illustrative Configuration #2

Combined wind and solar farm in remote location

Access to fresh water with some limitations

Underground hydrogen storage via salt dome

2

Decentralized

Successful businesses will understand that limited transmission capacity is a driving factor. Due to the constraints on the grid mentioned above, extra electricity entrepreneurs will benefit from being geographically dispersed and nearby or co-located with renewable operators.

Just as retail developers plan shopping centers around both a strong anchor and compatible secondary stores, wind and solar project developers should consider creating "Master Planned Communities" to accommodate the needs of co-located entrepreneurs. This could mean building interfaces for direct interconnection, as well as creating road, water, security, maintenance and telecommunications services that could be packaged and resold as a new additional revenue stream. This helps the entrepreneurs to focus their efforts and share the cost of this infrastructure in potentially remote locations.

As entrepreneurs and investors plan out what type of venture is the best fit for a certain project, they should consider the availability of valuable resources nearby, such as direct access to water, telecommunications access, pipeline availability, logistics infrastructure, ease of access, proximity to large metropolitan areas, etc. Planning an onsite collaboration strategy will be necessary for these entrepreneurs, including how they will cooperate not only with the renewable operator, but also

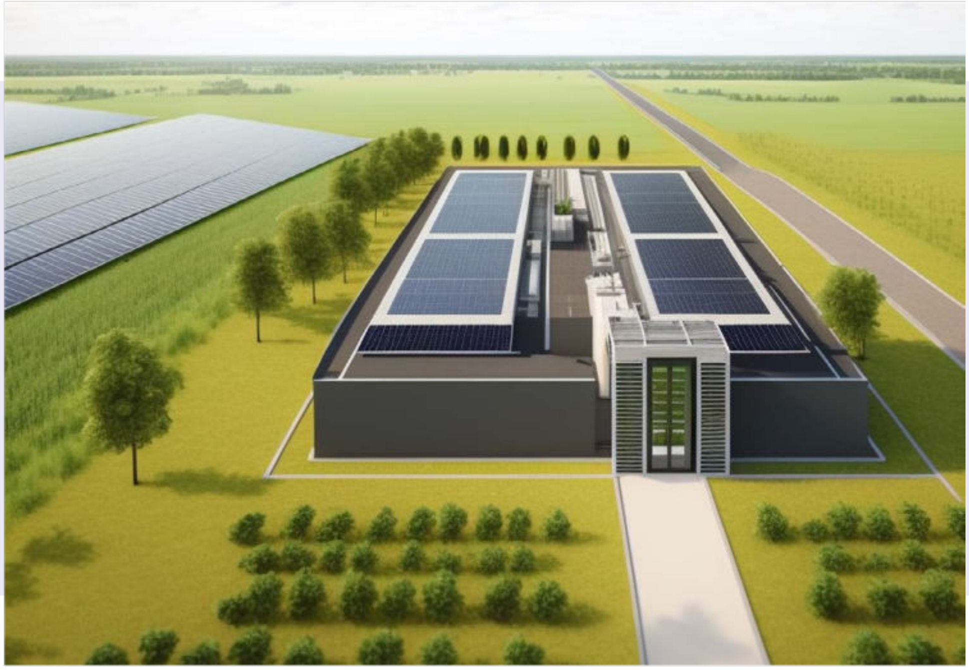
Illustrative Configuration #2

	Considerations	Unknowns
Dispatchable (High)	Green hydrogen market is nascent, high potential demand at any season Electrolysis process largely energy dependent, should be automatable Storage and transportation of hydrogen is difficult & potentially hazardous	How will hydrogen transportation capabilities evolve over time? At what price will cost of equipment and storage break even?
Decentralized (High)	Need locations with good access to suitable water sources and gas storage, proactively look to establish MOUs Hardware should be repeatable, modular to reduce per site engineering Size of each site based on water and storage capacity	Potential strain on fresh water availability? Storage capacity could limit amount of production during busy season
Digital	Labor needed for transportation & maintenance. Could reduce with pipeline infrastructure or additional automation. Develop digital integration with generators for start/stop events	How to structure workers with seasonally variable contracts? Gig economy tie in?

with other neighboring offtakers in the case of large projects.

Evaluating the level of decentralization for opportunities is equally important but more straightforward to consider compared to dispatchability of demand. Highly decentralizable opportunities will have small turnkey facilities where economies of scale are distributed. Designing a modular architecture that can be built in one place, and then transported and installed at many locations across the country or across the globe, will help bring down costs, improving the tight margins needed to take advantage of extra electricity. Suppose the architecture is highly modular (i.e. able to fit in a standard shipping container). In that case, businesses could even consider transporting these systems between latitudes depending on the season to best take advantage of the variation in environmental conditions.

The more an entrepreneur can simplify and modularize their technology, the more opportunities to create value from extra electricity will be available. In the extreme version of this, if an entrepreneur could develop a technology fit for residential consumers, they could create value from the extra electricity of distributed rooftop solar customers, increasing the market potential beyond the estimated $3 trillion.



Illustrative Configuration #3

Data center located near utility scale solar/wind facility

Direct interconnection

3

Digital

The third pillar is digital enablement. Successful businesses will need to act more like a technology start-up than an operating yield company. They should react in real time to market prices. A high level of digital interoperability between renewable operators and entrepreneurs will be required, and disconnecting human labor from the timing of energy availability will be needed to achieve high dispatchability or high decentralization.

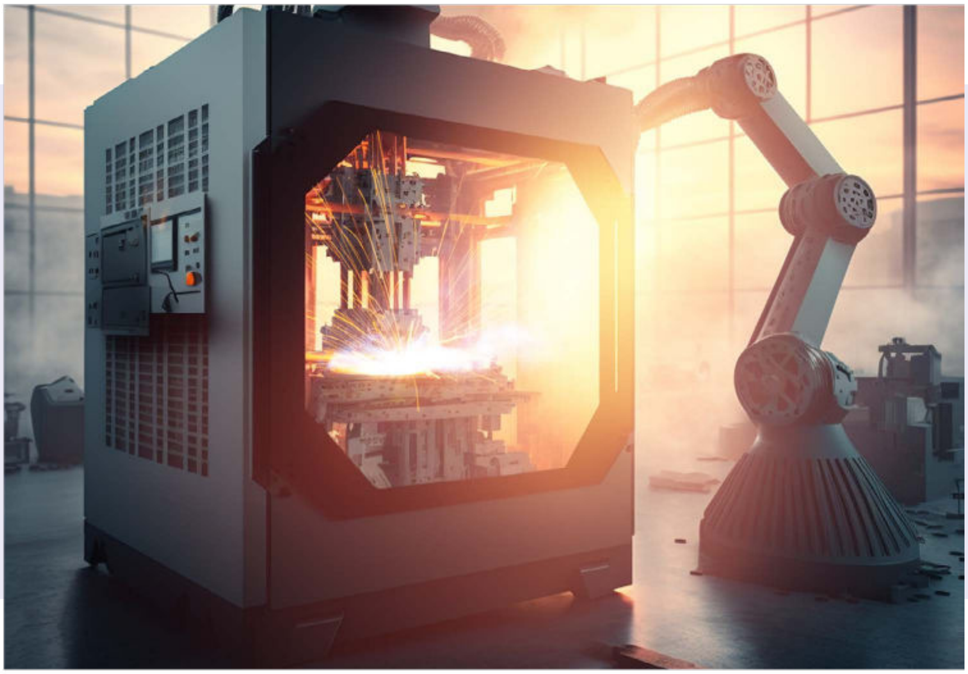
Industry standards for how the data interchange between renewable operators and their partners would be a great benefit and could potentially be shepherded by industry working groups, such as the Open Footprint Forum. Efforts by industry leaders to work together on these platforms rather than having varied proprietary standards will help reduce costs across the industry. Equally important will be a contractual framework for renewables projects to integrate systems with their partners, including technological, physical and operational across the organizations in ways that are mutually beneficial for all parties involved. Investors will play a key role in building out these frameworks and encouraging portfolio companies to participate.

Illustrative Configuration #3

	Considerations	Unknowns
Dispatchable (Medium)	Variable pricing (inverse surge pricing) based on time of use of compute Forecast of pricing to encourage customers to shift behavior Power price components of CPU/GPU processing and HVAC utilization	What types of customer workloads would be willing to time shift, including considerations for seasonal variance?
Decentralized (Medium/High)	Direct interconnection point between data center and solar/wind facility Development of solar/wind facilities near existing data centers or of new data centers near prime solar/wind locations	How to size and locate data centers as transmission capacity and levels of extra electricity change over time?
Digital	Develop digital integration with generators to broadcast extra electricity availability and resulting price fluctuations Ingress/egress data during off times to maximize compute efficiency during peak times	Could decentralize further with mini/distributed data center compute modules co-located with generation and aggregated virtually?

The opportunities dependent on high dispatchability will need access to real-time market prices and have highly automated interruptible operating systems, including automated systems for monitoring production and scheduling predictive maintenance around when extra electricity is forecast to be available.

Their whole architecture should be event-driven to act on signals from the partner without requiring any human intervention. Processes should be based on signals from the operators to start and stop production, with some level of energy storage to guarantee a minimum window of availability. They will also need to forecast their production timeframes to set customer expectations on daily output and, more importantly, output across seasons. This way, customers can plan for when products will be produced and delivered. For physical goods, outbound logistics will need to be signaled when a sufficient quantity of product is ready for delivery. This will ensure that operations are not hitting constraints on production when extra electricity availability is high.



Illustrative Configuration #4

Small/Modular container with high temperature 3D printing factory

Engineering grade feedstock

Automated removal of produced components from printer surface

Disconnecting human labor from daily timing will be necessary for these entrepreneurs because delays caused by human attention span and reaction times could quickly erode value. People don't do well in the sort of unpredictable shifting schedules that will be needed to react to real-time market prices. With core operations highly automated, logistics could then be ramped up and down with contractors based on the season.

For opportunities with high decentralization, a capable centralized technology development team will be important to automate standard operations across the portfolio. A shared operations team would also be advised to monitor events across the distributed sites.

Illustrative Configuration #4

	Considerations	Unknowns
Dispatchable (Medium/High)	Maintain backlog of orders to be manufactured as soon as extra electricity is available Leverage 3rd party logistics for package and transport of output due to seasonal variance	Current 3D printers require manual oversight for loading/unloading. Level of automation achievable will change with advancements in technology
Decentralized (High)	Advantage of 3D printing is ability to customize production for local needs–smaller facilities placed in a network would capitalize on this Traditional manufacturing with high energy needs could also be a possibility, but likely less amenable to decentralization	What size facility would be feasible considering level of automation vs. need for human involvement?
Digital	Develop digital integration with generators for start/stop events Invest in ML/AI and robotics technology for monitoring production and unloading of production output	Long tail of ML/AI and robotics capabilities needed to reduce human involvement sufficiently?

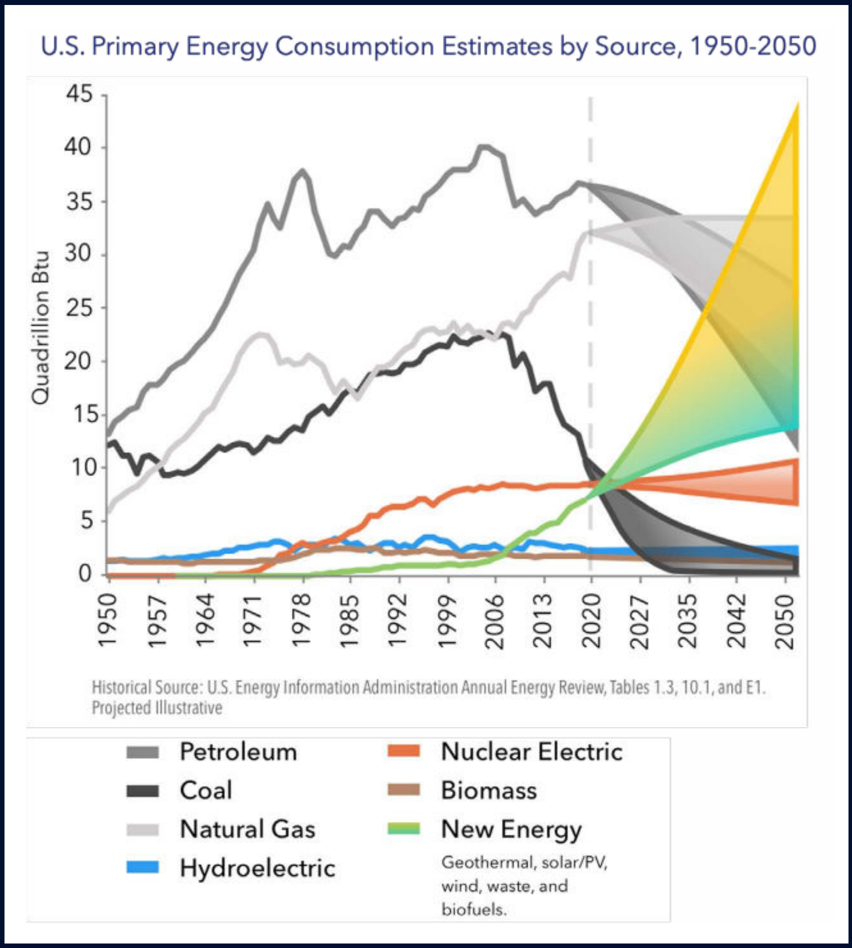
With core operations highly automated, logistics could then be ramped up and down with contractors based on the season

There are a range of possible future energy

As with any future prediction, many factors could change what now looks to be the most likely course of events. Investors and entrepreneurs should continually scan the market as they work to anticipate when dispatchable, decentralized opportunities will become viable.

1 The pace of the transition away from hydrocarbons may move slower than anticipated due to possible circumstances, such as challenges with storage or cost-effective solutions for carbon capture maturing quickly.

2 Other energy solutions could outcompete wind and solar. This could manifest as a breakthrough in long-duration storage, hydrogen, geothermal or nuclear technology. The breakthrough would have to have lower economic and environmental costs than our current renewable options and be able to be deployed at scale to be attractive. Also, it would need a stable level of generation or have the ability for generation to be increased to match market demand (dispatchable generation). Otherwise, dispatchable demand would still be needed, just for this new technology instead.



When and to what level overbuild and curtailment will peak is unknown

We are now in the early stages of the energy transition, which is needed because externalities not included in the current cost of energy are predicted to cause grave societal consequences. Social forces are leading investors and legislators to create pressures on businesses to look holistically at their operations and develop long-term decarbonization strategies. Soon, the SEC may require carbon disclosures according to established carbon accounting principles. Wind and solar technology costs have dropped dramatically over the last decade and are capable of being deployed at scale. Battery storage technology, while nascent, is also ramping up quickly and several large deployments have already been constructed.

Deployment of new technology typically follows an S-curve pattern, where initial adoption is slow but picks up gradually as economies of scale lead to acceleration. As the market becomes saturated and the most optimal opportunities are filled by a new technology, the adoption rate slows and levels off to arrive at a new stable equilibrium.

The process happens in reverse for the decommissioning of existing technologies. It begins slowly at first as new technologies displace and disrupt the incumbent where there is the greatest ROI, and then negative economies of scale lead to an accelerated decline. Decommissioning levels off as the last holdouts of the previous technology continue where either there is a perfect fit or the disruptive technology is challenged to replace all the needed requirements. Especially when existing infrastructure is entrenched and long-lasting, there may be a long tail before the old technology disappears. Coal generation is a great example of this, as a confluence of pressures led to faster displacement in the market than many thought possible; however, it will still likely take some time before coal completely disappears from the electricity generation market.

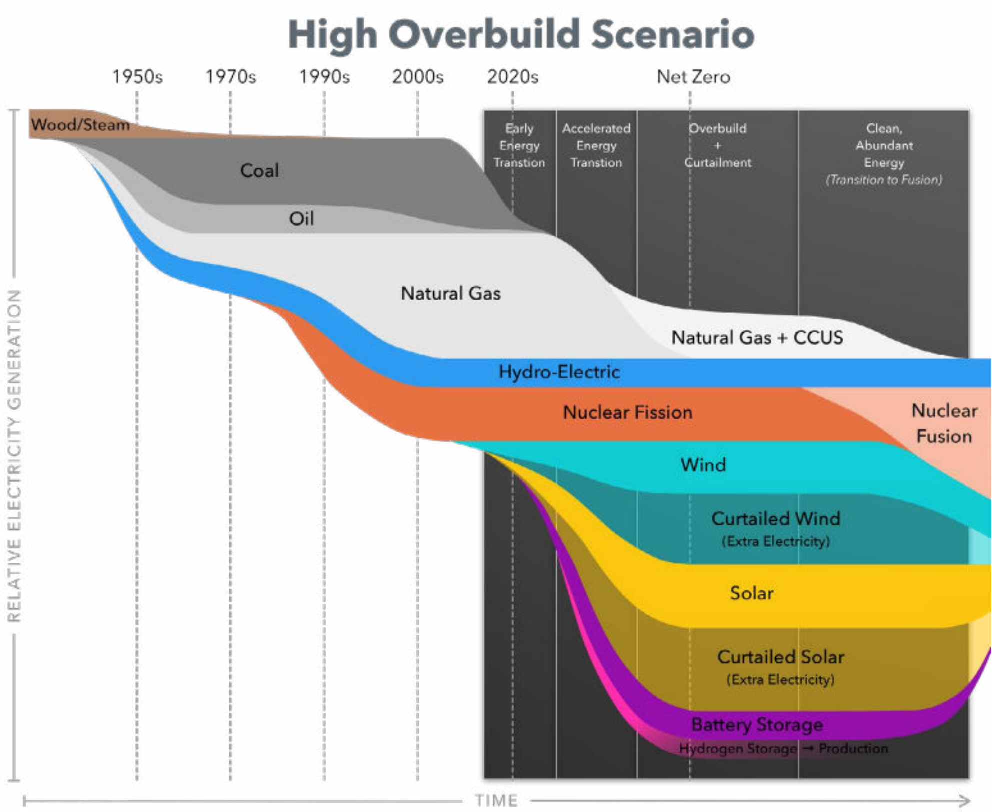
Analysts believe hydroelectric and nuclear fission are stable and may see some modest growth in market share during the energy transition, with the possibility of small modular nuclear reactors increasing the levels of nuclear construction if maintenance costs prove to be lower than for traditional projects. If (or when) carbon capture and storage paired with natural gas generation becomes economical with high levels of reliability, that would enable the economy to preserve that form of electrical generation while meeting net zero goals. Additionally, low temperature geo-thermal energy is showing some potential for wider deployment.

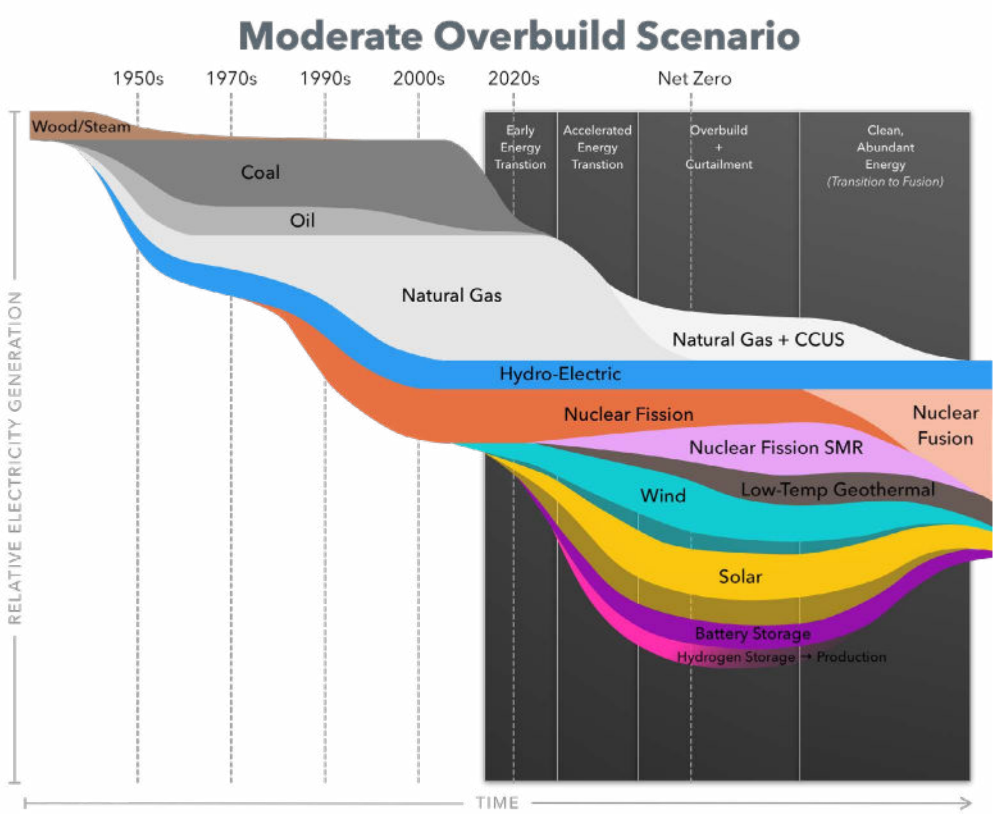
We are at the beginning of the S-curve for wind, solar and battery adoption, and deployment is expected to accelerate quickly in the coming years. Because wind and solar costs continue to fall, analysts expect the most economical configuration of the future net-zero grid to feature large wind and solar deployments.

Curtailment will start to grow after wind and solar penetration reaches higher levels within a region, which will spur investment in enough battery storage to manage the day-to-day variability of the grid. Widespread curtailment is expected to appear as the electricity market approaches net zero, likely in the 2030s, 2040s, or possibly later. Some regions will reach this new dynamic equilibrium earlier than others, with the earliest adopters needing to solve implementation challenges that could cause short-term disruption.

The conditions for overbuild and curtailment could exist for decades until the next energy transition begins, when the long-awaited promise of nuclear fusion generation technology becomes feasible, then scalable, then economical and commercialized. This new technology will compete with the low cost and installed physical footprint of wind and solar at that time, following a new S-curve as economies of scale shift over the subsequent decades.

In summary, it is plausible that the predicted state of overbuild and curtailment, with large quantities of extra electricity, will persist for several decades. At the end of this period, the dispatchable and decentralized ventures created by investors and entrepreneurs will be able to loosen the constraints of the dispatchable demand framework and capitalize on abundant, clean, low-cost energy.





The timeframe for when this will happen depends on the intersecting S-Curves of adoption and decommissioning

Technologies that enable a stable base load for the grid will decrease the likelihood of large amounts of overbuild

What now?

What should renewable operators, entrepreneurs, private equity investors and utilities be doing in the near term to evaluate potential opportunities and prepare for when this segment arrives?

In general, the profitability of extra electricity opportunities will shift as technologies mature and the relative cost of energy changes. As investors and entrepreneurs scan the market, they should consider how much the cost of energy factors into the overall profitability potential of an opportunity. When energy cost is a major factor, dispatchability and decentralization can be included to take advantage of low-cost energy and improve the chances of success of the venture. As discussed earlier, over long timeframes the energy industry is expected to trend toward cleaner, more abundant, less expensive energy. As a result, cost and process overhead associated with dispatchable demand and decentralized production will gradually ease. Business strategies should build in feedback loops to re-evaluate the operating model over time.

Renewables Operators

In the near-term, renewable operators should invest in digital platforms and build partnerships across the industry. Additionally, they can watch for shifts in contracting structures and signs of increasing market saturation and curtailment in their operating regions. As the conditions for overbuilding and curtailment approach, operators should develop co-location strategies and outline the engagement structure for partners interested in utilizing their extra electricity.

Extra Electricity Entrepreneurs

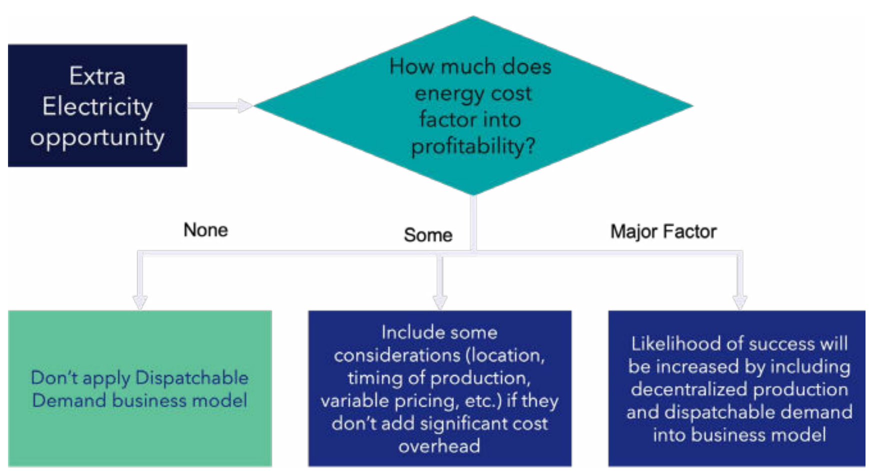
Research and development on value creation technologies should begin early enough to be ready when the right market opportunity emerges. Proofs of concept to test out functionality could start within the next couple of years. Technologies that show promise, but with energy use that is too high to be economical right now, are excellent candidates for this new value chain that will emerge. The development of digital operational systems will also be essential and may take time to get right.

In the future, as entrepreneurs move from the R&D stage to selecting an operational technology, they will need to simultaneously enact talent, capital and other strategies that allow for a dispatchable demand business model.

Private Equity Investors

Investors and private equity should now be looking at the land rights near their renewable projects to ensure they have the contract structures in place to capitalize on investment options in the future. This could include securing development rights to nearby areas that will become valuable for co-location opportunities. They can also be identifying areas with transmission bottlenecks, as that is the primary constraint that will lead to the conditions for extra electricity curtailment to emerge sooner in any given region. This analysis will help plan the first experiments into entrepreneurial ventures to use that excess electricity.

In the future they should continually monitor their portfolios, matching wind and solar investments with entrepreneurial ventures that are good companions in the same way you might hedge any investment. Then, as the technologies for value creation become more mature, investors will need to perform an in-depth ROI analysis of these different off-taker technologies to know which bets to take as the market matures.



As the energy market is disrupted, transformed and adapted to reduce society's dependence on hydrocarbons, this unique market opportunity will emerge over the next five, 10 or 15 years.

Operators, entrepreneurs, investors and utilities who watch closely and apply the pillars of dispatchable demand and decentralized production will be better prepared to create new value streams from the extra electricity that the grid will be unable to accept. By doing so, they will also be helping to accelerate the pace of the energy transition.

Derrick Bowen

HOUSTON PRINCIPAL

Derrick leads Cloud-first Software Development, Customer Experience and Strategy projects with a focus on tackling bold ideas as incremental improvements. The world has more uncertainty and is moving at a faster pace than ever before as power structures are shifting, energy is transitioning, and the daily flood of information creates transparency and fog at the same time. His focus during his career has been on solving those problems that span the edges between knowledge domains, technology stacks, or functional areas.

EXPERIENCE

Derrick has more than 13 years of consulting experience leading User-Centered Software Development, CRM, Business Intelligence, and Strategy projects in the Energy (renewable and traditional), Social Sector, Healthcare, Financial Services, and other industries. He is passionate about leveraging real-world feedback loops to help overcome subconscious bias and using jobs theory to reframe technical problems in terms of customer experience. He has worked with clients to utilize out-of-the-box or configurable solutions to serve important business functions and then develop custom fit solutions for core competitive advantages. He has architected solutions that combine on-premise and cloud, Amazon, Microsoft, and Salesforce, technical development and strategic process improvements to enable businesses as they transform to meet customer needs. Prior to Pariveda, Derrick worked and consulted in the Software as a Service industry.

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